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Political Economy of Mitigating Carbon Emissions with Mild Constraints: An Empirical Study on Employment Based on Low-Carbon City Pilot Policy

Yang Chen, Wenge Liu

Yang Chen (*corresponding author*, email: yangyangyang0314@163.com), School of International Economics and International Relations, Liaoning University, Shenyang, China

Wenge Liu (email: 2670196003@qq.com), School of International Economics and International Relations, Liaoning University, Shenyang, China

Abstract

The interaction between socioeconomic disparities and environmental degradation, which is highly pertinent to the issue of climate change, has garnered significant scholarly attention globally. Despite the critical importance of climate change in political economy, research into labour markets and environmental policies remains limited in the current literature. Therefore, the present study discusses the implementation of China's low-carbon city pilot policy (LCCPP) as an exogenous policy shock. Utilizing A-share data from listed companies on the Shanghai and Shenzhen stock exchanges spanning the period 2007–2020, we employ a multiperiod difference-in-differences model to scrutinize the influence and mechanisms of LCCPP on employment. Our study reveals a significant increase in employment levels within pilot cities due to LCCPP. The findings remain stable even after the results are subjected to a battery of robustness tests. Mechanistic analysis suggests that the policy substantially increases employment through the scale effect and factor substitution effect. Heterogeneous results demonstrate the policy's substantial promotion of employment levels in pilot cities across state-owned enterprises,[1] the first and second industrial sectors and low-carbon industry enterprises. These research findings support steering China's economic development towards a low-carbon, environmentally sustainable growth transformation. Furthermore, policymakers should encourage the LCCPP to stimulate employment while addressing socioeconomic disparities and environmental concerns simultaneously in political economy.

Keywords: Environmental regulation, low-carbon city pilot policies (LCCPP), employment, multiperiod difference-in-differences (multiperiod DID) model

JEL Classification: H23, O13, O44, Q56

1 In China, the primary industry encompasses agriculture, forestry, animal husbandry, and fisheries, among others. The secondary industry is predominantly represented by the processing and manufacturing industries, whereas the tertiary industry is largely constituted by the service industry.

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1. Introduction

Environmental poverty has emerged as a soaring issue globally and includes socioeconomic disparities and environmental concerns related to carbon emissions and a high risk of pollution, which threaten climate change and global warming around the world (Li *et al*., 2023). This form of poverty consists of vulnerable people who have access to fewer facilities and are more exposed to food insecurity and pollution. However, efforts around the world to curb the dangerous effects of climate change and exposure to pollution and other insecurities are focused on and debated, but issues persist in emerging countries, particularly in developing countries, and urgent solutions and clarity are needed (Z. Khan *et al*., 2023b). Understanding the political economy of countries is important for addressing the challenges and issues pertaining to carbon emissions and relevant environmental concerns.

To gain a more thorough interpretation of China's political economy, it is crucial to delve deeper into socioeconomic and environmental challenges as well as the promotion of sustainable development (Rasoulinezhad and Taghizadeh-Hesary, 2022). The inception of economic reforms and opening-up policies marked a period of rapid economic development for China, prompting China to ascend as the globe's second-largest economy. Notably, the dimensions of environmental poverty and political economy have gained significant attention, which indicates that these two concepts are strongly interconnected in the long term.

Nevertheless, this expansion has been accompanied by an economic model that heavily relies on resources, exerting profound impacts on the environment. Notably, the emissions of greenhouse gases, especially CO_2, disrupt ecosystems and pose a significant threat to human survival. The data gleaned from the Global Climate Risk Index 2021 underscore the profound impact of climate change from 2000 to 2019, manifesting in more than 11,000 extreme weather events worldwide. These events have resulted in more than 475,000 fatalities and inflicted economic losses approaching 2.56 trillion USD[2].

Consequently, addressing climate change, specifically by curtailing carbon dioxide emissions, has become an urgent global challenge. To address this issue, governmental bodies at various levels in China have implemented a series of standardized regulations, policies and corresponding punitive measures, consistently escalating environmental regulations. In September 2020, during the 75th session of the United Nations General Assembly, China declared its commitment to reaching peak carbon emissions by 2030 and achieving carbon neutrality by 2060. Presently, the Chinese government has rolled out various policies to facilitate low-carbon transformation, with the most notable being the phased implementation of the LCCPP in 2010, 2012 and 2017.

2 Source for Global Climate Risk Index: Germanwatch (2024).

However, as environmental regulations continue to strengthen in economies, scholars have redirected their research focus from analysing environmental issues to probing socioeconomic concerns. Despite the vibrant discourse surrounding environmental constraints and economic growth, previous studies have focused mostly on the consumption side of carbon emissions (Khan *et al*., 2014), technology (*i.e*., renewable energy) (Li *et al*., 2023; Z. Wang *et al*., 2023; Yu *et al*., 2024) and sustainable development (Ji *et al*., 2021; Z. Khan *et al*., 2023a; R. Wang *et al*., 2023). However, there are relatively few studies on the impact of environmental regulations on employment considering that the primary targets of environmental policy constraints are pollution-intensive enterprises, and policymakers must prioritize environmental pollution control and address livelihood and employment issues. Full employment is not only a linchpin for social stability but also directly influences macroeconomic stability, representing a vital macroeconomic goal. Therefore, it becomes imperative to scrutinize the influence of environmental policies on employment, a crucial consideration for future policymaking by central and local governments. This approach aims to achieve both environmental protection and full employment.

There are numerous factors that support and differentiate this study from previous ones. This study is motivated to focus on the urgent need to address the issues that reside in the labour market in relation to low- or high-carbon policies. Moreover, the research is aimed at drawing conclusions that focus on labour dynamics and provide room for the prevalence of low-carbon policies. Nevertheless, ensuring a smooth and affordable transition towards sustainable development should offset the priorities of socioeconomic and environmental perspectives.

The primary objective of this study is to determine the impact of LCCPP on employment in China. To the best of our knowledge, this study examines whether LCCPP have any role in employment in China. Moreover, our research looks at the role of LCCPP and their influence from a socioeconomic perspective. We aim to determine how LCCPP address socioeconomic disparities and whether they have an influence. Secondly, we collect the latest data on A-share listed firms and utilize the difference-in-differences (DID) model to assess the treatment effect, to understand whether any changes occurred after changes in LCCPP and to predict changes in employment, which covers the socioeconomic perspective of this research. Moreover, parallel trend tests are used to achieve similar objectives and predict trends in the relationships between two variables. Thirdly, this research will offers actionable insights for scholars and policymakers regarding the transition towards a low-carbon economy from a political economy perspective while considering socioeconomic perspectives and encouraging sustainable development.

2. Literature Review

2.1 Impact of environmental regulations on employment

The research into the impact of environmental regulations on employment can be broadly categorized into three categories. Firstly, some studies propose that environmental regulations enhance enterprise labour demand, promoting employment. Altman and Hunter (2015) concluded that carbon emission verification and the development of green projects create new job opportunities, leading to increased employment. Imposing pollution taxes stimulates employment in less pollution-intensive industries (Hafstead and Williams, 2018). Scholars have substantiated the conclusion of a dual dividend relationship between environmental regulations and employment. Some researchers have explored environmental policies in the context of energy policies. For example, Haroon (2024) specified that, in contrast, the focus on increasing energy and environmental regulations leads to the population adopting nonrenewable energy sources, which causes energy poverty and therefore should be reduced. In addition, Finger *et al*. (2024) investigated the environment and poverty nexus in Vietnam and reported that people with less education and greater energy poverty use natural resources and dirty sources of energy, which can have a greater negative influence on climate change. Della Valle *et al*. (2024) also found similar results in the case of behavioural studies, which suggests that studies should focus on climate change and try to change the situation of the environment and energy poverty.

Secondly, environmental regulation policies may reduce enterprise labour demand, suppressing employment. Li *et al*. (2023) examined the environmental protection law and empirically demonstrated that stringent environmental regulations inhibit corporate employment, resulting in an average reduction of approximately 5.1%. Studies by Lu (2011) and Li and Lu (2011) have indicated that carbon taxes in China may face challenges in achieving a double dividend for both the environment and employment, potentially leading to negative impacts on employment.

