

Research on the Impact of Urban Low-Carbon Pilot Policies on Employment from the Perspective of a Just Transition

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Research Article

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Research on the Impact of Urban Low-Carbon Pilot Policies on Employment from the Perspective of a Just Transition ——a “quasinatural experiment” of a multiperiod DID model

Abstract: Based on macro data from cities and micro data from listed companies from 2008 to 2024, this article uses the multiple time point double difference model to test the impact of a low-carbon city pilot policy on Chinese urban carbon emissions and employment. The results show that at the urban level, the pilot policy significantly reduced carbon emissions and promoted employment in pilot cities. Specifically, fully considering other factors, this policy resulted in a reduction of approximately 1.6% in carbon emissions and an increase of approximately 6.6% in employment. Moreover, enterprises located in low-carbon pilot cities have an average employment rate that is approximately 4.3% higher. The mechanism test reveals that the pilot policy affects employment through output and factor substitution effects. However, the policy benefits the employment of high-skilled individuals but is extremely detrimental to the employment of low-skilled individuals. The results of the heterogeneity analysis reveal that the pilot policy has a much greater promoting effect on employment in the tertiary industry than in the secondary industry, and has a negative effect on high-carbon industries but a positive effect on low-carbon industries. Moreover, the pilot policy has a greater effect on private enterprises than on state-owned enterprises and foreign-funded enterprises and has a negative effect on old enterprises but a positive effect on new enterprises. Therefore, the research suggests further improving the matching of low-carbon transformation policies and employment security policies, vigorously cultivating low-carbon industries/enterprises, and strengthening low-carbon industry training for workers.

Keywords: Just Transformation; Pilot Policies for Low-Carbon Cities; Employment; Multitemporal Double Difference Model; Quasinatural Experiment

1. Introduction

In 2010, China successively launched a low-carbon city pilot policy aimed at exploring low-carbon development paths that comply with China's national conditions. This policy created a spatial low-carbon governance structure with multiple levels and types by establishing batches of pilot cities with different characteristics. As the scope of the policy expanded, urban low-carbon transformation has become a key measure for China in terms of achieving the “dual carbon” goals (peak carbon emissions before 2030 and carbon neutrality before 2060). However, in the process of low-carbon transformation, traditional high-carbon industries are impacted, and the job market faces restructuring. Ensuring fairness and justice in this process has become an important issue that urgently needs to be addressed.

The concept of a “just transition” was first proposed by the North American labour union movement in the late 1970s to 1990s. Its original intention was to propose that unions need to

coordinate and achieve a truly just transition between ensuring decent job opportunities for workers and protecting the environment. Since then, it has often specifically referred to the need to pay attention to fairness issues in the employment and labour fields during the transition process (Pandey, 2019). This concept originally focused on protecting the rights and interests of unemployed workers when facing environmental policies. As global carbon neutrality has accelerated, its connotation continues to expand and now covers multiple dimensions, such as economic structure, employment security, and ecological restoration. In China, a fair transformation emphasizes the concept of “putting the people at the centre”, which requires a transformation process focused on the employment, livelihood, and capacity of the affected groups, ensuring that “no one is left behind” (Zhuang, 2025).

There is an inherent theoretical connection between low-carbon pilot policies and fair transformation (Lieu, 2025). Low-carbon pilot policies promote the decarbonization of the urban economy through environmental regulation, industrial adjustment, and technological innovation, inevitably changing the structure and scale of the employment market (Winchester, 2025). A just transition provides a theoretical framework and policy tools to address the employment impact caused by low-carbon policies. Integrating the concept of a fair transformation into low-carbon pilot policies can help alleviate social conflicts, reduce transformation resistance, and achieve a win-win situation for environmental and social benefits while promoting low-carbon development. As the world's largest developing country and carbon dioxide emitter, China must determine how to achieve the benefits of both environmental protection and economic and social development during high-quality development (Lin, 2024). Therefore, the Chinese government has successively introduced multiple environmental regulation policies. Among them, the low-carbon pilot policy, as one of the most important policy innovations in China's environmental regulation field, follows a “from point to surface” development logic. As of 2025, China has established 81 national low-carbon city pilot projects in three batches (2010, 2012, and 2017) (Lu S, 2025). These provinces and cities are committed to developing low-carbon strategic emerging industries and modern service industries and actively building a low-carbon industrial system characterized by greenness, environmental protection, and recycling. This transformation is a broad and profound social change that affects all aspects of the social system.

The impact of low-carbon pilot policies on employment is not simply an “increase” or

“decrease” but a process of structural adjustment. It is similar to “job migration”, which not only eliminates some traditional positions but also expedites new green professions and has differentiated effects on workers in various regions and those with different skills. Therefore, one question that needs to be answered is whether the low-carbon transformation of cities has affected employment. Although China's employment situation has been relatively poor in recent years, the reasons are diverse and include macroeconomic slowing, international trade frictions, and industrial chain disruptions. Is the green and low-carbon transformation of cities also a reason for the decline in employment rates? The existing research has not fully answered this question. On the one hand, this article clarifies the nonlinear and complex relationship between urban low-carbon transformation and employment through a theoretical analysis, and on the other hand, it verifies this relationship by combining macro data at the city level and micro data at the enterprise level.

The contributions of this article are as follows. First, the concept of a “just transformation” should be integrated, and the theoretical framework of environmental policy evaluation should be enriched. Traditional research focuses mostly on the overall or average employment effects of low-carbon policies (i.e., how many jobs are “created” or “eliminated”). This study introduces the core concept of “fair transformation” as an equity-oriented approach into the analytical framework, with labour no longer being treated as a homogeneous entirety. The focus is on the distribution effect of policies, that is, how employment shocks are distributed among different groups of workers (such as those in high-carbon industries vs. green industries), workers with different skill levels, and workers in different regions. This provides a more comprehensive and humane theoretical perspective for understanding the socioeconomic consequences of environmental policies. Second, this study aims to understand the process of “creative destruction”. Traditional research often acknowledges that low-carbon transformation is accompanied by processes of “destruction” (a reduction in high-carbon jobs) and “creation” (an increase in green jobs), but these processes often occur separately. In this study, the spatiotemporal asynchrony and skill mismatch in this process are analyzed in depth, thereby revealing the structural friction and costs in the transformation process and providing micro evidence from Chinese cities and enterprises in support of “creative destruction” theory. Third, this study adds to the interdisciplinary research between labour and environmental economics. This study is a typical interdisciplinary study. By

linking the just transition (social dimension) with low-carbon pilot projects (environmental dimension) and employment (economic dimension) and constructing a three-dimensional integrated analytical “environment–economy–society” paradigm, important theoretical references are provided for subsequent cross-disciplinary related research.

The structure of this article is as follows: Chapter 2 presents the literature review, Chapter 3 presents the theoretical hypotheses, Chapter 4 presents the model construction and data sources, Chapter 5 presents a discussion of the regression results, and Chapter 6 presents the conclusions and policy recommendations.

2. Literature review

This study evaluates the effectiveness of China's low-carbon city pilot policies and the impact of the economic and social low-carbon transformation on employment. To review these two types of research, this study categorizes the relevant thematic research literature into three types.

