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Full Length Article

Does low-carbon pilot policy in China improve corporate profitability? The role of innovation and subsidy

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ABSTRACT

In an effort to aggressively combat climate change, China implemented a low-carbon city pilot policy (LCCP) in 2010. This study analyzes the impact LCCP, which is a specific environmental regulation on firms' profitability and innovation performance. The study argues that LCCP has an impact on corporate profitability by enhancing corporate innovation. Based on the data of A-share listed enterprises from 2005 to 2020, this study employ a multi-period Differences-in-Differences (DID) method to explore whether and how the LCCP affects the profitability of enterprises. The study finds that: (1) LCCP can greatly increase enterprise profitability; (2) LCCP has a more prompt effect on the profitability of large companies; (3) LCCP increases innovation investment and financial subsidies, which in turn increases company profitability. The study enriches the body of knowledge on the effects of LCCP on large companies and SMEs, and provides crucial evidence base for the consequences of government's strategy to assist firms in achieving the low carbon growth.

1. Introduction

Global warming is a serious challenge related to the survival of mankind and the common interests of all countries. In this context, the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) created the intergovernmental body, the United Nations Intergovernmental Panel on Climate Change (IPCC), in 1988. In addition, the development of human society is accompanied by increasing levels of carbon emissions. The overall trend suggests that CO_2 emissions have been increasing gradually over the years with some fluctuations (as shown in Fig. 1). From 2005 to 2010, the CO_2 emissions increased from 28.6 million metric tons to 32.4 million metric tons, which is a significant increase of about 13%. This trend continued with a slight increase in the emissions until 2013. From 2014 to 2017, there were some fluctuations in the CO_2 emissions, but the trend remained generally upward. From 2017 to 2019, there was a significant increase in emissions. The CO_2 emissions then dropped in 2020 to 34.2 million metric tons, most likely due to the COVID-19 pandemic. However, the emissions then increased in 2021 to 36.3 million metric tons, and reached the highest annual level ever, indicating a continuation of the overall upward trend (IEA, 2021). Therefore, the overall trend suggests that CO_2 emissions have been increasing over time, with some fluctuations due to various factors such as economic activities and global events. This amount of CO_2 emissions pose a serious and ongoing threat to people's lives and wider society (Masson-Delmotte, 2018). As a result, the global community has given the issue of climate change significant attention and created worldwide accords to decrease greenhouse gas emissions.

In the same vein, the dire domestic situation has led China to place the fight against climate change at the forefront of its national governance. In 2005, China surpassed the United States in total CO_2 emissions and became the world's top CO_2 emitter. Fig. 2 demonstrates that China's carbon dioxide emissions increased rapidly from 2006 to 2008, reaching 8.44%. However, in 2008, the global financial crisis led to a significant reduction in economic activity and energy demand. Many industries were hit hard, resulting in lower production, reduced energy consumption, and lower growth of CO_2 emissions. After 2011, China started to enact stricter environmental protection regulations. Technologies for reducing emissions and using less energy were implemented at this period, and inhabitants' understanding of environmental preservation increased. The pace of expansion of carbon emissions started to slow. However, China's resurgence and economic recovery from the COVID-19 embargo in early 2020 may be the cause of the spike in CO_2 emissions in 2021 ((Long et al., 2022)).

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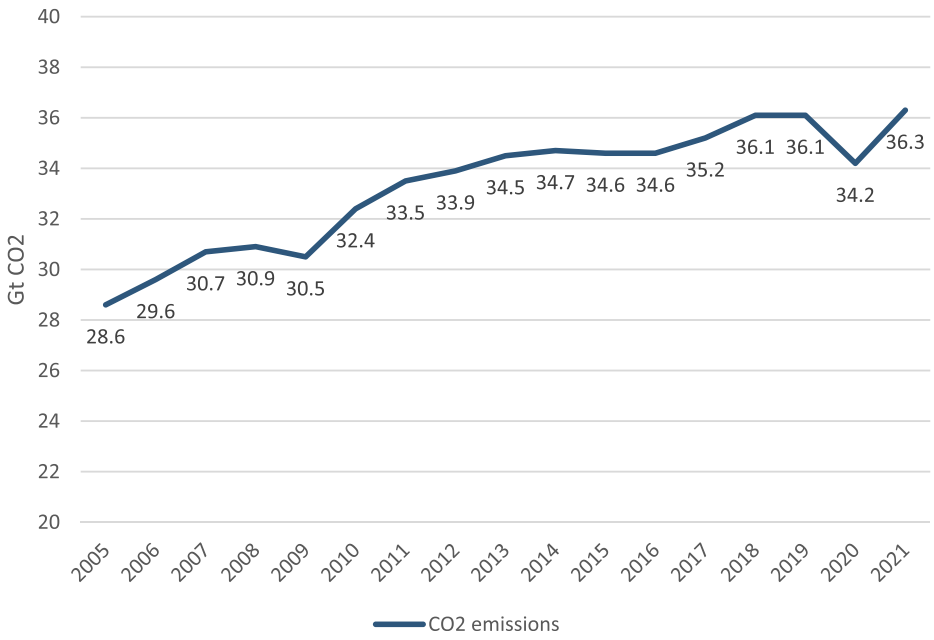

Fig. 1. Global carbon dioxide emissions 2005–2021 (source: IEA).

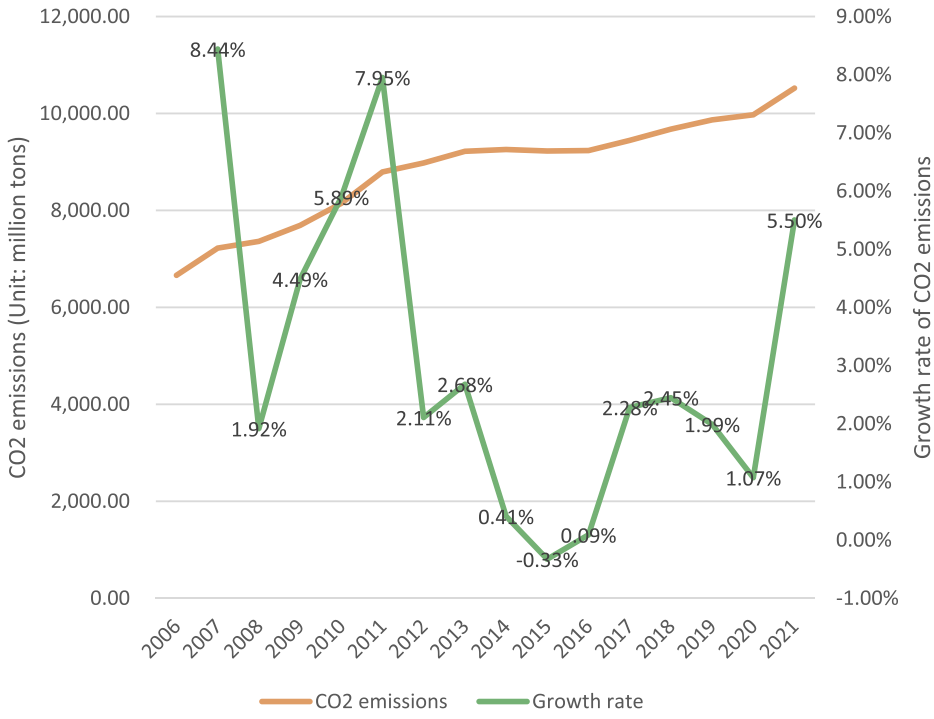

Fig. 2. China's carbon dioxide emissions from 2010 to 2020 (source: bp Statistical Review of World Energy 2022).

China has been actively promoting a comprehensive shift towards green economic and social growth, coupled with intensified efforts to reduce carbon emissions. Indeed, in his address to the United Nations General Assembly in September 2020, President Xi Jinping stated that "*China would increase its autonomous national contribution and adopt more robust policies to achieve peak CO2 emissions by 2030 and carbon neutrality by 2060.*" Furthermore, the Chinese government published a directive on the nation's efforts to meet carbon peaking and carbon neutrality objectives in accordance with the new development philosophy on October 24, 2021. The document outlines five main tasks for the systematic planning and overall deployment of the major work of carbon peaking and carbon neutrality (known as 'double carbon'). Moreover, the creation of a national ecological civilization has taken into account the requirement for 'double carbon'. The Chinese government has also been investigating efficient environmental management options to lower CO_2 emissions and make sure the 2030 objective for reducing greenhouse gas emissions is realized (Wang, Feng, Wang, & Chang, 2022). In August 2010, China's National Development and Reform Commission (NDRC, 2010) issued the "*Notice of China's Pilot Work on Low-Carbon Provinces, Regions, and Cities*" in an effort to aggressively combat climate change. The program has since been expanded twice, demonstrating the government's ongoing commitment to achieving low-carbon objectives.