Thirdly, the literature suggests that the influence of environmental regulation policies on employment is indeterminate and nonlinear. By constructing employment impact factor models, scholars have analysed the interplay between environmental regulation and stable employment. Using Chinese provincial panel data from 1995–2012, researchers have discovered a U-shaped relationship wherein environmental regulation initially inhibits and later promotes labour demand (S. Li, 2015). Moreover, studies have also mentioned the role of excessive natural resource usage, which has become a curse due to its hazardous health outcomes in terms of pollution and lower economic and environmental achievements (Ali *et al*., 2016; N. Khan *et al*., 2017; Li *et al*., 2023; Z. Wang *et al*., 2023; Yu *et al*., 2024). However, they have found only the CO_2 perspective in terms of natural resources and not the social perspective.

2.2 Research into implementation effects of LCCP

The initiation of LCCPP has become a focal point in academic discourse. Firstly, concerning the environmental impact of these policies, studies have concentrated on carbon emissions, carbon efficiency, energy efficiency and ecological efficiency. Research consistently indicates positive environmental outcomes, encompassing the mitigation of carbon emissions and the advancement of carbon efficiency, energy efficiency and ecological efficiency.

Regarding the influence of LCCPP on economic growth, Qiu *et al.* (2021) identified a substantial increase in green total factor productivity (GTFP) attributable to low-carbon policies. Chen *et al.* (2021) reported that these policies primarily increase green total factor productivity by fostering technological innovation and optimizing resource allocation. Some studies utilizing quasi-natural experiments on the first two batches of low-carbon pilot cities affirm an increase of approximately 1.9 units in urban GTFP (Zang and Sun, 2021).

Finally, research has discussed the effects of LCCPP on industrial structure, technological innovation, FDI and other dimensions. Some studies have shown the positive effects of LCCPP on enterprise innovation and improvements in industrial structure (Huang *et al*., 2020; Zheng *et al*., 2021). LCCPP can stimulate green technological innovation, fostering China's transition towards low-carbon transformation (Xu and Cui, 2020).

Moreover, the effects of financial inclusion and fiscal decentralization on CO_2 emissions have been studied (Tufail *et al*., 2022, 2023) and asymmetric effects have been found. This perspective is also studied in relation to CO_2 emissions.

The existing body of literature extensively explores the influence of environmental regulations on employment. However, discrepancies in research perspectives, objects, content, methods and time periods have prevented the establishment of a consensus in both domestic and international literature. While much research into implementing LCCPP has primarily concentrated on aspects of ecological and economic growth, there has been limited investigation into the intricate relationship between these policies and employment.

Our work addresses this gap by delving deeper into four key aspects. Firstly, it examines the effect of LCCPP on employment from a low-carbon perspective, thereby offering theoretical foundations and policy guidance essential for China's pursuit of "dual carbon" goals, economic development transformation and high-quality sustainable development. Secondly, the paper provides micro-level evidence on whether developing countries can realize a "double dividend" by effectively balancing ecological preservation and employment during the development and transformation process. Thirdly, we aim to elucidate how LCCPP influence employment, empirically confirming the roles of production scale effects and factor substitution effects. Finally, this paper

intends to explore the heterogeneous effects of LCCPP on employment, focusing on enterprise characteristics as a basis for analysis.

By addressing these aspects, this paper contributes to the literature by offering a comprehensive examination of the impact of LCCPP on employment, thereby providing valuable insights for policymakers, researchers and practitioners to achieve sustainable and economically transformative development.

3. Mechanism Analysis

Based on the theoretical frameworks proposed by Berman and Bui (2001) and Liu *et al*. (2021), this paper analyses the theoretical mechanism of the influence of LCCPP on employment from the perspectives of output scale and factor substitution.

Under the assumption that firms operate within a framework of perfect competition, their primary objective is to minimize final production costs. This entails adjusting "variable" factors, such as labour and capital, with "quasi-fixed" factors such as governance costs. This adjustment is necessary to align with environmental policy constraints and accommodate investments in emission reduction.

In this study, the costs incurred by firms to comply with low-carbon policy constraints, such as investments in pollution control, are considered "quasi-fixed" inputs. Concurrently, labour and capital are regarded as variable cost input-minimization processes. Consequently, under the condition of minimizing firm costs, the firm's variable cost function can be expressed as:

$$VC = \left(Y, V_1 \cdots V_m, Q_1 \cdots Q_n\right) \tag{1}$$

Here, VC represents the variable costs of the enterprise, Y denotes the output of the enterprise, V_m represents the price of variable factor inputs and Q_n represents the quasi-fixed factor inputs. According to Shepard's lemma, the demand for the variable factor, labour (L), is a function of the enterprise's output, the price of variable factor inputs and the level of quasi-fixed factor inputs. This can be expressed as:

$$L\left(Y, V_1 \cdots V_m, Q_1 \cdots Q_n\right) = \alpha + \rho_0 Y + \sum_{m=1}^{m} \delta_m V_m + \sum_{n=1}^{n} \beta_n Q_n \tag{2}$$

Here, α, ρ, δ and β are all parameters. The sign of the parameter β determines whether, under the influence of LCCPP, a complementary or substitutive relationship exists between the variable factor labour input and the quasi-fixed factor pollution control investment. Using R to denote the LCCPP, by means of the derivative of both sides of Equation (2) with respect to R, we obtain:

$$\frac{dL}{dR} = \rho_0 \frac{dY}{dR} + \sum_{m=1}^{m} \delta_m \frac{dV_m}{dR} + \sum_{n=1}^{n} \beta_n \frac{dQ_n}{dR} \tag{3}$$

Assuming that the enterprise operates on a perfectly competitive factor market, the variable factor price (V_m) is not influenced by the policy variable R. Given this premise and with the condition of $\sum_{m=1}^{m}\delta_m \frac{dV_m}{dR}$ being zero (5.3), Equation (3) can be simplified as follows:

$$\frac{dL}{dR} = \rho_0 \frac{dY}{dR} + \sum_{n=1}^{n}\beta_n \frac{dQ_n}{dR} \tag{4}$$

where $\rho_0\ dY/dR$ represents the influence of LCCPP on employment through their influence on the output scale, termed the output scale effect and $\sum_{n=1}^{n}\beta_n \frac{dQ_n}{dR}$ represents the effect of the policy through its influence on pollution control investment, termed the factor substitution effect. According to Equation (4), the influence of LCCPP on employment primarily depends on the dual action of the output scale effect and the factor substitution effect.

Concerning the specific impact of the output scale effect on employment, on the one hand, the constraints imposed by LCCPP increase the costs of reducing emissions for businesses. Consequently, firms may adjust their production scale downward, leading to a decrease in labour demand and a reduction in employment levels ($\rho_0 < 0$). Thus, the output scale effect has a passive influence on employment.

On the other hand, when enterprises employ means such as technological innovation to lower marginal costs to meet the constraints of LCCPP ($\rho_0 > 0$), the output scale effect can positively affect employment.

For a more nuanced exploration of the specific impact of the factor substitution effect on employment, it is imperative to consider several facets. On the one hand, implementing LCCPP is anticipated to incentivize enterprises to invest in pollution control and other quasi-fixed factors. This implies that companies will channel resources into acquiring clean production equipment, introducing or independently developing green technologies, phasing out outdated production capacity and innovating production processes. Consequently, this governance will positively influence the efficiency of the company's production, potentially leading to the substitution of labour factors.

As a result of this enhanced production efficiency, there is a likelihood of a decrease in the demand for labour, thereby contributing to a reduction in overall employment levels. The transformative impact of these policy-induced changes on the company's production process (Q_2) can manifest in a discernible shift towards a more automated or technologically advanced production environment, where the role of manual labour is diminished.

In summary, the factor substitution effect, triggered by LCCPP, is expected to stimulate investments in pollution control and innovation, leading to increased efficiency in production processes. However, this efficiency gain may come at the expense of a reduced demand for labour,

potentially resulting in a decrease in overall employment levels within the affected enterprises.

On the other hand, investments in pollution control, categorized as quasi-fixed factors, encompass not only the adoption of pollution control equipment but also the incorporation of end-of-pipe pollution treatment technologies. By overseeing the culmination of the production process (Q_1) within the company, installation, operation and maintenance of such equipment may serve as catalysts for creating new employment opportunities. This can lead to an increase in labour demand, thereby enhancing employment levels.

Moreover, enterprises responding to the imperatives of LCCPP may benefit from supportive measures initiated by the government. These could include subsidies, access to bank credit and other forms of external financial support. Such assistance plays a pivotal role in alleviating the financial constraints faced by enterprises, concurrently incentivizing them to broaden their business scope, expand their production scale and elevate their output levels. This expansionary trajectory, in turn, has the potential to escalate labour demand and foster increased employment within these enterprises.