2.1 Evaluation of low-carbon city pilot policies

Currently, the research on low-carbon city pilot policies has gone beyond simple effectiveness summaries towards a more systematic and thorough stage. The focus of research is shifting from “whether it is effective” to “why it is effective” and “how can it be more effective”, which covers multiple dimensions from macro effects to micro mechanisms and from domestic practices to international comparisons (Liu, 2022). The existing research covers five main points. The first is policy effectiveness evaluations, which identify the positive effects of policies on carbon reduction and promoting green innovation and include the construction of multidimensional indicator systems for quantitative measurements (Wu M, 2025). The second is analyses of the associated mechanisms and pathways, such as industrial structure upgrading, technological innovation incentives, and green finance support. The third involves innovative standards and methods that should be promoted to standardize and refine carbon emission accounting and provide a more scientific and comparable data foundation for evaluation (Xie, 2025). The fourth includes international collaborations on and comparisons of international green trade rules, as well as international comparative research on low-carbon development paths

between cities (Zhang Y, 2025). The fifth includes studies of policy coordination and integration, studies evaluating the synergistic effects of low-carbon policies with energy, economic, environmental and other policies, and studies aimed at pursuing the maximization of overall benefits (Zhu, 2025).

In addition to the mature fields mentioned above, the current research has pursued more refined and integrated directions, some of which deserve attention. First, some new research involves classification evaluations and precise profiling, that is, researchers have begun to realize that there are large differences in the foundations and types of objects and no longer use a single method to measure them (Araujo, 2026). Through clustering analyses and other methods, pilot cities can be categorized into different types (such as industry-led, resource-based, and comprehensive cities), and a more targeted evaluation index system can be constructed for each type of city to ensure the evaluation results are more scientific and policy recommendations more accurate (Ge, 2025; Wu Y, 2025). Second, studies now evaluate the entire process of pilot construction, including dynamic tracking and full process management, that is, the process of evaluation is no longer static (Sun J, 2025). Taking Shanghai as an example, its low-carbon pilot construction can be characterized as a complete management loop: “mid-term evaluation–final acceptance–case summary”, and the experience has been systematically reviewed via white papers and other methods. This dynamic tracking process helps detect problems and adjust the direction in a timely manner (Zhu, 2022). Third, studies have explored policy synergies, which means that the process of low-carbon transformation is a systematic project that cannot be handled by a single policy (Liu Q, 2025). New research has begun to use tools such as system dynamics models to quantitatively evaluate the synergistic effects of different policies (such as renewable energy subsidies) and simulate the effects of future policy combinations (Isnandar, 2024; Wei, 2024). Research has also begun to construct comprehensive assessment systems covering multiple dimensions, such as climate resilience (Ranjan, 2025), energy security, economic growth, and ecological benefits (Trinco, 2025; Joshua, 2025).

Although research has achieved rich results, there are still many challenges and spaces for exploration: ① The exploration of long-term evaluation mechanisms. The current research focuses on the pilot period. Low-carbon transformation is a long-term process, and it is necessary to establish a long-term evaluation and tracking mechanism that extends beyond the pilot period to

observe the sustainability and stability of policies. ② Fairness and transition costs. While emphasizing efficiency, future research will need to focus more on the social equity of the low-carbon transition, such as how to fairly share transition costs and the impact to the employment of traditional industry workers. ③ The integration of digitalization and decarbonization. “Digital carbon neutrality” is a burgeoning field. How to leverage digital technologies such as big data and artificial intelligence to empower low-carbon urban management and evaluation represents a highly promising research direction. ④ Theoretical applications of local practices. It will be important to determine how to systematically summarize the rich practical experience of various pilot cities (such as exploration of underdeveloped plateau areas in Xining city, China) and construct a theoretical model with universal guiding significance for local practices. The above are the research directions that the academic community should aim to pursue.

2.2 Impact of Environmental Regulations on Employment

The relationship between environmental regulations and employment is controversial and cannot be simplified to “as one falls, another rises.” In fact, there is a very complex nonlinear dynamic relationship between the two.

(1) The core theoretical debate is from “conflict theory” to “win–win theory”. The core logic of this theory is that environmental regulations increase the production costs of enterprises (such as by purchasing environmental protection equipment and paying pollution fees) and restrict productive investment, thereby decreasing enterprise competitiveness, output, and ultimately, labour demand, which could cause enterprise bankruptcy and unemployment. This theory is based on neoclassical economics, which takes environmental regulation as an exogenous shock, primarily focusing on its static costs (Zhang J, 2025; Kumail, 2025; André, 2025). This theory focuses mainly on two channels: one is the substitution effect, where companies replace labour with capital (environmental protection equipment) (Sun D, 2025), and the other is the scale effect, where rising costs lead to increased product prices and decreased market demand, and companies shrink their production scale, thereby reducing labour (Lu M, 2025).

(2) The revisionist viewpoint includes the Porter hypothesis and the win–win paradox. The core logic of this theory is that strict and appropriately designed environmental regulations can stimulate the “innovation compensation” effect of enterprises. By promoting technological innovation and improving resource productivity, it can not only offset compliance costs but also

enhance enterprise competitiveness, expand market share, and stabilize or increase employment. The theoretical basis of this view is the emphasis on the dynamic innovation incentive effect of environmental regulation (Chang, 2025). Three channels are noted: the first is innovation and competitiveness, where regulations force companies to develop new technologies and products and open up new markets; the second is industrial upgrading, which promotes the transformation of the economic structure towards greenness and high added value and creates new job opportunities; and the third is the creation of green employment, which directly stimulates employment opportunities in fields such as environmental protection and renewable energy (Jun, 2025).

(3) Empirical analyses have not yielded simple and consistent conclusions, and the results are highly dependent on differences in the research background, data, methods, and research subjects. First, the total effect ranges from “slightly negative” to “neutral or slightly positive”. Early research based on data from developed countries revealed that the overall negative impact of environmental regulations on employment is relatively small and even statistically insignificant (Ishora, 2025). However, recently, an increasing number of studies, especially in the context of China, have reported neutral or weak positive effects, supporting the validity of the Porter hypothesis under certain conditions (Chen, 2024). Second, heterogeneity analyses have yielded further insights. This is the core area of the current research and explains why contradictory conclusions exist. This body of research covers the heterogeneity of enterprises, industries, regions, and policy tools (Liu L, 2025). (3) Third, research has examined the influencing channels. Research has revealed that there are different channels for factor substitution. The main channels include the element substitution channel, which is the substitution of labour by capital (environmental protection equipment); the demand channel, which refers to the demand for new products and markets brought about by green innovation, thereby creating employment opportunities; and the industrial chain channel, in which environmental regulations affect employment in related industries through upstream and downstream linkages (Hamaguchi, 2024; Rousseli è re, 2024).

Therefore, we conclude that the impact of environmental regulations on employment is not a monolithic issue and that its effects are complex, multidimensional, and highly heterogeneous. Both simple “employment loss theory” and “win–win theory” are biased.

2.3 Impact of low-carbon city pilot policies on employment

China is the world's largest industrial country and carbon emitter and is among the most populous countries. Research on the impact of China's low-carbon city pilot policies on employment is very important. In recent years, scholars have conducted valuable research on this issue, and most of the results have shown that policies have positive effects. For example, Wang F's (2022) study revealed that the implementation of low-carbon city pilot policies has led to an average increase of approximately 5.11% in the number of employees in enterprises in pilot cities. From a theoretical perspective, Yan (2023) explained that low-carbon city pilot policies, by concentrating resources, have led to two different paths for urban low-carbon transformation, namely, prioritizing the development of the secondary industry and prioritizing the development of the tertiary industry. Both paths have their own advantages and disadvantages. On this basis, the “dual carbon” goals should be achieved through both industrial transformation and upgrading, as well as by enhancing the development of the tertiary industry. However, the optimal way is to develop the tertiary industry on the basis of industrial transformation and upgrading, and people must not blindly adopt deindustrialization just to achieve the carbon peak goal. Wang YQ (2024) found that urban green transformation mainly exerts effects on employment creation by promoting green technology innovation, driving industrial structure optimization, and enhancing residents' green consumption. It exists mainly in service-oriented industries, non-resource-based areas with good new infrastructure, regions with strong government innovation preferences, and regions with good economic endowments. Li Y (2024) also reported that low-carbon city pilot policies can significantly increase urban employment levels overall through two important transmission mechanisms: output effects and factor substitution effects. Tian (2025) further subdivided the research and reported that low-carbon city pilot policies can increase the employment scale of high-skilled labour in enterprises but have no effect on the employment of low-skilled labour. Low-carbon pilot policy cities exhibit increased agglomeration of high-skilled labour to economically developed cities while also causing low-skilled labour to migrate to economically underdeveloped cities, which may have a negative effect on the coordinated economic development among cities. These research conclusions provide useful insights for China to achieve the optimal allocation of labour factors and high-quality economic development in the process of low-carbon transformation.

