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The Belt and Road Initiative and enterprise green innovation: evidence from Chinese manufacturing enterprises

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Building a green silk road is an important path toward implementation of the UN 2030 sustainable development goals. The purpose of the paper is to discuss the sustainable development goals of the "Belt and Road" Initiative (BRI) by evaluating the relationship between the BRI and enterprise green innovation. Employing the technology–organization–environment (TOE) framework to build a theoretical model based on the micro data of Chinese manufacturing enterprises from 2011 to 2018, and using the difference-in-differences method, this paper analyzes the BRI's influence on the green innovation of enterprises. The research results indicate that the BRI has significantly enhanced the level of green innovation in Chinese manufacturing enterprises. This effect is still robust after the analysis of PSM-DID excluding the interference of policies in the same period and heterogeneity analysis. The results of the mechanism analysis show that the percentage of R&D employees, policy support and R&D expenditure can enhance the positive effects of the BRI's influence on enterprise green innovation. The marginal contribution of this paper is to identify the causal relationship between the BRI and green innovation, add a new micro perspective to the research on the relationship between the BRI and sustainable development, and reveal a new micro mechanism.

KEYWORDS

the Belt and Road Initiative, green innovation, manufacturing enterprises, TOE framework, difference-in-differences

1. Introduction

In 2013, Chinese President Xi Jinping proposed "the Belt and Road" Initiative (BRI), which has received great attention from the international community. In 2015, China released the "Vision and Actions on Jointly Building Silk Road Economic Belt and 21st-Century Maritime Silk Road" (hereinafter referred to as "the Vision"), which put forward the concept of "Building a Green Silk Road." In 2017, China introduced the "Guidance on Promoting Green Belt and Road," and building the Green Silk Road has become an important path toward implementation of the UN 2030 sustainable development goals (SDGs). The research literature points out that sustainability has become a major concern for the business community and that companies that are successful in environmentally sustainable projects can obtain greater financial success and social welfare beyond their economic responsibility (Zhu et al., 2019). Studies on the BRI have also paid extensive attention to environmental and sustainable development issues, with the literature discussing sustainable growth, energy consumption and environmental challenges in the "Belt and Road" countries (Rauf et al., 2020), carbon emission reduction in the "Belt and Road" countries (Chen et al., 2021a), and the energy intensity of the BRI and the countries along the" Belt and Road" (Qi et al., 2019). However, there is a lack of research on the relationship between the BRI and sustainable development that considers the enterprise level to discuss the impact of the BRI on green innovation in enterprises, especially manufacturing enterprises.

Green innovation is critical to both organizations and society as an important factor in maintaining environmental stewardship and sustainable development (Aguilera-Caracuel and Ortiz-de-Mandojana, 2013; Zhang et al., 2020; Xu et al., 2021). This importance is reflected in two aspects. On the one hand, in order to face the threat posed by environmental degradation to human society, many organizations and communities have adopted green innovation as a strategy to achieve environmental protection and economic growth (Takalo and Tooranloo, 2021), which is important for both organizations and society in terms of sustainability and economic profitability (Fliaster and Kolloch, 2017). On the other hand, from the perspective of the impact of green innovation on enterprises, green innovation can lead organizations to achieve a sustainable competitive advantage (Hur et al., 2013) and further enhance regional sustainability (Chege and Wang, 2020; Fu et al., 2020; Wang and Yang, 2021; Zhou et al., 2021). The research on corporate green innovation has been conducted from three perspectives as follows: (1) Studies on the factors influencing enterprise green innovation have argued that, as a systemic project, enterprise green innovation requires the creative integration of various internal and external resources. They achieve this through capacity development and capital investment (Lampikoski et al., 2014; Roper and Tapinos, 2016), the technological capabilities of firms (Leyva-de La Hiz et al., 2019; Zhang et al., 2020), firm heterogeneity (Xu et al., 2021), and environmental pressures (Cao and Chen, 2019), which have been identified as the main factors influencing enterprise green innovation. (2) Results of enterprise green innovation. Green innovation in enterprises can reduce energy consumption and pollution (Wang et al., 2017; Albort-Morant et al., 2018), improve resource-use efficiency (Wang et al., 2017), and enhance the environmental sustainability of enterprises (Chu et al., 2018). (3) The impacts of environmental policies on enterprise green innovation, include sustainability performance indicators (Wang and Yang, 2021), carbon trading rights (Chen et al., 2021b; Du et al., 2021), intellectual property rights and government support (Roh et al., 2021), etc.

However, the existing studies lack a comprehensive assessment of the promotion effect of the BRI on green innovation in Chinese manufacturing enterprises. The research gap mainly manifests in three aspects. First, the existing research mainly focuses on the relationship between the BRI and sustainable development from the national level, but there are few studies focusing on green innovation from the enterprise level. Second, existing studies have discussed the impact of policy environment on green innovation of enterprises, but there are few studies on the impact of the BRI on green innovation of enterprises. Third, in the research on the relationship between the BRI and sustainable development, the research focusing on green innovation in manufacturing needs further in-depth discussion.

The focus on green innovation in manufacturing enterprises is based on three main factors: (1) Manufacturing is one of the major causes of industrial waste production and environmental pollution, posing a threat to environmental sustainability, and enhancing the green innovation capacity of manufacturing enterprises is an important strategic tool to ensure environmental sustainability (Wang and Yang, 2021). As the Green Silk Road is an important path toward implementing the UN 2030 Agenda for Sustainable Development, studying the impact of the BRI on green innovation in manufacturing enterprises can provide important theoretical support for the realization of the SDGs of the BRI. Therefore, studying the impact of the BRI on green innovation in manufacturing enterprises can provide important theoretical support for achieving the SDGs of the BRI. (2) Consumers, manufacturers, government departments, and communities are increasingly aware of the importance of sustainability as well as environmental issues, which has created significant social pressure on manufacturing firms (Li et al., 2017), prompting manufacturing firms to incorporate green innovation into their production processes (Gupta and Barua, 2018), and the growing concern for social, economic, and environmental concerns has increased the importance of green innovation in manufacturing firms (Sarkar et al., 2020). (3) Manufacturing is one of the wide-ranging and dynamic industries that are attracting companies to transition toward green innovation (Wang and Yang, 2021). The BRI proposed the concept of supporting major industrial sectors to promote environmental technology innovation, providing an opportunity to study the impact of the BRI on green innovation of manufacturing enterprises.

Thus, this paper poses the following research question: Does the BRI promote green innovation of Chinese manufacturing enterprises? Does this effect have a heterogeneous impact? What is the mechanism of such impact? This paper uses a difference-in-differences approach to analyze the impact of the BRI on green innovation in Chinese manufacturing enterprises, discusses industry heterogeneity and firm ownership heterogeneity, and evaluates the impact of the BRI on green innovation in Chinese manufacturing enterprises based on a technology–organization–environment (TOE) framework (Tornatzky et al., 1990). We analyze the impact of the BRI on green innovation in Chinese manufacturing enterprises in terms of internal technological and organizational factors as well as external environmental factors. The research in this article is timely and necessary. On the one hand, the BRI is believed to enhance the strength and expand the influence of Chinese enterprises in the global economy. This study can add new content to this influence from the perspective of green innovation. On the other hand, this study can also provide valuable information for foreign investors and governments of countries along the BRI.

In the study of the relationship between the BRI and sustainable development, this paper makes marginal contributions in three areas compared to existing studies. (1) This paper extends the analysis to the level of manufacturing enterprises and discusses the impact of the BRI on green innovation in Chinese manufacturing enterprises compared to previous studies that have discussed the environmental impact of the BRI at the national macro level (Qi et al., 2019; Rauf et al., 2020; Chen et al., 2021a). This paper provides a micro perspective at the enterprise level on the relationship between the BRI and sustainable development. (2) This paper uses the method of difference-in-differences to take China's core cities along the "Belt and Road" as the objects to accept exogenous shocks, which is different from previous studies on countries along the "Belt and Road" as the objects to accept exogenous shocks (Du and Zhang, 2018; Yang et al., 2020; Nugent and Lu, 2021). This paper analyzes the intrinsic dynamics of corporate green innovation from the perspective of core cities along China's domestic routes, providing microlevel causal evidence of the relationship between the BRI and sustainable development. (3) This paper analyzes the impact mechanism of the BRI on Chinese manufacturing enterprises based on the TOE framework. Compared with previous studies on environmental issues of the Belt and Road (Qi et al., 2019; Rauf et al., 2020; Chen et al., 2021a), and research on enterprise digital innovation and green process innovation (Dong et al., 2023), this paper analyzes the role of technology, organization and environment at both internal and external levels and reveals the microlevel influence mechanism of the relationship between the BRI and sustainable development. At the same time, at the practical level, the study of these issues can help in the evaluation of the construction effect of the green Belt and Road and provide important theoretical references and decision-making bases for achieving the 2030 SDGs.

2. Theoretical framework

Building the Green Silk Road is an important concept of the BRI. In 2019, China signed a memorandum of understanding with the United Nations Environment Program on building a green Belt and Road and signed cooperation agreements on ecological and environmental protection with more than 30 countries along the route. The construction of the Green Silk Road has become an important path toward implementing the UN 2030 Agenda for Sustainable Development, and more than 100 partners from relevant countries and regions have jointly established the International Alliance for Green Development along the Belt and Road. Studies have found that the BRI reduces carbon emissions (Chen et al., 2021a) and energy intensity (Qi et al., 2019) and promotes sustainable development in the countries along the route (Rauf et al., 2020). Based on this, this paper assesses the promotion effect of the BRI on green innovation in Chinese manufacturing firms and further analyzes its impact mechanism using a TOE framework (Tornatzky et al., 1990).