In summary, the quasi-fixed factors associated with pollution control, specifically the introduction of equipment and technologies, can have a twofold effect. They create employment opportunities through the oversight and maintenance of these systems and contribute to a broader economic stimulus. The government's supportive policies and financial assistance further play a crucial role in encouraging enterprise expansion, leading to an augmented demand for labour and an overall positive impact on employment levels.

In this context, based on the inputs for the governance of the end of the production process (Q_1) and the inputs for the governance of the production process (Q_2), Equation (4) can be expressed as Equation (5):

$$\frac{dL}{dR} = \rho_0 \frac{dY}{dR} + \left(\beta_1 \frac{dQ_1}{dR} + \beta_2 \frac{dQ_2}{dR} \right) \tag{5}$$

Based on the aforementioned derivation, the analysis reveals that the influence of LCCPP on employment is contingent upon the dual effects of output scale and factor substitution. The specific effect of LCCPP on employment is determined by the combined influence of the output scale and factor substitution effects.

4. Research Methods and Data

4.1 Model specification

This study adopts the multiperiod DID model to test the impact of LCCPP. Enterprises in pilot cities constitute the experimental group, while those in non-pilot cities form the control group.

To account for potential lags in policy effects, this analysis designates the years 2010, 2013 and 2017 as the starting points for policy implementation. Furthermore, the model incorporates controls for firm and year fixed effects. The regression model is specified as follows:

$$labour_{it} = \alpha_1 + \beta_1 citylccpost_{it} + \lambda_1 control_{it} + \phi_i + \gamma_t + \varepsilon_{it} \quad (6)$$

In this context, $labour_{it}$ represents the dependent variable, indicating the employment of labour by the enterprise i in the year t; $citylccpost_{it}$ is the explanatory variable, denoting a dummy variable indicating whether the city where the enterprise i is located implemented the LCCPP in the year t. Assuming that the city implemented the LCCPP in the year t for the enterprise i, the variable takes the value of 1; otherwise, it takes the value of 0. In addition, $control_{it}$ represents a series of control variables, φ_i and γ_t denote the fixed effects for the enterprise and year, respectively, and ε_{it} represents the random error term.

In regression analysis, particular attention is paid to the regression coefficient β of the explanatory variable $citylccpost_{it}$. This coefficient reflects whether the implementation of LCCPP promotes employment in enterprises located in pilot cities. When β is significantly positive, this indicates that LCCPP significantly stimulate employment in enterprises located in pilot cities.

4.2 Variable selection

Dependent variable (*labour*): The total number of employees in a company is selected to measure employment.

Independent variable (*citylccpost*): This variable indicates whether the city in which the company i is located implemented LCCPP in the year t.

Control variables:

(1) *Wage* (*wage*, yuan): The average wage level of employees in a company is chosen to capture the inverse relationship between wage levels and labour demand. Higher wages indicate increased profitability, greater potential for expansion and elevated employment levels.

(2) *Size* (*size*, dimensionless): Following the findings of Li *et al*. (2017), the logarithm of total assets is used to measure company size. In most industries, a positive relationship exists between company size and labour demand.

(3) *Leverage ratio* (*lev*, %): Reflecting the company's capital structure, debt level and financial risk, the leverage ratio indirectly reflects the demand for labour. It is measured by the proportion of total liabilities to total assets.

(4) *Selling expense ratio* (*ser*, %): This ratio indicates the efficiency of a company's marketing efforts. Higher efficiency, as suggested by previous studies, reflects greater operational potential and increased demand for labour.

(5) *Income tax expense* (*tax*, thousand yuan): The income tax can influence labour demand both positively and negatively. It is measured by the logarithm of the income tax plus one to handle cases where the income tax is less than zero.

(6) *Growth capability* (*grow*, dimensionless): Representing various factors such as asset size, earnings and market share, Tobin's *Q* measures a company's growth capability, reflecting its expansion potential and, consequently, labour demand.

(7) *Return on assets* (*roa*, %): The net profit rate on total assets indicates a company's efficiency in obtaining net profits based on all assets. This ratio reflects the demand for labour, as companies with higher efficiency and cost control may also control employee wages. Inspired by Wang *et al*. (2012), the ratio of net profit to total assets is used.

4.3 Data source

This chapter utilizes data extracted from the Guotai An database, encompassing A-share listed companies on the China Shanghai and Shenzhen stock exchanges, spanning from 2007 to 2020. The dataset is subjected to the following procedures: (1) elimination of financial industry companies; (2) exclusion of companies with ST and *ST in their stock abbreviations; (3) removal of companies with ST, *ST, "suspended" and "terminated" listing statuses; (4) implementation of linear interpolation to fill in missing data for specific listed companies; and (5) exclusion of companies with significant data gaps. The resultant dataset constitutes non-balanced panel data featuring 3,733 listed companies and 28,858 observations.

Table 1: Descriptive statistics of variables

Variables	Obs.	Mean	Std. dev.	Min.	Max.
labour	28,858	7.6539	1.2518	4.6051	13.2227
citylccpost	28,858	0.5369	0.4986	0.0000	1.0000
wage	28,858	17.0410	1.6975	5.7519	23.3999
size	28,858	3.0942	0.0587	2.8799	3.3546
lev	28,858	0.4271	0.2137	0.0071	1.9667
ser	28,858	0.0707	0.0889	0.0000	1.6325
tax	28,858	17.1392	1.7779	0.3576	24.6218
grow	28,858	2.0173	1.6497	0.6735	102.4296
roa	28,858	0.0498	0.0689	–1.0813	0.8795

Source: Authors' own calculations

5. Results and Analysis

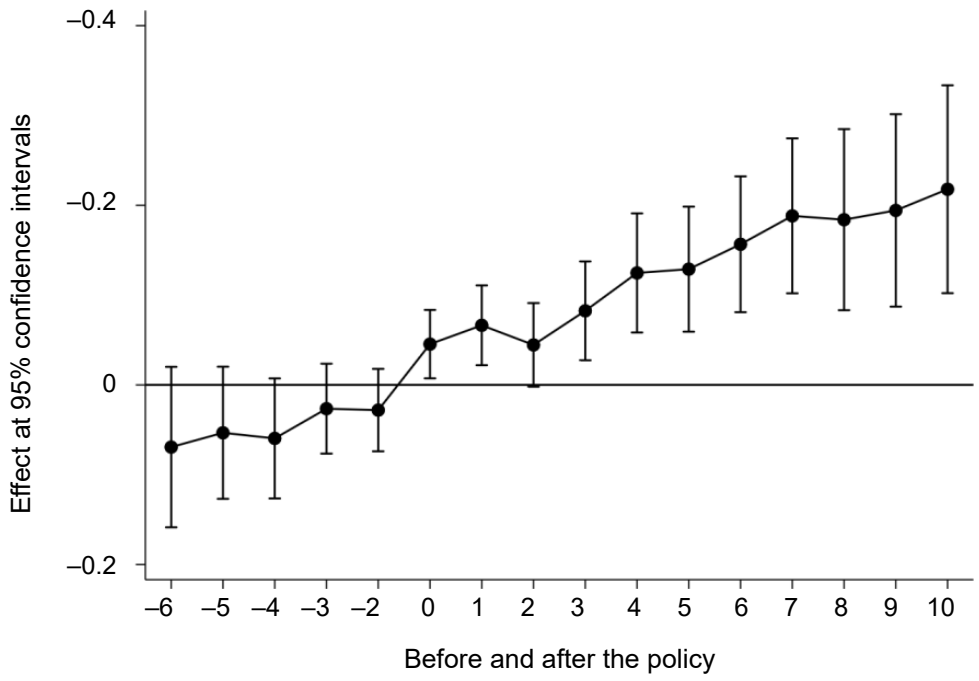
5.1 Parallel trend test

The multiperiod DID model relies on the crucial precondition that both the experimental and control groups demonstrate a consistent parallel trend in the evolution of the dependent variable before exposure to policy intervention. This assumption implies the absence of systematic differences in the pre-policy interference development trends of the dependent variable, ensuring a parallel trajectory. The parallel trend hypothesis is validated through the event research method, as proposed by Jacobson *et al*. (1993):

$$labor_{it} = \alpha_2 + \sum_{t=-5}^{6} \delta_t D_{it} + \lambda_2 control_{it} + \phi_i + \gamma_t + \varepsilon_{it} \tag{7}$$

where D_{it} represents a set of dummy variables, which are assigned a value of 1 if the city in which the company i is located implemented LCCPP in the year t and 0 otherwise. The meanings of the other variables are consistent with those in Equation (6). In Equation (7), particular attention needs to be paid to the coefficient δ_t, which reflects the magnitude of the impact of LCCPP on employment in the t-th year.