The relevant literature has laid the foundation for the research in this article. However, considering the differences in research perspectives and content, scholars have not reached consistent conclusions. Overall, there is still room for improvement on the existing literature. Therefore, this article comprehensively utilizes macro data at the city level and micro data at the enterprise level to examine the impact of low-carbon city pilot policies on employment. In addition, mechanism and heterogeneity analyses are conducted, with the goal of contributing to the development of the field of study.

3. Theoretical hypotheses

This paper draws upon mainstream academic views to analyse the theoretical mechanisms underlying the effect of low-carbon city pilot policies on employment from two aspects, namely, the output effect and the factor substitution effect.

From the output perspective, urban low-carbon pilot policies primarily stimulate and create employment opportunities by generating new market demands, guiding green investments, and promoting industrial upgrading (Wu Y, 2025). The specific path and performance are as follows. First, the expansion of green emerging industries is promoted, that is, policies stimulate market demand for renewable energy, energy conservation and environmental protection industries, directly driving related investment and output. Second, the green upgrading of traditional industries is promoted, which means that policies, such as ultralow emission transformation and energy efficiency improvement projects for steel enterprises, force high-carbon industries to undergo green transformation. Third, the innovation and application of green technologies is encouraged, that is, policies inspire enterprises to increase R&D investment and promote the innovation and industrialization of green technologies (such as carbon reduction technologies). Fourth, the construction and operation of low-carbon scenarios is promoted, that is, policies promoting the construction of new urban infrastructure, such as zero-carbon parks, zero-carbon buildings, and slow traffic systems. There are two crucial points for understanding the path of job creation mentioned above. One is the upgrading of the employment structure. The new jobs from the output effect generally have a greater demand for high-skilled labour. This means that policy implementation requires supporting vocational training and skill enhancement plans to help the workforce adapt to new market requirements. The second reflects the importance of policy

synergy. A single policy may have limited effectiveness or generate negative effects. For example, implementing pilot policies for innovative cities in advance can provide a better technological and talent foundation for subsequent low-carbon policies. Overall, low-carbon pilot policies have effectively played the role of “employment engines” in cities through four main output paths: promoting new industries, transforming old production capacity, stimulating innovation, and building new scenarios. These policies do not simply add or reduce jobs but also promote a structural upgrading of the job market towards greener and higher-skilled directions.

Therefore, Hypothesis 1 is proposed: Low-carbon city pilot policies affect employment through output effects.

From the perspective of the factor substitution effect, low-carbon pilot policies effectively promote the improvement of employment quality in cities by changing the input combination of factors such as capital, labour, and skills in the enterprise production process. This not only increases job opportunities but also increases the value of work. The specific path is as follows. First, low-carbon pilot policies promote skill upgrading, that is, they encourage enterprises to adopt new technologies, new equipment, and new production methods that require more skilled labour. Second, low-carbon pilot policies optimize factor allocation, which means that enterprises will carry out capital transformation and adjust factor investment to cope with transformation, further increasing the demand for high-skilled talent and increasing their income portion. Third, low-carbon pilot policies reshape the industrial structure and guide policies to concentrate resources towards the high value-added and low-energy consumption tertiary industry. However, while the factor substitution effect improves the quality of employment, it also has some negative effects that should be noted. For example, the factor substitution effect can lead to potential skill mismatches and structural unemployment. Low-carbon transformation may create new jobs, but it may also put some workers in traditional high-carbon jobs at risk of unemployment. Therefore, it is necessary to strengthen vocational skills training to help workers smoothly transition to new green positions. For example, many developed countries have begun to carry out green and low-carbon vocational skills training and cultivate specialized “green collar” talent (Hopper, 2025). Moreover, the research also suggests that the risk of low-carbon transformation may lead to high-carbon-emitting companies responding to pressure through layoffs and salary cuts, thereby reducing the labour income share of their employees. This means that in the process of improving

the overall quality of employment, it is necessary to pay attention to the effects on specific groups and alleviate these adverse effects through policy tools such as strengthening labour protections and easing corporate financing constraints. In summary, low-carbon pilot policies have promoted the upgrading of employment quality in cities through factor substitution effects, mainly on the basis of three aspects: skill structure, income distribution, and industrial structure. These policies promote the development of the labour market towards higher skill levels, higher rewards, and more sustainable directions. This process is clearly accompanied by structural adjustment difficulties. By supporting skills training, precise labour protection policies, and the selection of appropriate industrial development paths, a win–win situation of “promoting employment” and “improving quality” can be more easily achieved.

Therefore, Hypothesis 2 is proposed: Low-carbon city pilot policies affect employment through factor substitution effects.

The socioeconomic system is extremely complex, and the impact of low-carbon city pilot policies on this system involves both complex nonlinear effects and the differentiated performance of different entities. First, enterprises of different ownership types and ages have various types of performance. China is a socialist country, and the state-owned economy plays a crucial role in the economic system. State-owned enterprises and private-owned enterprises have completely different endowments in terms of key resources such as authority, funds, and talent. This directly determines their ability and approach to responding to policies and carrying out green transformation, which differ. State-owned enterprises can focus on long-term strategies, whereas nonstate-owned enterprises are more concerned with immediate market feedback and cost–benefit analyses (He, 2024). The research has shown that low-carbon city pilot policies promote enterprise transformation and upgrading through two main paths: promoting technological innovation and alleviating financing constraints. For state-owned enterprises that typically have a more advantageous financing environment, the effect on technological innovation may be more pronounced; for nonstate-owned enterprises that often face financing difficulties, once policies can effectively improve their financing situation, the driving effect on employment may become more prominent. Low-carbon city pilot policies also have differential effects on employment for enterprises of different ages. We suppose that new businesses/startups are more likely to benefit from these policies because they were created for emerging markets and typically focus more on

green technologies. They can quickly seize opportunities in areas such as green financing and entrepreneurial vitality brought about by these policies, thereby creating new job opportunities. This allows them to be able to directly convert entrepreneurial vitality into green employment opportunities, enjoy policy dividends, and achieve net employment growth. In addition, these enterprises do not face the heavy burden of traditional production models and can adjust their business direction more flexibly to adapt to new low-carbon market demands. Mature/incumbent enterprises face significant challenges and opportunities. On the one hand, they need to address the risk of skill mismatch, that is, the technological progress brought about by low-carbon transformation places greater demands on workers' skills. If the skills of existing employees in mature enterprises cannot be maintained, the problem of skill mismatch may occur. On the other hand, these enterprises experience the net result of internal structural change and comparison, namely, the reduction of traditional positions and the expansion of green-related positions.

Therefore, Hypothesis 3 is proposed: The effect of low-carbon city pilot policies on employment is influenced by heterogeneity in enterprise ownership and age.