We first analyze the reasons for the impact of the BRI on the sustainable development of Chinese enterprises, and then analyze the impact mechanism of the BRI on green innovation of Chinese enterprises. The BRI serves as a high-level open platform where various partners can promote the development of an open world economic system by strengthening interregional cooperation (Duan et al., 2018) and thereby allowing Chinese companies to gain value in the international market. The impact of the BRI on the sustainable development of Chinese enterprises can be summarized in the following three outcomes. (1) Resource allocation optimization effect. The BRI promotes the transfer of industries and the restructuring of domestic industries by promoting foreign direct investment in countries along the route; it also optimizes the resource allocation of enterprises in home countries and improves production processes and processing techniques, thus promoting the green transformation and upgrading of enterprises (Yu et al., 2019; Yang and Li, 2021). (2) Achieving economies of scale and improving technical efficiency. As part of a broad international market, the BRI can greatly increase external demand for Chinese products, expand market capacity, achieve economies of scale, and improve production efficiency (Liu and Xin, 2019). (3) Increase competitive pressure and achieve technological progress. While the wide international market brings more room for development for Chinese enterprises, it also imposes higher development requirements for effective survival, i.e., the demand for diversified and high-end products, creating a strong squeezing mechanism for enterprises that want to enter the international market, which needs to prioritize technological innovation and green production to be competitive (Ji et al., 2018).

In order to explain the impact of the above the BRI on the sustainable development of Chinese enterprises, we discuss the impact mechanism of the BRI on green innovation of Chinese enterprises from the perspective of green innovation based on the TOE framework. Tornatzky et al. (1990) developed a TOE framework to describe the factors that influence firms' technological innovation decisions. The technological context reflects the technological infrastructure and capabilities that influence the implementation of a firm's innovation. Technological infrastructure includes a firm's current equipment and technology practices, which are important in innovation decisions because they determine the scope and speed of technological change that can be achieved by a firm (Hue, 2019). Technological capabilities, on the other hand, reflect the expertise and skills needed to effectively utilize the components of technological infrastructure (Aboelmaged, 2014). The literature proposes measuring technological infrastructure and capabilities using the quality of the workforce and the industry sector in which the firm is located, among them, quality of the workforce is measured by the percentage of high-quality employees (Castillejo et al., 2006). In addition, innovation ecosystem theory suggests that high-level talent is a key factor influencing the performance of innovation ecosystems, as the high quality of high-level talent already available can reduce the cost of learning, save the organization's time costs and improve management efficiency (Valkokari, 2015). Based on the above analysis, this study will analyze technological factors from the perspective of innovation talent and measure innovation talent in terms of R&D employees.

The organizational context is concerned with the resources and interactions associated with innovation. Existing studies have discussed the impact of organizational-level factors on innovation from multiple perspectives. Studies from an organizational characteristics perspective have argued that characteristics such as organizational size, organizational ownership structure, and organizational competition affect firm innovation (Hue, 2019; Kinkel et al., 2021). Studies based on the organizational support perspective have found that factors such as organizational support and managerial barriers will also affect firm innovation (Aboelmaged, 2018; Nam et al., 2019). Studies have also combined the TOE framework with absorptive capacity theory to highlight the important role of R&D in innovation (Jantunen, 2005; Liao et al., 2021) and have found that organizational R&D expenditures play an important role in the transformation of science and technology to create new knowledge and enhance innovation capacity (Kim et al., 2020). To manage organizational change for green innovation (Dangelico et al., 2017), firms require expertise in absorptive capacity and sustainability to facilitate the implementation of green innovation (Aboelmaged and Hashem, 2019), and in this sense, R&D is an organizational level that is required for green innovation at the organizational level (Zhang et al., 2020). Therefore, this paper focuses on analyzing the impact of organizational-level factors on green innovation from the perspective of R&D based on the perspective of the TOE framework combined with absorptive capacity theory.

The environmental context reflects the impact of external factors such as competition, stakeholder pressure, and regulatory environment on firm innovation (Tornatzky et al., 1990). The existing literature generally analyzes the impact of environmental factors on firm innovation from two perspectives. On the one hand, the role of factors such as market competition, competitive pressure, customer demand and customer pressure is discussed from the perspective of market stakeholders (Dai et al., 2018; Nam et al., 2019; Qalati et al., 2021). On the other hand, the role of factors such as government laws, environmental protection requirements, and government support are discussed from the perspective of government stakeholders (Aboelmaged, 2018; Chen et al., 2018; Hue, 2019; Nam et al., 2019). It is found that government support for innovation activities conducted by firms through policy support, such as policy leaning and financial subsidies, helps firms break through the resource bottlenecks faced in the process of innovation activities (Hue, 2019). Because this paper focuses on the impact of the BRI on green innovation in manufacturing enterprises, the role of environmental factors is mainly analyzed from the perspective of government support.

According to the TOE framework, firm innovation can be facilitated when internal and external drivers can be effectively established, and one of the key advantages of the TOE framework is its flexible nature, which allows for the categorization of studies that reflect factors that stimulate or hinder firm innovation (Aboelmaged, 2014). Many empirical studies have used the TOE framework as a theoretical basis to examine the adoption of new technologies by firms (Chiu et al., 2017) and the factors influencing innovation (Hue, 2019); environmentally sustainable practices and technological innovation in SMEs (Chege and Wang, 2020); competitive ability and sustainable practices (Aboelmaged, 2018); and climate change, sustainability and economic growth (Ferreira et al., 2020). Therefore, this paper analyzes the influence mechanism of technology–organization–environment factors on the relationship between the BRI and green innovation in manufacturing firms based on the TOE framework, as shown in Figure 1.

3. Research hypothesis

Corporate green innovation refers to innovative activities that contribute to resource conservation and environmental protection in terms of reducing resource and energy consumption, avoiding or reducing pollution emissions, and reducing environmental risks (Castellacci and Lie, 2017). Green innovation can create new opportunities for environmentally friendly practices in firms (Albort-Morant et al., 2018), reduce the pollution rate of firms (Castellacci and Lie, 2017) and save energy (Huang and Li, 2017; Wang et al., 2017). Therefore, green innovation is an important tool that can help societies, organizations, and firms reach environmental sustainability goals, improve economic performance, face the challenges of green and environmental innovation, and play an important role in achieving competitive advantage (Takalo and Tooranloo, 2021).

3.1. BRI and green innovation in manufacturing enterprises

Recent studies have focused on the relationship between the BRI and carbon emission reduction, sustainable development, energy intensity, and green total factor productivity. Country-based studies have found that Chinese outward foreign direct investment (OFDI) helps increase the capacity efficiency of countries along the Belt and Road, thereby reducing their carbon emissions (Chen et al., 2021a). Rauf et al. analyzed the interrelationships among energy consumption, economic growth, population growth, financial development, and carbon emissions in 65 countries along the "Belt and Road" and found that energy consumption, high-tech industries, and economic growth deteriorated environmental quality, while financial and renewable energy consumption had a favorable impact on the environment (Rauf et al., 2020). A study on the relationship between the BRI and energy intensity found that, under the premise of reducing energy intensity, the scale of trade between China and countries along the "Belt and Road" contributes to the convergence rate of energy intensity when the trade threshold is exceeded, and technology effects will accelerate the convergence of energy intensity (Qi et al., 2019). A study at the provincial level in China found that the BRI increased green total factor productivity in the provinces along the route and that technological progress played a major driving role (Liu and Xin, 2019). These studies provide preliminary evidence on the relationship between the "Belt and Road" and green development at the macro level. At the micro level, studies have also begun to discuss the relationship between green innovation of enterprises along the "Belt and Road." Two recent studies have found that firms investing in Belt and Road countries have higher green innovation performance than other firms (Zhu and Sun, 2020; Yang and Li, 2021). Based on the

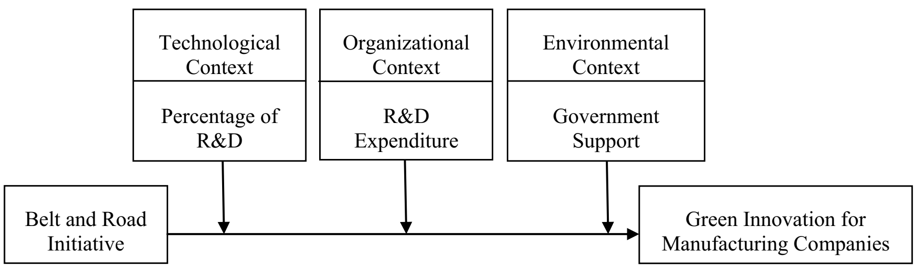

FIGURE 1
Theoretical framework.

above analysis, we believe that the BRI will promote green innovation in Chinese manufacturing enterprises, for which the following hypothesis is proposed.

> *H1*: The BRI will improve the level of green innovation in Chinese manufacturing enterprises.

3.2. Technological factors and green innovation in manufacturing companies

According to the analysis in the theoretical framework section, the quality of the workforce can be a key element in measuring technological infrastructure and capabilities (Castillejo et al., 2006), and in the TOE framework, the technological dimension is crucial for firm innovation because it determines the technological changes that can be made at the firm level (Tornatzky et al., 1990). The value of a technological resource depends to a large extent on the extent to which it works in concert with other technologies being used and facilitates green innovation activities (Zhang et al., 2020). The quality of the workforce as a technological resource affects firm innovation performance (Castillejo et al., 2006), and skilled employees such as R&D staff are an important knowledge resource for the firm because they carry the firm's knowledge and culture to the greatest extent and have the potential to improve the firm's ability to identify, absorb, and manage knowledge and thus promote innovation in the firm (Hue, 2019). Based on the above discussion, we believe that the higher the percentage of R&D employees, the stronger the contribution of the BRI to enterprises green innovation, and we propose the following hypothesis.

> *H2*: The higher the percentage of R&D employees, the stronger the promotion effect of the BRI will be on green innovation in Chinese manufacturing enterprises compared to those with a lower percentage of R&D employees.

3.3. Organizational factors and green innovation in manufacturing companies

This paper discusses the role of organizational factors by combining the TOE framework with absorptive capacity theory (Jantunen, 2005; Liao et al., 2021). According to the TOE framework, organizational capabilities are also an important factor influencing firm innovation (Tornatzky et al., 1990), where innovation capabilities help firms enhance their green innovation (Zhang et al., 2020), while absorptive capacity theory emphasizes R&D importance (Aboelmaged and Hashem, 2019), arguing that R&D is a driving factor that affects firms' innovation capabilities (Kim et al., 2020; Papanastassiou et al., 2020). The impact of R&D on firm innovation in the context of the BRI has also received extensive attention in the literature, and these studies have found that the BRI promotes foreign direct investment in R&D by Chinese firms, which in turn leads to an increase in firm innovation efficiency (Zhao and Fang, 2019). Companies that actively participate in the BRI are able to acquire green technologies for cash through foreign direct investment and cross-border mergers and acquisitions, thus promoting the green R&D capabilities of enterprises (Zhu and Sun, 2020). The BRI enhances the R&D efficiency of enterprises, thus promoting their green upgrading and transformation (Yang and Li, 2021). These studies provide supportive evidence for the relationship between R&D and innovation in the BRI, for which the following hypotheses are proposed.