Enterprises, as actual participants in low-carbon programs, are one of the three main actors in developing a low-carbon economy and

subsequently building low-carbon cities (Ma, Hu, Shen, & Wei, 2021). Enterprises need government policy support and environmental control to compel them to actively implement this policy. In concrete practice, therefore, the government needs to assess the pilot policy's efficacy to determine the future course of the policy. Some scholars contend that environmental regulations can place undue private costs on firms and thus negatively affects their profitability. However, others argue that appropriately designed regulations can actually stimulate innovation and boost productivity (Hua & Wang, 2023). In support of this perspective, Porter's hypothesis suggests that businesses engaged in environmentally responsible practices can experience increased profitability due to improved operational efficiency and enhanced reputation in the marketplace.

From combing through previous studies in the extant literature, it can be observes that there is a gap in the knowledge base regarding the impact of LCCP on firm level profitability, which has not been theoretically explained through a normative mathematical model. Therefore, this empirical research employs the DID model to explore the effect of LCCP on the financial performance of A-share listed firms between 2005 and 2020. The objective of this study is to investigate whether and how the LCCP impacts firms' profitability.

The empirical results based on DID show that LCCP can significantly and consistently improve the profitability of enterprises. In addition, this policy has a more significant effect on the profitability of large firms than that of SMEs (small and medium-sized enterprises). Moreover, the mechanism of action analysis shows that LCCP promotes the profitability of firms by increasing innovation investment and financial subsidies. The study's findings may be used to determine if the LCCP increases company profitability while concomitantly encouraging green business development. The effectiveness of this policy will be determined by whether it increases corporate profits; if not, it has to be revised. The company's financial indicator data and other corporate-level data are obtained from the Guotaian database, Wind database and CNRDS database. Data on city characteristics and local environmental indicators are obtained from *China City Statistical Yearbook* and *Local Statistical Yearbook*, respectively.

The contributions of this study are as follows: Firstly, using the DID method to assess the impact of the LCCP on enterprise profitability, and thereby adding to the literature on how this policy will affect micro-enterprises (Chen, Yang, & Chen, 2020; Fu, He, & Luo, 2021; Liu & Qin, 2016; Pan, A., Zhang, W., Shi, X., & Dai, L., 2022; Sun & Wang, 2021). Secondly, from the perspective of innovation effect and financial subsidies, the study investigates the impact mechanism of this policy on the development of corporate profitability and offers a practical reference value for the government to assist businesses in achieving the "double carbon" objective strategy. Thirdly, the study identifies the different impacts of pilot policies on profitability and proposes targeted policy recommendations for the low-carbon transition of various types of firms. Unlike existing studies that consider heterogeneity from other perspectives (Chen, Guo, et al., 2021; Gao, Li, & Li, 2022), this study investigates the heterogeneity and mechanisms of the impact of pilot policies on the profitability of low-carbon cities from the perspective of firms of different sizes.

The remainder of this study is structured as follows: The second section is the literature review; the third section introduces the background of the low-carbon city pilot policy and outlines the research hypotheses; the fourth section constructs the regression model and identifies the variables of interest, preprocesses the panel data, and describes the data; the fifth section presents the empirical results, including robustness checks and heterogeneity analysis; the sixth section offers a mechanism analysis. Finally, the conclusion and policy recommendations are provided in the seventh section.

2. Literature review

2.1. Studies on low carbon city pilot policy (LCCP)

China implemented the LCCP in 2010 as a measure to decrease CO_2 emissions. The impact of this policy has become a widely studied topic. Existing literature mainly focuses on the evaluation of the pilot cities involved in the environmental pilot policy. For example, many scholars have demonstrated the positive impact of the LCCP on different aspects, including atmospheric environmental performance (AEP) policy improvements (Li, Fang, Chen, & Mao, 2022), green economic growth (Su & Gao, 2022), carbon emission reduction (Liu & Qin, 2016; Chen et al., 2020; Fu et al., 2021; Sun & Wang, 2021) and low-carbon innovation (Pan, A., Zhang, W., Shi, X., & Dai, L., 2022). Among them, since the policy is centered on reducing carbon emissions, the majority of scholars appear to study how the policy can help achieve the carbon reduction goals of cities by focusing on the carbon intensity of low-carbon cities.

Additionally, previous research has generally focused on the two major categories of technology innovation and structural optimization that affect LCCP impacts on cities. For instance, Yang, Zhang, Ren, & Ran (2021) studied the impact of low-carbon city construction on high-quality urban development and its transmission mechanism. They argue that both green technology innovation and industrial structure upgrading have partial mediating effects between LCCP and high-quality urban development performance. Whereas Liu (2022) and Zhang, Feng, and Zhou (2022) have similar findings: The LCCP has a positive effect on carbon emission reduction through technological innovation and industrial restructuring.

Scholars that explore the effects of LCCP on businesses from a micro viewpoint frequently base their discussions on the Porter's hypothesis. Some scholars argue that environmental regulation generates higher production costs for firms, which is detrimental to socio-economic growth. An empirical study of the Swedish paper industry by Brännlund, Färe, and Grosskopf (1995) found that environmental regulations increased firms' costs and reduced their profits. Similarly, Darnall, Jolley, and Ytterhus (2007) combined theoretical models and empirical studies and found that when firms face strict environmental regulations, the greater the cost of environmental accidents are at that time. The likelihood of a decline in environmental ratings also rises, which makes it more difficult for firms to raise capital and thereby increases the cost of doing business. The final result is that strict environmental regulations lead to a decline in business performance. However, according to Porter's hypothesis, moderate environmental regulation stimulates technological innovation (Porter & Linde, 1995). Regulated businesses enhance manufacturing processes in order to lower the cost of pollution management, which may lessen the expense associated with environmental protection. Furthermore, there is currently a substantial corpus of research that backs the Porter hypothesis (Qi, Zhou, Li, & Tang, 2021). For example, many scholars (Luo et al., 2022; Ma, Hu, Shen, & Wei, 2021; Tian & Liu, 2021) have found the positive effects of environmental regulations on innovation, providing a compensatory mechanism to promote innovation in green technology. Liu, Zhou, Liu, Xie, & Zeng (2020) examined the impact of the LCCP on firms' green total factor productivity (GTFP) and determined that it is creating a win-win development for China. This indicates that the LCCP is not sacrificing economic benefits while achieving carbon reduction targets.

With the development of spatial econometrics, many scholars began to include spatial factors in their studies and consider spillover effects. For instance, Zhu and Lee (2022) demonstrated that the LCCP promotes technological innovation in neighboring cities of the pilot cities. The reason for this phenomenon is that innovation is spread between cities through knowledge diffusion mechanisms and externality mechanisms, so its spatial linkages are usually characterized by knowledge spillovers. In addition, human capital, from neighboring cities is attracted due to an improved living environment. This efficient allocation of human capital drives technological innovation in the local and neighboring areas. According to Chen and Wang (2022), LCCP improves local environmental performance in pilot cities by suppressing industrial activities and industrial energy consumption. Meanwhile, the Spatial-DID model results indicate that the LCCP can also reduce CO_2 emissions in the surrounding

areas of pilot cities, contributing to the promotion of environmental friendliness in nearby regions.

2.2. Studies on the impact of different policies on corporate profitability

Different scholars have different views on the selection of indicators to reflect the profitability of a company. An example is the use of return on assets (ROA) to measure firm level performance, which has been widely adopted in various studies (Choi, Kwak, & Choe, 2010; Laskar, 2019). Another measure is return on equity (ROE). ROA and ROE are two profitability measures used by Pessarossi, Thevenon, and Weill (2020). They contend that these indicators gauge the "absolute" or "intrinsic" amount of bank profitability. According to Novy-Marx (2013), gross profit is the most accurate accounting measure of economic profitability since, as one moves farther down the income statement, the profitability indicator becomes tainted and loses its applicability to real profitability. In addition, other scholars prefer to use DCF (discounted cash flow) to estimate the profitability of a project according to calculation of either the NPV (net present value) or IRR (internal rate of return). It is a broad economic assessment method that considers only cash inflows and outflows (Cucchiella, D'Adamo, Gastaldi, & Miliacca, 2018).