There are also significant differences in the effect of low-carbon city pilot policies on employment among the first, secondary, and third industries. Overall, policies promote the transfer of labour to the service industry. However, policies not only change the number of employed people but also promote employment quality. On the one hand, policies promote the upgrading of the industrial structure. Policy guidance has tilted resources towards low-carbon and efficient industries, promoting the upgrading of the industrial structure and changing the distribution of employment demand. On the other hand, policies have encouraged innovation in green technologies. Policies have forced enterprises to innovate in green technologies, giving rise to emerging green industries and jobs and creating new employment opportunities. Through these channels, the demand for high-skilled labour in enterprises has significantly increased. This means that the low-carbon transformation is driving the upwards optimization of the skill structure in the labour market. Therefore, local governments need to be wary of simple “deindustrialization” tendencies when promoting the low-carbon transformation. The optimal way should be to vigorously develop the tertiary industry and the green and low-carbon high-end manufacturing industry by promoting industrial transformation and upgrading to achieve a balance between the quantity and quality of employment. Skill training is also important. Owing to the significant

increase in demand for high-skilled labour through policies, strengthening vocational skills training and helping workers adapt to new market demands are crucial for achieving a “just transition”.

The impact of low-carbon city pilot policies on employment indeed varies significantly depending on the carbon emission intensity of different industries. This study suggests that policies promote the transfer of labour from high-carbon-intensity industries to low-carbon-intensity industries and profoundly affect the scale and skill structure of employment in this process. The employment opportunities in high-carbon industries, such as coal, thermal power, steel, and cement, decrease because of energy structure adjustments and the elimination of outdated production capacity. However, this process is not exactly the same. By improving energy efficiency through technological transformation and developing a circular economy, these industries can also stabilize some employment during the transformation process and put forwards new requirements for the skills of retained labour. Low-carbon emerging industries, such as wind power, solar energy, energy-saving services, carbon emission management, and other related industries, will flourish under green investment, creating many new job opportunities. Overall, the impact of low-carbon city pilot policies on employment in industries with different carbon emission intensities involves structural adjustments. Although it may negatively impact high-carbon-intensity industries in the short term, it also creates development opportunities for low-carbon-intensity industries and drives the labour market to upgrade towards higher skills and a greener direction in the long term.

Therefore, Hypothesis 4 is proposed: The impact of low-carbon city pilot policies on employment is influenced by heterogeneity in industry differences.

The above theoretical bases indicate that low-carbon city pilot policies affect employment through two mechanisms: the output effect and the factor substitution effect. On the basis of the results of this study, a mechanism diagram of the impact of low-carbon city pilot policies on employment can be drawn (see Figure 1).

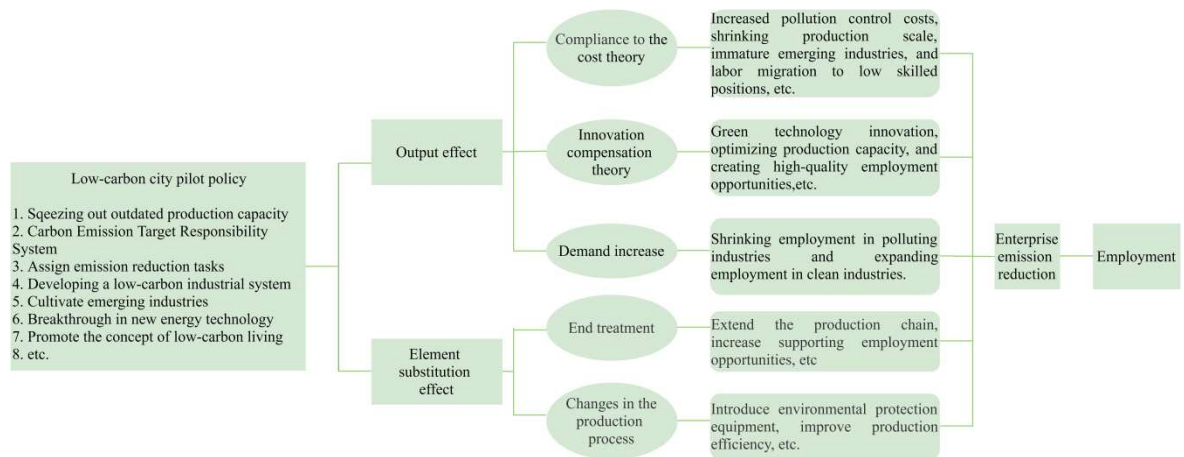


Figure 1 Mechanism through which low-carbon city pilot policies effect employment.

4. Method and Data

4.1 Model Construction

China's low-carbon city pilot policy began in 2010. By 2025, three batches of low-carbon city pilots had been implemented nationwide, covering 87 provinces and cities and forming a multitiered and multisector low-carbon development framework¹. The core purpose of establishing low-carbon pilot cities in China was to explore and summarize low-carbon development models and experiences that can be replicated and promoted nationwide through establishing pilots in these specific areas. Furthermore, the aim was to promote the optimization of the energy structure, industrial transformation and upgrading, and technological innovation to find a green development path that effectively controls greenhouse gas emissions while maintaining economic growth, ultimately providing practical support for China to achieve its “dual carbon” goals (carbon peak and carbon neutrality) and addressing global climate change. If China's low-carbon city pilot policy has achieved the expected main goals, it would have had effects on the energy structure, low-carbon industrial system, institutional and technological innovation, and people's low-carbon lifestyles in the pilot cities. Undoubtedly, the employment of the labour force in the pilot cities would also be affected. Therefore, to increase rigor, this study takes whether the pilot cities have achieved carbon emissions reduction as the primary goal of policy implementation. First, whether the policy has significantly achieved carbon emissions reduction is

¹ Note: The first batch of pilot projects (launched in 2010) was primarily implemented in cities such as Beijing, Shanghai, and Baoding, with a focus on exploring low-carbon development models. The second batch of pilot projects (launched in 2012) expanded to include cities such as Nanchang, further broadening the scope of the pilot. The third batch of pilot projects (launched in 2017) added 81 cities, including Wuhai, Shenyang, and Dalian, covering more regions and specifying additional objectives.

tested, and then whether the policy has affected employment while achieving emissions reduction is further tested.

The double difference method is the most widely accepted and used empirical approach for evaluating the effectiveness of policy implementation. The principle of this method is to take institutional pilot programs and the implementation of new policies as a “quasinatural experiment” that is exogenous to the economic system (Wu MR, 2024). The reason is that the implementation of China's low-carbon city pilot policy may lead to differences in carbon emissions and employment in the same pilot city before and after policy implementation, as well as differences in indicators at the same time between pilot and nonpilot cities. Therefore, model regression estimation based on this dual difference can effectively control for the impact of other synchronic policies and the difference between pilot and nonpilot cities, thereby identifying the net impact of policy shocks on carbon emissions and employment in cities. The low-carbon policy pilot cities in China can be seen as a typical “quasinatural experiment”. Given that China's low-carbon city pilot policy was launched in three batches, this study uses a multiple time point double difference model.

(1) Evaluation model for the emission reduction effects of the low-carbon city pilot policy. On the basis of the previous discussion, this study first evaluates the effect of implementing a low-carbon city pilot policy on carbon emission reductions at the urban level. The double difference model used for evaluation is as follows:

$$citycarbon_{i,t} = \alpha_1 + \theta_1 citypilot_{i,t} + \lambda_1 Z_{i,t}^1 + \eta_i + \mu_t + \varepsilon_{i,t}^1 \quad (1)$$

Here, the dependent variable $citycarbon_{i,t}$ refers to the carbon emissions of city i in year t , and the core explanatory variable $citypilot_{i,t}$ is a dummy variable that reflects whether city i implemented low-carbon city pilot programs in year t ; if implemented, $citypilot_{i,t}$ takes a value of 1; otherwise, it takes a value of 0. η_i and μ_t represent individual (city) and year fixed effects, respectively. $\varepsilon_{i,t}^1$ is a random disturbance term that affects urban carbon emissions. θ_1 is the coefficient of the double difference item, which measures the effectiveness of the pilot policy. $Z_{i,t}^1$ represents a series of control variables that affect the carbon emissions of city i in year t .