> *H3*: The stronger the R&D expenditures of firms, the stronger the green innovation effect of the BRI will be on Chinese manufacturing firms compared to the weak R&D expenditures of firms.

3.4. Environmental factors and green innovation in manufacturing companies

This paper assesses the impact of the BRI on green innovation in Chinese manufacturing firms and therefore focuses more on the role of external environmental factors at the governmental level. Environmental factors are the external factors that influence firms' innovation in the TOE framework (Tornatzky et al., 1990), among which government support is one of the external environmental factors that influence firms' innovation (Zhu et al., 2004; Hue, 2019). The focus of cooperation in the BRI involves economic, cultural, political, and transportation areas, which are included in the policy communication, facility connection, trade flow, financial integration, and people-to-people communication proposed in the Vision. The "five links" are the main cooperation elements of the "Belt and Road," among which policy communication is the most basic link and plays a fundamental role (Lu et al., 2021). In China, local governments along the Belt and Road will help enterprises better participate in the construction of the Belt and Road by introducing relevant support policies and improving the local policy environment (Lu et al., 2021). It was found that policy support from local governments along the BRI enhanced the export quality of enterprises in core cities along the BRI (Lu et al., 2021). In addition, government subsidies, as a kind of government-supported institutional arrangement, also play a significant role in enterprises' production and operation (Yu, 2021), based on which we infer that support from local governments will enhance the green innovation level of manufacturing enterprises through the BRI.

> *H4*: The stronger the support from local governments, the stronger the promotion effect of the BRI will be on the green innovation of Chinese manufacturing enterprises.

4. Research design

4.1. Econometric model setting

The main objective of this empirical study is to identify the causal relationship between the BRI and enterprises green innovation. In existing literature, quasi natural experimental design and fsQCA are commonly used methods for identifying causal relationships. For example, the existing research used quasi natural experimental design to discuss the BRI and foreign direct investment (Yu et al., 2019; Nugent and Lu, 2021), there are also literature using the fsQCA method to discuss the issue of digital green innovation in enterprises (Yin and Yu, 2022). This paper uses the research design of quasi natural experiments to identify causal relationships. We use the BRI as a quasi-natural experiment and apply the difference-in-differences method to study the impact of the BRI on green innovation in Chinese manufacturing enterprises. In assessing the effect of the BRI, we choose the year 2014, when the BRI officially appeared in the Government Work Report, as a time of exogenous shocks (Zhu and Sun, 2020). The focus of our analysis is the level of green innovation of Chinese manufacturing firms, so we use the core cities along the Belt and Road in China as the grouping variable. The manufacturing firms located in the core cities along the Belt and Road are in the experimental group, while those located in other cities are in the control group. This research design is consistent with existing literature in terms of selecting grouping variables, the difference is that the existing literature discusses the relationship between the BRI and China's high-quality exports (Lu et al., 2021), while this paper examines the impact of the BRI on green innovation of Chinese manufacturing enterprises.

According to the above design scheme, a two-way fixed effects difference-in-differences model is constructed:

$$GreInv_{it} = \alpha + \beta Dcity_i * post_t + \mu_i + \lambda_t + \gamma X_{it} + \varepsilon_{it} \tag{1}$$

Equation 1 is a two-way fixed effects difference-in-differences model that considers individual fixed effects (μ_i) and time fixed effects (λ_t). In the model, $GreInv_{it}$indicates the green innovation level of enterprises, measured by green patents. $Dcity_i$ is a grouping variable of core cities along the Belt and Road, which takes the value of 1 when the city where the enterprise is located is a core city along the Belt and Road; otherwise, it takes the value of 0. $post_t$ is a dummy variable of the treatment effect period (Zhu and Sun, 2020; Lu et al., 2021). $Dcity_i * post_t$ is a difference-in-differences interaction term used to estimate the micro impact of the BRI. X_{it} is a set of firm-level control variables, and ε_{it} is a random disturbance term. β is the coefficient of the difference-in-differences interaction term that is our focus, and its economic significance is the promotion effect of the BRI on green innovation in manufacturing firms.

4.2. Variables and data

4.2.1. Variables

(1) Corporate green innovation. It is measured by the number of green patents including the number of green invention applications (LnGreInvia), the number of green invention acquisitions (LnGreInvig), and the sum of the number of green invention applications and acquisitions (LnGreInviaig). In the specific analysis of the data, the above three variables were logarithmically transformed, which will be +1 to the number of each green patent and then taking the natural logarithm value.

(2) Variables related to the BRI. In this paper, we construct a difference-in-differences model in two city-year dimensions to identify the micro impacts of the initiative. In the city dimension, we take the 39 core cities along the Belt and Road mentioned in the Vision as the basis; refer to existing studies (Lu et al., 2021); and exclude two cities, "Hong Kong, China" and "Macau, China," which lack data, leaving 37 core cities along the Belt and Road. If an enterprise is located in a core city along the Belt and Road, the value is 1, indicating that the enterprise enters the experimental group; if an enterprise is located in a noncore city along the Belt and Road, the value is 0, indicating that the enterprise enters the control group. In terms of the time dimension, we refer to the existing studies (Zhu and Sun, 2020; Lu et al., 2021) and use 2014, the second year of the BRI, as the starting year when the treatment effect begins to take effect.

(3) Relevant variables for mechanism analysis. In this paper, we apply the TOE framework to analyze the mechanism of the impact of the BRI on green innovation in Chinese manufacturing enterprises, including the technology dimension, measured by the share of R&D personnel (RDpr) (Hue, 2019); the organizational dimension, measured by the logarithm of R&D expenditures (lnRDexp) (Zhang et al., 2020); and the environmental level dimensions, measured by government support (pro_degree) and government grants (govgrants) (Lu et al., 2021; Yu, 2021).

(4) Control variables. Referring to existing studies (Zhu and Sun, 2020; Yang and Li, 2021), the control variable X_{it} is a set of firm-level variables, including total net asset margin (ROAA), operating profit margin (OPR), total asset growth rate (TagrA), operating income growth rate (OrgrA), cash ratio (Cashr), gearing ratio (Alr) Total Assets (Tassets), and Total Operating Income (Toincomes).

4.2.2. Data

The data in this paper are mainly obtained from the China Stock Market & Accounting Research (CSMAR) database and the China Research Data Service Platform (CNRDS). Among them, the basic information of listed companies, financial data and city-level data are obtained from the CSMAR database for the time interval of 2011–2018. The data on green innovation were obtained from the CNRDS Green Patent Database. We first merged the basic information and financial data of listed companies from the CSMAR database into one data file based on the stock codes of listed companies. We then merged the patent data from the CNRDS Green Patent Database, based on the stock codes of listed companies, into the financial data file of listed companies, which became the data file for the analysis of this paper, with a total of 13,424 observations in the data file. In the robustness analysis, city-level data were added.

5. Results

5.1. Baseline regression

The first descriptive statistical analysis was performed for the main variables, as shown in Table 1. The first column in Table 1 shows the names of the variables in the DID model, and the second column shows the meanings of the variables. The first to third rows are the dependent variables in the DID model, and the three measures of green innovation are taken as logarithms; the fourth row is the grouping variables of core cities along the Belt and Road, and the fifth row is the dummy variables of the treatment effect period. The other rows are the variables related to mechanism analysis and control variables.

TABLE 1 Descriptive statistical analysis of the main variables.

Variables	Meaning	Mean	SD	Min	Max
LnGreInvia	Logarithm of the number of green invention applications	0.502	0.908	0	6.810
LnGreInvig	Logarithm of the amount of green inventions obtained	0.242	0.591	0	5.670
LnGreInviaig	Logarithm of the sum of the number of green invention applications and acquisitions	0.597	0.985	0	7.087
Dcity	Core city dummy variables	0.429	0.495	0	1
post	Treatment effect period dummy variables	0.685	0.464	0	1
RDpr	Percentage of R&D staff	8.659103	12.91791	0	94.49
lnRDexp	Logarithm of R&D expenditures	17.50	1.655	6.908	24.62
govgrants	Government grants	3.909e+07	1.363e+08	−4.796e+06	3.985e+09
ROAA	Net profit margin on total assets	0.0395	0.0828	−3.994	0.482
OPR	Operating margin	0.0640	0.452	−25.94	19.16
TagrA	Total assets growth rate	0.234	0.751	−0.928	45.46
OrgrA	Operating income growth rate	0.968	41.66	−5.408	4,500
Cashr	Cash ratio	1.079	3.076	−4.359	167.5
Alr	Gearing ratio	0.391	0.204	0.00708	1.758
lnTassets	Logarithm of total assets	21.87	1.178	17.64	27.39
lnToincomes	Logarithm of total operating income	21.26	1.369	15.51	27.53
Dchangj	Yangtze river economic belt cities dummy variable	0.0853	0.279	0	1
Dprocap	Dummy variables for provincial capital cities or municipalities directly under the central government	0.368	0.482	0	1

In this paper, a difference-in-differences model is constructed to assess the impact of the BRI on green innovation in Chinese manufacturing enterprises. Specifically, the effect of the initiative on green innovation is estimated according to Equation 1, controlling for both individual fixed effects and time fixed effects as well as firm-level and city-level variables; the estimation results are presented in Table 2. The first column of the dependent variable is the number of green inventions applied for, the second column is the number of green inventions obtained, and the third column is the sum of the number of green inventions applied for and obtained. From the results, the BRI has a significant promotion effect at the level of 0.05 ($\beta = 0.0451, p < 0.05$) on the number of applications for green inventions by manufacturing enterprises, a significant promotion effect at the level of 0.1 ($\beta = 0.0269, p < 0.1$), on the number of acquisitions of green inventions, and a significant promotion effect at the level of 0.1 on the number of applications and acquisitions of green inventions by manufacturing enterprises. and a significant contribution effect on the sum of applications and acquisitions of green inventions at the level of 0.05 ($\beta = 0.0512, p < 0.05$). The fourth to sixth columns further control for whether the city where the enterprise is located is a core city in the Yangtze River Economic Belt and whether it is a provincial capital city (or a municipality directly under the central government), and the results remain robust after controlling for city-level variables. The effect on the number of green invention applications and the sum of green invention applications and acquisitions in the manufacturing industry of the BRI remains significant, and the effect on the number of green invention acquisitions is significant at the 0.1 level. From the results of the control variables, the impact of the cash ratio, total assets, gross operating income, and core cities of the Yangtze River Economic Belt on green innovation is significantly positive, while the impact of the total assets growth rate and provincial capital cities (municipalities directly under the central government) on green innovation is negative. From the estimation results of the benchmark model, the “Belt and Road” Initiative does have a catalytic effect on the green innovation level of Chinese manufacturing enterprises, and H1 is supported.