Figure 1: Parallel trend test



Note: The solid dots represent the estimated coefficients δ_t from Equation (7), while the short vertical lines indicate the 95% confidence intervals corresponding to robust standard errors.
Source: Authors' own elaboration

Due to relatively limited data for the five years before policy implementation and the six years after, this study aggregates data from the five years before policy implementation into the pre-implementation period, denoted as −5 periods and consolidates data from the six years after policy implementation into the post-implementation period, denoted as 6 periods. Additionally, the pre-implementation period of −1 is treated as the baseline.

As shown in Figure 1, the regression coefficients for the policy pre-implementation period are not statistically significant. This indicates no significant differences in employment levels in the periods before the implementation of the LCCPP. Hence, the research sample satisfies the parallel trend assumption.

5.2 Benchmark regression results

This study employs a multiperiod DID model and utilizes a two-way fixed effects approach, as outlined in Equation (6), to empirically investigate the impact of LCCPP on employment. The detailed empirical results are presented in Table 2, where Columns (1) and (2) show the estimates without and including control variables, respectively.

Notably, the estimated coefficient of the LCCPP variable consistently exhibits a positive value and passes significance tests, both with and without the inclusion of control variables. This shows that the LCCPP has always significantly promoted employment in pilot cities.

Examining the influence of control variables, factors such as company size, wage levels, the leverage ratio, the selling expense ratio and company growth capability all contribute to enhancing employment within companies.

Expansion in company size correlates positively with an increased demand for labour, thereby significantly stimulating employment. Elevated wage levels indicate improved profitability, greater potential for expansion and consequently, promotion of employment. A moderate leverage ratio enables companies to possess relatively sufficient funds, facilitating strategic investments in capital and labour. Simultaneously, a balanced leverage ratio enhances shareholder returns, elevates profit and promotes employment opportunities. As the selling expense ratio increases, product sales increase, leading to higher revenue and profits, thereby driving the demand for labour and fostering employment. A strong company growth capability signals positive prospects, substantial potential for expansion and an increased demand for labour, presenting potential for employment promotion.

Conversely, total asset turnover (*roa*) and income tax expenses (*tax*) hinder company employment. A higher ROA may be attributed to greater operational efficiency, stringent cost control and a more disciplined approach to labour input, thereby limiting employment opportunities. An increase in the income tax implies higher capital costs, compression of profit margins and, to some extent, restriction of investment in labour, which adversely affects employment.

To delve deeper into the nuanced impact of LCCPP on employment across distinct periods, we employ regression estimates based on Equation (6). The first and second batches of pilot cities are treated sequentially as the experimental groups and the outcomes are summarized in Table 2. Columns (3) and (4) of the table present regression results considering solely the influence of the first and second batches of LCCPP on employment.

Notably, both the first and second batches of policies significantly stimulate employment. Examining the impact coefficients reveals that the employment-enhancing effect of the first batch of policies surpasses that of the second batch. Moreover, compared to the overall policy impact, the isolated impact of the first batch is more pronounced. In contrast, the isolated impact of the second batch aligns closely with the overall policy impact.

Table 2: Impact of LCCPP on employment: multiperiod DID model regression results

Variables	(1)	(2)	(3)	(4)
citylccpost	0.0534*** (0.0146)	0.0440*** (0.0087)	0.1014*** (0.0143)	0.0439*** (0.0112)
roa	−0.1332 (0.0453)	−0.1315*** (0.0453)	−0.1338*** (0.0453)	−0.1332 (0.0453)
size	11.5639*** (0.1532)	11.5559*** (0.1531)	11.5605*** (0.1532)	11.5639*** (0.1532)
wage	0.1498*** (0.0034)	0.1497*** (0.0034)	0.1500*** (0.0034)	0.1498*** (0.0034)
lev	0.1892*** (0.0585)	0.1904*** (0.0225)	0.1878*** (0.0226)	0.1892*** (0.0585)
ser	0.2974** (0.0610)	0.3021*** (0.0609)	0.2918*** (0.0610)	0.2974** (0.0610)
tax	−0.0077 (0.0026)	−0.0075*** (0.0026)	−0.0077*** (0.0026)	−0.0077 (0.0026)
grow	0.0095*** (0.0019)	0.0093*** (0.0019)	0.0094*** (0.0019)	0.0095*** (0.0019)
City FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Constant	7.6942*** (0.0038)	−30.6498*** (0.4361)	−30.6328*** (0.4357)	−30.6256*** (0.4360)
Observations	28,858	28,858	28,858	28,858
R^2	0.8795	0.9286	0.9287	0.9286

Note: *, ** and *** represent significance levels of 10%, 5% and 1%, respectively.
Source: Authors' own calculations

5.3 Robustness check

5.3.1 PSM-DID model

Due to substantial variations in the inherent characteristics of individual enterprises, such heterogeneity may influence the parallel trend assumption crucial for the design of the DID model. Simultaneously, this approach can introduce biases in the evaluation results. This chapter employs propensity score matching (PSM) methods to address potential issues to eliminate differences among individual enterprises, thereby mitigating potential errors in the DID model. Specifically, variables such as enterprise wage levels, size, the leverage ratio and income tax expenses are matched using the radius, nearest-neighbour and kernel matching methods. Unmatched enterprise samples are excluded, followed by a multiperiod DID model regression estimation and robustness testing. For robustness and validation purposes, DID has been used to check the pre- and post-treatment effectiveness of variables and to determine the causality of one variable over the other.

Table 3: Average treatment effect estimates under different matching methods

Variables	Radius matching		Nearest neighbour		Nuclear matching	
	(1)	(2)	(3)	(4)	(5)	(6)
citylccpost	0.0477** (0.022)	0.0436*** (0.016)	0.0479** (0.022)	0.0438*** (0.016)	0.0478** (0.022)	0.0437*** (0.016)
roa	–	−0.1655** (0.084)	–	−0.1560* (0.083)	–	−0.1559* (0.084)
size	–	11.5749*** (0.418)	–	11.5745*** (0.417)	–	11.5746*** (0.417)
wage	–	0.1497*** (0.010)	–	0.1497*** (0.010)	–	0.1497*** (0.010)
lev	–	0.1803*** (0.058)	–	0.1835*** (0.057)	–	0.1825*** (0.057)
ser	–	0.2919** (0.1434)	–	0.2931** (0.1434)	–	0.2930** (0.1434)
tax	–	−0.0073 (0.0054)	–	−0.0075 (0.0053)	–	−0.0074 (0.0053)
grow	–	0.0107*** (0.0039)	–	0.0106*** (0.0038)	–	0.0106*** (0.0038)
City FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Constant	7.2492*** (0.0229)	−30.4420*** (1.2177)	7.2492*** (0.0229)	−30.4396*** (0.2172)	7.2492*** (0.0229)	−30.4395*** (0.2170)
Observations	28,844	28,844	28,850	28,850	28,850	28,850
R^2	0.1791	0.5132	0.1791	0.5130	0.1791	0.5130

Note: *, ** and *** represent significance levels of 10%, 5% and 1%, respectively.
Source: Authors' own calculations

The estimation results are shown in Table 3. Columns (1), (3), (5), (2), (4) and (6) in the table show the estimation results without and with control variables, respectively. The regression estimation coefficient of the LCCPP variable is always significantly positive at the 5% and 10% levels. This suggests, to some extent, that the individual characteristics of the sampled enterprises and sample selection affect the results of the influence of LCCPP on employment.

5.3.2 Filtration of sample data

In an effort to alleviate the potential influences of extreme values in the sample data on regression outcomes, a re-estimation of the regression is undertaken by truncating 5% of the dependent variable – the number of employed individuals – with Equation (5). The results are shown in the first column of Table 4, revealing that even after excluding extreme values, the regression coefficient of the LCCPP variable remains significantly positive, passing the 1% significance test.