The impact of different policies on firm profitability has been extensively studied. Zhou, Qiu, and Wang (2021) examine the impact of the newly revised Environmental Protection Law (EPL) on firm performance from the perspective of the strong Porter effect. They discovered that the new EPL's implementation greatly increased heavy polluters' profits. This was achieved by combining corporate expense management and removing low-profit small firms. The new EPL, however, did not successfully encourage businesses to innovate. Whereas Tian, Ding, Yang, & Peng (2022) found that the de-capitalization policy significantly increased ROE of the experimental group. De Schoenmaker, Van Cauwenberge, and Vander Bauwhede (2014) confirmed that local fiscal policies have a non-negligible negative impact on return on assets (ROA) in the hospitality industry. Finally, Toni, Milan, Saciloto, & Larentis (2017) found that value-based pricing strategies and high price levels positively influence firm profitability, as measured by average profitability. These results suggest that pricing policies have a significant impact on a firm's financial performance.

2.3. Studies on the impact of LCCP on corporate profitability

Overall, there is a large body of literature exploring the impact of low-carbon city pilot policies in terms of cities and firms, and the impact of various policies on firm profitability. However, even though there is significant literature on the economic effects of this environmental policy on firms from different perspectives, no consistent conclusions have been reached, and especially in the empirical studies. The reasons for these inconsistent empirical findings are mainly the following three:

Firstly, the selection of environmental regulation indicators is a problem. The choice of environmental regulation indicators is crucial in testing the effect of environmental regulation as different indicators have their advantages and disadvantages. When studying the impact of environmental regulation on enterprises, the use of conventional proxy variables such as emission fees, pollutant emissions, and pollution control investment for each enterprise may present two issues (Du & Li, 2020). The study of the impact of environmental regulations on firms is important but challenging due to the difficulty of measuring environmental regulation variables at the firm level. As a result, much of the literature has examined the impact of environmental regulations at the regional or industry level, where the policy or type of regulation is often identical for all firms. However, this has led to relatively small and controversial findings in the literature.

Secondly, the heterogeneity of enterprises or regions targeted by environmental regulation is problematic. Due to the differences in their own characteristics, different enterprises or regions do not have exactly the same objectives when implementing environmental regulations on the one hand, and their ability to implement environmental regulations on the other hand.

Thirdly, the most serious problem is the endogeneity problem caused by the proxy variables. The main sources of endogeneity are omitted variable bias, selection bias, and reverse causality (Elwert & Winship, 2014), which seriously interfere with the examination of the economic effects of environmental regulations. Generally, scholars address endogeneity issues by using instrumental variables (IV) and Heckman models (Vandenberghe & Robin, 2004; Stubbs, Reinsberg, Kentikelenis, & King, 2018; Xu et al., 2020; Zuo & Hong, 2022). However, this study is multi-period DID analysis, it is usually not necessary to use IV to control for endogeneity. This is because the identification strategy is based on a strong assumption that the treatment effect remains constant over time and the trends of the treatment and control groups are parallel in the absence of treatment. If these assumptions hold, any differences in outcomes between the treatment and control groups after treatment can be attributed to the treatment itself rather than other endogenous factors (Wang et al., 2021). Therefore, in multi-period DID analysis, IV is typically not needed to control for endogeneity. Additionally, Hackman test is commonly used to test for endogeneity issues in DID analysis. However, in multi-period DID analysis, Hackman test is not applicable because it assumes that the policy variable is endogenous, while in multi-period DID analysis, the policy variable is exogenous, based on the identification strategy that relies on time trends and policy changes. Therefore, in multi-period DID analysis, Hackman test is usually not needed to test for endogeneity.

Profitability is a prerequisite for long-term existence and is a typical measure of a company's financial performance (De Schoenmaker et al., 2014). Profitability, the basis for the survival of a company in its industry, is the result of the interaction between the company's internal production capacity and the level of demand for its products in the external market. Profits can be a good indication of a company's profitability. The main concern of a company is profit, which ensures the improvement of employee welfare facilities and wider stability of the enterprise. Profit, which indicates the performance of the operator's operations and management efficiency and is a key component of a company's performance and competitiveness, is the source of investment income for investors and principle and interest for creditors.

3. Potential mechanisms to address the challenge

3.1. Background of LCCP

The low-carbon city pilot project in China has brought about a new approach to urban management that combines top-down planning with targeted pilot demonstrations. The pilot cities have adopted a low-carbon economy as their development model and direction, with the concept of low-carbon living gaining acceptance among the population. The government has also planned to pilot the construction of low-carbon provinces, regions, and cities, using a low-carbon society as the blueprint. The LCCP is a critical strategy to reduce carbon emissions and promote high-quality development in China, covering large first-tier cities as well as smaller second- and third-tier cities and areas. The distribution of the LCCP is illustrated in Fig. 3.

Low-carbon city pilots are strategically distributed across the country's regions, with the east having a higher concentration. Despite having fewer provinces and a smaller size than the western coastal region, the eastern coastal region has the most intense distribution of low-carbon pilot zones. The selection of low-carbon pilot cities is also an important consideration. In particular, the first batch of low-carbon city pilots was chosen by the central government, whereas the subsequent batches of pilots were chosen in a more adaptable and diverse way through local declarations and expert evaluations to select pilot cities in a more transparent and scientific manner (see Table 1). This approach is conducive to the expansion of the scale of low-carbon city pilots, promoting positive inter-regional interaction and bringing into play the

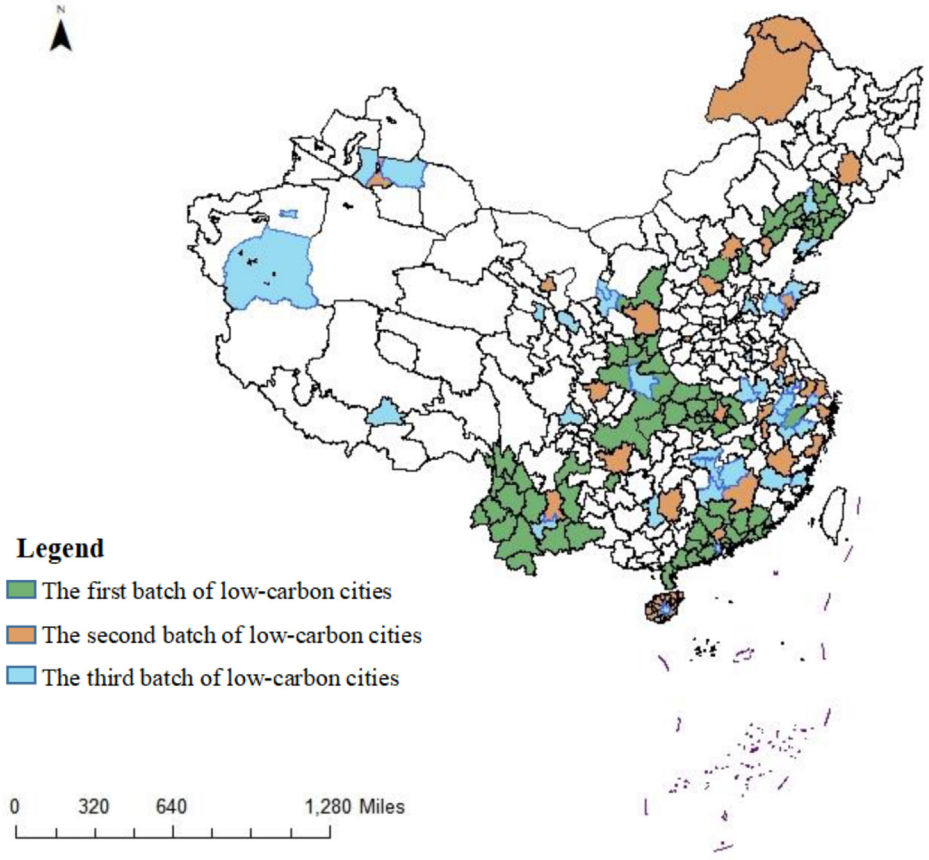

Fig. 3. Spatial distribution of three batches of low-carbon pilot areas in China.

Table 1
Overview of LCCP for low-carbon cities.