Referring to the research framework of Wang F (2022), this article selects the following control variables: the level of economic development (*eco*), expressed as the logarithm of per

capita regional GDP; population size (*pop*), expressed as the logarithm of the total population of the city at the end of the year; industrialization level (*ind_lev*), measured as the proportion of the added value of the secondary industry to the regional gross domestic product; urbanization level (*urb_lev*), expressed as the proportion of the urban population to the total population; and the energy structure (*ene_str*), measured as the ratio of coal consumption to total energy consumption.

(2) Evaluation model for the effects of the low-carbon city pilot policy on urban employment. On the basis of evaluating the emission reduction effect of the low-carbon city pilot policy, this article measures the impact of the policy on employment at the urban level, hoping to examine the overall employment effect of the policy at the urban level. The specific model is as follows:

$$citywork_{i,t} = \alpha_2 + \theta_2 citypilot_{i,t} + \lambda_2 Z_{i,t}^2 + \eta_i + \mu_t + \varepsilon_{i,t}^2 \quad (2)$$

The dependent variable $citywork_{i,t}$ represents the employment of city i in year t , expressed by the logarithm of the average number of employed workers in the city; $\varepsilon_{i,t}^2$ is a random disturbance term that affects urban employment; θ_2 is the coefficient of the double difference item, which measures the effectiveness of the pilot policy; and $Z_{i,t}^2$ represents a series of control variables that affect the employment of city i in year t . The other variables have the same meanings as above. Similarly, population size (*pop*), economic development level (*eco*), urban consumption level (*city_consum*), and urban wage level (*city_wage*) are selected as control variables. The calculation methods of *pop* and *eco* are the same as noted above; *cityconsum* is expressed as the logarithm of the total retail sales of consumer goods, and *citywage* is expressed as the average wage of urban on-duty employees.

(3) Evaluation model for the effect of the low-carbon city pilot policy on employment at the enterprise level. In this section, we attempt to elaborate on the impact of the low-carbon city pilot policy on employment at the enterprise level, and the specific model is as follows:

$$corpwork_{i,t} = \alpha_3 + \theta_3 corppilot_{i,t} + \lambda_3 X_{i,t} + \varphi_i + \mu_t + \varepsilon_{i,t} \quad (3)$$

The dependent variable $corpwork_{i,t}$ represents the number of employees of company i in year t , expressed as the logarithm of the number of employees in the company. The core explanatory variable $corppilot_{i,t}$ represents whether the city where enterprise i is located implemented the low-carbon city pilot policy in year t ; if the city where enterprise i is located implemented the pilot policy in year t , $corppilot_{i,t}$ takes a value of 1; otherwise, it takes a value

of 0. φ_i is a random perturbation term that affects employment at the enterprise level; θ_3 is a double difference estimator, which represents the impact of low-carbon city pilot policies on employment measured at the enterprise level; and $X_{i,t}$ represents a series of control variables.

On the basis of the previous literature, this article selects some control variables at the enterprise level, including the enterprise wage level (*corp_wage*), which is measured by the average wage of employees; company size (*corp_size*), which is measured by the logarithm of the total assets of the enterprise; asset liability ratio (*corp_lev*), which is measured by the ratio of total liabilities to total assets; sales expense ratio (*corp_ser*), which is measured as the ratio of sales expenses to operating revenue; income tax expense (*corp_tax*), which is measured by the logarithm of the corporate income tax number added to 1; degree of growth ability (*corp_grow*), which is measured by the Tobin's Q value; and profit margin of total assets (*corp_roa*), which is measured by the ratio of net profit to total assets.

(4) Parallel trend test calculation model. Parallel trend testing is a necessary prerequisite for the double difference model, which means that before policy implementation, the changing trends of pilot cities and nonpilot cities should be parallel and consistent. Therefore, this article uses the event study method proposed by Kenneth (2010) for parallel trend testing, which can be expressed as follows:

$$corpwork_{i,t} = \alpha_3 + \sum_{-5}^4 \delta_i D_{i,t} + \lambda_3 X_{i,t} + \varphi_i + \mu_t + \varepsilon_{i,t} \quad (4)$$

where $D_{i,t}$ is a set of dummy variables. If the city where enterprise i is located implements the low-carbon city pilot policy in year t , $D_{i,t}$ takes a value of 1; otherwise, it takes a value of 0. The meanings of the other variable symbols are the same as above. This section focuses on the coefficient δ_i , which reflects the employment gap between enterprises in pilot cities and nonpilot cities in year t of the implementation of the low-carbon city pilot policy.

4.2 Sample selection and data sources

This study is divided into two parts.

First, on the basis of Equations (1) and (2), this paper evaluates the impact of the low-carbon city pilot policy on carbon emissions and employment at the urban level. The research period is from 2008 to 2024, and 168 cities in China, including 87 pilot cities and 81 nonpilot cities, were chosen as the research sample. In Equation (1), the dependent variable is the carbon emissions of

the city, expressed as the logarithm of the city's carbon dioxide emissions, which is denoted as *citycarbon*. The data are sourced from the China Emission Accounts & Datasets (CEADs). In Equation (2), the dependent variable is the level of urban employment, which is calculated by the logarithm of the average number of employed workers in the city and is denoted as *citywork*. The data are from the “China Urban Statistical Yearbook” (2009–2025).

The next step is to evaluate the impact of low-carbon pilot city construction on employment at the enterprise level via Equation (3). This article uses Chinese listed companies from 2008 to 2024 as the research sample. To avoid the influence of abnormal samples, the raw data are preprocessed according to the following four steps. First, listed companies with stock abbreviations containing “ST” and “* ST” are excluded. Second, companies whose listing status has been suspended or terminated are excluded. Third, listed companies with severely missing data are excluded. Fourth, linear interpolation is used to fill in individual missing data. After processing, we obtain a total of 2,721 listed companies and 26,257 observations as unbalanced panel data. The dependent variable in Equation (3) is enterprise employment, denoted as *corpwork*, and all the data are sourced from the CSMAR database. The low-carbon city pilot policy was launched in China in three batches: July 2010, December 2012, and January 2017 (Wang F, 2022). Therefore, in this study, the start times of the quasinatural experiment were 2010, 2013, and 2017. All the cities within the pilot provinces are considered pilot cities.

5. Results and discussion

5.1 Baseline Regression Results

(1) Impact of the low-carbon city pilot policy on urban carbon emissions.

The basic regression results are presented in Table 1.

Table 1 Impact of the low-carbon city pilot policy on urban carbon emissions and employment

<i>Variable</i>	<i>citycarbon</i>	<i>Variable</i>	<i>citywork</i>
	(1)		(2)
<i>citypilot</i>	-0.016* (-1.68)	<i>citypilot</i>	0.066*** (3.12)
<i>eco</i>	0.078** (3.47)	<i>eco</i>	0.195** (2.96)
<i>pop</i>	0.065* (0.86)	<i>pop</i>	0.845*** (4.57)

<i>ind_lev</i>	0.0007*	<i>city_wage</i>	-0.037**
	(1.19)		(-1.73)
<i>urb_lev</i>	0.021***	<i>city_consum</i>	0.036**
	(6.26)		(2.35)
<i>ene_str</i>	0.515***		
	(4.03)		
<i>_cons</i>	9.739***	<i>_cons</i>	-3.937**
	(17.66)		(-3.3)
<i>City and year fixed effects</i>	是		是
<i>Observations</i>	2856		2856
<i>Adjusted R²</i>	0.879		0.767

Note: The values in parentheses are t values. *, **, and *** indicate that the variables are significant at the 10%, 5%, and 1% levels, respectively. Same below.