5.3.3 Impact of urban benchmark factors

The ideal condition of the DID model is to randomly select policy pilot cities. However, baseline factors, for example, the geographical location of the city, whether it serves as a provincial capital, its designation as an economic zone, its position east of the Hu Huanyong Line and its alignment with the Belt and Road Initiative, may influence the choice of low-carbon pilot cities, subsequently affecting employment. This introduces the potential for bias in the effect of LCCPP. To address the non-random selection of pilot cities, this research adopts the method of Wang and Ge (2022) to incorporate the interaction terms of city benchmark factors and time trends into Equation (5), as shown in Equation (8):

$$labor_{it} = \alpha_3 + \beta_3 citylccpost_{it} + \lambda_3 control_{it} + \xi Q_{city} \times trend_t + \phi_i + \gamma_t + \varepsilon_{it} \quad (8)$$

where Q_{city} represents the city benchmark factor and $trend_t$ represents the time trend component. The regression estimates for Equation (8) are presented in Columns (2), (3) and (4) of Table 4. The results indicate that even after incorporating the city benchmark factor, the regression estimate coefficient for the LCCPP variable remains significantly positive and passes the 1% significance test.

Table 4: Robustness test estimates

Variables	(1)	(2)	(3)	(4)	(5)
citylccpost	0.0392** (0.0158)	0.0431*** (0.0165)	0.0439*** (0.0165)	0.0432*** (0.0165)	0.0428*** (0.0164)
roa	−0.1268 (0.0785)	−0.1338 (0.0823)	−0.1330* (0.0823)	−0.1322 (0.0822)	−0.1335 (0.0822)
size	10.9412*** (0.3941)	11.5591*** (0.4159)	11.5638*** (0.4160)	11.5695*** (0.4159)	11.5644*** (0.4163)
wage	0.1420*** (0.0094)	0.1499*** (0.0101)	0.1499** (0.0101)	0.1497*** (0.0100)	0.1497*** (0.0101)
lev	0.2072*** (0.0569)	0.1886*** (0.0586)	0.1893*** (0.0585)	0.1892*** (0.0584)	0.1887*** (0.0585)
ser	0.3349** (0.1370)	0.2969** (0.1435)	0.2972** (0.1435)	0.3016** (0.1432)	0.2984** (0.1436)
tax	−0.0087* (0.0052)	−0.0077 (0.0054)	−0.0077 (0.0053)	−0.0077 (0.0053)	−0.0076 (0.0054)
grow	0.0081*** (0.0030)	0.0095*** (0.0031)	0.0095*** (0.0031)	0.0094*** (0.0031)	0.0094*** (0.0031)
Truncated	Yes	No	No	No	No
Capital × trend	No	Yes	No	No	No
SEZ × trend	No	No	Yes	No	No
Hu Huanyong × trend	No	No	No	Yes	No
Belt & Road × trend	No	No	No	No	Yes
City FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Constant	−28.3804*** (1.1357)	−30.4177*** (1.2109)	−30.4132*** (1.2113)	−30.6328*** (1.1400)	−30.4086*** (1.2120)
Observations	28,858	28,858	28,858	28,858	28,858
R^2	0.5924	0.6176	0.6210	0.6193	0.6204

Note: *, ** and *** represent significance levels of 10%, 5% and 1%, respectively.

Source: Authors' own calculations

5.3.4 Impact of policy interference

This chapter systematically addresses this concern by acknowledging the influence of other policies on employment during the study period and the potential introduction of bias into the research results. By means of a thorough review of the relevant literature and policy documents,

three significant policies, namely, the National Innovative City Pilot, New Energy Demonstration City Pilot and Carbon Emission Trading Pilot, are identified for policy interference testing. The baseline regression model in Equation (5) is augmented by incorporating dummy variables for these three policies. Subsequently, we test the coefficient and significance change of the effect of LCCPP on employment by regression estimation.

(1) Interference test of National Innovative City Pilot policy

This policy commenced in 2008 and has been implemented in 103 cities to date. To eliminate interference from this policy, a dummy variable is introduced into the baseline regression equation to examine whether the results, after excluding the influence of this policy, align with those of the baseline regression. The detailed results are presented in Table 5. The regression coefficient of the LCCPP variable remains significantly positive even after excluding the influence of the National Innovative City Pilot policy. The magnitude of the coefficient shows no substantial change, indicating that LCCPP continues to significantly stimulate employment after accounting for the influence of the National Innovative City Pilot policy.

(2) Interference test of New Energy Demonstration City policy

Introduced in 2014 to promote energy structure transformation and increase the share of new energy consumption, the New Energy Demonstration City policy identified 81 demonstration cities and eight industrial parks. Li *et al*. (2023) proved that this policy can significantly improve green innovation in demonstration cities. To assess whether this policy interferes with the baseline results regarding the effect of LCCPP on employment, the dummy variable for the New Energy Demonstration City policy is added to the baseline regression equation. The results, detailed in Table 5, reveal that the regression coefficient of the LCCPP variable remains significantly positive, with no significant change in its magnitude. This indicates that LCCPP continue to promote employment significantly even after accounting for the effects of the New Energy Demonstration City policy.

(3) Interference test of Carbon Emission Trading Pilot policy

Initiated in June 2013 to achieve dual carbon goals and facilitate low-carbon transformation in economic development, the Carbon Emission Trading Pilot policy was launched in seven provinces and cities in China. Ren *et al*. (2019) concluded that the policy promoted carbon emission intensity in pilot areas. To evaluate whether this policy interferes with the research results, a dummy variable for this policy is added to the baseline regression equation. The results, detailed in Table 5, demonstrate that the regression coefficient of the LCCPP variable remains significantly positive, with no substantial change in its magnitude. This indicates that LCCPP continue to stimulate employment significantly.

Table 5: Exclusion of policy interference tests

Variables	Exclude National Innovative City Pilot	Exclude New Energy Demonstration City	Exclude Carbon Emission Trading Pilot
citylccpost	0.0438*** (0.0165)	0.0400* (0.0241)	0.0298* (0.0161)
roa	−0.1323 (0.0823)	−0.1336 (0.0821)	−0.1361* (0.0821)
size	11.5634*** (0.4159)	11.5534*** (0.4164)	11.5598*** (0.4177)
wage	0.1498*** (0.0101)	0.1499*** (0.0101)	0.1489*** (0.0101)
lev	0.1891*** (0.0585)	0.1866*** (0.0584)	0.1802*** (0.0585)
ser	0.2984** (0.1435)	0.3003** (0.1432)	0.2979** (0.1425)
tax	−0.0077 (0.0053)	−0.0076 (0.0053)	−0.0075 (0.0053)
grow	0.0094*** (0.0031)	0.0094*** (0.0031)	0.0092*** (0.0031)
National Innovative City Pilot policy	Control	Not controlled	Not controlled
New Energy Demonstration City policy	Not controlled	Control	Not controlled
Carbon Emission Trading Pilot policy	Not controlled	Not controlled	Control
City FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Constant	−30.4069*** (1.2109)	−30.3793*** (1.2123)	−39.3800*** (1.2153)
Observations	28,858	28,858	28,858
R^2	0.6210	0.6208	0.6176

Note: *, ** and *** represent significance levels of 10%, 5% and 1%, respectively.

Source: Authors' own calculations

5.3.5 Counterfactual test

To mitigate potential temporal differences in employment levels between the experimental and control groups, this chapter artificially advances the implementation time of the LCCPP by 1, 2 and 3 years. The fictitious policy implementation times are denoted as *citylccpost_1*, *citylccpost_2* and *citylccpost_3*. Regression estimates based on Equation (5) are then calculated and the results are presented in Table 6.

Table 6: Results of time placebo test

Variables	(1)	(2)	(3)
citylccpost_1	0.0224 (0.0177)	–	–
citylccpost_2	–	0.0103 (0.0193)	–
citylccpost_3	–	–	−0.0047 (0.0228)
roa	−0.1342* (0.0824)	−0.1348 (0.0823)	−0.1349 (0.0823)
size	11.5563*** (0.4158)	11.5539*** (0.4158)	11.5508*** (0.4157)
wage	0.1502*** (0.0101)	0.1501*** (0.0101)	0.1501*** (0.0100)
lev	0.1899*** (0.0585)	0.1899*** (0.0585)	0.1902*** (0.0585)
ser	0.2960** (0.1433)	0.2950** (0.1432)	0.2945** (0.1430)
tax	−0.0076 (0.0054)	−0.0076 (0.0053)	−0.0075 (0.0053)
grow	0.0095*** (0.0031)	0.0095*** (0.0030)	0.0094*** (0.0031)
City FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Constant	−30.3911*** (1.2105)	−30.3837*** (1.2106)	−30.3724*** (1.2106)
Observations	28,858	28,858	28,858
R^2	0.6215	0.6220	0.6226

Note: *, ** and *** represent significance levels of 10%, 5% and 1%, respectively.