5.2. Parallel trend and placebo test

5.2.1. Parallel trend test

The baseline regression tested the causal effect of the BRI on the green innovation of Chinese manufacturing enterprises, but the validity of the difference-in-differences results must be tested by the parallel trend, so we tested the common trend of the green invention applications of the experimental group and the control group. The results are shown in Figure 2. Before the BRI, the green invention applications of the experimental group and the control group maintained a common growth trend, and after the initiative was proposed, the green invention applications of the experimental group were significantly higher than those of the control group, and the parallel trend test was passed.

TABLE 2 Baseline regression results.

Variables	(1)	(2)	(3)	(4)	(5)	(6)
	LnGreInvia	LnGreInvig	LnGreInviaig	LnGreInvia	LnGreInvig	LnGreInviaig
c.Dcity#c.post	0.0451** (0.0207)	0.0269* (0.0152)	0.0512** (0.0210)	0.0478** (0.0208)	0.0255* (0.0153)	0.0533** (0.0210)
ROAA	−0.0770 (0.0745)	−0.1274** (0.0513)	−0.1208 (0.0796)	−0.0808 (0.0746)	−0.1272** (0.0513)	−0.1244 (0.0798)
OPR	−0.0051 (0.0201)	−0.0061 (0.0118)	−0.0120 (0.0232)	−0.0055 (0.0201)	−0.0060 (0.0118)	−0.0123 (0.0232)
TagrA	−0.0357*** (0.0090)	−0.0180*** (0.0040)	−0.0382*** (0.0087)	−0.0357*** (0.0090)	−0.0180*** (0.0040)	−0.0381*** (0.0087)
OrgrA	0.0001 (0.0003)	−0.0001 (0.0001)	0.0001 (0.0003)	0.0001 (0.0003)	−0.0001 (0.0001)	0.0001 (0.0003)
Cashr	0.0045** (0.0020)	0.0036*** (0.0011)	0.0048** (0.0020)	0.0045** (0.0020)	0.0035*** (0.0011)	0.0048** (0.0020)
Alr	−0.0474 (0.0576)	0.0162 (0.0383)	−0.0406 (0.0582)	−0.0484 (0.0576)	0.0166 (0.0383)	−0.0415 (0.0583)
lnTassets	0.2854*** (0.0261)	0.1223*** (0.0163)	0.3093*** (0.0265)	0.2841*** (0.0261)	0.1228*** (0.0163)	0.3082*** (0.0265)
lnToincomes	0.0423** (0.0193)	−0.0019 (0.0122)	0.0369* (0.0197)	0.0452** (0.0194)	−0.0025 (0.0122)	0.0395** (0.0198)
Dchangj				0.6266*** (0.2393)	0.0314 (0.1207)	0.6093** (0.2556)
Dprocap				−0.2426** (0.1026)	0.0839 (0.0726)	−0.2081* (0.1085)
Constant	−6.6247*** (0.4193)	−2.3968*** (0.2581)	−6.9389*** (0.4166)	−6.6222*** (0.4206)	−2.4281*** (0.2595)	−6.9455*** (0.4183)
Observations	13,424	13,424	13,424	13,424	13,424	13,424
R-squared	0.7446	0.6848	0.7819	0.7447	0.6849	0.7820
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes

Robust standard errors in parentheses.
***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

5.2.2. Placebo test

As the results of the baseline regression may also be affected by aspects such as omitted variables and random factors, we refer to the methods of existing studies (La Ferrara et al., 2012; Li et al., 2016) by randomly generating the reform time and randomly screening the Belt and Road along the core cities and constructing a randomized experiment at both reform time-city levels to conduct a placebo test. Specifically, randomized experiments were conducted according to the fourth column in Table 2, that is, after controlling for individual fixed effects, time-fixed effects, and firm-level and city-level control variables, to examine the effect of randomly generated reform time-city on firms' green invention filings and to judge the reliability of the findings based on the probabilities of the estimated coefficients of the benchmark regressions obtained from the spurious experiments. We repeat the above placebo test 500 times to enhance the validity of the placebo test and finally plot the distribution of the estimated coefficients of the impact of the BRI on the green innovation of manufacturing enterprises to test whether the level of green innovation of Chinese manufacturing enterprises is also affected by factors other than the BRI. If the estimated coefficients of the impact of the BRI on green innovation are distributed at approximately 0 in the randomized experiment, it indicates that the model setting of Equation 1 does not omit sufficiently important factors, and the estimated results in the baseline regression are indeed due to the BRI. The results of the placebo test are shown in Figure 3, where most of the spurious estimated coefficients are distributed at approximately 0, indicating that the randomly generated combination of reform time and city did not have a significant impact on green innovation, there is no serious problem of omitted variables in the benchmark model setting, and the core findings remain robust.

5.3. Robustness tests

5.3.1. Propensity score matching difference-in-differences model analysis

In the baseline regression analysis, we grouped the firms by whether their cities are core cities along the Belt and Road, which may have advantages in terms of transportation conditions or development strength, making them more likely to enter the experimental group (Lu et al., 2021). Baseline regression may have the problem of sample selection bias. To better select the control group, this paper further employs propensity score matching analysis to test the causal relationship between the BRI and corporate green innovation, all other things being equal.

To match the propensity score, a logit model of whether a city is a core city along the "Belt and Road" is established. The model controls for whether the city is a core city in the Yangtze River Economic Belt, whether it is a provincial capital city or a municipality directly under the central government, the city's GDP, the city's population, the local budget revenue, and the city's total industrial output above the limit. The nearest 1:1 matching is adopted to match the Chinese cities, and then the matched samples are used to estimate the difference-in-differences.

Before performing PSM-DID estimation, the validity of the matching method was examined by plotting kernel density plots of the *p* value scores of the experimental and control groups before and after matching. From the kernel density plots, it can be seen that the matched control group can better serve as a counterfactual outcome for causal inference for the treatment group. The kernel density plots are shown in Figures 4, 5.

Table 3 reports the results of the propensity score matched difference-in-differences model analysis, controlling for firm-level

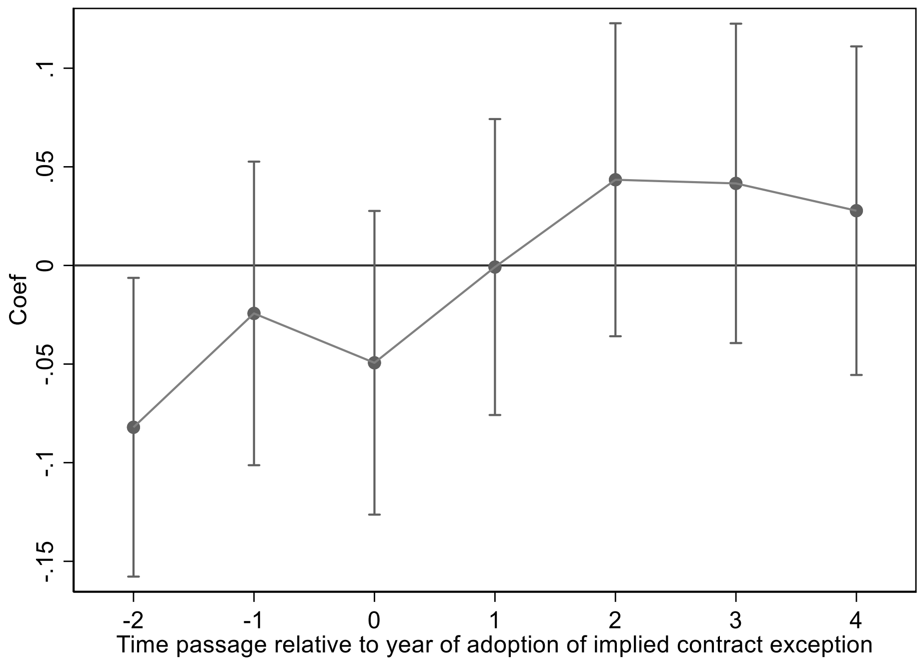

FIGURE 2
Parallel trend test.

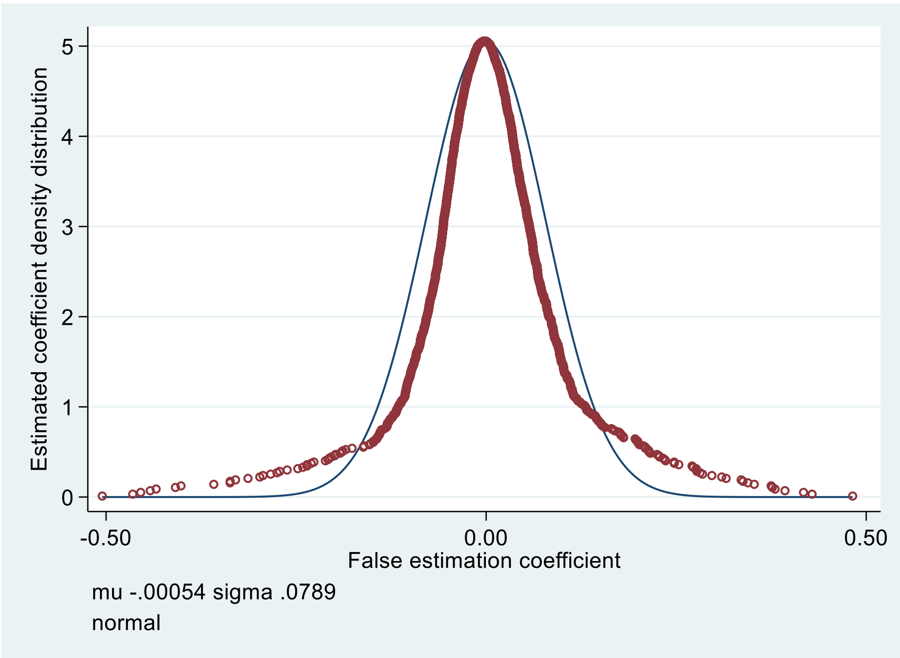

FIGURE 3
Placebo test.

variables in the first column and further controlling for city-level variables in the second column, and the estimation results show that the promotion effect of the BRI on corporate green innovation is significant. In the model controlling only for firm-level variables, the effect of the BRI on green invention applications is significant at the 0.05 level ($\beta = 0.0469, p < 0.05$), the results are still significant at the 0.05 level after controlling for city-level variables ($\beta = 0.0497, p < 0.05$), and the estimation results of the baseline model are still robust.

