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# Can climate policy promote high-quality development of enterprises? Evidence from China

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Climate policy is of great importance for China's climate goals of achieving peak carbon emissions by 2030 and carbon neutrality by 2060. However, whether the climate policy can consider economic performance and achieve high-quality economic development remains to be tested. Based on the perspective of high-quality economic development, this study takes three batches of low-carbon city pilots in China as a quasi-natural experiment and uses time-varying difference-in-differences to examine the impact of climate policy on high-quality development of enterprises. The findings show that the current climate policy in general does not promote the high-quality development of enterprises, when comprehensively considering the gradually strengthening regulation intensity of pilot policy in batches. The result holds after a battery of robustness tests. Further analysis shows that the economic mechanism behind it lies in that the environmental regulation arising from the climate policy only triggers the "compliance costs effect" instead of the "innovation offset effect." It also finds that the inhibition effect of climate policy on high-quality development is more pronounced for non-state-owned enterprises, small-scale enterprises, and the sample with strong local environmental law enforcement. The findings of this study would complement existing theoretical research *via* evaluating the effectiveness of China's current low-carbon policy at the micro level and provide policy implications for the implementation of future climate policies so as to mitigate climate change and achieve high-quality economic development. In addition, our estimation strategy can serve as a scientific reference for similar studies in other developing countries.

KEYWORDS

**climate policy, time-varying difference-in-differences, high-quality economic development, peak carbon emissions and carbon neutrality, low-carbon city pilot policy**

## 1 Introduction

Major climate changes will have significant impacts on human survival and global sustainable development (Zheng et al., 2020). China has become the world's largest emitter of $CO_2$ since 2016. In 2018, the average $CO_2$ emissions of all provinces and regions in China reached 394.53 million tons[1]. In order to achieve sustainable economic development and

1 Excluding Tibet, Taiwan, Hong Kong, and Macao.

highlight its role as a major country in the construction of the world's ecological environment, China attempts to explore climate policies at the city level, notably the low-carbon city pilot policy (LCCPP). In August 2010, China initially launched a low-carbon pilot project in five provinces and eight cities. Drawing on the successful experience of the first batch of low-carbon city pilots[2], China further expanded the pilot scope in 2012 and released the list of the second batch of low-carbon city pilots[3], including one province and 28 cities. The pilot scope was expanded again in 2017[4]. Up to now, a total of six provinces, 78 cities, two counties, and one region have been involved in the low-carbon pilot areas. On this basis, China has, for the first time, proposed the long-term strategic goal of "peaking carbon emissions by 2030 and achieving carbon neutrality by 2060" at the 75th Session of the United Nations General Assembly in 2020. A series of climate policy implementation not only demonstrates China's determination to participate in global environmental governance but also lead to profound changes in the way enterprises operate.

In fact, China's climate policy is not only to reduce carbon emissions but also to take into account economic performance to explore a win–win path between environmental and economic performances, eventually to achieve high-quality economic development. Under this version, the LCCPP or the target of peaking carbon emissions by 2030 and achieving carbon neutrality by 2060 would not only further challenge the development of enterprises but also become an important opportunity for the industry's future green and high-quality development. As an important participant in the construction of low-carbon cities, enterprises would promote and apply low-carbon technologies, putting into effect carbon emission reduction. In other words, enterprises may be the most direct object affected by climate policies. Taking climate policy as a strategic opportunity to improve economic performance and promoting productivity of enterprises by releasing the enthusiasm and creativity to participate in the implementation of climate action are the key to improving enterprise development resilience and competitiveness in the new development stage. Therefore, it would be of great interest to explore whether China's current low-carbon policy can promote high-quality development of micro-enterprises that balances environmental protection and economic efficiency and to explore the economic mechanism behind it.

As a kind of climate policy, LCCPP can also be seen as a means of government environmental regulation. Confronted with increasingly stringent environmental regulation, there have been many debates on their impacts on enterprise behaviors. One important branch of the literature focused on relationship between environmental regulation and high-quality development of enterprises based on the compliance costs hypothesis and the Porter hypothesis. More specifically, high-quality development of enterprises is a transition from denotative growth to connotative growth, which is mostly reflected in the improvement of total factor productivity (TFP) (Xue et al., 2022; Dong et al., 2021; Ge et al., 2022). Neoclassical economics school believed that the implementation of environmental regulations would bring economic burden on enterprises for pollution control to a certain extent, forcing enterprises to allocate more resources to the field of pollution control and squeezing out production resources (Gray, 1987). Thus, at least in the short-term, the implementation of environmental regulation may reduce the production efficiency and competitiveness of enterprises, which has been confirmed by Walley and Whitehead (1994), Gray and Shadbegian (2003), and other scholars. On the contrary, the "Porter hypothesis" proposed that strict and appropriate environmental regulations could improve their production efficiency through such transmission channels as innovation offset effect and optimal allocation of resources (Porter and Van der Linde, 1995; Li N et al., 2022; Peng and Zhang, 2022). In addition, there are also a few studies combining these two views that environmental regulation only plays a positive role in specific areas due to differences in policy choice timing and institutional environment (Berman and Bui, 2001).

Continuing the aforementioned theoretical logic, the current literature studies the evaluation of the economic effects of the LCCPP from the aspects of green technological innovation of enterprises, foreign direct investment, and green GDP (Cheng et al., 2019; Gao et al., 2022); some existing studies have analyzed the impact of LCCPP on the TFP of enterprises (Chen et al., 2021; Shen et al., 2021) and have found a positive relationship between them. Due to the limitations of the research sample and other factors, however, they only examined the effects of the first two batches of low-carbon city pilot policies using the standard difference-in-differences (DID) approach. Less attention has been paid to the possible estimation deviation induced by the change of regulation intensity among different batches of pilot policies. In reality, different from other climate policies, LCCPP has adopted the "pilot-diffusion" mechanism to achieve effective carbon emission. Thus, the three batches of low-carbon city pilots carried out successively reflect the pilot path from small to large, from weak to gradually strengthened. For example, compared with the first two batches of pilot policies, the third batch further expanded the pilot scope and continuously improved the intensity of the policy, such as clearly proposing the carbon emission peak target and declaring construction system target including 14 indicators as total carbon emissions and carbon emissions per unit GDP (Table 1). The expansion of the pilot scope and the strengthening of policy intensity may affect the benefits and behaviors of enterprises; thus, whether the LCCPP improve the high-quality development of enterprises remains to be further verified. Faced with a lack of literature that approaches the economic performance of climate policy when comprehensively considering the gradually strengthening regulation intensity of policies, we explore the following question—Can climate policy promote high-quality

2 The first batch of pilot areas include Guangdong, Hubei, Liaoning, Shaanxi, Yunnan, Tianjin, Chongqing, Shenzhen, Xiamen, Hangzhou, Nanchang, Guiyang, and Baoding.

3 The second batch of pilot areas include Beijing, Shanghai, Hainan, Shijiazhuang, Qinhuangdao, Jincheng, Hulunbuir, Jilin, greater Hinggan Mountains, Suzhou, Huai'an, Zhenjiang, Ningbo, Wenzhou, Chizhou, Nanping, Jingdezhen, Ganzhou, Qingdao, Jiyuan, Wuhan, Guangzhou, Guilin, Guangyuan, Zunyi, Kunming, Yan'an, Jinchang, and Urumqi.

4 The third batch of pilot areas include Wuhai, Shenyang, Dalian, Chaoyang, Xunke, Nanjing, Changzho, Jiaxing, Jinhua, Quzhou, Hefei, Huaibei, Huangshan, Lu'an, Xuancheng, Sanming, Gongqing, Ji'an, Fuzhou, Jinan, Yantai, Weifang, Changyang, Xiangtan, Chenzhou, Changsha, Zhuzhou, Zhongshan, Liuzhou, Sanya, Qiongzhong, Chengdu, Yuxi, Pu'er, Lhasa, Ankang, Lanzhou, Dunhuang, Xining, Yinchuan, Wuzhong, Changji, Yining, Hotan, and Ala'er.

TABLE 1 Comparisons of three batches of low-carbon city pilot.

| Project | The first batch of pilot | The second batch of pilot | The third batch of pilot |
|---|---|---|---|
| Start-up time | July 2010 | November 2012 | January 2017 |
| Coverage | Five provinces and eight cities | One province and 29 cities | 45 cities (including districts and counties) |
| Representative city | Shenzhen, Baoding | Wuhan, Jiyuan | Changsha, Zhongshan |
| Policy objectives | Mobilize enthusiasm and accumulate work experience | Give play to comparative advantages, promote positive interaction between regions, explore emission reduction paths, and achieve green and low-carbon development | Explore and summarize low-carbon development experience |
| Policy content (task) | Prepare low-carbon development plan, issue work implementation plan or policy document, establish low-carbon industrial system, strengthen greenhouse gas emission data management, and advocate low-carbon green life | On the basis of the first batch of tasks, emphasize the responsibility system for carbon dioxide emission control objectives | On the basis of the first two batches of work tasks, it is required to establish a carbon dioxide emission target assessment system, smart energy management, and set a carbon dioxide emission peak |

development of enterprises? This study will conduct an empirical analysis using panel data of 3,365 enterprises in 333 cities of three batches of low-carbon city pilots in China from 2007 to 2020, to answer this question.