Source: Authors' own calculations

The regression coefficients for *citylccpost_1*, *citylccpost_2* and *citylccpost_3* do not pass the significance tests at the 10% level. This finding implies that there is no systematic difference in the temporal evolution of employment levels between the experimental and control group enterprises. Thus, the robustness of the finding that LCCPP significantly promote employment remains unchanged.

5.4 Heterogeneity test

5.4.1 Effect analysis of ownership heterogeneity

Based on ownership distinctions, the whole sample was divided into three subsamples: state-owned, private and foreign-owned enterprises. The objective is to examine the differential impact of LCCPP on employment across enterprises with different ownership structures. The detailed results are presented in Table 7.

It is evident that the coefficient representing the effect of LCCPP on state-owned enterprises' employment is significantly positive at the 1% level. This indicates that implementing LCCPP significantly stimulates employment in state-owned enterprises within pilot cities. However, the impact on non-state-owned enterprises, including private and foreign-owned enterprises, is not statistically significant.

One possible explanation is that state-owned enterprises, making use of their political advantages and the motivation for advancement inherent in state-owned enterprise promotion, are better positioned to garner support for policies such as fiscal subsidies targeted at enterprises implementing low-carbon initiatives. State-owned enterprises may, through the output scale effect, expand their operations by increasing the enterprise scale or, through the factor substitution effect, redirect a significant portion of investment in pollution control and other quasi-fixed factor inputs towards the end-of-pipe treatment process, creating new employment opportunities and promoting employment in state-owned enterprises.

On the other hand, under the constraints of LCCPP, private enterprises may find it more feasible to relocate or shut down operations in areas with lower environmental restrictions, thus inhibiting employment. Simultaneously, with the support of complementary policies such as government subsidies and green financial credit provided by LCCPP, increased investment in environmental governance can enhance competitiveness, expand business scale and promote employment. In the interplay of these opposing forces, the effect of LCCPP on employment in private enterprises is not statistically significant. This suggests that further adjustments and optimizations are needed at the level of private enterprises for LCCPP. Foreign-owned enterprises, which largely possess advanced technology and environmental equipment, are less likely to be affected by LCCPP.

Table 7: Results of heterogeneity analysis

Variables	Labour		
	State-owned enterprises	Private enterprises	Foreign-owned enterprises
citylccpost	0.0554** (0.0243)	0.0179 (0.0216)	0.0310 (0.738)
roa	−0.3634** (0.1597)	−0.0460 (0.0950)	0.1730 (0.3937)
size	11.4757*** (0.7707)	11.6448*** (0.4747)	8.0144*** (2.3850)
wage	0.1228*** (0.0136)	0.1621*** (0.0147)	0.2091*** (0.0545)
lev	0.2276** (0.1057)	0.1249* (0.0701)	0.3229 (0.2582)
ser	0.1001 (0.3329)	0.4451*** (0.1425)	0.7227 (0.5049)
tax	−0.0060 (0.0083)	−0.0054 (0.0066)	−0.0305 (0.0219)
grow	0.0067 (0.0064)	0.0137*** (0.0039)	−0.0006 (0.0121)
City FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Constant	−29.7124*** (2.2971)	−30.8377*** (1.3618)	−20.3828*** (6.8852)
Observations	12,029	15,836	993
R^2	0.5912	0.5629	0.5445

Note: *, ** and *** represent significance levels of 10%, 5% and 1%, respectively.
Source: Authors' own calculations

5.4.2 Effect analysis of industry heterogeneity

The entire sample of enterprises is categorized based on the different industries in which they operate, specifically the primary, secondary and tertiary industrial sectors. The effects of LCCPP on the employment of enterprises in different industrial sectors are investigated and the results are shown in Table 8.

The implementation of LCCPP significantly stimulates employment in enterprises operating in primary and secondary industrial sectors. However, the impact on employment in enterprises operating in tertiary industry is not evident.

One plausible explanation for this pattern is the sector-specific nature of LCCPP. The emergence of industries such as organic agriculture, forest carbon sinks, soil carbon sequestration and carbon offset services, which are primarily associated with primary industry, is fostered under the impetus of low-carbon transformation. In the process of industry linkages, these developments create a substantial number of employment opportunities. Tertiary industry, dominated by labour-intensive and technology-intensive sectors, including the service industry and emerging technology-related industries, has less pronounced effects on employment due to its lower carbon emissions than secondary industry. Therefore, the impact of LCCPP on employment in tertiary industry is not as prominent.

5.4.3 Effect analysis of carbon emission heterogeneity

This chapter divides the sample enterprises into two subgroups: high-carbon industry and low-carbon industry. The objective is to investigate the heterogeneity of the effect of LCCPP on employment across enterprises in high- and low-carbon industries. The detailed results are presented in Table 8.

The regression results show that the coefficients of LCCPP for enterprises in low-carbon industries are significantly positive at the 1% level. In contrast, the coefficients for enterprises in high-carbon industries are not statistically significant. This finding indicates that LCCPP significantly promote employment in enterprises within low-carbon industries relative to high-carbon industries.

One possible explanation is that the costs and pressures of low-carbon transformation are greater for enterprises in high-carbon industries. The environmental barrier effect under LCCPP is more pronounced for high-carbon industry enterprises. These enterprises face substantial environmental policy compliance costs, leading to crowding-out effects on productive investments. This, in turn, weakens the innovative initiatives of high-carbon industry enterprises. Most high-carbon industry enterprises do not choose to expand their scale. Additionally, high-carbon industry enterprises are predominantly capital-intensive industries, for example, steel, petrochemicals and heavy machinery, with slow feedback from policy effects. Therefore, LCCPP do not significantly increase employment in high-carbon industry enterprises.

Table 8: Empirical analysis results of heterogeneity of industry and carbon emissions on impact of LCCPP on employment

Variables	Labour				
	Agriculture	Industry	Services	High-carbon industry	Low-carbon industry
citylccpost	0.3645** (0.1437)	0.0407** (0.0174)	0.0235 (0.0338)	0.0459 (0.0350)	0.0442** (0.0185)
roa	0.1894 (0.2549)	−0.1985** (0.0883)	−0.0237 (0.1385)	−0.6345*** (0.2058)	−0.0343 (0.0912)
size	6.4757*** (2.0054)	12.1699*** (0.4458)	11.1844*** (0.9455)	10.4601*** (1.0143)	11.7192*** (0.4591)
wage	0.3881*** (0.0575)	0.1255*** (0.0097)	0.1446*** (0.0184)	0.1393*** (0.0206)	0.1516*** (0.0112)
lev	−0.0296 (0.3200)	0.2479*** (0.0605)	0.0345 (0.1137)	0.2210*** (0.1376)	0.1773*** (0.0645)
ser	−1.2086 (0.9001)	0.1871 (0.1499)	0.6259* (0.3211)	0.6276 (0.7867)	0.2894** (0.1465)
tax	−0.0208 (0.0288)	−0.0027 (0.0047)	0.0078 (0.0115)	−0.0036 (0.0091)	−0.0084 (0.0063)
grow	−0.0474 (0.0309)	0.0094** (0.0041)	0.0113* (0.0060)	−0.0131 (0.0125)	0.0109*** (0.0032)
City FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Constant	−18.2030 (5.7866)	−31.8201*** (1.2918)	−30.1858*** (2.8839)	−26.8404*** (2.9413)	−30.9082*** (1.3360)
Observations	351	21,174	7,333	5,014	23,844
R^2	0.6652	0.7035	0.4722	0.7657	0.5938

Note: *, ** and *** represent significance levels of 10%, 5% and 1%, respectively.
Source: Authors' own calculations

5.5 Mechanism analysis

The implementation of LCCPP will increase the production costs of enterprises; this needs to be analysed from two perspectives. Firstly, based on the compliance cost effect, enterprises may reduce their scale to meet policy constraints. Secondly, according to the Porter hypothesis, appropriate environmental regulations can accelerate technological innovation, leading to increased

production efficiency or reduced carbon emissions, thereby meeting the requirements of low-carbon policies. Changes in enterprise scale and technological innovation both affect labour demand and consequently influence employment. The earlier baseline regression results provide detailed evidence for this causal relationship, confirming that LCCPP significantly promote employment in enterprises.