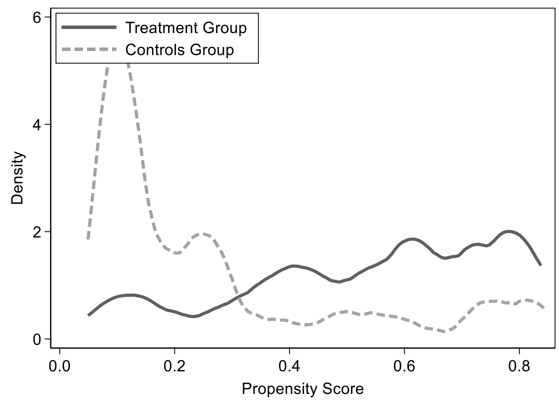

FIGURE 4
p-value fractional Kernel density before matching.

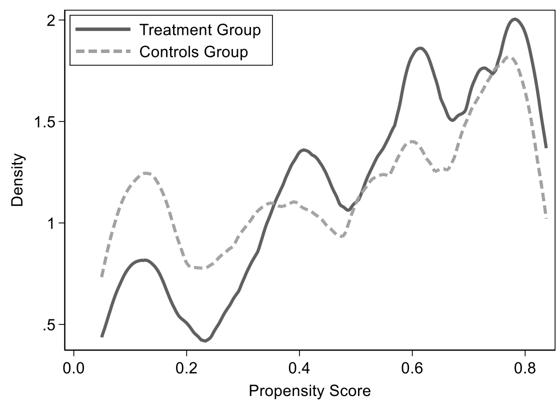

FIGURE 5
P-worthy fractional Kernel density after matching.

5.3.2. Excluding interference from contemporaneous policies

Around the time of the BRI in 2013, there were other policies in China that might affect corporate green innovation. For example, the establishment of the China (Shanghai) Pilot Free Trade Zone in September 2013 and the policy arrangement of expanding the scope of the "VAT reform" pilot in August 2012 will have an impact on enterprise innovation (Liu and Wang, 2018; Wang and Lu, 2019), which may affect the estimation results of the benchmark regression. Therefore, this paper will try to reduce the interference of contemporaneous policies.

(1) Exclude the interference of Shanghai free trade zone

Table 4 reports the effect of the BRI on corporate green innovation after controlling for the Shanghai Free Trade Zone, where Shanghai_after is a dummy variable for the Shanghai Free Trade Zone, which takes the value of 1 for Shanghai after the implementation of the BRI and 0 for Shanghai before. This variable is added to the model as a control variable, representing the effect of controlling for the Shanghai FTA. The first to third columns control for firm-level factors, and the fourth to sixth columns further control for city-level factors. As shown by the results, the effect of the BRI on corporate green innovation is significant after controlling for the effect of the Shanghai Free Trade Zone, and the results of the benchmark regression remain robust.

TABLE 3 PSM-DID estimation results.

Variables	(1)	(2)
	LnGreInvia	LnGreInvia
c.Dcity#c.post	0.0469** (0.0222)	0.0497** (0.0222)
ROAA	−0.0850 (0.0755)	−0.0900 (0.0757)
OPR	−0.0047 (0.0201)	−0.0052 (0.0201)
TagrA	−0.0369*** (0.0092)	−0.0368*** (0.0092)
OrgrA	0.0001 (0.0003)	0.0001 (0.0003)
Cashr	0.0042** (0.0020)	0.0042** (0.0020)
Alr	−0.0407 (0.0606)	−0.0424 (0.0608)
lnTassets	0.2788*** (0.0271)	0.2776*** (0.0271)
lnToincomes	0.0405** (0.0201)	0.0441** (0.0202)
Dchangj		0.7886*** (0.2702)
Dprocap		−0.2440** (0.1039)
Constant	−6.4464*** (0.4396)	−6.4815*** (0.4430)
Observations	12,411	12,411
R-squared	0.7495	0.7497
Firm FE	Yes	Yes
Year FE	Yes	Yes

Robust standard errors in parentheses.
***$p<0.01$, **$p<0.05$, *$p<0.1$.

(2) Excluding the interference of the "VAT Reform" policy

Table 5 reports the effect of the BRI on corporate green innovation after controlling for vat_after. Among them, vat_after is the dummy variable of "VAT reform," and the pilot cities of "VAT reform" are taken as 1 after the BRI and 0 before the initiative. This variable is added to the model as a control variable to represent the effect of controlling for the impact of the "VAT reform" policy. The first to third columns control for firm-level factors, and the fourth to sixth columns further control for city-level factors. From the results, we can see that after controlling for the effect of "VAT reform," except for the insignificant effect of the fifth column on the amount of green inventions, the effect of the BRI on the green innovation of enterprises is significant, and the results of the benchmark regression are basically robust.

5.3.3. Heterogeneity test

(1) Heterogeneity of advanced manufacturing and traditional manufacturing

Although the industries analyzed in this paper include only manufacturing industries, 10 major areas are proposed as key development directions according to the plan of the action program of Made in China 2025 to achieve the goal of manufacturing power. Based on Made in China 2025, this paper identifies advanced and traditional manufacturing industries in China's manufacturing sector with reference to the existing literature (Hongjian et al., 2021) and analyzes their heterogeneous impact on the relationship between the BRI and green innovation.

We constructed a heterogeneous DID model for estimation by constructing triple interaction terms in three dimensions: city-industry-year. Table 6 reports the estimation results of the heterogeneous DID model, where tttt is the city-industry-years

TABLE 4 Excluding the impact of the shanghai free trade zone.

Variables	(1)	(2)	(3)	(4)	(5)	(6)
	LnGreInvia	LnGreInvig	LnGreInviaig	LnGreInvia	LnGreInvig	LnGreInviaig
c.Dcity#c.post	0.0443** (0.0218)	0.0388** (0.0161)	0.0579*** (0.0221)	0.0475** (0.0218)	0.0373** (0.0162)	0.0606*** (0.0221)
shanghai_after	0.0058 (0.0444)	−0.0859*** (0.0318)	−0.0491 (0.0453)	0.0022 (0.0445)	−0.0859*** (0.0319)	−0.0527 (0.0454)
ROAA	−0.0769 (0.0745)	−0.1280** (0.0515)	−0.1212 (0.0796)	−0.0808 (0.0746)	−0.1279** (0.0515)	−0.1249 (0.0798)
OPR	−0.0051 (0.0201)	−0.0059 (0.0118)	−0.0119 (0.0232)	−0.0055 (0.0201)	−0.0059 (0.0118)	−0.0122 (0.0232)
TagrA	−0.0358*** (0.0090)	−0.0176*** (0.0041)	−0.0379*** (0.0088)	−0.0357*** (0.0090)	−0.0175*** (0.0041)	−0.0379*** (0.0088)
OrgrA	0.0001 (0.0003)	−0.0001 (0.0001)	0.0001 (0.0003)	0.0001 (0.0003)	−0.0001 (0.0001)	0.0001 (0.0003)
Cashr	0.0045** (0.0020)	0.0035*** (0.0010)	0.0047** (0.0020)	0.0045** (0.0020)	0.0035*** (0.0010)	0.0048** (0.0020)
Alr	−0.0474 (0.0576)	0.0157 (0.0383)	−0.0410 (0.0582)	−0.0484 (0.0576)	0.0160 (0.0383)	−0.0419 (0.0582)
lnTassets	0.2854*** (0.0261)	0.1218*** (0.0163)	0.3090*** (0.0265)	0.2841*** (0.0261)	0.1222*** (0.0163)	0.3079*** (0.0265)
lnToincomes	0.0423** (0.0193)	−0.0016 (0.0122)	0.0371* (0.0197)	0.0452** (0.0194)	−0.0021 (0.0122)	0.0397** (0.0198)
Dchangj				0.6260*** (0.2398)	0.0566 (0.1127)	0.6247** (0.2505)
Dprocap				−0.2425** (0.1026)	0.0802 (0.0729)	−0.2104* (0.1087)
Constant	−6.6250*** (0.4192)	−2.3923*** (0.2579)	−6.9363*** (0.4163)	−6.6223*** (0.4206)	−2.4254*** (0.2593)	−6.9439*** (0.4181)
Observations	13,424	13,424	13,424	13,424	13,424	13,424
R-squared	0.7446	0.6850	0.7819	0.7447	0.6851	0.7820
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes

Robust standard errors in parentheses.
***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

TABLE 5 Excluding the impact of "VAT reform ".