Based on the aforementioned practical observation and theoretical analysis, this study uses all batches of LCCPP as a quasi-natural experiment to comprehensively explore the relationship between LCCPP and high-quality development of enterprises. The potential contributions of this paper are as follows. First, while the existing literature primarily examines the policy effect of LCCPP on enterprises' economic performance, they ignore the possible deviation of estimation results caused by the change of climate policy intensity. This study attempts to fill that gap and to discuss the economic performance of climate policy from the enterprise level[5], eventually identifying the policy effectiveness in a more comprehensive and objective manner. Second, through the mechanism analysis, this study proves that a series of environmental regulations arising from LCCPP only triggers the "compliance costs effect" instead of the "innovation offset effect," when comprehensively considering the gradually strengthening regulation intensity of the batch pilot policy. Thus, the existing conclusion regarding the impacts of LCCPP are completely reversed, that is, the LCCPP could not promote the high-quality development of the enterprises in general. Third, this study shows that the inhibition effect of LCCPPs on high-quality development is more pronounced for non-state-owned enterprises (non-SOEs), small-scale enterprises, and the sample with strong local environmental law enforcement. Therefore, the research in this paper will broaden the evaluation of the policy effect of the low-carbon city pilot in heterogeneous enterprises and provide test evidence and beneficial enlightenment for China to achieve the goal of "peaking carbon emissions by 2030 and achieving carbon neutrality by 2060" and high-quality economic development.

5 Though Gao et al. (2022) use the three batches of low-carbon city pilot project as a sample period to explore the relationship of the LCCPP and the green total factor energy efficiency, they only did their research from the aspect of cities but not enterprises.

The rest of this paper is arranged as follows: The second part is theoretical analysis and research hypothesis; the third part introduces methods and data; the fourth part presents the results; the fifth part is discussions; the sixth part gives the conclusion and policy implications; the seventh part proposes limitation and future recommendations.

## 2 Theoretical analysis and hypothesis presentation

As an environmental regulation policy at the city level, LCCPP aims to promote the economic development model of low energy consumption low pollution and low emission. As of now, Chinese government has carried out three batches of low-carbon city pilot projects, and they were introduced in 2010, 2012, and 2017, respectively. With the continuous advancement of LCCPP, its content, objectives and tasks become more sharp and specific. For example, in addition to preparing low-carbon development plans and supporting policies, the third batch of pilot cities is clearly required to establish the carbon dioxide emission target assessment system and set peak targets to improve the management capacity of low-carbon development. Many pilot cities establish the "dual control" system for total carbon emissions and intensity and build the carbon data management mechanism. It can be seen that the requirements for LCCPP are becoming more and more stringent, which may create a profound impact on enterprise operations.

With the gradual strengthening of regulations, the LCCPP may increase the compliance costs of enterprises. First of all, in order to achieve the goal of reducing carbon emission, the governments of pilot cities will impose the task of emission reduction to enterprises. Thus, enterprises will be subject to more stringent assessment of low-carbon indicators and higher requirements for industrial upgrading. In this case, the labor, capital, and other factors invested in productive activities are transferred to non-productive activities aimed at reducing carbon emission, resulting in the crowding of production resources and ultimately reducing the production efficiency of enterprises (Stefan et al., 2013). Second, the central government set up a series of financial policies, such as tax and fee reduction, green special fund support, and financial subsidies (Huo et al., 2022), to help enterprises broaden financing channels and ease cost pressure (Li et al., 2021; Liu and Xiong, 2022). However, as a weak incentive and constraint policy, during the implementation of these policies, LCCPP has not set up a central special fund, and local government subsidies are limited, which makes it difficult to completely alleviate the financial difficulties faced by enterprise transformation. Moreover, due to information asymmetry between the government and enterprises, it is difficult to accurately assess the external costs borne by enterprises, resulting in low resource allocation efficiency of limited subsidies. If LCCPP cannot connect the advanced green ideas of pilot cities with the backward transformation, the cost of environmental regulation will be further aggravated, which would increase the external burden of enterprises (Paul et al., 2008).

When faced with the increasing environmental compliance costs caused by the LCCPP, enterprises pursuing profit maximization flexibly may choose to increase production efficiency to reduce production costs and ultimately offset the cost pressure (Chen et al., 2021). Thus, some studies believed that climate policies can force enterprises to optimize production and promote R&D innovation, indirectly promoting economic performance of enterprises (Chen et al., 2021; Shen et al., 2021). However, the indirect effect of innovation depends on two factors. On the one hand, either the optimization of production or the improvement of energy consumption technology calls for sufficient abilities of R&D. A large number of empirical studies proved that enterprise innovation activities have strong inertia and believed that R&D is a cumulative process (Hannan and Freeman, 1984; Schoemaker and Marais, 1996). Although many pilot cities have proposed a series of policies, such as tax reduction and fee reduction, green special fund support, financial subsidies, and talent introduction, to encourage R&D, use of new technologies, new materials and new equipment, and effective innovation of enterprises is hard to break through in the short-term. On the other hand, the effect of innovation depends on the strength of environmental regulation. According to the "weak Porter hypothesis," only appropriate environmental regulation can stimulate enterprises to choose technological innovation. With the gradual strengthening of the policy, it may squeeze out research investments and suppress patent output, and its influence in promoting enterprise innovation tends to weaken, thereby affecting the productivity and competitiveness of enterprises (Testa et al., 2011; Yuan and Xiang, 2018). Hence, the LCCPP may not stimulate the technological innovation of enterprises.

Combined with the aforementioned considerations, under the dual needs of environmental protection and high-quality development, enterprises have to pay more attention to pollution reduction and cover high costs to meet pollution emission standards. In addition, under the strong policy regulation, it is difficult for enterprises to create a compensating effect through innovation in the short-term, even with the support of many government policies. In other words, the incentive effect of environmental regulation on technological innovation of enterprises usually has a time lag. Hence, the LCCPP may cause a "compliance costs effect" instead of "innovation offset effect," which is not conducive to high-quality development of enterprises. Accordingly, we draw the following research hypotheses:

**H1;** The LCCPP may not promote the high-quality development of enterprises.

To realize low carbon emission, LCCPP will use legal means, such as collection and management of carbon emission information, management of the carbon emission market, and punishment for non-compliance with the trading rules. The strength of environmental law enforcement may affect the relationship between LCCPP and high-quality development of enterprises. In pilot areas with strong environmental law enforcement, a series of more mandatory environmental regulation measures will be adopted, such as raising the approval threshold and passing standards for projects in high pollution and high carbon emission industries. This will eliminate the backward production capacity of high pollution and high carbon emission enterprises and increase the pollution punishment of high-energy consumption and high emission industries. In general, the stronger the environmental law enforcement is, the bigger the compliance costs faced by enterprises will be. On the contrary, in pilot areas with weak environmental law enforcement, the cost and innovation pressure of enterprises will be relatively smaller. Accordingly, we draw the following research hypotheses:

**H2;** The inhibition effect of the LCCPP on high-quality development is more pronounced for the enterprises with strong local environmental law enforcement.

Enterprises with different ownership have different sensitivity and executive power of the LCCPP, which may affect their economic performance. On the one hand, as policy tools, state-owned enterprises (SOEs) are more likely to obtain financial support from the government; they also have natural resource advantages in terms of financial subsidies, tax relief, etc., which help them to ease the pressure of compliance costs caused by LCCPP (Yu et al., 2021). On the contrary, non-state-owned enterprises face more difficulty to obtain financial support, thus bearing greater pressure of compliance costs. On the other hand, state-owned enterprises are more sensitive to government policies and have stronger ability to implement them, and they are more willing to pay attention to carbon emission and green production (Li X et al., 2022). Meanwhile, investment of R&D in state-owned enterprises is also more stable than that in non-state-owned enterprises, which ensures green technological innovation of them. Accordingly, we draw the following research hypotheses:

**H3;** The inhibition effect of the LCCPP on high-quality development is more pronounced for non-state-owned enterprises.