Implementation time	July 2010	November 2012	January 2017
Batch	1	2	3
Selection Tools	Central Government Formulation	Local declaration + central evaluation	Local declaration + central evaluation
Purpose	Effectively control greenhouse gas emissions, properly respond to climate change, and strive to achieve a green, low-pollution, low-energy-consumption production and consumption system	Take advantage of comparative advantages, promote positive interaction between regions, explore emission reduction paths and achieve green and low-carbon development	Explore and summarize the new pattern of low-carbon city development with harmonious development of human and nature
Work Tasks	Create strategies for low-carbon development, formulate supporting policies, strengthen the management of greenhouse gas emissions, and advocate low-carbon lifestyles	The target accountability for carbon emissions is proposed on the basis of the first batch	Based on the first two batches, cities are required to set local peak emissions of CO_2

(Source: arranged by the author).

comparative advantages of cities with different resource endowments. The level of cities covered is also more diversified, rather than just the first-tier developed cities.

According to the "*Notice on Promoting the Pilot Work of National Innovative Cities*" issued in 2010, the Chinese government laid out specific tasks for the pilot areas; with slight differences in the work requirements for each area. However, the way the government carries out the pilot low-carbon city mainly includes several considerations: (1) Adjusting the industrial structure of the pilot area. This involves achieving low-carbon industrial upgrading through technical advancement; supporting a circular economy; creating low-carbon industries; and changing urban industrialization's purpose to that of a service industry (Hao, Li, Ren, Wu, & Hao, 2023). (2) Adjusting the energy structure of the pilot area. This includes improving energy efficiency; employing more green and renewable energy; and lowering greenhouse gas emissions in pilot regions. (3) Creating a green and low-carbon comprehensive transportation system, and optimizing and adjusting the transportation structure. This involves vigorously develop low-carbon urban transportation systems, actively developing public transportation, and reducing carbon emissions (Chen et al., 2021). (4) Actively promoting green architecture and energy-efficient construction. Moreover, as part of the green and low-carbon development in the construction industry, the mandatory engineering construction specifications will include the essential standards for green buildings, while the energy-saving renovation of existing buildings will be implemented. This will contribute to the development of high-quality green buildings, in line with the criteria for sustainable development (Hariyani, Mishra, Hariyani, & Sharma, 2023; Mgomezulu, Machira, Edriss, & Pangapanga-Phiri, 2023).

As a "bottom-up" policy, LCCP emphasizes the need for more local implementation (Wang, Song, He, & Qi, 2015). Low-carbon pilot cities have established specific low-carbon targets that are tailored to their own developmental levels. For instance, Qingdao has set a differentiated target for reducing regional carbon emission intensity by taking into account the current situation and future development layout of the area. In Chenan,

Hebei, Licang, and Laoshan districts, the city aims to reduce carbon dioxide emissions per unit of gross regional product by 20.5% compared to 2020, while in the West Coast New Area, Chengyang, Jimo, and Jiaozhou districts, the target is a 22.5% reduction. Such targets not only help to promote low-carbon development but also enable local governments to monitor their progress towards a sustainable future (Qingdao News, 2022). In addition, Wuhan has implemented various initiatives as part of its local urban work plan to promote low-carbon development. These measures include restructuring and optimizing the energy mix, encouraging key industries to take the lead in achieving the "3060" carbon reduction target, establishing a national carbon finance center, and promoting a new low-carbon culture in society (Changjiang Daily, 2021).

3.2. Hypothesis formulation

The LCCP enhances the social reputation of enterprises while improving their competitiveness. With the increasing global environmental pollution problem, the green transformation of enterprises is the inevitable path for their development (Zhao, Wen, Zou, Wang, & Chang, 2022). At the same time, social reputation reflects a company's socially responsible attitude. Companies need to pay attention to their own social reputation if they want to develop sustainably in the long term (Zheng, Feng, Jiang, & Chang, 2022). During the implementation of the LCCP, some enterprises have taken the initiative to adopt the environmental responsibility of greening their production processes and reducing emissions, which is a manifestation of their more active response to the "double carbon" target. As a result, such enterprises can accumulate better moral capital, win the trust of customers and build a good corporate image among them. At the same time, these enterprises have started to shift from the traditional end-to-end treatment of pollution first and treatment later to the greening of the whole process covering the source of production, transmission process and terminal control. They subsequently occupy a competitive advantage in the market and realize the improvement of enterprise profitability. These enterprises that initiate the transition to a low-carbon, green economy may respond to external environmental uncertainties more effectively, maintain their competitive edge in the market (Porter & Linde, 1995; Yang, Zhang, Ren, & Ran, 2021), and ensure constant growth in corporate profitability.

Thus, the study proposes hypothesis H1: LCCP significantly improves the profitability of firms.

The impact of LCCP on enterprise profitability can be divided into two paths. In the short term, companies have to follow the policy requirements to develop a series of low-carbon measures, such as increasing pollution control expenditures and improving pollution control technology. This will make the investment in environmental control increase the cost of investment and operation of companies. The short-term impact of environmental regulations on enterprises' economic indicators may be negative. However, according to Porter's hypothesis (Porter & Linde, 1995), the degree to which environmental regulations improve firm profitability depends on the amount of innovation compensation gain. Such regulations can motivate firms to innovate and promote innovation. To some extent, the benefits of innovation can offset the increased costs of complying with environmental regulations and even boost firms' profitability. For one thing, local governments set clear requirements in terms of emission standards and production technologies (Raihan, 2023), and establish mandatory market guidelines to urge enterprises to improve green technology innovation (Fu, Gong, Zhao, & Chang, 2022). The enactment of LCCP by the government means that the green innovation behavior of enterprises will be subject to less administrative control and constraints (Wen, Yin, Jang, Uchida, & Chang, 2023), such as the simplification of the regulatory approval process for investment projects. All these measures increase the incentive for green-related innovation projects of enterprises. For another, the government has implemented various market-based tools, including environmental taxes, subsidies, and carbon trading, to incentivize enterprises to internalize the costs of environmental pollution and prioritize energy conservation and emission reduction benefits. Through the implementation of such tools, the government seeks to encourage enterprises to incorporate environmental resources as inputs of production.

Therefore, the study proposes hypothesis H2: LCCP affects firm profitability through encouraging innovation.

The second path is to enhance the profitability of enterprises through financial subsidies. During the initial phase of the LCCP implementation, enterprises in pilot regions face challenges in upgrading their facilities and transitioning to low-carbon production due to high externalities, risks, and slow returns. In other words, when facing strict environmental regulations, firms will bear higher operating costs and may find it difficult to benefit from environmental investments in the short term. Therefore, relying on market forces alone is often difficult to ensure adequate environmental protection investment. Furthermore, the government can incentivize enterprises to reduce emissions and adopt energy-saving technologies by offering subsidies. This approach helps enterprises to internalize the positive externalities of green transformation and motivates them to take actions that align with the government's low-carbon development goals (Peng, Zou, Zhao, & Chang, 2022). The government supports project development through subsidies and interest rates, thus greatly alleviating the problem of corporate financing constraints and guaranteeing the improvement of corporate profitability. To effectively advance the "double carbon" paradigm, various incentives and subsidies have been introduced to promote carbon emission reduction. The NDRC of China and the pilot provinces and municipalities, when deploying the pilot work, clearly proposed that enterprises actively participating in energy saving and carbon reduction will be given priority in providing financial special funding support (Jiangsu Provincial Department of Finance, 2022; NDRC, 2021; Shanghai Xuhui Area Government, 2022). In addition, the government encourages financial institutions to provide financial products related to energy conservation and emission reduction to these enterprises. Consequently, these measures motivate enterprises to continuously promote R&D innovation, alleviate the pressure of emission reduction, and improve enterprise performance.

Based on the above, the study proposes hypothesis H3: The implementation of the LCCP will increase the financial subsidy income of enterprises in the pilot areas.