5.5.1 Output scale mechanism test

The theoretical analysis helps us understand the influence of LCCPP on the output scale of enterprises, considering the combined compliance cost and innovation compensation effects brought about by policy implementation. Empirical testing further examines the influence of LCCPP on the output scale of enterprises and the results are detailed in Table 9, Column (1). The results show that the regression coefficient of the LCCPP variable is significantly positive and passes the 1% significance test. This finding implies that LCCPP significantly stimulate enterprises' output scale in pilot cities.

Concerning the influence of the output scale on employment in enterprises, a regression estimate is conducted using two-way fixed effects and the results are shown in Table 9, Column (2). The results show that the output scale significantly promotes employment in enterprises. In conclusion, the output scale plays an intermediate role in the influence of LCCPP on employment in enterprises, indicating that the output scale is a mechanism through which LCCPP influence employment.

5.5.2 Factor substitution mechanism test

Concerning the impact of LCCPP on factor substitution, this chapter selects the environmental pollution control investment indicator to represent the factor substitution relationship. A regression estimate is conducted on the impact of LCCPP on environmental pollution control investment and the results are shown in Table 9, Column (3). The results show that the LCCPP variable is significantly positive and passes the 10% significance test. This affects the ability of LCCPP to significantly promote environmental pollution control investment in enterprises, positively increasing the input of environmental governance investment and other quasi-fixed factors associated with complying with environmental constraints.

Furthermore, regarding the effect of environmental pollution control investment on employment in enterprises, a regression estimate is conducted using two-way fixed effects and the results are shown in Table 9, Column (4). The results demonstrate that environmental pollution control investment significantly promotes employment in enterprises. This suggests that the increase

in environmental pollution control investment by enterprises through governance at the end of the production process may create new employment opportunities in equipment installation, operation and maintenance. Additionally, enterprises responding to LCCPP supported by relevant government policies are likely to alleviate financial constraints, encouraging them to expand their business scope, production scale and output levels. This, in turn, increases labour demand and promotes employment. In conclusion, factor substitution plays an intermediate role in the effect of LCCPP on employment in enterprises, indicating that factor substitution is a mechanism through which LCCPP influence employment.

Table 9: Test results for scale output and factor substitution mechanisms

Variables	Scale output		Factor substitution	
	sale	***labour***	***epi***	***labour***
	(1)	**(2)**	**(3)**	**(4)**
citylccpost	0.2632*** (0.0564)	–	0.0298* (0.0154)	–
roa	–	0.0074* (0.0044)	–	–
size	–	–	–	0.0260*** (0.0038)
wage	−0.0192 (0.1994)	0.1426* (0.0818)	0.2321*** (0.0753)	−0.1933*** (0.0464)
lev	11.9443*** (2.0699)	8.6795*** (0.3407)	9.4374*** (0.2524)	11.9548*** (0.1598)
ser	−0.0332 (0.0443)	0.1260*** (0.0096)	0.0025** (0.0061)	0.1523*** (0.0038)
tax	−0.0248 (0.1827)	0.3439*** (0.0596)	0.0354*** (0.0234)	0.0863*** (0.0144)
grow	−2.39288*** (0.7540)	0.1983 (0.1468)	−0.1608*** (0.1076)	0.2931*** (0.0663)
City FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Constant	−37.0163*** (6.3743)	−21.4255*** (0.9534)	−28.9837*** (0.7141)	−31.8889*** (0.4540)
Observations	28,858	28,858	28,858	28,858
R^2	0.1045	0.6199	0.8373	0.9166

Note: *, ** and *** represent significance levels of 10%, 5% and 1%, respectively.
Source: Authors' own calculations

6. Conclusion and Policy Recommendations

Recent research into socioeconomic inequalities and environmental degradation has introduced a novel perspective. However, while most economic-environmental research related to climate change within political economies has been extensively conducted, studies from a socioeconomic perspective remain scarce. This study employs low-carbon city pilot policies (LCCPP) as an exogenous shock variable to construct a multiperiod difference-in-differences (DID) model. Through theoretical analysis and empirical testing, this study investigates the impact of LCCPP on employment and its underlying mechanisms. The results indicate that LCCPP significantly enhance employment. Specifically, the average employment level in pilot cities increased by approximately 4.40% compared to that in non-pilot cities. Additionally, the effects of LCCPP on employment vary significantly across different periods. The conclusion that LCCPP boost employment is robust, supported by various rigorous tests, including parallel trends, propensity score matching DID (PSM-DID), sample data filtration, accounting for city baseline factors, exclusion of policy interference and counterfactual tests. Nevertheless, LCCPP significantly promote employment in state-owned enterprises, with a coefficient of 0.346%, while their effects on non-state-owned enterprises are less pronounced. The policy positively affects employment in the first, second and third industrial sectors, with the strongest effect observed in the first, followed by the third and second industrial sectors. Additionally, the policy significantly promotes employment in low-carbon industries, while its impact on high-carbon industries is not apparent. Furthermore, the output scale and factor substitution mechanisms serve as the pathways through which LCCPP promote employment. In other words, the policy positively influences employment by stimulating output scale and environmental governance investment as part of factor substitution.

In conclusion, LCCPP significantly and positively affect employment, particularly in state-owned enterprises, the first industrial sector and low-carbon industries. The mechanisms of output scale expansion and factor substitution identified in this study play crucial roles in mediating the influence of the policy on employment.

According to the empirical findings outlined above, the following policy recommendations are proposed. Firstly, the construction of LCCPP should be accelerated and the scope of trials should be expanded. Initiating LCCPP projects in China helps mitigate policy risks associated with inappropriate implementations and facilitates continuous learning and improvement through trial and error. The research presented in this study demonstrates that LCCPP significantly promote workforce employment. These policies enhance carbon emission efficiency and stimulate employment, offering the dual benefit of energy conservation and employment growth. Therefore, building upon existing pilot experience, it is recommended that advanced pilot models be propagated, the scope of low-carbon city trials be continuously broadened and the influences of LCCPP

be fully utilized. This has substantial implications for China's goals of achieving a carbon peak by 2030, achieving carbon neutrality by 2060 and achieving high-quality sustainable development. Secondly, relationships between the output scale and factor substitution are used to stabilize employment. Thirdly, the study concludes that LCCPP substantially boost employment through their output scale and factor substitution. Consequently, in driving green and low-carbon transformation through these policies, local governments should intervene in the enterprise innovation process using market mechanisms. This can be achieved by increasing research and development funding, establishing platforms for green technology exchange, formulating green subsidy policies and ensuring strict adherence to environmental constraints by high-carbon enterprises. These measures aim to create a positive feedback mechanism where technological innovation propels green and low-carbon transformations, promoting stable employment. Fourth, by implementing differentiated policy models to address ownership heterogeneity among enterprises under LCCPP, policies should be refined. Enhancing environmental industry policy support for non-state-owned enterprises, expanding the output scale and driving factor substitution can be achieved through targeted green subsidy incentives. This approach aims to increase the enthusiasm of non-state-owned enterprises for environmental governance and technological innovation, reduce their negative environmental externalities and stabilize and promote non-state-owned enterprise employment. Regarding second industrial sector and high-carbon industry enterprises, which may exhibit technological path dependence, targeted low-carbon policies tailored to specific industrial sectors are necessary. Understanding enterprises' difficulties in each industry and providing targeted policy measures to address these challenges will facilitate a phased transition to low-carbon practices. This approach categorically addresses workforce training, transition and reemployment issues based on the varying degrees of transformation difficulty and speed across different enterprises.

6.1 Research limitations and future research directions

The above conclusions and implications and insights in the field of employment and sustainable development are exclusive. This research is limited to single-country studies, which mostly substantiates the gap in carbon policies and the transition towards a low-carbon economy. However, future researchers could take the opportunity to extend the data to panel research for developed economies to observe broader outcomes and evaluate the perspectives of developed countries. Moreover, researchers could include more variables that are relevant to socioeconomic perspectives, such as urbanization, human capital and sustainable development, in parallel studies. Moreover, future researchers should adapt or adopt this study to other conceptual frameworks and could utilize this concept through panel advances and novel methods to have a greater impact on its outcomes.