There are differences in fixed assets, financial status, technological upgrading capability, R&D capability, and talents among enterprises of different size, which may lead to different cost affordability and innovation capabilities (Shen, et al., 2021). Thus, the LCCPP may have different impacts on the economic performance of different sizes of enterprises. On the one hand, since large-scale enterprises can obtain green financial support more easily than small-scale enterprises, the impact of LCCPP on small-scale enterprise is more stringent, which leads to a greater increase in their compliance costs. On the other hand, innovation requires investment in R&D and talents, and large-scale enterprises have more sufficient resources and capabilities to conduct technological transformation than small-scale enterprises, which may help them to realize innovation offset. Accordingly, we draw the following research hypotheses:

**H4;** The inhibition effect of the LCCPP on high-quality development is more pronounced for small-scale enterprises.

# 3 Methodology and data

## 3.1 Model setting

The purpose of this research is to evaluate the effect of climate policies on high-quality development of enterprises. Since the implementation of the LCCPP in China provides a "quasi-natural experiment" and an exogenous shock for the low-carbon policy change, a DID model is usually used in which the first difference is the enterprise and the second difference is the time. Compared with other empirical methods, the DID model can solve endogenous problems caused by missing variables and other reasons, thus obtaining reliable results by comparing the differences of the "treatment group" with policy intervention and the "control group" without policy intervention. Specifically, in view of the three batches of pilot lists published during the observation period, the processing time of individual enterprises is not completely consistent, and the virtual variables in the processing time are also different due to individual differences. Therefore, following Beck et al. (2010), we adopt time-varying difference-in-differences (time-varying DID)[6], which can reduce sample losses and include data from multi-batch pilot cities, to study the impact of climate policy on the high-quality development of enterprises. We identify the average treatment effect by comparing the high-quality development of enterprises in the pilot and non-pilot cities before and after the experiment. The time-varying DID model was constructed as follows:

$$Y_{ijt} = \beta_0 + \beta_1 Pilot_{ijt} + \lambda X_{ijt} + \gamma_t + \mu_i + \varepsilon_{ijt} \tag{1}$$

where $Y_{ijt}$ stands for high-quality development of enterprise, i denotes the enterprise i, j denotes the city, and t denotes the year. $Pilot_{ijt} = 1$ indicates that enterprise i in city j is located in a low-carbon pilot area in year t, whereas $Pilot_{ijt} = 0$ indicates that enterprise i in city j is not located in a low-carbon pilot area in year t. $X_{ijt}$ is a series of control variables, and $\gamma_t$ is the year-fixed effect. $\mu_i$ is the enterprise fixed effect, and $\varepsilon_{ijt}$ is a random disturbance term. This study focuses on the net effect of the LCCPP on high-quality development of enterprises—the coefficient $\beta_1$ of $Pilot_{ijt}$. A positive and significant $\beta_1$ suggests that the LCCPP could promote high-quality development of enterprises, while a negative and significant $\beta_1$ indicates that the policy could not promote high-quality development of enterprises.

In this study, we used the econometric software Stata 15.1. The specific econometric commands used in the analysis included xtset, sum, winsor2, xtreg, psmatch2, and so on. These commands were used to perform preliminary tests and estimated the model. The research framework of this study is illustrated in Figure 1.

## 3.2 Variables and data

### 3.2.1 Dependent variable

The dependent variable of this study is high-quality development of enterprises. High-quality development is a transition from denotative growth to connotative growth, which is often reflected in the improvement of productivity and competitiveness (Zhao et al., 2021). As for enterprises, high-quality development refers to the pursuit of a high level and high efficiency of economic value and social value creation (Ge et al., 2022). Following Zhao et al. (2021), this study took TFP of enterprises as a suitable proxy for high-quality development, which is quantifiable to reflect the output of enterprise's technological innovation activities most intuitively, and spillover inside and outside the industry (Chen et al., 2021). The measurement method of TFP was mainly proposed by Olley and Pakes (1996) and Levinsohn and Petrin (2003) (referred as the OP method and LP method, respectively), which could solve the simultaneity bias well. In baseline regression, we use the OP method to measure TFP of A-share listed manufacturing enterprises in Shanghai and Shenzhen from 2007 to 2020, while we use the LP method for the robustness test.

### 3.2.2 Independent variable

The dummy variable $Pilot_{ijt}$ is the independent variable concerned, which was constructed for the LCCPP, and the effect of the policy is examined by comparing the enterprises in pilot cities and enterprises in non-pilot cities. If the LCCPP is implemented in the city of the listed companies during the sample period (2007–2020), $Pilot_{ijt}$ is 1, otherwise, it is 0. We use three batches of pilot of the LCCPP that were implemented in 2010, 2012, and 2017. The three batches of pilot cities are defined as the treatment group, whereas their counterparts that have yet to introduce this plan serve as the control group. The final number of sample cities was 333, including 123 pilot and 210 non-pilot cities.

6 DID is the most widely used measurement method in estimating processing effects. The idea of this method was first put forward by John Snow (1855) when he studied the cholera epidemic in London, and it was introduced into economics when Obenauer and von der Nienburg (1915) studied the effect of the minimum wage method. In order to estimate the treatment effect and compare the difference between the post-treatment and pre-treatment, the treatment effect is obtained by subtracting the pre- and post-treatment changes of the control group from the post-treatment changes of the treatment group, hence the name "difference-in-differences." The traditional DID assumes that all the individuals in the treatment group start to be impacted by the policy at the same time, but there will be cases where the individuals in the treatment group accept the treatment at different time points, for example, the time when the pilot policy of China's low-carbon cities is launched in different regions is inconsistent. Time-varying DID is to describe the situation that the time points of individual processing periods are not completely consistent, which is widely used by many scholars in policy evaluation (Beck et al., 2010). Moreover, time-varying DID can handle endogenous problems well, so we can use the time-varying DID method to explore the influence of LCCPP on the high-quality development of enterprises.

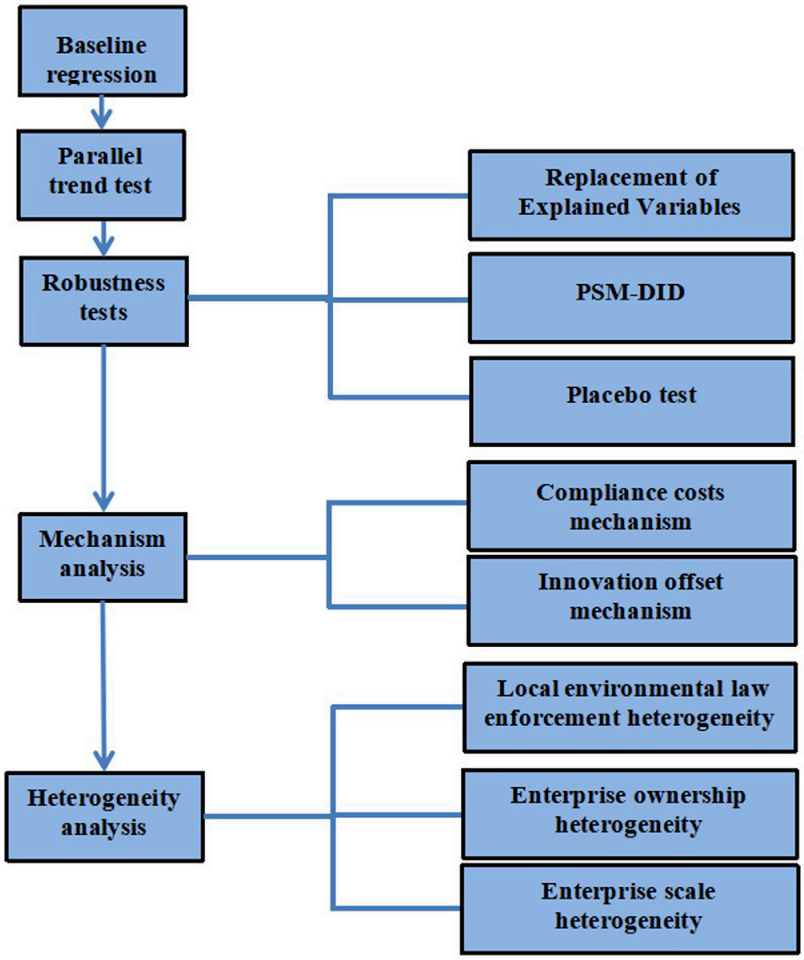


FIGURE 1
Research framework and process.