First, Line (1) of Table 1 shows the impact of the low-carbon pilot policy on urban carbon emissions. The estimated coefficient of the policy variable *citypilot* is -0.016 and passes the significance test at the 10% level. This means that the low-carbon city pilot policy has significantly reduced the carbon emissions of pilot cities; that is, after all the other factors are fully considered, compared with nonpilot cities, the policy has reduced the carbon emissions of pilot cities by approximately 1.6%. These results are consistent with those of Xie (2025), Wang F (2022), Lu S (2025), and others and not only confirm the research hypothesis of this study but also lay the foundation for verifying the impact of the policy on employment. According to existing research conclusions, the effectiveness of China's low-carbon pilot policy presents a complex picture: on the one hand, the policy has had positive effects on promoting technological innovation and industrial structure upgrading; On the other hand, there are significant differences in the emission reduction effects among the pilot projects in different regions and the long-term effectiveness of the policy and institutional guarantees also face challenges. Although many studies have confirmed the value of low-carbon pilot projects, Chinese scholar Guo more cautiously concluded in a re-evaluation study of the three batches of pilot cities in 2023 that only the first (2010) and second (2012) batches of pilot projects showed an obvious trend towards carbon reduction, whereas the third batch (2017) of pilot projects did not show significant effects in terms of emission reduction trends or low-carbon status. This reveals a marginal decreasing trend in policy effectiveness (Guo, 2023), suggesting that China must continue to strengthen institutional guarantees, improve long-term incentive mechanisms, and deepen policy

coordination.

According to the regression results of the control variables, all the variable coefficients are positive, indicating that improvements in economic development, population size, the industrialization level, the urbanization level, and the energy structure (the proportion of coal consumption to energy consumption) increase urban carbon emissions. This conclusion is consistent with the findings of Rousselière (2024) and Tian (2025). As Chinese cities experience rapid economic growth and industrialization, their continuously expanding population size and increasing urbanization level constitute a very large driving force for carbon emission growth. On the one hand, industrialization, as the core engine of economic growth, is accompanied by an industrial development model characterized by high energy consumption; On the other hand, the agglomeration of the urban population not only increases the demand for housing, transportation, and public services but also changes consumption patterns, leading to a significant increase in daily energy consumption. However, most importantly, in the development process, the energy structure dominated by coal has not fundamentally transformed, and coal consumption still accounts for a relatively high proportion of the total energy consumption. This pattern of dependence on high-carbon energy results in the energy demands from economic activities, population agglomeration, and urbanization processes ultimately being reflected as significant carbon emissions, thereby increasing the total carbon emissions of cities.

(2) Column (2) of Table 1 shows the impact of the low-carbon city pilot policy on urban employment. The estimated coefficient of *citypilot* is 0.066, which is significant at the 1% level. These findings indicate that the low-carbon city pilot policy significantly promotes employment in the pilot cities, and when other factors are fully considered, the policy increases employment in the pilot cities by an average of 6.6% compared with nonpilot cities. These results are surprising and are consistent with the conclusions of Wang YQ (2024) and Li Y (2024). The low-carbon city pilot policy has not only caused a reduction in some employment positions but also created new employment opportunities, and the number of newly added employment positions exceeds the number of reduced positions, resulting in a positive overall employment effect.

For the control variables, only the coefficient of the urban wage level is negative, while the coefficients of economic growth, population size, and the urban consumption level are positive. Despite the continuous economic expansion, population agglomeration, and steady improvement

in residents' consumption levels in Chinese cities, which have jointly created more job opportunities and effectively driven the growth of urban employment rates, the supply pressure on the labour market has also increased. On the one hand, economic growth and consumption upgrading have expedited a large number of service industry and labour-intensive jobs and have absorbed many employed persons; On the other hand, the continuous influx of population and the relative surplus of the labour supply has diluted the average wage levels. Moreover, the newly added positions may be more concentrated in industries with lower average salaries, resulting in a negative coefficient of the urban wage level on employment rates overall. This reflects that while the total employment volume has increased, the quality of employment and income distribution structure still need to be optimized.

(3) On the basis of the effectiveness of the low-carbon city pilot policy in reducing carbon emissions and promoting urban employment, the impact of the policy on enterprise employment is evaluated. The results are shown in Table 2.

Table 2 Impact of the Low-Carbon City Pilot Policy on Enterprise Employment

<i>Variable</i>	<i>cropwork</i>	<i>cropwork</i>
	(1)	(2)
<i>croppilot</i>	0.051** (2.34)	0.043** (2.64)
<i>crop_wage</i>		-0.006** (-2.96)
<i>crop_size</i>		0.61*** (23.68)
<i>crop_lev</i>		0.233*** (3.28)
<i>crop_ser</i>		0.498** (2.83)
<i>crop_tax</i>		0.014** (2.95)
<i>crop_grow</i>		0.023*** (4.58)
<i>crop_roa</i>		-0.078 (-0.86)
<i>_cons</i>	7.71*** (6.23)	-0.56* (-1.74)
<i>City and year fixed effects</i>	是	是
<i>Observations</i>	23116	23116
<i>Adjusted R²</i>	0.811	0.747

In Table 2, Column (1) shows the estimated results without considering the control variables. The coefficient of the dummy variable *croppilot* in this column is estimated to be 0.051 and passes the significance test at the 5% level. The coefficient in Column (2) is slightly smaller than that in Column (1), indicating that the control variables affect enterprise employment. Statistically, it is more accurate to consider the estimation results of controlled variables because the influence of other factors is removed, allowing the “true” or “pure” causal relationship between the variables of interest to be more closely observed. The estimated results in Column (2) indicate that compared with enterprises not located in the pilot cities, enterprises located in low-carbon pilot cities have an average employment increase of approximately 4.3%. These results are consistent with those of Wang YQ (2024) and Li Y (2024). Moreover, Nie (2025) further reported that low-carbon city pilot policies can attract labour inflows by improving the environment, increasing the supply of green public services, and motivating high-tech enterprises to start businesses.

Among the controlled variables, only the coefficients of the wage level and total asset profit of the enterprise are negative (the latter does not pass the significance test and is not discussed here), while the coefficients of enterprise size, asset liability ratio, sales expense ratio, income tax, and growth ability are positive. These empirical results reveal the complex interaction between the labour market and internal resource allocation within enterprises. We attempt to explain this finding below. In Chinese listed companies, the expansion of the enterprise scale, an increase in the leverage ratio, an increase in market investment, an increase in the profitability growth ability, and a reduction in the actual tax burden usually indicate an increase in business expansion or operational activity. These factors directly create more job opportunities, thereby positively increasing the number of employed people. However, only the wage level had a negative effect, which may reflect two key mechanisms behind it. One is the cost effect, that is, an increase in wages, as the main cost of enterprises, will decrease profit margins, which prompts enterprises to recruit more cautiously to control total costs and even replace labour with capital (such as automation equipment), thereby decreasing employment growth. The second is the efficiency wage effect, which means that high wages may attract higher-quality or more efficient workers, allowing companies to complete equal or greater business volume without increasing or even reducing the number of employees. Therefore, although other expansionary factors drive

employment, the cost pressure brought by wage increases and the increase in labour productivity collectively result in a negative net effect on employment numbers.

5.2 Parallel Trend Test Results

Considering the limited data available for the first 5 years and the last 5 years of policy implementation, this article summarizes the data for the first 5 years into the negative fifth period and the data for the last 5 years into the fourth period. In addition, this article takes the fifth phase before the implementation of the low-carbon city pilot policy as the base period. The parallel trend test results are shown in Figure 2 and indicate that the estimated coefficients for each period before the implementation of the low-carbon city pilot policy are not significant. This finding indicates that there was no significant difference between pilot and nonpilot city enterprises before policy implementation and that the research sample passes the parallel trend test.