4. Empirical design

4.1. Model setting

The DID method, a commonly used empirical approach in policy evaluation, is employed in this study to examine the effect of LCCP implementation on the profitability of different groups. By comparing the differences between the impact of pilot and non-pilot areas before and after policy implementation, this method allows for the separation of the policy treatment effect from non-varying and unobservable factors over time, providing a straightforward causal effect of the policy evaluation. The central objective of this study is to investigate the impact of LCCP implementation on profitability. For this purpose, the DID method is used to construct the regression equation: The pilot cities are used as the treatment group and the other cities are used as the control group. The net effect of LCCP on profitability is measured by calculating the relative differences in profitability between the treatment and control groups before and after policy implementation.

$$\text{Profitability}_{it} = \partial_1 + \partial_2 \text{LCCP}_{it} + \beta \text{CONTROL}_{it} + \mu_t + \gamma_i + \varepsilon_{it} \quad (1)$$

where, i, t denote the listed company and the year, respectively. Profitability$_{it}$ denotes the profitability indicator of firm i in year t. LCCP$_{it}$ is a dummy variable product of Treat and Period, which reflects the effect of the implementation of LCCP in year t on the profitability of control and experimental group enterprises. Treat and Period are two dummy variables that denote whether the firm's city is a pilot city and whether the

LCCP is implemented, respectively. Treat takes the value of 1 when the firm's city is a pilot city (treatment group) announced by the LCCP, and 0 when it is a non-pilot city (control group). As the LCCP is divided into three batches, according to different batches, the value is 0 before the policy point in time; and 1 after the policy point in time.

∂_2 denotes the effect of LCCP on firm profitability and is the core coefficient. $CONTROL_{it}$ denotes the control variable. As this study utilizes a longitudinal data set, it accounts for both time-fixed effects and firm-fixed effects. γ_i and μ_t denote firm fixed effects and time fixed effects, respectively, and ε_{it} is a random disturbance term. Specifically, this study controls for all firm characteristics that do not vary over time and all temporal characteristics that do not vary with individuals.

4.2. Variable selection

4.2.1. Explained variables

To precisely evaluate the profitability of companies, this study employs net profit and earnings per share as indicators. These metrics gauge the amount of profit generated by the company's assets and the profitability of common shares, reflecting the effectiveness of the firm's capital management and operations.

4.2.2. Explanatory variables

To investigate the impact of the LCCP on enterprise profitability, this study focuses on three batches of policy implementation in 2010, 2012, and 2017 in the pilot cities. The pilot cities are designated as the treatment group with a value of 1, while the non-pilot cities serve as the control group with a value of 0, referred to as Treat. The policy was implemented at different times, thus affecting the Treat variable differently across the years of policy implementation. Therefore, this study sets the years in the sample for the policy issuance and after as 1 and the years before the policy issuance as 0, denoted by Period. In addition, the first batch of the program focused on piloting low-carbon development at the provincial level, while the second and third batches were implemented at a more localized level, targeting specific cities or districts. In the specific determination process, there are provinces and cities with scope crossover situations. Specifically, many of the second three batches of cities (including districts and counties) in the provinces where the first batch has been included in the scope of the pilot. For example, Guangdong Province carried out the pilot in the first batch in 2010, while Guangzhou City carried out the pilot in the second batch. In this case, therefore, this study follows the principle of more refinement and focuses on the implementation time of the policy in the city where the enterprise is located, i.e., the batch with a later implementation time.

4.2.3. Variables used in mechanism analyses

This study analyzes firm R&D investment (R&D) to explore whether the strength of R&D investment influences the impact of LCCP and company profitability as part of the mechanism analysis. R&D investment refers to the various funds invested by a company to ensure the continuous and smooth development of its own R&D activities and thus the total expenditure.

Financial subsidies (FS) are divided into explicit and implicit subsidies based on the degree of transparency. In particular, explicit subsidies are financial subsidies that are paid directly to recipients as budgeted expenditure items in accordance with normal expenditure procedures. The implicit subsidy means that the recipient does not directly receive the subsidy income, but only benefits from the reduction of contribution and expenditure savings (Schwartz & Clements, 1999). Therefore, in this study, the sum of government subsidies and tax benefits disclosed by the sample of listed companies represents the financial subsidies received by the company.

4.2.4. Control variables

A number of firm level economic characteristics and city-level effects are chosen as control variables in this study since they may potentially have an impact on business profitability. For example, firm age (De Schoenmaker et al., 2014). Firms that have been established for a longer period can benefit from economies of experience, which are based on accumulated learning, and can avoid the costs associated with being a new entrant. Firm size is an important control variable (Majumdar & Chhibber, 1999; Wang, Cui, & Dong, 2023), since larger firms may have a wider range of capabilities and can take advantage of economies of scale. On the contrary, larger enterprises may have coordination problems, which will have a negative impact on performance (Anum Mohd Ghazali, 2010). A moderate debt level can help the company achieve the maximization of interests and strategic objectives (Xue et al., 2022; Yin, Chang, & Wang, 2022). Therefore, the asset-liability ratio should be regarded as a control variable (Khalid et al., 2022; Peng & Tao, 2022). In addition, GDP per capita of each prefecture-level city, level of foreign direct investment, value added of secondary industry, and environmental regulations are selected as the control variable at the city-level (Chai, Wu, & Hao, 2022; Ren, Hao, & Wu, 2022; Zou, Peng, Zhao, & Chang, 2023; Tang, Li, & He, 2023). Table 2 displays the definitions of the indicators used.

Table 2
The definitions and explanations of variables.

Types	Variables	Symbols	Definitions
Explained variables	Corporate Profitability	Profitability	Net profit, earnings per share
Explanatory variables	Low-carbon City Pilot Policy	LCCP	Dummy variable, the city (region) where the enterprise is located implements or has implemented the low carbon city pilot policy in the period, takes the value of 1, otherwise 0
Variables used in mechanism analyses	Innovation	R&D	Corporate R&D investment
	Financial Subsidies	FS	Financial subsidies received by enterprises
Control variables	Firm Age	Age	Length of time a company has been listed
	Firm Size	Size	Natural logarithm of the total assets
	Asset-liability ratio	DAR	Ratio of total liabilities to total assets
	Industrial Structure	IS	Natural logarithm of added value of secondary industry
	Economic Development Status	PerGDP	Natural logarithm of GDP per capita
	Foreign Direct Investment Level	FDI	Natural logarithm of the amount of foreign investment
	Environmental Regulation	SO_2	Industrial sulfur dioxide emissions

4.3. Descriptive statistics

This study uses Chinese A-share listed companies from 2005 to 2020 as the research sample. Data on financial indicators and other corporate-level data of companies are obtained from Guotaian database, Wind database and CNRDS database. Data on city characteristics and local environmental indicators are obtained from China City Statistical Yearbook and local statistical yearbooks. In addition, for some of the variables, this study divides the raw data by the CPI from 2005 as the base period. The purpose of doing so is to exclude price factors from the data. The descriptive statistics for the primary variables considered in this study are displayed in Table 3. The table shows that the mean net profit and standard deviation are 3.966 and 13.640, respectively. As a result,

Table 3
Descriptive statistics.

Variable	Obs	Mean	Std. Dev.	Min	Max
Net Profit (Unit: million yuan)	37,464	3.966	13.640	−8.709	105.913
Earnings per share (Unit: yuan)	37,464	.316	.570	−10.965	14.941
LCCP	37,464	.531	.499	0	1
R&D (Unit: million yuan)	23,925	142.652	639.201	4.85e-06	35060.19
FS (Unit: billion yuan)	37,464	1.288	8.901	0	491.676
PerGDP (Unit: null)	37,464	7.323	1.292	3.466	8.199
FDI (Unit: null)	37,464	7.225	1.066	1.099	8.141
SO_2 (Unit: ton)	37,346	57403.210	75847.850	0	426800
IS (Unit: million yuan)	37,172	7.532	1.018	4.573	8.892
Age (Unit: year)	37,464	8.840	7.275	0	30
Size (Unit: null)	37,462	21.483	1.659	17.901	26.705
DAR (Unit: %)	33,566	.443	.227	.041	1.085

the coefficient of variation is 3.439, which suggests that there are large variations in each firm's profitability. This serves as the framework for the empirical analysis.

5. Results

5.1. Baseline results

To examine hypothesis H1, we employed a two-way fixed effects model (1) in our regression analysis to control for individual and time effects. The estimated results are presented in Table 4. The first and third columns of Table 4 show the regression outcomes without incorporating control variables (CONTROL). The first two columns are net profit as the explanatory variable to explore the relationship between policy and firm profitability, while the third and fourth columns are earnings per share. Among them, model (1), (2) and (4) report that the regression coefficient of LCCP is significantly positive at the 5% level, thereby indicating that the LCCP generate positive financial returns for firms in the pilot cities relative to the control group. Therefore, assuming that hypothesis H1 can be proven to be valid. Unlike previous studies, which focused on enterprise innovation (Ma, Hu, Shen, & Wei, 2021; Tian & Liu, 2021) and enterprise GTFP (Liu, Zhou, Liu, Xie, & Zeng, 2020; Zheng, Feng, Zhao, & Chang, 2023), the study examines the profitability of enterprises through net profit and earnings per share. However, the coefficient of LCCP in model 3 is not significant, which may be due to the omission of important variables.