### 3.2.3 Control variables

Control variables are selected in terms of both enterprise characteristics and city characteristics, where the selected enterprise characteristics are Tobin's Q (Tobin_q), agency cost (Acost), growth rate of total assets (Grta), intangible assets ratio (Ria) and net operating cash flow (Nocf), and the city characteristics are urban GDP *per capita* (Fgdp) and share of secondary industry in GDP(Industry). (1) Tobin's Q is a measure of a company's ability to create social value, and the larger the number, the more social wealth the company creates and the higher its awareness of quality development (Tobin, 1969), so we choose Tobin_q as control variable. (2) In the field of corporate governance, agency cost is an important factor affecting the production and development of enterprises (Iyer et al., 2017), so we choose Acost as the control variable. (3) The higher the growth rate of total assets, the faster the expansion of asset management scale, and the more conductive to scale economies of enterprises .The effect of scale economies can reduce the cost and improve the competitiveness of enterprises (Krugman, 1980). So we choose Grta as a control variable. (4) A higher ratio of intangible assets can make enterprises adapt to the trend of international economic and technological development, which is beneficial to the long-term development of enterprises, so we choose Ria as the control variable. (5) To a great extent, the cash flow of an enterprise determines the survival and development ability of the enterprise, so we choose Nocf as the control variable. (6) Considering the possible influence of the economic development level and industrial structure changes on the high-quality development of enterprises, we choose Fgdp and Industry as the control variables at the city level. Table 2 shows the descriptions for each variable.

### 3.2.4 Data specification and summary statistics

Our selected sample covers a dataset of enterprise-level and city-level in China from 2007 to 2020. Based on enterprise-level data, the A-share listed manufacturing enterprises in Shanghai and Shenzhen from 2007 to 2020 are selected as the samples as they are more involved in environmental governance than those in other industries (Jennifer Ho and Taylor, 2007), and the policy most directly affects the transformation, upgrading, and productivity of manufacturing enterprises (Gu and Wang, 2018). In addition, the period from 2007 to 2020 is chosen as the sample period because the earliest

**TABLE 2** Definitions of major variables.

| Type | Variable | Abbr. | Definition |
|---|---|---|---|
| Independent variable | High-quality development of enterprises | lntfp_op | Logarithm of the TFP of enterprises is calculated by using the OP method. |
| | | lntfp_lp | Logarithm of the TFP of enterprises is calculated by using the LP method. |
| Dependent variable | LCCPP | Pilot | Assigning a value of 1 if LCCPP is implemented in the city of the listed companies during the sample period, otherwise 0. |
| Control variables | Intangible assets ratio | Ria | Total intangible assets/total assets |
| | Growth rate of total assets | Grta | Change in total assets/prior period total assets |
| | Tobin's Q | Tobin_q | Total enterprise market value/assets |
| | Agency cost | Acost | Administrative expenses/prime operating revenue |
| | Net operating cash flow | Nocf | Net cash flow from operating/total assets |
| | Share of secondary industry in GDP | Industry | Total output of secondary industry/GDP |
| | Regional GDP per capita | Fgdp | GDP/urban population |

**TABLE 3** Summary statistics.

| Variable | N | Mean | Sd | Min | Med | Max |
|---|---|---|---|---|---|---|
| lntfp_op | 20,941 | 2.008 | 0.108 | 0.924 | 2.004 | 2.369 |
| lntfp_lp | 18,682 | 8.959 | 1.021 | 5.714 | 8.871 | 12.616 |
| Pilot | 31,023 | 0.482 | 0.500 | 0.000 | 0.000 | 1.000 |
| Ria | 30,365 | 0.047 | 0.044 | 0.000 | 0.037 | 0.699 |
| Grta | 23,382 | 0.229 | 0.785 | −1.000 | 0.103 | 72.521 |
| Tobin_q | 21,988 | 2.191 | 2.700 | 0.684 | 1.675 | 126.951 |
| Acost | 23,933 | 0.049 | 0.083 | −1.938 | 0.047 | 2.222 |
| Nocf | 23,926 | 0.163 | 4.536 | −0.006 | 0.075 | 551.352 |
| Industry | 29,488 | 43.763 | 8.297 | 15.800 | 44.791 | 61.500 |
| Fgdp | 29,488 | 68907.958 | 32604.202 | 6915.000 | 64168.300 | 164889.470 |

batch of areas where the low-carbon city pilot policy was implemented began in 2010, and the latest batch was implemented in 2017, so there is a window period of 3 years before the earliest batch was implemented, and there is also a window period of 3 years after the latest batch was implemented in the same year, which maintains certain symmetry and ensures a reasonable length of the event window.

The following steps have been taken on the enterprises data. First, listed manufacturing enterprises that suffer consecutive losses are removed (referred to as ST and *ST enterprises). Second, enterprises with too much significant missing financial data are excluded. Third, continuous variables are winsorized at 1%–99%. Enterprise-level data are obtained from WIND and CSMAR databases, resulting in the samples of 3365 A-share listed manufacturing enterprises in Shanghai and Shenzhen. City-level data come from the Urban Statistical Yearbook of China. Table 3 reports summary statistics of all the variables.

# 4 Empirical results

## 4.1 Baseline regression results

We used a time-varying DID method to assess the effects of the LCCPP on the high-quality development of enterprises. Table 4 shows the baseline regression results. The results of the baseline regression are shown in columns (1)–(2) of Table 4. Column (1) is the basic regression result without adding other control variables. It can be seen that the regression coefficient was −0.006 at 1% significance, which suggests that the TFP of enterprise will be significantly reduced after the LCCPP. Column (2) added control variables, and after controlling year and enterprise fixed effects, the coefficient of *Pilot* is −0.007, which is also significantly negative at the 1% level. The regression showed that the LCCPP could indeed significantly inhibit the high-quality development of enterprises.

The empirical results support Hypothesis 1. The existing literature suggested that climate policy may have positive effects

**TABLE 4 Baseline regressions.**

| Variables | Baseline regression | |
|---|---|---|
| | lntfp_op | lntfp_op |
| | (1) | (2) |
| Pilot | −0.006*** | −0.007*** |
| | (−3.728) | (−4.632) |
| Constant | 1.950*** | 1.966*** |
| | (1127.208) | (240.065) |
| Control variables | N | Y |
| Year FE | Y | Y |
| Enterprise FE | Y | Y |
| Observations | 20,941 | 18,295 |
| $R^2$ | 0.257 | 0.365 |

Note: This table examines the impact of the LCCPP on high-quality enterprise development. Column (1) controls for year and enterprise fixed effects. Column (2) adds a series of control variables to column (1), which are defined in Table 2. ***, **, and * indicate significance at the levels of 1%, 5%, and 10%, respectively. Values in parentheses are winsorized t-values. Y denotes "Yes." N denotes "No."

on high-quality development of enterprises. This study concludes that gradually strengthening regulation intensity of pilot policy in batches leads to a significant inhibition in high-quality development of enterprises, possibly because the stricter requirement of carbon emission brings about excess burden to enterprises, which curbs their productivity.

## 4.2 Parallel trend test

An important requirement of the DID method is that the parallel trend assumption must be met; that is, before the implementation of the LCCPP, there should be no significant difference in high-quality development of enterprises trends of the pilot and non-pilot cities. To test whether the empirical model in this study meets the parallel trend hypothesis, we expanded the model (1) as follows:

$$Y_{ijt} = \alpha + \sum_{k=-3}^{k=3} \beta Polit_{ijt}^{k} + \lambda X_{ijt} + \gamma_t + \mu_i + \varepsilon_{ijt} \qquad (2)$$

In Eq. 2, $Polit_{ijt}^{k}$ is a dummy variable representing the "$k$" year of the LCCPP ($i$ = 1, 2, 3, . . .3365; $j$ = 1, 2, 3, . . . 333; $t$ = 2007, 2008, 2009, . . ., 2020). For example, $k$ = 0 indicates the benchmark year when city $j$ introduces the policy, $k$ = 1 indicates the first year of the implementation of the LCCPP in city $i$, and $k$ = -1 indicates the year before the implementation of the policy. This study examines the policy effects in the 3 years prior to and 3 years after its implementation. The coefficient "$\beta$" indicates the differences in high-quality development of enterprises between the pilot and non-pilot cities in the "$k$" year of the policy. If the coefficient $\beta$ is not significant in the period $k < 0$, then the differences in high-quality development of enterprises between pilot and non-pilot cities are caused by the LCCPP. On the contrary, if the coefficient $\beta$ is significant in the period $k < 0$, then the differences in high-quality development of enterprises between the pilot and non-pilot cities are not caused by the policy, which does not conform to the parallel trend hypothesis.

Figure 2 shows a parallel trend test for the 3 years before and after the policy, the result shows that the coefficients of the policy variable are not significant before the implementation of LCCPP, indicating that there is no significant difference between the treatment group and the control group before the implementation of the policy, so the hypothesis of the parallel trend is established.

## 4.3 Robustness test

The robustness test is conducted to ensure the reliability of the aforementioned results by using the LP method to measure TFP of enterprises, the replacement with the propensity score matching difference-in-differences (PSM–DID) method and the placebo test.

First, we apply the LP method to measure TFP by taking its logarithm (*lntfp_lp*) to replace the dependent variables in Eq. 1 and running a regression. The regression results are shown in columns (1) and (2) of Table 5. Changing the measure of TFP does not affect the findings, which verifies the conclusion that there is a negative effect of LCCPP on high-quality development of enterprises.