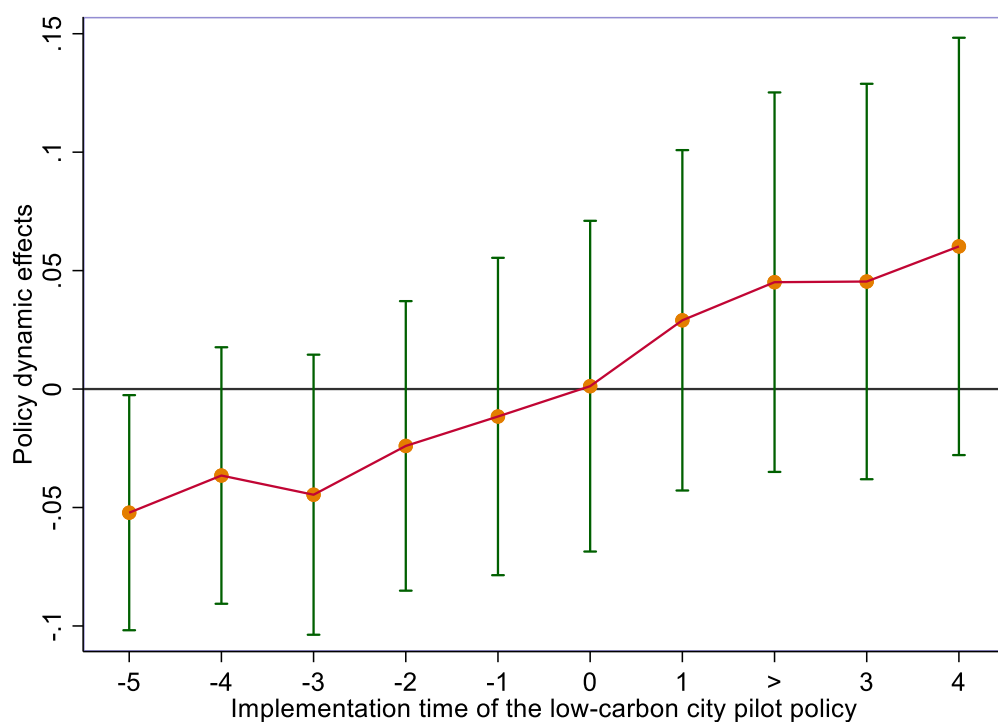


Figure 2 Parallel Trend Test.

Note: The solid dots represent the estimated coefficient δ_i of Equation (4), and the short vertical lines represents the 95% confidence intervals corresponding to the robust standard errors at the enterprise level for clustering.

5.3 Time placebo test results

The core principle of the time placebo test is to “fabricate” the time point at which a policy or intervention occurred to a period when it did not actually occur and then re-run the regression

analysis. If a “significant” processing effect is still found at this fictional time point, it indicates that there may be a problem with the original model, and the previously discovered effect may be false (due to other confounding factors or model setting errors). In contrast, if the effect disappears, it provides supporting evidence for the reliability of the original results. To avoid the employment difference between the treatment group and the control group being caused by changes in time, on the basis of the results of the parallel trend test in the previous section, this article advances the implementation time of the low-carbon city pilot policy by 1, 2, 3, and 4 years, constructs $citypilot^{virtual1}$, $citypilot^{virtual2}$, $citypilot^{virtual3}$ and $citypilot^{virtual4}$, respectively, and regresses them on Equation (3). The result is showed in Table 3.

Table 3 Time Placebo Test				
Variable	<i>citywork</i>	<i>citywork</i>	<i>citywork</i>	<i>citywork</i>
	(1)	(2)	(3)	(4)
$citypilot^{virtual1}$	-0.006 (-0.29)			
$citypilot^{virtual2}$		-0.023 (-0.94)		
$citypilot^{virtual3}$			-0.053 (-1.95)	
$citypilot^{virtual4}$				-0.056 (-1.51)
Control variables	Control	Control	Control	Control
City and year fixed effects	yes	yes	yes	yes
Observations	23116	23116	23116	23116
Adjusted R ²	0.908	0.896	0.903	0.904

The results show that the estimated coefficients of $citypilot^{virtual1}$, $citypilot^{virtual2}$, $citypilot^{virtual3}$ and $citypilot^{virtual4}$ do not pass the significance test at the 10% level. This finding indicates that there is no systematic difference in the time trend between the treatment group and the control group enterprises and once again proves that the low-carbon city pilot policy promotes enterprise employment.

5.4 Robustness test results

The basic regression results indicate that the low-carbon city pilot policy increases enterprise employment opportunities. However, to eliminate the interference of confounding factors on the research conclusions, a series of robustness tests are still needed. In this article, multiple

dimensions are analysed, such as changing the sample interval, adding benchmark variables to mitigate the impact of selection, adding control variables, and building propensity score matching models, to ensure the robustness of the estimation results. ① Changing the sample interval. To avoid the influence of extreme values on the regression results, the samples of the variables *citywork* and *corpwork* are truncated by 1% and 5%, respectively, and the regression of Equation (3) is re-run. The estimation results indicate that after extreme values are removed, the coefficient estimates of *citypilot* and *croppilot* still pass the significance test at the 10% level, which is consistent with the baseline estimation results. ② For urban employment, the impact of choice can be mitigated by adding benchmark variables. If the list of low-carbon city pilot projects is related to factors such as the city's economic development level and geographical location, the differences in these factors over time may have different effects on enterprise employment, resulting in estimation bias. To avoid selecting nonrandom samples for testing the low-carbon city pilot policy, an interaction term between urban benchmark factors and time trends is added to the regression model. The urban benchmark factor refers to whether the city is located in the economically developed eastern region (if yes, it takes a value of 1; if not, it takes a value of 0). The test results show that the estimated coefficient of *citypilot* is significant at the 10% level, indicating that with the inclusion of the benchmark variable, the low-carbon city pilot policy still significantly promotes enterprise employment, which is consistent with the baseline results. ③ For enterprise employment, the robustness of the results is tested by adding control variables. Three other control variables, namely, the executive shareholding ratio, the total asset turnover ratio, and the book-to-market ratio, are added to the regression analysis. The conclusions are consistent with those of the baseline regression, which proves that the conclusions of the model are robust. ④ Constructing a propensity score matching double difference model. To avoid endogeneity issues caused by reverse causality and sample selection bias, this study uses the nearest neighbour matching, kernel matching, and radius matching methods. The estimated coefficients of *croppilot* pass the significance test at the 10% level. These findings further demonstrate that the low-carbon city pilot policy indeed promotes enterprise employment.

5.5 Testing the Impact Mechanism

In this section, the mechanism of the impact is examined from the perspectives of output effects and factor substitution effects.

(1) Output effect test. According to the results of the theoretical analysis, the low-carbon pilot policy in cities can provide more employment opportunities through “expansion”. Therefore, in this study, enterprise size (*crop_size*) is chosen to represent enterprise output to verify the impact of the low-carbon city pilot policy on employment through the output effect. The results are shown in Table 4.