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References

Ali, K., Khan, Z., Khan, N., et al. (2016). Performance Evaluation of UK Acquiring Companies in the Pre and Post-Acquisitions Periods. *Asian Journal of Economics and Empirical Research*, 3(2), 130–138. https://doi.org/10.20448/journal.501/2016.3.2/501.2.130.138

Altman, I., Hunter, A. M. (2015). The employment and income effects of cleaner coal: : The case of FutureGen and rural Illinois. *Clean Technologies & Environmental Policy*, 17(6), 1475–1485. https://doi.org/10.1007/s10098-014-0872-y

Berman, E., Bui, L. T. M. (2001). Environmental regulation and productivity: Evidence from oil refineries. *Review of Economics and Statistics*, 83(3), 498–510. https://doi.org/10.1162/00346530152480144

Chen, H., Guo, W., Feng, X., et al. (2021). The Impact of Low-Carbon City Pilot Policy on the Total Factor Productivity of Listed Enterprises in China. *Resources Conservation and Recycling*, 169, 105457. https://doi.org/10.1016/j.resconrec.2021.105457

Germanwatch (2024). *Global Climate Risk Index.* [Retrieved 2021-01-25] Available at: https://www.germanwatch.org/en/cri

Hafstead, M. A. C., Williams, R. C. (2018). Unemployment and Environmental Regulation in General Equilibrium. *Social Science Electronic Publishing*, 160(4), 50–65. https://doi.org/10.1016/j.jpubeco.2018.01.013

Haroon, M. (2024). Energy poverty in the face of stringent environmental policies: An analysis of mitigating role of energy storage in China. *Journal of Energy Storage*, 81, 110396. https://doi.org/10.1016/j.est.2023.110396

Huang, J., Zhao, J., Cao, J. (2020). Environmental Regulation and Corporate R&D Investment – Evidence from a Quasi-Natural Experiment. *International Review of Economics and Finance*, 72, 154–174. https://doi.org/10.1016/j.iref.2020.11.018

Jacobson, L. S., Lalonde, R. J., Sullivan, D. G. (1993). Earnings Losses of Displaced Workers Revisited. *American Economic Review*, 83, 685–709.

Ji, X., Umar, M., Ali, S. et al. (2021). Does fiscal decentralization and eco-innovation promote sustainable environment? A case study of selected fiscally decentralized countries. *Sustainable Development*, 29(1), 79–88. https://doi.org/10.1002/SD.2132

Khan, N., Ali, K., Kiran, A., et al. (2017). Factors that Affect the Derivatives Usage of Non-Financial Listed Firms of Pakistan to Hedge Foreign Exchange Exposure. *Journal of Banking and Financial Dynamics*, 1(1), 9–20. https://doi.org/10.20448/JOURNAL.525/2017.1.1/525.1.9.20

Khan, Z., Badeeb, R. A., Hassan, T., et al. (2023a). Emissions-Adjusted International Trade for Sustainable Development in China: Evidence from dynamic autoregressive distributed lags model and kernel based regression. *Sustainable Development*, 31(1), 379–392. https://doi.org/10.1002/SD.2398

Khan, Z., Badeeb, R. A., Zhang, C., et al. (2023b). Financial inclusion and energy efficiency: role of green innovation and human capital for Malaysia. *Applied Economics*, 56(27), 3262–3277. https://doi.org/10.1080/00036846.2023.2206109

Li, H., Tang, Y., Zuo, J. (2017). Government Intervention, Ultimate Control Right and Enterprise Employment Behavior: Research Based on Chinese Private Listed Companies. *Journal of Finance and Economics*, 7, 20–31. https://doi.org/10.16538/j.cnki.jfe.2017.07.002

Li, S. (2015). Effects of Environmental Regulation on Heterogeneous Labors' Employment: An Analysis Based on Provincial Dynamic Panel Data. *China Population, Resources and Environment*, 25(8), 135–143. https://doi.org/10.3390/ijerph14121598

Li, Y., Cheng, H., Ni, C. (2023). Energy transition policy and urban green innovation vitality: a quasi-natural experiment based on the new energy demonstration city policy. *China Population, Resources and Environment*, 33(1), 137–149. https://doi.org/10.12062/cpre.20220918

Li, Y., Lu, W. (2011). The Economy-wide Rebound Effects of Energy Efficiency Increase in Production. *China Population, Resources and Environment*, 21(11), 44–49. https://doi.org/10.3969/j.issn.1002-2104.2011.11.008

Li, M., Zhang, K., Alamri, A. M., et al. (2023). Resource curse hypothesis and sustainable development: Evaluating the role of renewable energy and R&D. *Resources Policy*, 81. https://doi.org/10.1016/j.resourpol.2022.103283

Liu, M., Tan, R., Zhang, B. (2021). The costs of "blue sky": environmental regulation, technology upgrading, and labour demand in China. *Journal of Development Economics*, 150, 102610. https://doi.org/10.1016/j.jdeveco.2020.102610

Lu, Y. (2011). Green Policies and Jobs in China: A Double Dividend? *Economic Research Journal*, 46(7), 42–54.

Qiu, S. L., Wang, Z. L., Liu, S. (2021). The policy outcomes of low-carbon city construction on urban green development: Evidence from a quasi-natural experiment conducted in China. *Sustainable Cities and Society*, 66, 102699. https://doi.org/10.1016/j.scs.2020.102699

Rasoulinezhad, E., Taghizadeh-Hesary, F. (2022). Role of green finance in improving energy efficiency and renewable energy development. *Energy Efficiency*, 15(2), https://doi.org/10.1007/s12053-022-10021-4

Ren, Y., Fu, J. (2019). Research on the effect of carbon emissions trading on emission reduction and green development. *China Population, Resources and Environment*, 29(5), 11–20.

Tufail, M., Song, L., Umut, A., et al. (2022). Does financial inclusion promote a green economic system? Evaluating the role of energy efficiency. *Economic Research-Ekonomska Istraživanja*, 35(1), 6780–6800. https://doi.org/10.1080/1331677X.2022.2053363

Tufail, M., Song, L., Wang, W., et al. (2023). Race to Top or Race to Bottom Approach: Disaggregated Effect of Fiscal Decentralization and Its Implications for Consumption-Based Carbon Emissions. *Journal of the Knowledge Economy*, 15(3), 15243–15277. https://doi.org/10.1007/s13132-023-01690-2

Wang, F., Ge, X. (2022). Can Low-carbon Transition Impact Employment – Empirical Evidence from Low-carbon City Pilot Policy. *China Industrial Economics*, 5, 81–99. https://doi.org/10.19581/j.cnki.ciejournal.2022.05.004

Wang Y., Wang, G., Peng, Y. (2012). Does Ownership Nature Affect Tax Sensitiveness? – Evidence Based on Firm's Labor Demand. *Economic Research Journal*. 47(4), 52–63.

Wang, R., Destek, M. A., Weimei, C., et al. (2023). Drivers of Sustainable Green Finance: Country's Level Risk and Trade Perspective for OECD Countries. *The Journal of Environment & Development*, 33(1), 125–148. https://doi.org/10.1177/10704965231217046

Wang, Z., Alamri, A. M., Mawad, J. L., et al. (2023). Sustainable growth and a green environment? Evidence from nonparametric methods provincial data of China. *Economic Research-Ekonomska Istraživanja*, 36(3). https://doi.org/10.1080/1331677X.2022.2152070

Xu, J., Cui, J. (2020). Low-Carbon Cities and Firms' Green Technological Innovation. *China Industrial Economics*, 12, 178–196. https://doi.org/10.19581/j.cnki.ciejournal.2020.12.008

Yu, S., Liang, Y., Zhu, Z., et al. (2024). Dutch disease perspective of energy sector: Natural resources and energy sector nexus with the role of renewable energy consumption. *Resources Policy*, 90, 104740. https://doi.org/10.1016/j.resourpol.2024.104740

Zang, C., Sun, P. (2021). Does Low-carbon City Construction Promote Local Green Development? Empirical Evidence from Quasi-natural Experiments. *Finance and Trade Research*, 32(10), 27–40. https://doi.org/10.19337/j.cnki.34-1093/f.2021.10.003

Zheng, J., Shao, X., Liu, W., et al. (2021). The Impact of the Pilot Program on Industrial Structure Upgrading in Low-Carbon Cities. *Journal of Cleaner Production*, 290, 125868. https://doi.org/10.1016/j.jclepro.2021.125868