Second, to further control for this systematic bias, this study adopted the PSM–DID model as a robustness test; we use the nearest neighbor matching method to repeat the sampling calculations. The scores were determined to match the control groups of the treatment groups, and then, the matched results were further used for regression of the DID method. The results in columns (3) and (4) of Table 5 show that the dummy variable's estimated coefficients are both significantly negative at the 1% level after eliminating sample selection bias using the PSM method, indicating that the conclusions obtained in this study are still robust.

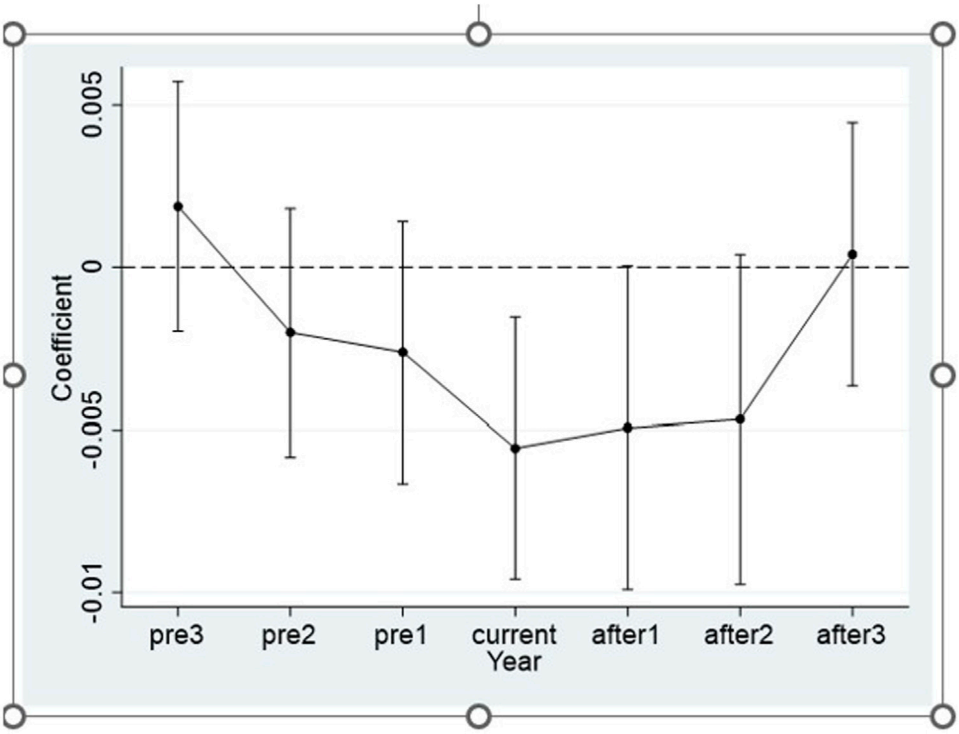


FIGURE 2
Parallel trend test.

**TABLE 5 Robustness test.**

| Variable | Replacement of explained variable | | PSM-DID | |
|---|---|---|---|---|
| | lntfp_lp | lntfp_lp | lntfp_op | lntfp_op |
| | (1) | (2) | (3) | (4) |
| Pilot | -0.037*** | -0.034*** | -0.007*** | -0.007*** |
| | (-2.983) | (-2.808) | (-4.576) | (-4.632) |
| Constant | 8.379*** | 8.349*** | 1.955*** | 1.966*** |
| | (538.614) | (126.180) | (1076.308) | (240.065) |
| Control variables | N | Y | N | Y |
| Year FE | Y | Y | Y | Y |
| Enterprise FE | Y | Y | Y | Y |
| Observations | 18,682 | 17,680 | 18,295 | 18,295 |
| $R^2$ | 0.339 | 0.409 | 0.270 | 0.365 |

Note: This table examines the robustness of the LCCPP's impact on high-quality enterprise development. Columns (1)–(2) show the TFP that replaces the explanatory variable of the OP measure with the LP measure. Column (3)–(4) show PSM-DID. Columns (1) and (3) do not have control variables, and columns (2) and (4) have control variables. Columns (1)–(4) all control for year and enterprise fixed effects. ***, **, and * indicate significance at the levels of 1%, 5%, and 10%, respectively. Values in parentheses are winsorized t-values. Y denotes "Yes." N denotes "No."

Third, a placebo test is conducted to avoid the influence of other unobservable factors. We classify the enterprises' data according to the cities at first and randomly select a time in all experimental years as its pseudo policy time. Then, we re-evaluate the previous estimates. The corresponding cross-product term is $Polit_{ijt}^{false}$. Since the pseudo-policy time is randomly selected, the coefficient $\beta_1^{fasle}$ of $Polit_{ijt}^{k}$ should theoretically be 0. We repeat the exercise 500 times in this study in case our estimation was accidental, and 500 coefficient estimates results are obtained. Figure 3 plots the kernel density and the corresponding $p$ value distribution of the

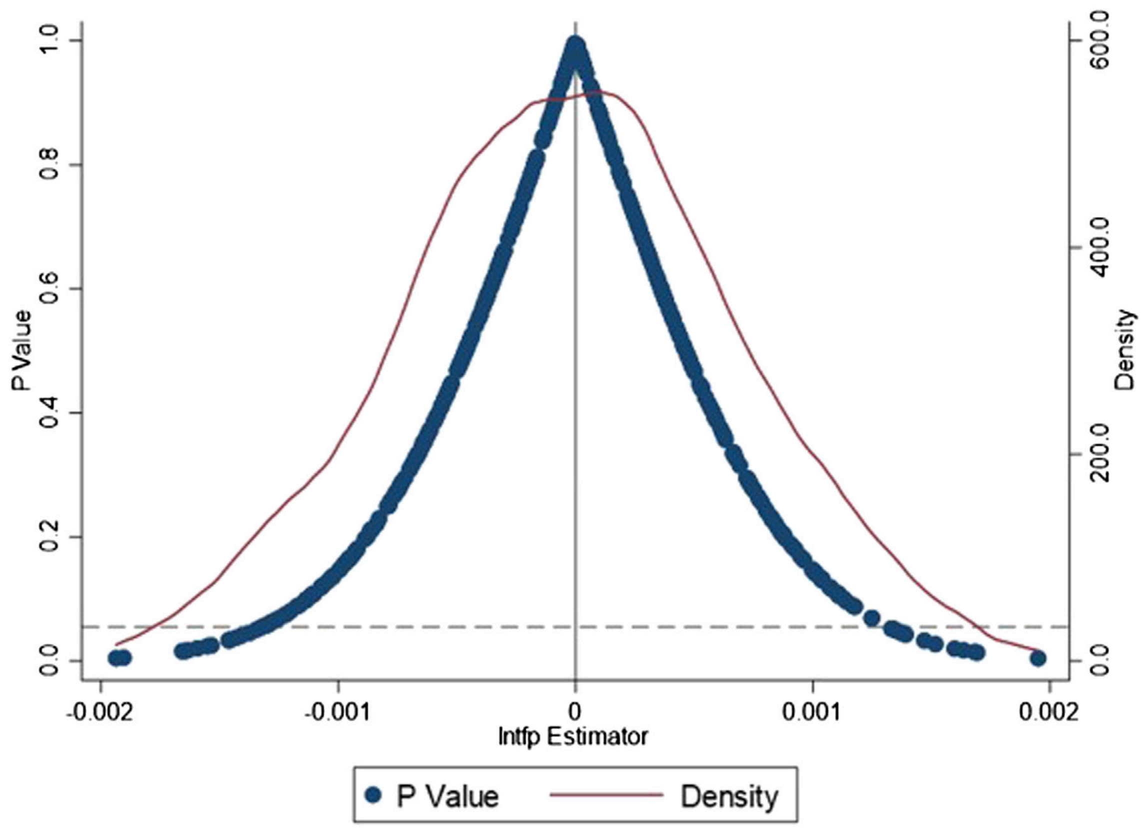


FIGURE 3
Results of the placebo test.

estimates after 500 exercises. The curve denotes the kernel density distribution, the hollow circle represents corresponding $p$ values, and the vertical dotted line on the right is the afore-estimated value of the coefficient $\beta_1$ for the dummy variable $Pilot_{ijt}$. It is clear that the coefficient distribution corresponding to the pseudo-policy time concentrates around 0 and obeys the normal distribution, whereas the distribution of $p$ values indicates that the estimates of these coefficients all significantly reject the null hypothesis of $\beta_1^{fasle}$. It illustrates that our aforementioned finding is not a coincidence of the experimental arrangement.

## 4.4 Mechanism analysis

A significant inhibition effect of climate policy on high-quality development of enterprise is shown in the "Empirical results" section. Then, what is the transmission mechanism behind it? As discussed in theoretical analysis, the LCCPP may affect the high-quality development of enterprises through compliance costs and innovation offset. We empirically tested these potential internal mechanisms respectively.