Table 4
The average effect of the LCCP on enterprise profitability.

VARIABLES	Net Profit	Net Profit	Earnings per share	Earnings per share
	(1)	(2)	(3)	(4)
LCCP	0.552**	0.509**	0.013	0.025**
	(0.256)	(0.254)	(0.014)	(0.013)
PerGDP		−0.208***		−0.001
		(0.065)		(0.003)
FDI		−0.001		0.003
		(0.052)		(0.003)
SO_2		−0.000		−0.000***
		(0.000)		(0.000)
IS		−0.095		0.058***
		(0.379)		(0.019)
Age		1.847***		0.412***
		(0.404)		(0.027)
Size		2.356***		0.084***
		(0.233)		(0.008)
DAR		−3.197***		−0.715***
		(0.498)		(0.034)
Constant	0.533**	−45.483***	0.185***	−1.874***
	(0.269)	(4.490)	(0.017)	(0.205)
Observations	37,464	33,197	37,464	33,197
R-squared	0.045	0.095	0.045	0.103
Number of Stock Code	4056	3687	4056	3687
Stock Code FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES

Note: The number in the parentheses is standard errors.
Significance: *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

5.2. Robustness check

5.2.1. Dynamic effects test

In order to apply the DID approach, it is necessary to ensure that the time trends of the outcome variables in the treatment and control groups are consistent before the policy implementation. This requires that the changes in profitability trends of firms located in the pilot cities and those in non-pilot cities are synchronized. If there are systematic differences between the two sample groups prior to implementation of this policy, this indicates the presence of unobservable and time-varying influences during the period that is difficult to test using the DID model. The prior baseline analysis does not account for differences in the policy's performance over time; it merely evaluated the average impact of the LCCP on firm profitability. It is evident from the implementation of the LCCP that it is a typical asymptotic DID model. Recent research advances in DID point to estimation bias if the traditional Two-way Fixed Effects (TWFE) is used to identify treatment effects (de Chaisemartin & D'Haultfœuille, 2020). Therefore, many scholars have now proposed alternative estimation methods for TWFE, and they have gradually favored the event study approach to examine the "dynamic effects" of policy implementation (Sun, 2022). This study, which follows Sun and Abraham's (2021) method, uses an event study approach to empirically investigate the dynamic changes in firm profitability in the pilot cities before and after the policy's adoption in order to analyze the dynamic impacts of the LCCP. The estimated model is as follows:

$$\text{Profitability}_{it} = \partial_1 + \Sigma_{-k}^{k}\text{event}_{t_{i0+k}} + \beta\text{CONTROL}_{it} + \mu_t + \gamma_i + \varepsilon_{it} \quad (2)$$

where, $\text{event}_{t_{i0+k}}$ represents the event window dummy variable before and after the implementation of the LCCP. t_{i0} is the year in which the firm was affected by the policy. t_{i0+k} refers to each year before and after the implementation of the policy. Where K takes values from −10 to 10. The rest of the control variables are similar to the baseline model.

Fig. 4 displays the dynamic effects of the policy between years in a visual form, using the period one prior to the policy implementation as the base period. The figure shows that the coefficients of the interaction term between the dummy variables before the year of LCCP implementation and the treatment group dummy variables are basically not significantly different from 0. This finding supports the parallel trend hypothesis, which indicates that the trend in firm profitability is the same for both the control and treatment groups before the implementation of LCCP. In addition, the coefficients of the interaction terms of the dummy variables for the post-implementation of the policy and the dummy variables for the treatment group are both positive. This indicates a significant positive effect that accumulates over time and dissipates in the sixth period after the policy implementation. Thus, these results confirm that the parallel

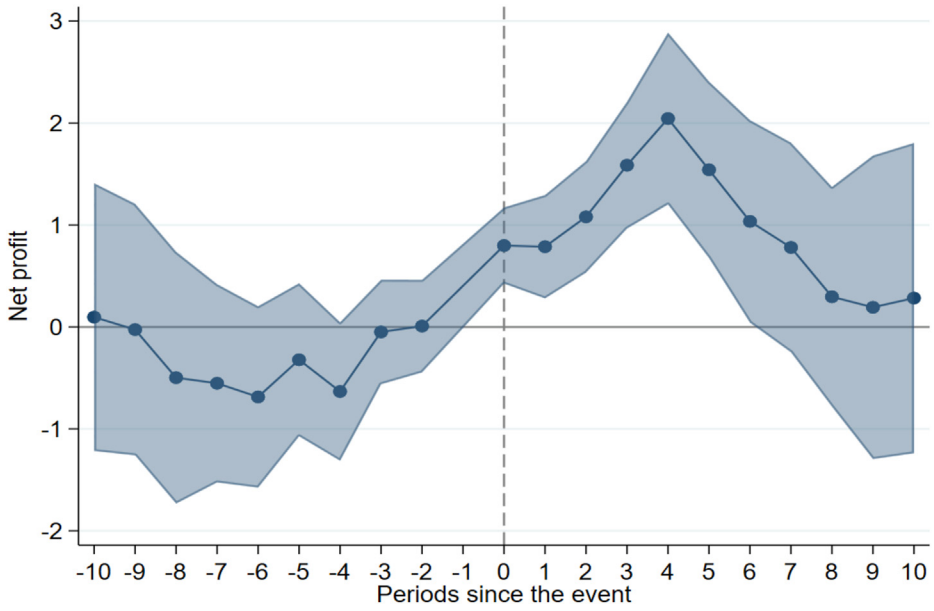

Fig. 4. The dynamic effect of the LCCP on enterprises' net profit. Notes: The same control variables in Equation (1) are used in the regression of Fig. 4.

trend assumption holds, and the effect of policy implementation has some degree of persistence.

5.2.2. Placebo test

In order to create a new treatment group with randomized firms and policy implementation time, this study randomly selects the same number of samples from all samples as the original treatment group (Lin & Zhu, 2019). The baseline regression model equation (1) was then re-estimated and the experiment was randomly repeated 500 times. Figure 5a,b shows the distribution of the estimated coefficients and p-values of the 500 pseudo-policy dummy variables, respectively. The curve in Figure 5a is the kernel density distribution of the estimated coefficients, and the black dots in Figure (b) correspond to the p-values of the estimated coefficients. The vertical dashed lines in both figures are the true estimates of the multi-period DID model (2) of 0.509. The kernel density distribution of the estimated coefficients in Figure (a) indicates that they are mostly concentrated in the range of −1 to 0.5, while the true estimate of 0.509 is a clear outlier. This suggests that the placebo effect on the dependent variable is not significant. In other words, when the change in policy occurs, the dummy DID effect is not significant anymore. This further confirms the robustness and reliability of the real DID regression analysis results. Most of the estimates in Figure (b) have p-values greater than 0.1, implying that they are unlikely to have been obtained by chance or influenced by other policy or randomness factors.

5.3. Heterogeneity analysis results

The estimated coefficients of multi-period DID analysis identified not the average treatment effect of treated individuals, but a weighted average of group-time treatment effects. Many scholars have pointed out the potential for multi-period DID to produce biased estimates (Goodman-Bacon, 2021; Athey & Imbens, 2022; Baker, Larcker, & Wang, 2022). Indeed, Baker et al. (2022) found through data simulations that the estimated coefficients are unbiased in the single-period DID case, regardless of whether the treatment effects vary over time. However, multi-period DID estimates with biased treatment effects can even result in the opposite sign of the true treatment effects. The main reason for this situation is that multi-period DID estimation is by nature a weighted average of several different treatment effects. However, when negative weights are included, the average treatment effect (ATE) may end up being in the opposite direction of the true ATE. To overcome this issue, Callaway and Sant'Anna (2021) have suggested a solution, which involves computing the total treatment effect as the sum of the Group-time ATE. Specifically, this method divides the sample into different groups, estimates the ATT(g) of each group, and sums the ATT(g) of the different groups by a specific strategy to calculate the ATT of the sample period. The principle of this method is to reduce the summed weight of the ATT(g) of those groups that may have bias. Therefore, this study used the method of Callaway and Sant'Anna (2021) to calculate the ATT(Average Treatment Effects on Treated) to identify heterogeneous multi-period DID.