Variables	(1)	(2)	(3)	(4)	(5)	(6)
	LnGreInvia	LnGreInvig	LnGreInviaig	LnGreInvia	LnGreUmig	LnGreInviaig
c.Dcity#c.post	0.0428** (0.0208)	0.0261* (0.0153)	0.0490** (0.0211)	0.0456** (0.0209)	0.0235 (0.0209)	0.0512** (0.0212)
vat_after	0.0395* (0.0209)	0.0137 (0.0152)	0.0379* (0.0212)	0.0366* (0.0210)	0.0148 (0.0208)	0.0352* (0.0213)
ROAA	−0.0740 (0.0744)	−0.1264** (0.0513)	−0.1180 (0.0794)	−0.0779 (0.0745)	0.0394 (0.0692)	−0.1217 (0.0797)
OPR	−0.0048 (0.0201)	−0.0059 (0.0118)	−0.0117 (0.0232)	−0.0052 (0.0201)	−0.0212* (0.0127)	−0.0120 (0.0232)
TagrA	−0.0358*** (0.0090)	−0.0180*** (0.0040)	−0.0382*** (0.0087)	−0.0358*** (0.0090)	−0.0280*** (0.0082)	−0.0382*** (0.0087)
OrgrA	0.0001 (0.0003)	−0.0001 (0.0001)	0.0001 (0.0003)	0.0001 (0.0003)	0.0003 (0.0003)	0.0001 (0.0003)
Cashr	0.0046** (0.0020)	0.0036*** (0.0011)	0.0049** (0.0020)	0.0047** (0.0020)	0.0051*** (0.0016)	0.0050** (0.0020)
Alr	−0.0487 (0.0575)	0.0158 (0.0383)	−0.0419 (0.0581)	−0.0496 (0.0576)	0.1001* (0.0563)	−0.0427 (0.0582)
lnTassets	0.2852*** (0.0261)	0.1222*** (0.0163)	0.3092*** (0.0265)	0.2840*** (0.0261)	0.2367*** (0.0244)	0.3082*** (0.0265)
lnToincomes	0.0407** (0.0193)	−0.0025 (0.0122)	0.0354* (0.0197)	0.0436** (0.0194)	0.0145 (0.0188)	0.0379* (0.0198)
Dchangj				0.5967** (0.2386)	0.2242 (0.1968)	0.5804** (0.2547)
Dprocap				−0.2339** (0.1021)	0.0936 (0.1076)	−0.1997* (0.1078)
Constant	−6.6042*** (0.4195)	−2.3897*** (0.2581)	−6.9192*** (0.4167)	−6.6024*** (0.4209)	−5.1004*** (0.3985)	−6.9265*** (0.4185)
Observations	13,424	13,424	13,424	13,424	13,424	13,424
R-squared	0.7447	0.6849	0.7820	0.7448	0.7094	0.7821
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes

Robust standard errors in parentheses.
***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

triple interaction term. The coefficients of the triple interaction term are all significant, indicating that the BRI has a more significant effect in promoting green innovation in advanced manufacturing industries than in traditional manufacturing industries. The coefficient of the triple interaction term is significant, which indicates that the BRI promotes green innovation in the advanced manufacturing industry compared with the traditional manufacturing industry.

(2) Heterogeneity of enterprise ownership

In recent years, due to the increasing reform of state-owned enterprises (SOEs), further analysis is needed to determine whether the impact of the BRI on corporate green innovation differs between SOEs and non-SOEs. To this end, we constructed a triple interaction term based on three dimensions, city-ownership-years, and conducted a heterogeneous DID model analysis. Among the three dimensions, enterprise ownership is a dummy variable that takes the value of 1 when it is a state-owned enterprise and 0 otherwise. The estimation results of the heterogeneous DID model are shown in Table 7. Ottt is the city-enterprise ownership-year triple interaction term, and it can be seen from the results that all three interaction terms are significant, indicating that relative to non-SOEs, the BRI has a more significant promotion effect on the green innovation of SOEs.

6. Mechanism analysis

Based on the DID model, we found that the BRI has a significant promotion effect on enterprise green innovation. How does the BRI influence corporate green innovation, and what are the mechanisms of influence? Based on the TOE framework, this section discusses the role of technology, organization and environment at the internal and external levels and analyzes the impact mechanism of the BRI on green innovation in enterprises.

6.1. The role of technical factors

To examine the role of technology factors in the relationship between the BRI and corporate green innovation, we analyze the technology factors of enterprises from the perspective of skilled employees and use the percentage of R&D employees as an indicator of technology factors. We construct a heterogeneous DID model by constructing a triple interaction term with three dimensions: city-skilled employee ratio-years. The estimation results are reported in Table 8, where RNDpr_ttt is the triple interaction term with a significantly positive coefficient. The results show that the promotion effect of the BRI on green innovation is more significant for firms with a higher percentage of R&D employees than for those with a lower percentage of R&D employees, and the results test the role of the technology factor, which is supported by H2.

To further analyze the role of technology factors in the BRI, we conducted a difference-in-differences analysis with the percentage of R&D personnel as the dependent variable, and the results are shown in Table 9 ($\beta = 1.0431, p < 0.01$), indicating that the BRI has strengthened the investment in R&D personnel in core cities, which in turn has enhanced the promotion effect of the initiative on green innovation in manufacturing enterprises.

6.2. The role of R&D expenditures

According to the TOE framework, corporate R&D expenditures will also have an impact on corporate green innovation, so we examine

TABLE 6 Industry heterogeneity.

Variables	(1)	(2)	(3)	(4)	(5)	(6)
	LnGreInvia	LnGreInvig	LnGreInviaig	LnGreInvia	LnGreInvig	LnGreInviaig
ttt	0.1094*** (0.0316)	0.0986*** (0.0232)	0.1301*** (0.0323)	0.1094*** (0.0315)	0.0987*** (0.0232)	0.1302*** (0.0322)
tt	−0.0190 (0.0249)	−0.0310 (0.0190)	−0.0251 (0.0259)	−0.0164 (0.0249)	−0.0327* (0.0190)	−0.0231 (0.0259)
ROAA	−0.0620 (0.0729)	−0.1205** (0.0497)	−0.1055 (0.0768)	−0.0667 (0.0730)	−0.1207** (0.0497)	−0.1101 (0.0770)
OPR	−0.0048 (0.0197)	−0.0057 (0.0116)	−0.0114 (0.0226)	−0.0052 (0.0196)	−0.0056 (0.0115)	−0.0118 (0.0227)
TagrA	−0.0365*** (0.0083)	−0.0181*** (0.0042)	−0.0390*** (0.0080)	−0.0364*** (0.0083)	−0.0180*** (0.0042)	−0.0389*** (0.0080)
OrgrA	−0.0000 (0.0003)	−0.0001 (0.0001)	−0.0000 (0.0003)	−0.0000 (0.0003)	−0.0001 (0.0001)	−0.0000 (0.0003)
Cashr	0.0043** (0.0019)	0.0034*** (0.0010)	0.0046** (0.0020)	0.0043** (0.0020)	0.0033*** (0.0010)	0.0046** (0.0020)
Alr	−0.0635 (0.0580)	0.0069 (0.0385)	−0.0575 (0.0585)	−0.0652 (0.0580)	0.0066 (0.0385)	−0.0591 (0.0585)
lnTassets	0.2797*** (0.0255)	0.1200*** (0.0159)	0.3028*** (0.0259)	0.2784*** (0.0254)	0.1206*** (0.0159)	0.3017*** (0.0258)
lnToincomes	0.0474** (0.0193)	−0.0003 (0.0121)	0.0423** (0.0196)	0.0505*** (0.0193)	−0.0006 (0.0121)	0.0452** (0.0196)
Dchangj				0.7397*** (0.2123)	0.1625 (0.1015)	0.7612*** (0.2162)
Dprocap				−0.2397** (0.1032)	0.0884 (0.0739)	−0.2058* (0.1101)
Constant	−6.6050*** (0.4113)	−2.3783*** (0.2576)	−6.9067*** (0.4083)	−6.6155*** (0.4134)	−2.4299*** (0.2596)	−6.9319*** (0.4108)
Observations	13,423	13,423	13,423	13,423	13,423	13,423
R-squared	0.7465	0.6870	0.7839	0.7467	0.6871	0.7841
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes

Robust standard errors in parentheses.
$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

TABLE 7 Business ownership heterogeneity.

Variables	(1)	(2)	(3)	(4)	(5)	(6)
	LnGreInvia	LnGreInvig	LnGreInviaig	LnGreInvia	LnGreInvig	LnGreInviaig
Ottt	0.0764** (0.0354)	0.0922*** (0.0277)	0.0831** (0.0361)	0.0791** (0.0353)	0.0917*** (0.0278)	0.0856** (0.0360)
Ott	0.0226 (0.0230)	−0.0002 (0.0165)	0.0269 (0.0234)	0.0246 (0.0231)	−0.0014 (0.0165)	0.0284 (0.0234)
ROAA	−0.0788 (0.0748)	−0.1301** (0.0517)	−0.1231 (0.0799)	−0.0828 (0.0750)	−0.1300** (0.0517)	−0.1268 (0.0801)
OPR	−0.0051 (0.0201)	−0.0061 (0.0119)	−0.0120 (0.0233)	−0.0055 (0.0201)	−0.0061 (0.0118)	−0.0123 (0.0233)
TagrA	−0.0356*** (0.0090)	−0.0183*** (0.0039)	−0.0380*** (0.0087)	−0.0356*** (0.0090)	−0.0182*** (0.0039)	−0.0380*** (0.0087)
OrgrA	0.0001 (0.0003)	−0.0001 (0.0001)	0.0001 (0.0003)	0.0001 (0.0003)	−0.0001 (0.0001)	0.0001 (0.0003)
Cashr	0.0042** (0.0019)	0.0032*** (0.0010)	0.0045** (0.0020)	0.0043** (0.0019)	0.0032*** (0.0010)	0.0045** (0.0020)
Alr	−0.0430 (0.0576)	0.0216 (0.0382)	−0.0360 (0.0581)	−0.0439 (0.0576)	0.0218 (0.0382)	−0.0367 (0.0582)
lnTassets	0.2855*** (0.0262)	0.1226*** (0.0163)	0.3093*** (0.0266)	0.2842*** (0.0262)	0.1231*** (0.0163)	0.3082*** (0.0266)
lnToincomes	0.0431** (0.0194)	−0.0008 (0.0122)	0.0378* (0.0198)	0.0461** (0.0194)	−0.0013 (0.0122)	0.0405** (0.0198)
Dchangj				0.6423*** (0.2371)	0.0495 (0.1175)	0.6260** (0.2530)
Dprocap				−0.2496** (0.1034)	0.0755 (0.0730)	−0.2157** (0.1093)
Constant	−6.6440*** (0.4224)	−2.4282*** (0.2601)	−6.9561*** (0.4194)	−6.6425*** (0.4237)	−2.4586*** (0.2615)	−6.9635*** (0.4211)
Observations	13,349	13,349	13,349	13,349	13,349	13,349
R-squared	0.7440	0.6846	0.7814	0.7442	0.6846	0.7815

Robust standard errors in parentheses.
***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

TABLE 8 The role of R&D staff share.