### 4.4.1 Compliance costs mechanism

In order to reach peak carbon and carbon neutrality targets, low-carbon pilot cities have adopted more and more strict environmental policies in batches and may cause a sharp rise in costs of enterprises, namely, "compliance costs effect," which is not conducive to high-quality development of enterprises. This study constructs an intermediary model based on the baseline model (3) to test the mechanism of compliance costs. The models are set up as follows:

$$Y_{ijt} = \beta_0 + \beta_1 Pilot_{ijt} + \lambda X_{ijt} + \gamma_t + \mu_i + \varepsilon_{ijt} \quad (1)$$

$$ER_{ijt} = \beta_0 + \beta_1 Pilot_{ijt} + \lambda X_{ijt} + \gamma_t + \mu_i + \varepsilon_{ijt} \quad (3)$$

$$Y_{ijt} = \beta_0 + \beta_1 Pilot_{ijt} + \rho ER_{ijt} + \lambda X_{ijt} + \gamma_t + \mu_i + \varepsilon_{ijt} \quad (4)$$

where $ER_{ijt}$ denotes the compliance costs of enterprises i in city j at the end of year t, which is used to measure the ratio of environmental protection investment and main business income.

Regarding the effect of compliance costs, Table 6 reports the corresponding regression results. Column (1) is the regression results of model (1), where the coefficients of $Pilot_{ijt}$ are significantly negative, indicating that the LCCPP notably inhibits the high-quality development of enterprises. Column (2) is the regression results of model (3), where the coefficients of $Pilot_{ijt}$ are significantly positive, indicating that the implementation of the policy increased the compliance costs of enterprises. Column (3) shows the regression results of model (4), where the coefficients of $ER_{ijt}$ and $Pilot_{ijt}$ are both significantly negative. This result suggests that the "compliance costs effect" of LCCPP is exactly as expected, and compliance costs are indeed the intermediary mechanism

TABLE 6 Mechanism test.

| Variable | lntfp_op | ER | lntfp_op | Lnpatent | lntfp_op |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) |
| Pilot | −0.007*** | 0.001* | −0.007*** | 0.011 | −0.007*** |
| | (−4.632) | (1.717) | (−4.572) | (0.346) | (−4.676) |
| ER | | | −0.099*** | | |
| | | | (−4.185) | | |
| lnpatent | | | | | 0.005*** |
| | | | | | (14.771) |
| Constant | 1.966*** | 0.005* | 1.967*** | 1.465*** | 1.959*** |
| | (240.065) | (1.740) | (240.223) | (8.338) | (240.242) |
| Control variable | Y | Y | Y | Y | Y |
| Year FE | Y | Y | Y | Y | Y |
| Enterprise FE | Y | Y | Y | Y | Y |
| Observations | 18,295 | 18,924 | 18,295 | 18,852 | 18,295 |
| $R^2$ | 0.365 | 0.002 | 0.365 | 0.248 | 0.373 |

Note: This table shows the results of mechanism analysis. Columns (1)–(3) are the results of compliance costs mechanism test. Columns (1), (4), and (5) are the results of innovation mechanism test. Columns (1)–(5) add a series of control variables, control for year and enterprise fixed effects. ***, **, and * indicate significance at the levels of 1%, 5%, and 10%, respectively. Values in parentheses are winsorized t-values. Y denotes "Yes." N denotes "No."

through which the climate policy inhibits high-quality development of enterprises.

This result is consistent with theoretical expectations. With the gradual strengthening of the pilot policy in batches, enterprises face more and more strict carbon emission and industrial green transformation requirements, which evidently curb their economic efficiency and competitiveness. In addition, current financial support is not enough so as to ease the cost pressure of enterprises; thereby, the current climate policy is difficult to promote the high-quality development of enterprises.

### 4.4.2 Innovation offset mechanism

According to Hypothesis 1, this section examines whether there is "innovation offset effect" of LCCPP, which may affect high-quality development of enterprises. We construct an intermediary model of enterprise technological innovation based on the baseline model (6) to test the mechanism. The models are set up as follows:

$$Y_{ijt} = \beta_0 + \beta_1 Pilot_{ijt} + \lambda X_{ijt} + \gamma_t + \mu_i + \varepsilon_{ijt} \quad (1)$$

$$lnpatent_{ijt} = \beta_0 + \beta_1 Pilot_{ijt} + \lambda X_{ijt} + \gamma_t + \mu_i + \varepsilon_{ijt} \quad (5)$$

$$Y_{ijt} = \beta_0 + \beta_1 Pilot_{ijt} + \rho lnpatent_{ijt} + \lambda X_{ijt} + \gamma_t + \mu_i + \varepsilon_{ijt} \quad (6)$$

where $lnpatent_{ijt}$ denotes the technological innovation of enterprises i in city j at the end of year t, which used patent applications of enterprise as a proxy variable.

Table 6 reports the corresponding regression results. The regression result of model (1) is shown in column (1). The coefficients of $Pilot_{ijt}$ are significantly negative at the 1% level, indicating that the implementation of the LCCPP significantly inhibits the high-quality development of enterprises. Column (4) is the regression results of model (5), where the coefficient of $Pilot_{ijt}$ is not significant, suggesting that the policy could not promote technological innovation of enterprises. In addition, Column (5) shows the regression results of model (6), where the coefficients of technological innovation of enterprises is significantly positive and the coefficient of policy variables $Pilot_{ijt}$ is significantly negative. The aforementioned empirical test results show that there is no "innovation offset effect" between the LCCPP and the high-quality development of enterprises.

Regarding the effect of innovation offset, the LCCPP could not improve high-quality development of enterprises by promoting innovation, which is consistent with our theoretical expectations. The empirical results support that with the gradual strengthening of pilot policy in batches, enterprises can hardly promote R&D innovation to compensate production costs and maximize profit, which challenges the strong Porter hypothesis.

## 4.5 Heterogeneity analysis

The aforementioned results show that the LCCPP could not improve high-quality development of enterprise in pilot cities. Its mechanism analysis illustrates that compliance costs and innovation offset are two crucial influencing channels. However, there are considerable differences among policy enforcement and enterprises characteristic. We present a further analysis of heterogeneous effects of the LCCPP on high-quality development of enterprises in terms of local environmental law enforcement, enterprise ownership, and scale of enterprise, respectively.

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**TABLE 7** Heterogeneity test.

| Variable | Strong environmental law enforcement | Weak environmental law enforcement | SOEs | Non-SOEs | Large-scale | Small-scale |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Pilot | −0.007*** | −0.006** | −0.002 | −0.007*** | −0.003 | −0.007*** |
| | (−3.946) | (−2.024) | (−0.811) | (−3.302) | (−1.250) | (−3.673) |
| Constant | 1.935*** | 1.993*** | 2.007*** | 1.917*** | 1.996*** | 1.998*** |
| | (157.385) | (174.433) | (175.353) | (166.151) | (147.986) | (155.430) |
| Control variables | Y | Y | Y | Y | Y | Y |
| Time FE | Y | Y | Y | Y | Y | Y |
| Enterprise FE | Y | Y | Y | Y | Y | Y |
| Observations | 13,919 | 4,376 | 5,813 | 12,429 | 9,790 | 8,505 |
| $R^2$ | 0.374 | 0.348 | 0.358 | 0.37 | 0.331 | 0.276 |

Note: This table shows the results of heterogeneity analysis . Column (1)–(2) are the results of the local environmental law enforcement heterogeneity test. Column (3)–(4) are the results of enterprise ownership heterogeneity test. Column (5)–(6) are the results of enterprise Scale heterogeneity test. Columns (1)–(6) add a series of control variables and all control for year and enterprise fixed effects. ***, **, and * indicate significance at the levels of 1%, 5% and 10%, respectively. Values in parentheses are winsorized t-values. Y denotes "Yes." N denotes "No."

### 4.5.1 Local environmental law enforcement heterogeneity

We split the samples into enterprises in regions with strong environmental law enforcement and in regions with weak environmental law enforcement to examine whether the results change. The number of environmental administrative punishment cases in each province is used to measure the local environmental law enforcement, and the samples are divided according to the number of environmental administrative punishment cases in the year before the implementation of LCCPP (2009). The provinces with the number of environmental administrative punishment cases equal to or lower than the 50-percentile value are defined as the provinces with weak environmental law enforcement, and the provinces with the number of environmental administrative punishment cases higher than the 50-percentile value are defined as the provinces with high environmental law enforcement. Columns (1)–(2) of Table 7 report the regression results, the coefficients of $Pilot_{ijt}$ in columns (1) and (2) are both significantly negative, while the significance in column (1) is at the 1% level and in column (2) is at the 5% level. That means the inhibition effect of the policy is more pronounced for the enterprises with strong local environmental law enforcement.