Table 5 shows the results of the heterogeneity analysis. This study divides the total assets of firms into 2 segments using its median to obtain Asset-F1 and 2. The study divides these firms into two main categories: F1 represents small firms with fewer total assets and F2 is large firms. Specifically, the total assets of small enterprises are less than 2169986653 yuan, while the total assets of large companies are more than 2169986653 yuan. The results of the explanatory variables are the estimated net income and earnings per share are shown in columns 2–4 and columns 5–7 of the table, respectively.

Table 5 shows that the p-value for large companies is less than 0.01 regardless of whether the explanatory variable is net profit or earnings per share, which indicates that large companies tend to profit more under this policy. This may be because large companies generally operate in a wide range of areas and have more opportunities to undertake new innovative activities along with experience in many areas and are more capable of investing in R&D. Therefore, large companies are more able to innovate than smaller companies, which can effectively contribute to the potential enhanced profitability larger companies. Moreover, the R&D and investment behavior of enterprises will also receive more support from the government, thus prompting them to invest more in innovation (Raihan et al., 2023; Sui & Yao, 2023). When firms are involved in this policy, larger firms tend to have strong market control and are better able

Table 5
The heterogeneous analysis of the impact of the LCCP on net profit and earnings per share.

	Net Profit			Earnings per share		
	Asset-F1	Asset-F2	Full sample	Asset-F1	Asset-F2	Full sample
ATT	.007	1.876 **	.696**	−.004	.107 **	.036

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

Table 6
What is the impact of the LCCP on firm profitability? A perspective from the lens of innovation.

VARIABLES		Net Profit	R&D	Net Profit
LCCP		0.509**	−0.011	0.517*
		(0.254)	(0.039)	(0.273)
R&D				0.298***
				(0.094)
Control		YES	YES	YES
Year FE		YES	YES	YES
Stock Code FE		YES	YES	YES
Number of Stock Code		3687	3414	3414
95% confidence interval of the Bootstrap test	Direct effect	[−0.712, −0.232]		
	Indirect effect	[0.072, 0.153]		

Note: The number in the parentheses is standard errors.
Significance: *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

to cope with long innovation project cycles. They are also relatively rich in financial and technological resources, which can support firms to carry out innovation activities in multiple fields while spreading R&D risks. They are able to respond more effectively to the uncertainty of the external environment, stabilize their competitive advantages in the market, and guarantee a steady increase in corporate profitability.

6. Mechanisms

The baseline regression results suggest that LCCP contributes to firm profitability. But what are the mechanisms through which this policy effect is realized? The previous section's theoretical analysis suggests that LCCP may affect firm profitability through the technological innovation effect and financial subsidies, and this section will test its role. The technology innovation effect is selected with firm R&D expenditure as a proxy variable. This study first uses stepwise test regression coefficients (Baron & Kenny, 1986) to investigate whether LCCP can have an impact on firm profitability through innovation. Table 6 presents the regression results indicating the impact of LCCP on firm profitability and the potential mediating mechanism of technological innovation and financial subsidies. Specifically, the second and fourth columns reveal that the coefficients of LCCP are positively and significantly related to firm profitability at a 5% level of significance. However, the third column suggests that the effect of LCCP on the mediating variable, which is technological innovation, is not statistically significant. Therefore, this study follows Wen, Zhang, Hou, and Liu (2004) and Chen, Zheng, and Liu (2013) to assess the mediating effects arising from R&D inputs using Bootstrap test (500 times). The 95% confidence interval of the indirect effect that does not contain 0 is shown in Table 6, which indicates that the indirect effect is significant. In addition, the direct effect of LCCP on improving profitability is 0.517 and the indirect effect of LCCP on improving profitability through the innovation effect is −0.003. The opposite signs of the direct and indirect effects indicate a confounding effect, which leads to increase the total effect between the independent and dependent variables. Combining the above results, it can be inferred that hypothesis H2 is supported, and that the Porter hypothesis holds true in this study.

Researchers that have examined the link between innovation and profitability at the firm or institutional level claim that innovators outperform non-innovators in terms of profitability (Abanyie, Ampadu, Frimpong, & Amuah, 2023; Hu & Jefferson, 2004; Love, Roper, & Du, 2009). This could very well be the case because inventors are able to shield new products or services from the rivals, which if not done can generally eat away at such earnings, perhaps as a result of their market position. Alternatively, because innovative firms are able to introduce multiple innovations over time, they can maintain high profits. The higher the intensity of corporate R&D investment, the stronger the economic and material basis for innovative activities (Parisi, Schiantarelli, & Sembenelli, 2006). This provides strong support for enterprises to expand the scope of R&D activities, accumulate research talents, promote knowledge turnover, and greatly improve the learning efficiency of enterprises. Therefore, enterprises can use various resources to absorb a wider external innovation network and create a favorable corporate innovation climate, which further drives corporate performance and innovation efficiency.

Table 7
What is the impact of the LCCP on firm profitability? A perspective from the lens of financial subsidies.

VARIABLES	Net Profit	FS	Net Profit
LCCP	0.509**	0.276***	0.458*
	(0.254)	(0.102)	(0.248)
FS			0.184***
			(0.061)
Control	YES	YES	YES
Year FE	YES	YES	YES
Stock Code FE	YES	YES	YES
Number of Stock Code	3687	3687	3687

Note: The number in the parentheses is standard errors.
Significance: *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

Based on the results presented in Table 7, it can be observed that the total effect of LCCP on profitability is 0.509, which is statistically significant. The direct effect of LCCP on financial subsidies is 0.276, and although the result is significant, the impact is not substantial. The indirect effect of LCCP on profitability through financial subsidies is 0.507 (=0.276*0.184). The mediating effect of financial subsidies accounts for 99.6% of the total effect. Therefore, it can be concluded that hypothesis H3 is supported by the findings.

The LCCP policy has been found to be an effective way of improving corporate profitability through financial subsidies in Table 7. Such subsidies can effectively alleviate the problem of corporate financing constraints and guarantee the improvement of corporate profitability (Hussain, Pal, & Villanthenkodath, 2023; Qiao & Fei, 2022). Firstly, financial subsidies directly improve the surplus level of enterprises. For enterprises, the granting of financial subsidies is the external capital without capital cost that can directly promote the development and growth of enterprises. The subsidies issued by the government in the form of governmental grants or tax incentives effectively expand the cash flow of enterprise operations and improve the solvency, profitability and development ability of enterprises to a certain extent (Yang, Feng, Zhao, & Chang, 2022).

Moreover, financial subsidies provide valuable investment signals to outside investors (Wu, 2017). They can effectively mitigate the information asymmetry between firms and outside investors, and enable subsidized firms to attract more external investments, which can improve their profitability.

In addition, the government provides financial support for enterprises, which makes enterprises' innovation resources improve and reduces their R&D risks (Bai, Song, Jiao, & Yang, 2019). Usually, enterprises need to invest a lot of resources to conduct R&D innovation. They need sufficient financial support for purchasing technologically advanced equipment and introducing high-technology talents. The limited ability of enterprises to take risks makes them maintain a cautious decision-making attitude towards innovation projects, which limits their R&D motivation. Companies that receive financial subsidies can not only optimize their R&D base and increase the number of R&D personnel through flexible use of funds, but also cooperate and learn from external technologies through open innovation to improve their technological innovation capabilities, which in turn improves their profitability.