Variables	(1)	(2)
	LnGreInvia	LnGreInviaig
RNDpr_ttt	0.0925*** (0.0247)	0.1096*** (0.0245)
RNDpr_tt	0.0002 (0.0231)	−0.0031 (0.0232)
ROAA	−0.0771 (0.0744)	−0.1206 (0.0794)
OPR	−0.0055 (0.0199)	−0.0124 (0.0230)
TagrA	−0.0349*** (0.0090)	−0.0372*** (0.0088)
OrgrA	0.0001 (0.0003)	0.0001 (0.0003)
Cashr	0.0047** (0.0020)	0.0050** (0.0021)
Alr	−0.0566 (0.0577)	−0.0514 (0.0582)
lnTassets	0.2823*** (0.0261)	0.3061*** (0.0265)
lnToincomes	0.0448** (0.0193)	0.0391** (0.0197)
Dchangj	0.6359*** (0.2320)	0.6203** (0.2467)
Dprocap	−0.2391** (0.1028)	−0.2040* (0.1087)
Constant	−6.5761*** (0.4208)	−6.8917*** (0.4184)
Observations	13,423	13,423
R-squared	0.7451	0.7824
Firm FE	Yes	Yes
Year FE	Yes	Yes

Robust standard errors in parentheses.
***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

the role of corporate R&D expenditures in the relationship between the BRI and corporate green innovation. We constructed a heterogeneous DID model by constructing a triple interaction term with three dimensions: city-R&D expenditure-years. Table 10 reports the estimation results, where RND_ttt is the triple interaction term and its coefficient is significantly positive. The results show that the promotion effect of the BRI on green innovation is more significant for firms with higher R&D expenditures than for those with lower R&D expenditures, and H3 is supported.

To further analyze the role of organizational factors in the BRI, we conducted a difference-in-differences analysis using R&D expenditure (logarithm) as the dependent variable, and the results are shown in Table 11. The BRI significantly boosted the R&D expenditures of manufacturing enterprises ($\beta = 0.0631$, $p < 0.05$), suggesting that the BRI has strengthened the R&D expenditures of enterprises in core cities, which in turn has enhanced its impact on the promotion effect of the initiative on green innovation in manufacturing enterprises.

6.3. The role of government support and subsidies

(1) The role of policy support

According to the TOE framework, government support, as an external factor, affects firm innovation. In this paper, we analyze the role of government support in terms of policy support from local governments and government subsidies. In the difference-in-differences model constructed in this paper, whether enterprises participate in Belt and Road construction is grouped by whether their locations are core cities along the Belt and Road route. This grouping plan actually highlights the principle that China will give full play to the comparative advantages of each domestic region to promote the construction of the Belt and Road, as mentioned in the Vision. When considering local advantages, the policy support of local governments for Belt and Road construction will have an

TABLE 9 Impact of the BRI on the share of R&D employees in enterprises.

Variables	RDpr
c.Dcity#c.post	1.0431*** (0.2297)
ROAA	−2.6528*** (0.8574)
OPR	−0.4049** (0.1748)
TagrA	−0.2011** (0.0993)
OrgrA	−0.0087** (0.0039)
Cashr	−0.2730*** (0.0950)
Alr	0.1842 (0.7639)
lnTassets	1.4301*** (0.3060)
lnToincomes	0.6569** (0.2626)
Dchangj	1.8735 (3.3717)
Dprocap	−1.5826 (1.7194)
Constant	−37.1575*** (4.5837)
Observations	13,423
R-squared	0.7627
Firm FE	Yes
Year FE	Yes

Robust standard errors in parentheses.
$^{***}p<0.01$, $^{**}p<0.05$, $^{*}p<0.1$.

TABLE 11 Impact of BRI on enterprise R&D expenditure.

Variables	lnRDexp
c.Dcity#c.post	0.0631** (0.0247)
ROAA	−0.0050 (0.1360)
OPR	−0.0633** (0.0258)
TagrA	−0.0544*** (0.0086)
OrgrA	−0.0001 (0.0003)
Cashr	0.0019 (0.0020)
Alr	−0.3926*** (0.0846)
lnTassets	0.4220*** (0.0354)
lnToincomes	0.4785*** (0.0320)
Dchangj	0.8465** (0.4006)
Dprocap	−0.1953 (0.2982)
Constant	−1.5947*** (0.5137)
Observations	12,699
R-squared	0.8918
Firm FE	Yes
Year FE	Yes

Robust standard errors in parentheses.
$^{***}p<0.01$, $^{**}p<0.05$, $^{*}p<0.1$.

TABLE 10 The role of R&D expenditures.

Variables	(1)	(2)
	LnGreInvia	LnGreInviaig
RND_ttt	0.2811*** (0.0351)	0.2797*** (0.0350)
RND_tt	−0.0288 (0.0212)	−0.0229 (0.0216)
ROAA	−0.0821 (0.0744)	−0.1258 (0.0787)
OPR	−0.0044 (0.0198)	−0.0112 (0.0230)
TagrA	−0.0335*** (0.0090)	−0.0359*** (0.0088)
OrgrA	0.0001 (0.0003)	0.0001 (0.0003)
Cashr	0.0036** (0.0018)	0.0039** (0.0019)
Alr	−0.0349 (0.0572)	−0.0280 (0.0578)
lnTassets	0.2770*** (0.0257)	0.3012*** (0.0261)
lnToincomes	0.0405** (0.0192)	0.0349* (0.0196)
Dchangj	0.6600*** (0.2253)	0.6424*** (0.2412)
Dprocap	−0.2603** (0.1058)	−0.2257** (0.1115)
Constant	−6.3660*** (0.4110)	−6.6905*** (0.4091)
Observations	13,424	13,424
R-squared	0.7469	0.7839
Firm FE	Yes	Yes
Year FE	Yes	Yes

Robust standard errors in parentheses.
$^{***}p<0.01$, $^{**}p<0.05$, $^{*}p<0.1$.

important impact on the effect of the BRI. We refer to the study of Lu et al. (2021) and use the research report of the Belt and Road Data Center of China National Information Center (2016) to group the top 10 provinces in terms of policy support as high. The top 10 provinces in the report are considered to be high policy support provinces while the other provinces are considered to be low policy support provinces, and the triple interaction term of city-policy support-years is constructed to analyze the heterogeneity DID model. The estimated results are shown in Table 12, where pro_ttt is the city-policy support-years triple interaction term with a significantly positive estimated coefficient. The heterogeneous DID model examines the role of policy support at the provincial level and shows that the promotion effect of the BRI on corporate green innovation is marginally significant at the level of 0.1 in provinces with higher policy support compared to provinces with lower policy support.

(2) The role of government subsidies

In addition, we examine the role of government subsidies in the relationship between the BRI and corporate green innovation. We construct a heterogeneous DID model by constructing a triple interaction term with three dimensions: city-government subsidy-years. Table 13 reports the estimation results, where gra_ttt is the triple interaction term with a significant positive coefficient. The results indicate that the promotion effect of the BRI on green innovation is more significant for firms with higher government subsidies than for those with lower government subsidies, and H4 is supported.

To further analyze the role of environmental factors in the BRI, we conducted a difference-in-differences analysis with government subsidies as the dependent variable, and the results are shown in Table 14 ($\beta = 1.1247\text{e}+07, p < 0.01$), indicating that the BRI strengthens the government subsidies of enterprises in core cities, which in turn enhances the promotion effect of the initiative on the green innovation of manufacturing enterprises.

TABLE 12 The role of policy support efforts.

Variables	(1)	(2)
	LnGreInvia	LnGreInviaig
pro_ttt	0.0608* (0.0345)	0.0577 (0.0355)
pro_tt	0.0096 (0.0307)	0.0181 (0.0316)
ROAA	0.0592 (0.0657)	−0.0023 (0.0645)
TagrA	0.0072 (0.0084)	0.0079 (0.0084)
OrgrA	0.0004 (0.0004)	0.0005 (0.0004)
Cashr	0.0025* (0.0015)	0.0026* (0.0015)
Constant	0.4982*** (0.0083)	0.5963*** (0.0084)
Observations	13,424	13,424
R-squared	0.7337	0.7715
Firm FE	Yes	Yes
Year FE	Yes	Yes

Robust standard errors in parentheses.
***$p<0.01$, **$p<0.05$, *$p<0.1$.

TABLE 13 The role of government grants.

Variables	(1)	(2)
	LnGreInvia	LnGreInviaig
gra_ttt	0.1225*** (0.0277)	0.1322*** (0.0277)
gra_tt	0.0139 (0.0212)	0.0174 (0.0216)
ROAA	−0.0825 (0.0751)	−0.1278 (0.0799)
OPR	−0.0058 (0.0200)	−0.0125 (0.0232)
TagrA	−0.0346*** (0.0090)	−0.0367*** (0.0088)
OrgrA	0.0001 (0.0003)	0.0001 (0.0003)
Cashr	0.0044** (0.0020)	0.0047** (0.0020)
Alr	−0.0583 (0.0581)	−0.0481 (0.0586)
lnTassets	0.2815*** (0.0260)	0.3041*** (0.0265)
lnToincomes	0.0474** (0.0194)	0.0416** (0.0198)
Dprocap	−0.2890** (0.1266)	−0.2613** (0.1267)
Constant	−6.5386*** (0.4179)	−6.8257*** (0.4161)
Observations	13,424	13,424
R-squared	0.7462	0.7832
Firm FE	Yes	Yes
Year FE	Yes	Yes

Robust standard errors in parentheses.
***$p<0.01$, **$p<0.05$, *$p<0.1$.

7. Conclusion and implications

7.1. Discussion

Through the analysis of DID, this paper finds that the BRI has promoted the green innovation of Chinese manufacturing enterprises, and this result is still robust after the placebo test and robustness test. This result is a strong response to the discussion on the relationship between the BRI and sustainable development in the existing literature (Hu et al., 2023; Zhang et al., 2023). Based on the existing literature on the BRI and renewable energy consumption (Fang et al., 2022), ecological environment (Zhang et al., 2021), sustainable development goals (Senadjki et al., 2022), this paper adds evidence that the BRI promotes green innovation in manufacturing enterprises. The results of heterogeneity analysis show that the BRI plays a stronger role in promoting green innovation in advanced manufacturing industries and state-owned enterprises, and this result can provide a basis for government decision-making. Mechanism analysis is based on the TOE framework, discovering the roles of technology, research and development, and government support. The research results add insightful explanations to existing research on the impact mechanism of green innovation in enterprises (Yin et al., 2022). In addition, the research results of this paper can also provide reference for the development of green innovation in other regions, such as the Pacific Rim region (West and Von Geusau, 2019). In fact, smart specialization in Europe also places great emphasis on the role of policy support in innovation (Balland et al., 2019; Pintar and Scherngell, 2022).