The empirical results support Hypothesis 2. One possible explanation is that strong environmental law enforcement leads to higher compliance costs and is more harmful for technological innovation. Compared with the regions with weak environmental law enforcement, the regions with strong environmental law enforcement have adopted a series of more mandatory environmental supervision measures, which makes the compliance costs of enterprises rise rapidly in a short period of time, thus squeezing out the production funds of enterprises, hindering technological innovation of enterprises, and finally inhibiting the high-quality development of enterprises. This also proves that strengthening of the pilot policy in batches is not conducive to high-quality development of enterprises.

### 4.5.2 Enterprise ownership heterogeneity

From the perspective of ownership of enterprises, we examine whether the behaviors of state-owned enterprises and non-state-owned enterprises are different under the climate policy. Columns (3)–(4) of Table 7 report the regression results for state-owned enterprises and non-state-owned enterprises , respectively. The regression coefficient of non-SOEs is significantly negative at 1% level, while the regression coefficient of SOEs is negative but not significant. The empirical results show that the inhibition effect of this climate policy on the high-quality development of enterprises is more pronounced for non-SOEs.

The empirical results support Hypothesis 3. A possible reason is that non-SOEs are more sensitive to changes in production costs affected by government intervention. Compared with SOEs, it is more difficult for non-SOEs to obtain financial support from the government and financial institutions, which might bring greater cost pressure to them. With the rising environmental compliance costs of enterprises, non-SOEs can only mobilize their own funds to meet the emission reduction requirements, thus squeezing out the production funds, which is not conducive to their technological innovation and economic efficiency.

### 4.5.3 Enterprise scale heterogeneity

According to the size of total assets, this study split the sample into large-scale enterprises and small-scale enterprises. Columns (5)–(6) of Table 7 report the regression results. The regression coefficient of small-scale enterprise is significantly negative at the 1% level, while the regression coefficient of large-scale enterprise is negative but not significant. The results show that the inhibition effect of this climate policy on the high-quality development of enterprises is more pronounced for small-scale enterprises.

The empirical results support Hypothesis 4. The possible reason is that the financing and R&D capabilities of small-scale enterprises are inferior to large-scale enterprises. With gradual strengthening policy, the "compliance costs effect" is more stringent on the small-scale enterprises, which is not conductive to high-quality development of them.

# 5 Discussion

This study regards the LCCPP as a quasi-natural experiment. Based on panel data of 3,365 enterprises in 333 cities in China from 2007 to 2020, we adopt the time-varying DID model with two-way fixed effects to investigate the impact of China's climate policy on high-quality development of enterprises. After controlling the influence of enterprise fixed-effect, time fixed-effect, and controlled variables, the LCCPP does not improve TFP of enterprises in pilot cities, which is not consistent with the conclusions of existing related research. That means, China's climate policy does not promote high-quality development of enterprises and has not achieved a win–win path between environmental and economic performance. In light of this finding, we asked the following question: What are the possible explanations for the results found?

One possible explanation for the results is that the strengthening regulation intensity of pilot policy in batches has just triggered "compliance costs effect" instead of "innovation offset effect." Since the implementation of the LCCPP, the pilot cities have achieved positive performance in carbon emissions. From 2010 to 2011, the $CO_2$ emissions per unit of GDP of 32 cities in the first batch of pilot cities had decreased more than that of their provinces. In addition, from 2010 to 2016, the land transfer of energy-intensive industries in the first two batches of pilot cities decreased by 26.271 ha and 29.158 ha on average (Tang et al., 2018). This positive performance in carbon emissions is attributed to gradually strengthened pilot policies. However, with the in-depth implementation of the pilot policy, the compliance costs of enterprises have continued to rise, which inhibited them from technological innovation and could not promote productivity. The results of heterogeneity test have also verified this mechanism. The stronger the environmental law enforcement is, the more likely it is to increase the environmental compliance costs, the less likely it is for enterprises to innovate under the pressure of compliance costs, especially for private enterprises and small enterprises.

Another possible explanation for the results is that the preferential government policies in the pilot cities have not played roles in alleviating the rising compliance costs and stimulating innovation. Due to the weak incentives and constraints of the LCCPP, the central government has not allocated any financial resources and policy preferences to local governments except for a small amount of funding support for pilot projects. The central government only requires and encourages pilot cities to set policy goals according to national goals, such as putting forward the goal of reaching the peak of carbon emissions, but there is no economic support and policy preference, so the pilot cities cannot enrich local financial resources through market innovation, resulting in insufficient incentives for enterprise innovation and financing mitigation. In fact, the preferential intensity of the policies of the pilot cities is also different due to the basis and capacity of economic development. It is more difficult for pilot cities with a low economic development level to guarantee the financial support of low-carbon pilot projects.

# 6 Conclusion and policy implications

The implementation of the climate policy is of great significance to the realization of "peak carbon emissions by 2030 and carbon neutrality by 2060," and it is also an important measure to achieve a win–win path between environmental performance and economic performance. Comprehensively considering the gradually strengthening regulation intensity of batch pilot policy, this study uses three batches of the low carbon city pilot project as a quasi-natural experiment and builds a time-varying DID model to examine whether the climate policy can promote the high-quality development of enterprises. The main conclusions are as follows:

(1) The current climate policy in general does not promote the high-quality development of enterprises, when comprehensively considering the gradually strengthening regulation intensity of pilot policy in batches. The results of the baseline regression are still valid after a series of robustness tests. This result complements the existing research in relevant fields, making up for the negligence of the change of climate policy intensity in previous related studies. The empirical results provide a reference and basis for the implementation of China's climate policy and how to balance carbon emissions and economic development has become an important issue in the formulation of China's climate policy.
(2) The mechanism analysis showed that the climate policy could not promote high-quality development of enterprises through the innovation offset channel but in the meantime, curbs their productivity through the compliance costs channel. That means environmental regulation arising from the climate policy only triggers the "compliance costs effect" instead of the "innovation offset effect." The empirical results answered our central question in this paper and gave the reason why China's current climate policy does not promote high-quality development of enterprises. It also provides implications for the design of climate policy tools.
(3) The heterogeneity analysis showed the inhibition effect of the climate policy on high-quality development of enterprises is more pronounced for non-state-owned enterprises, small-scale enterprises, and the sample with strong local environmental law enforcement. These results make up for the negligence of the existing LCCPP effect identification research. In addition, the identification method of this study can be used as a scientific reference for conducting similar research in other emerging countries.

Based on the aforementioned results, the following policy implications are further proposed. First of all, gradually strengthened pilot policies are not conducive to improving the economic performance of enterprises; thus, the local government should adopt an appropriate intensity of the climate policy and promote the low-carbon transformation of enterprises through more market incentive ways instead of "command and control" means. Second, in view of the current policy that the central government has not yet established financial support for low-carbon pilot projects, it is suggested to set up a central special fund to solve the problem of limited local government subsidies so as to alleviate the financial difficulties in transition of enterprises. The special funds by the government can also guide more social risk funds to flow into enterprises, reduce the innovation cost of enterprises, and enhance the willingness and ability to undertake green innovation of enterprises. Third, attention should be paid to the inhibition effect of the LCCPP on the green technology innovation of enterprises with low innovation capacity, non-SOEs and small-scale enterprises, reasonable coordination of innovation and financial resources according to the technological innovation weaknesses of enterprises, and improvement of the willingness of enterprises in green technology innovation.

# 7 Limitations and future recommendations

First, our research object only focused on samples in China, and we did not examine the policy effects, mechanisms, and heterogeneity of climate policies in other emerging market economies or developing countries from a spatial dimension, which means there is a lack of broader empirical arguments. Future research studies can increase the sample of emerging economies and make the research conclusion more general and extensive.

Second, we use TFP to measure the high-quality development of enterprises in this study. TFP measures the economic growth degree of desirable output driven by not only tangible factors such as labor and capital, but also intangible factors such as technological progress and allocation efficiency improvement. However, TFP does not include the undesirable output caused by environmental pollution. There is another indicator called "The green total factor productivity," incorporating the undesirable output of pollution emissions into the growth performance measurement framework, which can better represent the true level of high-quality economic development. Future research studies could be carried out based on green total factor productivity to conduct a more in-depth 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 author.

# Author contributions

All authors contributed to the study conception and design. XC and HC conceived and designed the research question and wrote the manuscript. YH and SY constructed the models and analyzed the optimal solutions. XC and HC reviewed and edited the manuscript. All authors read and approved the manuscript.

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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.