7. Conclusions and policy implications

The LCCP has had a considerable influence on China's control of carbon emissions as an essential environmental policy. This empirical

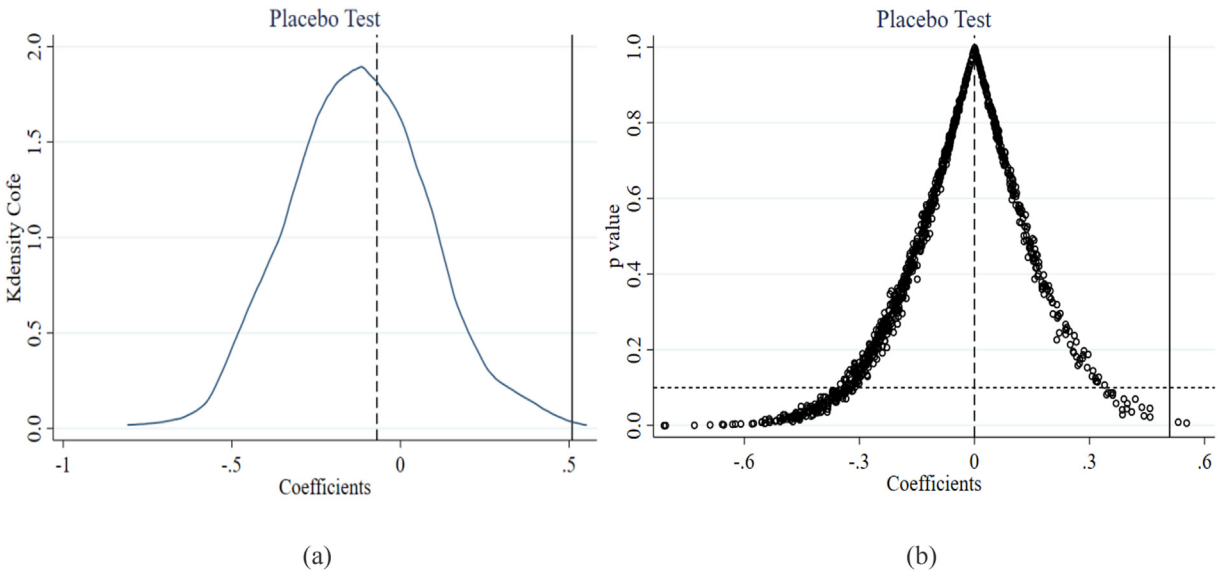

Fig. 5. (a) Distribution of estimated coefficients of the placebo test, (b) Distribution of the corresponding p-values.

analysis calls into question whether the profitability of the enterprise will be impacted by the policy. The study can assist China in further refining this approach and offer useful information and viewpoints to other nations. Because of this, implementation of the LCCP is used in this work as a quasi-natural experiment. This study utilizes data from Chinese A-share listed companies spanning 2005 to 2020 to investigate the effect of LCCP on firm profitability through the DID method. Additionally, the study examines the mechanisms behind the relationship between LCCP and firm level profitability, focusing on the impact of firm R&D investment and financial subsidies. The results show that (1) LCCP has a significant and lasting effect on firm profitability. (2) Considering heterogeneity, the profitability of firms of different sizes is affected differently by the LCCP. Specifically, large companies are more significantly affected by this policy's profitability-boosting effects. (3) Finally, the mechanism analysis shows that consistent with hypotheses H2 and H3, the LCCP promotes firm profitability through increased innovation inputs and financial subsidies.

Evidence based policy recommendations are made by this study according to the aforementioned findings. Firstly, in light of the baseline results, the government should actively promote implementation of the LCCP and integrate green and low-carbon efforts into the whole life cycle of enterprises. Green and low-carbon transformation under the “double carbon” target will undoubtedly become an indispensable guideline for the future high-quality economic development of enterprises, particularly for those in heavily polluting industries. In order to accomplish green low-carbon development across the whole production process, businesses should establish a culture of green low-carbon production as soon as feasibly possible; starting their green low-carbon transformation as soon as possible, and do all in their power to do so. These actions can aid enterprises in gaining a first-mover advantage, securing a competitive edge in the market, and enhancing their profitability. Enterprises may more quickly and effectively adjust to the demands of the new environment of high-quality manufacturing sector development, resulting in a scenario where both enterprises and the environment benefit.

Secondly, the DID approach, which takes into account the differences between the treatment group and the control group, supports the conclusion that the LCCP increases the profitability of businesses in the pilot cities. In reality, as shown in Fig. 6, the growth rate of all enterprises' profitability actually decreased dramatically in 2010. In order to increase the relative and absolute profitability of enterprises, the government should adopt the necessary supporting measures (such as providing incentive subsidies and financial support to businesses) once the policy has been strictly enforced. This is in agreement with the outcome of hypothesis H3. To create a strong basis for reaching the “double carbon” objective, policymakers should continue to optimize pilot level policy to promote and grow green and low-carbon firms in a fair and equitable way.

In addition, LCCP encourages enterprises to green their innovative R&D and improve the conversion rate of R&D results. It can be observed that LCCP has a significant positive impact on enterprises' innovation investment, which is a factor that cannot be ignored to enhance enterprises' profitability. Furthermore, enterprise innovation needs to assess the efficiency of innovation results conversion, and innovation patent results conversion also needs time for commercial benefits to be realized. For enterprises to accurately grasp the timing of investment, requires decision-makers and investors to deeply understand and grasp the changes in the external market environment and layout effective plans in advance. In this context, enterprises guided by the LCCP are able to establish green and low-carbon concepts and continue to innovate, achieve efficient integration and conversion of innovation inputs and innovation outputs, and continuously improve the level of high-tech and green development. These measures effectively promote the green and low-carbon transformation of enterprises, paving the way for high-quality and efficient high-end development.

Finally, from the heterogeneity analysis of different enterprise sizes, the LCCP is not as relatively significant for large enterprises when compared to improving the profitability of small enterprises. In order to motivate SMEs to accelerate green technology transformation, different enterprise sizes should be considered when formulating policies. Specific policies to help SMEs, such as more preferences in tax benefits, financial subsidies and financial support, can therefore be formulated to motivate SMEs to accelerate technological upgrading.

This study has some limitations due to incomplete disclosure and limited availability of relevant company data. While analyzing the impact of LCCP on the profitability of listed firms and its impact pathway, this study is not exhaustive, and there may be data omissions and missing cases. The majority of the data used in this study are secondary sources, which could limit the accuracy of the findings. Additionally, the categorization and processing procedures involve subjectivity, especially in the absence of precise and formal classification standards for the size of firms. To differentiate across business sizes, this study uses the

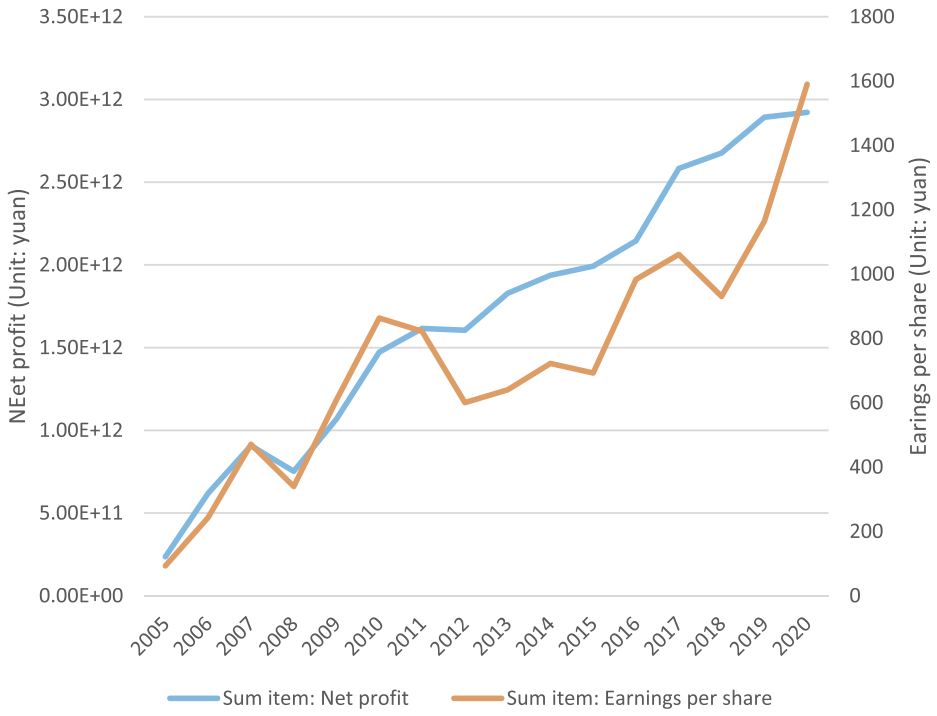

Fig. 6. Changes in net profit and earnings per share of A-share enterprises from 2005 to 2020 (source: arranged by the author).

dichotomous quantile of total assets across all samples, which may lead to inaccurate categorization outcomes. Future research should track the long-term dynamic impact of the policy and explore other ways in which LCCP can improve the profitability of firms while promoting sustainable economic development.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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