7.2. Conclusion

This paper joins the discussion on the relationship between the BRI and sustainable development by studying the impact of the Initiative on green innovation in Chinese manufacturing enterprises. Based on the core cities along the Belt and Road, we use the difference-in-differences method to identify the causal relationship between the BRI and the green innovation of Chinese manufacturing enterprises and analyze the impact mechanism. Through empirical analysis, we found that (1) the BRI has a significant promotion effect on the green innovation of Chinese manufacturing enterprises. The BRI has significantly increased the number of green invention applications by manufacturing enterprises in core cities along the route, and there is also a significant promotion effect in the total number of green patents (the sum of green invention applications and green inventions obtained), which remains robust after the propensity score matching difference-in-differences analysis, excluding contemporaneous policy interference and heterogeneity analysis. (2) In the benchmark regression, the BRI has a marginally significant impact on the amount of green inventions obtained by enterprises after controlling for the effect of the Shanghai Free Trade Zone in the same period. (3) The results of the heterogeneity test reveal that the BRI has a more significant effect on promoting green innovation in advanced manufacturing enterprises than in traditional manufacturing industries. Compared with nonstate-owned enterprises, the promotion effect of the BRI on the green innovation of state-owned enterprises is more significant. (4) The mechanism analysis shows that the TOE framework explains the impact mechanism of the BRI on green innovation in Chinese manufacturing firms. The BRI has led companies in the core cities to increase their focus on skilled employees, and through the knowledge they bring to the table, the BRI has had an enhanced effect on green innovation in Chinese manufacturing companies. The BRI has prompted enterprises in the core cities to increase their R&D expenditures and enhance their innovation capabilities by strengthening R&D, which has enhanced the green innovation effect of the BRI on Chinese manufacturing enterprises. The BRI has strengthened government support for enterprises by increasing

TABLE 14 Impact of the BRI on government subsidies for enterprises.

Variables	govgrants
c.Dcity#c.post	1.1247e+07*** (3746333.6866)
ROAA	1.3460e+07 (1.2935e+07)
OPR	−2.7104e+06 (1,747,288.3118)
TagrA	−6.2097e+06*** (1,241,305.2326)
OrgrA	19,306.6042 (22,988.1522)
Cashr	155,844.7250 (126,575.5345)
Alr	−2.0970e+07* (1.0760e+07)
lnTassets	4.4382e+07*** (6,522,303.1575)
lnToincomes	−5.4659e+06 (3,887,224.5251)
Dprocap	−3.3426e+06 (3.5821e+07)
Constant	−8.0907e+08*** (9.2210e+07)
Observations	12,802
R-squared	0.6753
Firm FE	Yes
Year FE	Yes

Robust standard errors in parentheses.
***$p<0.01$, **$p<0.05$, *$p<0.1$.

subsidies for enterprises, which has enhanced the effect of the BRI in promoting green innovation in Chinese manufacturing enterprises.

7.3. Theoretical contributions

This paper uses a difference-in-differences approach to assess the impact of the BRI on green innovation in Chinese manufacturing enterprises, enriching the study of the relationship between the BRI and sustainable development, with the following major marginal contributions: (1) This paper analyzes the impact of the BRI on the green innovation of Chinese manufacturing enterprises at the level of manufacturing enterprises, providing a new micro perspective on the relationship between the BRI and sustainable development on the basis of the existing macrolevel research. (2) This paper uses the difference-in-differences method to assess the impact of the BRI on the green innovation of Chinese manufacturing enterprises and identifies the causal relationship between the BRI and green innovation by using the core cities of the Belt and Road in China as the recipients of exogenous shocks. (3) Based on the TOE framework, this paper analyzes the impact mechanism of the BRI on the green innovation of Chinese manufacturing enterprises and examines the TOE mechanism at both the internal and external levels, revealing a new micro mechanism for the study of the relationship between the BRI and sustainable development.

7.4. Policy implications

(1) Actively promoting the participation of enterprises and striving to promote green transformation. Manufacturing enterprises can enhance their green innovation level by actively participating in the construction of the Belt and Road. This paper finds that the BRI can significantly improve the green innovation level of manufacturing enterprises in core cities along the route, indicating that participation in Belt and Road construction is an important way to improve the green innovation level of manufacturing enterprises. As important implementers of Belt and Road construction, enterprises should further increase their participation, expand overseas markets, enhance international management capabilities, achieve economies of scale and improve technical efficiency. Manufacturing enterprises in core cities can strengthen green technology exchange and sustainable development cooperation with developed countries along the Belt and Road, absorb advanced production concepts and technologies, and improve green innovation capabilities.

(2) Focusing on the development of advanced manufacturing vigorously promotes the upgrading of state-owned enterprises. Advanced manufacturing enterprises and state-owned enterprises should become an important force in the construction of the Green Silk Road. This paper finds that the BRI can enhance the green innovation level of advanced manufacturing enterprises and state-owned enterprises; therefore, the policy should encourage and support advanced manufacturing enterprises and state-owned enterprises to participate in Belt and Road construction. The current global science and technology innovation has entered a period of unprecedented intensity and activity, and a new phase of scientific and technological revolution and industrial change is reshaping the global innovation map and the global economic structure. By participating in Belt and Road construction, Chinese advanced manufacturing enterprises and state-owned enterprises can more rationally integrate into global industrial and value chains, upgrade their manufacturing processes, optimize their production processes, produce more energy-efficient and high-end products, continuously promote the level of green innovation in their enterprises, and promote the sustainable development process along the Belt and Road.

(3) Continuously improve the innovation mechanism and provide solid talent guarantees. Provide talent guarantees for enterprises' green innovation by improving the innovation mechanism. This paper finds that enterprises with a high proportion of R&D staff have a stronger promotion effect of the BRI on green innovation, so building a high-level R&D workforce is crucial to improve the green innovation capacity of enterprises. First, from the perspective of core cities along the route, the cities should strengthen ecological supervision, refine supervision measures, improve innovation mechanisms and reduce green innovation costs; these cities should recruit high-level talent from overseas and establish an effective talent recruitment mechanism. Second, at the enterprise level, enterprises can start with recruitment, training, incentive and international exchange to vigorously attract innovative talent and improve knowledge reserves to provide human resource guarantees for green innovation and sustainable development.

(4) Improving and optimizing R&D structure and effectively guaranteeing financial support. R&D structure and R&D capital expenditure are the key elements of green innovation. This paper finds that for manufacturing enterprises with strong R&D expenditures, the BRI has a stronger effect on green innovation, so the expenditures of R&D manufacturing enterprises should be enhanced. In terms of the composition of R&D structure, local governments should invest more in R&D and encourage enterprises, universities and other R&D institutions to increase their R&D

expenditures. In addition, R&D distribution structures should be kept rational to avoid resource redundancy and overlap to reduce waste, improve factor utilization, and provide financial security for sustainable development.

(5) Implementing the green concept and strengthening and consolidating policy foundation. The policy support of local governments should be enhanced to provide policy support and economic subsidies for achieving SDGs. This paper finds that provinces with strong local government support have a stronger effect of the BRI in promoting green innovation in manufacturing enterprises; the higher the government subsidies, the stronger the effect of the BRI in promoting green innovation in enterprises. Therefore, the support of local governments should be enhanced. In terms of the development concept, local governments need to adhere to the concept of sustainable development and strive to fully integrate the concept of ecological civilization and green development into economic and trade cooperation. In terms of development and construction, they can support the construction of a number of green industry cooperation demonstration bases, green technology exchange and transfer bases, technology demonstration and promotion bases, science and technology parks and other international green industry cooperation platforms to create a Belt and Road Green supply chain platform. In terms of financial support, they can actively participate in subsidizing manufacturing enterprises' Belt and Road construction. On the one hand, this can provide support to manufacturing enterprises to reduce their negative impact on the environment, and on the other hand, it can also establish an effective green development pattern in Belt and Road construction where ecological and environmental protection and economic and trade cooperation complement each other.

7.5. Limitations and future research directions

This paper also has the following limitations. First, this paper assesses the impact of the BRI on green innovation in Chinese manufacturing enterprises from the perspective of production processes, but the literature also points out that green innovation includes not only innovation in production processes but also in management methods (Horbach et al., 2013), and digital green innovation (Yin and Yu, 2022). Therefore, in the future, the scope of the study can be expanded to include management innovation and digital green innovation to analyze the impact of the BRI on corporate green innovation. Second, this paper focuses on the impact of the BRI on green innovation in Chinese manufacturing enterprises but does not discuss the impact of the BRI on green innovation in the countries along the route, although the impact of the BRI on green innovation in the countries along the route has already been discussed in the literature. Although the impact of the BRI on environmental issues such as carbon emissions has been discussed from the perspective of the countries along the route (Chen et al., 2021a), few studies have focused on green innovation. Future studies can assess the impact of the BRI on green innovation in countries along the route. Third, this paper analyzes the impact of the BRI on the green innovation of manufacturing enterprises using the core cities along the Belt and Road in China as a grouping variable. Although it discusses the heterogeneity of advanced manufacturing and enterprise ownership at the enterprise level, it does not analyze the spatial and temporal heterogeneity at the regional level. Although the heterogeneity between advanced manufacturing and firm ownership was discussed by this paper at the firm level, spatiotemporal heterogeneity was not analyzed at the regional level (Zhou et al., 2021), and future studies could incorporate spatiotemporal heterogeneity into the analysis.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding authors.

Author contributions

XC contributed to conceptualization, formal analysis, funding acquisition, methodology, and writing – original draft preparation. FZ contributed to conceptualization, formal analysis, funding acquisition, and writing—original draft preparation. YW and YD contributed to data curation and formal analysis. HZ contributed to conceptualization, formal analysis, and writing–original draft preparation. XH contributed to conceptualization, funding acquisition, and writing—review and editing. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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