# Publisher's note



# References

Beck, T., Levine, R., and Levkov, A. (2010). Big bad banks? The winners and losers from bank deregulation in the United States. *J. Finance* 65 (5), 1637–1667. doi:10.1111/j.1540-6261.2010.01589.x

Berman, E., and Bui, L. (2001). Environmental regulation and productivity: Evidence from oil refineries. *Rev. Econ. Statistics* 83 (3), 498–510. doi:10.1162/00346530152480144

Chen, H., Guo, W., Feng, X., Wei, W., Liu, H., Feng, Y., et al. (2021). The impact of low-carbon city pilot policy on the total factor productivity of listed enterprises in China. *Resour. Conservation Recycl.* 169, 105457. doi:10.1016/j.resconrec.2021.105457

Cheng, J., Yi, J., Dai, S., and Xiong, Y. (2019). Can low-carbon city construction facilitate green growth? Evidence from China's pilot low-carbon city initiative. *J. Clean. Prod.* 231 (9), 1158–1170. doi:10.1016/j.jclepro.2019.05.327

Dong, J., Ju, Y., Dong, P., Giannakis, M., Wang, A., Liang, Y., et al. (2021). Evaluate and select state-owned enterprises with sustainable high-quality development capacity by integrating FAHP-LDA and bidirectional projection methods. *J. Clean. Prod.* 329, 129771. doi:10.1016/j.jclepro.2021.129771

Gao, D., Li, Y., and Li, G. (2022). Boosting the green total factor energy efficiency in urban China: Does low-carbon city policy matter? *Environ. Sci. Pollut. Res.* 29 (37), 56341–56356. doi:10.1007/s11356-022-19553-9

Ge, G., Xiao, X., Li, Z., and Dai, Q. (2022). Does ESG performance promote high-quality development of enterprises in China? The mediating role of innovation input. *Sustainability* 14 (7), 3843. doi:10.3390/su14073843

Gray, W. B., and Shadbegian, R. J. (2003). Plant vintage, technology, and environmental regulation. *J. Environ. Econ. Manag.* 46 (3), 384–402. doi:10.1016/S0095-0696(03)00031-7

Gray, W. B. (1987). The cost of regulation: OSHA, EPA and the productivity slowdown. *Am. Econ. Rev.* 77 (5), 998–1006. https://www.jstor.org/stable/1810223.

Gu, G., and Wang, Z. (2018). China's carbon emissions abatement under industrial restructuring by investment restriction. *Struct. Change Econ. Dyn.* 47, 133–144. doi:10.1016/j.strueco.2018.08.007

Hannan, M. T., and Freeman, J. (1984). Structural inertia and organizational change. *Am. Sociol. Rev.* 49 (2), 149–164. doi:10.2307/2095567

Huo, W., Qi, J., Yang, T., Liu, J., Liu, M., and Zhou, Z. (2022). Effects of China's pilot low-carbon city policy on carbon emission reduction: A quasi-natural experiment based on satellite data. *Technol. Forecast. Soc. Change* 175, 121422. doi:10.1016/j.techfore.2021.121422

Iyer, S. R., Sankaran, H., and Nejadmalayeri, A. (2017). CEO overconfidence and agency cost of debt: An empirical analysis of CEO turnover events. *North Am. J. Econ. Finance* 42, 300–313. doi:10.1016/j.najef.2017.07.014

Jennifer Ho, L. C., and Taylor, M. E. (2007). An empirical analysis of triple bottom-line reporting and its determinants: Evidence from the United States and Japan. *J. Int. Financial Manag. Account.* 18 (2), 123–150. doi:10.1111/j.1467-646X.2007.01010.x

Krugman, P. (1980). Scale economies, product differentiation, and the pattern of trade. *Am. Econ. Rev.* 70 (5), 950–959.

Levinsohn, J., and Petrin, A. (2003). Estimating production functions using inputs to control for unobservables. *Rev. Econ. Stud.* 70 (2), 317–341. doi:10.1111/1467-937X.00246

Li, K., Xia, B., Chen, Y., Ding, N., and Wang, J. (2021). Environmental uncertainty, financing constraints and corporate investment: Evidence from China. *Pacific-Basin Finance J.* 70, 101665. doi:10.1016/j.pacfin.2021.101665

Li, N., Feng, C., Shi, B., Kang, R., and Wei, W. (2022). Does the change of official promotion assessment standards contribute to the improvement of urban environmental quality? *J. Clean. Prod.* 348, 131254. doi:10.1016/j.jclepro.2022.131254

Li, X., Du, K., Ouyang, X., and Liu, L. (2022). Does more stringent environmental regulation induce Firms'Iinnovation? Evidence from the 11th five-year plan in China. *Energy Econ.* 112, 106110. doi:10.1016/j.eneco.2022.106110

Liu, C., and Xiong, M. (2022). Green finance reform and corporate innovation: Evidence from China. *Finance Res. Lett.* 48, 102993. doi:10.1016/j.frl.2022.102993

Obenauer, M. L., and von der Nienburg, B. (1915). *Effect of minimum-wage determination in Oregon*. Washington, DC: US Department of Labor. Bureau of Labor Statistics Bulletin No. 176.

Olley, G. S., and Pakes, Ax. (1996). The dynamics of productivity in the telecommunications equipment industry. *Econometrica* 64 (6), 1263–1297. doi:10.3386/w3977

Paul, L., Michel, P., and Richard, L. (2008). Environmental regulation and productivity: Testing the porter hypothesis. *J. Prod. Aanalysis* 30 (2), 121–128. doi:10.1007/s11123-008-0108-4

Peng, N., and Zhang, X. (2022). The impact of environmental regulations on the location choice of newly built polluting firms: Based on the perspective of new economic geography. *Environ. Sci. Pollut. Res.* 29 (39), 59802–59815. doi:10.1007/s11356-022-19956-8

Porter, M. E., and Van der Linde, C. (1995). Toward a new conception of the environment-competitiveness relationship. *J. Econ. Perspect.* 9 (4), 97–118. doi:10.1257/jep.9.4.97

Schoemaker, P. J., and Marais, M. L. (1996). "Technological innovation and firm inertia," in *Organization and strategy in the evolution of the enterprise* (London: Palgrave Macmillan), 179–205.

Shen, W., Wang, y., and Luo, W. (2021). Does the porter hypothesis hold in China? Evidence from the low-carbon city pilot policy. *J. Appl. Econ.* 24 (1), 246–269. doi:10.1080/15140326.2020.1858224

Snow, J. (1855). *On the mode of communication of cholera*. London: John Churchill.

Stefan, A., Mark, A. C., Stewart, E., and Paul, L. (2013). The porter hypothesis at 20: Can environmental regulation enhance innovation and competitiveness? *Rev. Environ. Econ. Policy* 7 (1), 2–22. doi:10.1093/reep/res016

Tang, P., Yang, S., Shen, J., and Fu, S. (2018). Does China's low-carbon pilot programme really take off? Evidence from land transfer of energy-intensive industry. *Energy Policy* 114 (3), 482–491. doi:10.1016/j.enpol.2017.12.032

Testa, F., Iraldo, F., and Frey, M. (2011). The effect of environmental regulation on firms' competitive performance: The case of the building &construction sector in some EU regions. *J. Environ. Manag.* 92 (9), 2136–2144. doi:10.1016/j.jenvman.2011.03.039

Tobin, J. (1969). A general equilibrium approach to monetary theory. *J. money, credit Bank.* 1 (1), 15–29. doi:10.2307/1991374

Walley, N., Whitehead, B., Wong, B., and Keshav, S. (1994). It's not easy being green. *Read. Bus. Environ.* 36 (81), 211–222. doi:10.1145/2377677.2377719

Xue, Y., Jiang, C., Guo, Y., Liu, J., Wu, H., and Hao, Y. (2022). Corporate social responsibility and high-quality development: Do green innovation, environmental investment and corporate governance matter? *Emerg. Mark. Finance Trade* 58 (11), 3191–3214. doi:10.1080/1540496X.2022.2034616

Yu, C. H., Wu, X., Zhang, D., Chen, S., and Zhao, J. (2021). Demand for green finance: Resolving financing constraints on green innovation in China. *Energy Policy* 153, 112255. doi:10.1016/j.enpol.2021.112255

Yuan, B., and Xiang, Q. (2018). Environmental regulation, industrial innovation and green development of Chinese manufacturing: Based on anextended CDM model. *J. Clean. Prod.* 176, 895–908. doi:10.1016/j.jclepro.2017.12.034

Zhao, T., Xiao, X., and Dai, Q. (2021). Transportation infrastructure construction and high-quality development of enterprises: Evidence from the quasi-natural experiment of high-speed railway opening in China. *Sustainability* 13 (23), 13316. doi:10.3390/su132313316

Zheng, J., Ma, G., Wei, J., Wei, W., He, Y., Jiao, Y., et al. (2020). Evolutionary process of household waste separation behavior based on social networks. *Resour. Conservation Recycl.* 161, 105009. doi:10.1016/j.resconrec.2020.105009