Table 4: Impact of the Low-Carbon City Pilot Policy on Employment through the Output Effect

<i>Variable</i>	<i>Enterprise output</i>	<i>corpwork</i>	<i>Highly skilled</i>	<i>Low skilled</i>
	(1)	(2)	(3)	(4)
<i>citypilot</i>	0.004*** (4.82)			
<i>Enterprise output</i>		0.611*** (3.86)	1.853*** (1.08)	-20.003** (-2.87)
<i>Observations</i>	23116	23116	23116	23116
<i>Adjusted R²</i>	0.755	0.695	0.738	0.824

Column (1) of Table 4 shows that the estimated coefficient value of *citypilot* is 0.004 and passes the significance test at the 1% level. This finding indicates that under the joint influence of follow-cost theory and induced-innovation theory, the low-carbon city pilot policy has expanded the scale of enterprises and increased their output. Column (2) shows that the estimated coefficient of enterprise output is 0.611 and passes the significance test at the 1% level. This finding indicates that the low-carbon city pilot policy has affected employment through the output effect.

This section further divides enterprise employment into high-skilled employment and low-skilled employment (those with a bachelor's degree or above are considered highly educated, whereas those with no bachelor's degree or below are considered low educated). Columns (3) and (4) of the table show the different estimation results. The output expansion caused by the low-carbon city pilot policy is beneficial for the employment of high-skilled personnel (coefficient of 1.853) but very detrimental to the employment of low-skilled personnel (coefficient of -20.003), and the coefficient value for low-skilled personnel is much greater than that for high-skilled personnel. These results support the findings of Hopper (2025) and Sun J (2025). This result is easy to understand. By promoting industrial upgrading and technological innovation, the low-carbon city pilot policy has stimulated a large demand for high-skilled positions such as green technology research and development, carbon trading management, and high-end manufacturing,

thereby significantly promoting the employment of high-skilled personnel. However, this policy is also accompanied by restrictions and the elimination of traditional industries with high levels of pollution and energy consumption, which are areas of concentration of low-skilled personnel. Moreover, emerging green industries usually face high technological and knowledge barriers, making it difficult for low-skilled personnel to adapt and transform quickly. In addition, the challenges of industrial restructuring may lead to the elimination of some traditional positions. Therefore, in the job market, this policy has had a negative crowding out effect on low-skilled personnel in the short term, exacerbating their employment pressure.

(2) Factor substitution effect test. The substitution effect of factors is manifested mainly in the low-carbon city pilot policy, which affects employment by influencing the environmental governance of enterprises. This effect is related to whether cities and enterprises choose environmental governance or green innovation under environmental regulations. To test the potential mechanism of the factor substitution effect, this article evaluates whether the low-carbon city pilot policy affects employment through environmental governance investment. Owing to data dispersion, we draw inspiration from Wang F's (2022) approach that environmental governance investment can be manifested as companies purchasing fixed assets, intangible assets, and other long-term assets. The low-carbon city pilot policy has increased the carbon emission standards for enterprises. To meet these standards, enterprises may invest in environmental governance, such as by purchasing advanced production equipment and terminal treatment equipment, as well as intangible assets such as patented technology. Considering the availability of data on environmental governance investment at the corporate level, this article uses the following variables as alternative variables for corporate environmental governance investment: enterprise acquisition and the construction of fixed assets, intangible assets, and the ratio of cash paid from other long-term assets to total assets for corporate environmental governance investment. The results are shown in Table 5.

Table 5: Impact of the Low-Carbon Pilot Policy on Employment through Factor Substitution Effects

<i>Variable</i>	<i>Environmental governance investment</i>	<i>corpwork</i>	<i>Highly skilled</i>	<i>Low skilled</i>
	(1)	(2)	(3)	(4)
<i>citypilot</i>	0.071*** (4.26)			

Environmental governance investment		0.242*** (34.81)	1.385*** (4.92)	0.186* (3.87)
Observations	22759	22759	15437	15296
Adjusted R ²	0.883	0.715	0.909	0.79

The estimated effect of the low-carbon city pilot policy on environmental governance investment is shown in Column (1) of Table 5, with an estimated coefficient of 0.071 for *citypilot*, which passes the significance test at the 1% level. This finding implies that the low-carbon city pilot policy has significantly promoted investment in environmental governance. We further estimate the impact of environmental governance investment on employment. Column (2) shows the estimated impact of environmental governance investment on employment, with a coefficient value of 0.242, which passes the significance test at the 1% level. This means that the low-carbon city pilot policy has stimulated employment by promoting investment in environmental governance. On this basis, this article also estimates the impact of environmental governance investment on the employment of high- and low-skilled workers. The results also show that the pilot policy has more strongly promoted the employment of high-skilled workers.

5.6 Heterogeneity Analysis Results

This section is divided into two parts, which discuss the heterogeneity of industries and enterprises separately.

(1) Heterogeneity analysis based on industry aspects

The heterogeneity analysis at the industry level is conducted from two main perspectives: property and carbon emission intensity.

Table 6 Heterogeneity Analysis on the basis of Industrial Property and Carbon Emission Intensity Differences

Variable	<i>corpwork</i>	<i>corpwork</i>	<i>corpwork</i>	<i>corpwork</i>	<i>corpwork</i>
	Primary	Secondary	Tertiary	High carbon	Low carbon
	industry	industry	industry	industry	industry
<i>citypilot</i>	0.317 (23.22)	0.168** (3.51)	1.85*** (2.75)	-0.023*** (-0.05)	0.315** (0.46)
Observations	308	18463	8191	7028	13576
Adjusted R ²	0.732	0.822	0.758	0.816	0.727

Columns (1)–(3) of Table 6 show the regression results for industries with different properties. The regression coefficients of the primary industry are not significant, whereas the

coefficients of the secondary and tertiary industries pass the significance test at the 5% level. Moreover, the coefficient values of the tertiary industry are much greater than those of the secondary industry. With respect to these results, this article speculates that the reason is that the green transformation driven by policies is essentially an upgrade of the economic structure and service models. The low-carbon path of the secondary industry relies mainly on technological transformation and energy efficiency improvement, which is often accompanied by the replacement of manual labour by machines, and its effect on employment creation is limited. However, the tertiary industry directly benefits from the new consumer market and service formats generated by low-carbon living, such as green finance, carbon management consulting, and new energy travel services. These emerging fields are labour intensive and can directly create a large number of job opportunities; thus, their employment coefficient response is more significant.

Columns (4) and (5) of Table 6 show the regression results for enterprises with different carbon emission intensities, and both regression results pass the significance test at the 5% level. The coefficient values indicate that the pilot policy has had a negative effect on high-carbon industries (-0.023) and a positive effect on low-carbon industries (0.315). The low-carbon city pilot policy in China has had completely opposite effects on employment; the main reason is the asymmetric forces exerted by the policy on different industries through cost constraints and market incentives. For high-carbon industries, the policy has directly imposed strict carbon emission constraints and compliance costs, forcing them to compress traditional production scales or carry out capital-intensive technological transformations to reduce emissions. This is often addressed through layoffs or reduced recruitment, which has a negative effect on employment. In contrast, for low-carbon industries, the policy has directly created a vast green market and demand and lowered their expansion threshold through supporting measures such as green finance, enabling them to continuously create many new job opportunities during the rapid development of the industry, thereby positively increasing employment.

(2) Heterogeneity analysis based on enterprise aspects

Enterprise heterogeneity is analysed from two main perspectives: property ownership and age. First, enterprises are divided into state-owned enterprises, private-owned enterprises, and foreign-funded enterprises. Second, using the median age of the sample enterprises, the sample

enterprises are divided into new enterprises and old enterprises. The results of the separate regressions are shown in Table 7.

Table 7 Heterogeneity Analysis on the basis of Enterprise Ownership Nature and Age

<i>Variable</i>	<i>corpwork</i>	<i>corpwork</i>	<i>corpwork</i>	<i>corpwork</i>	<i>corpwork</i>
	<i>State-owned</i>	<i>Private-owned</i>	<i>Foreign-funded</i>	<i>Old</i>	<i>New</i>
<i>citypilot</i>	2.604*** (7.67)	9.333*** (81.95)	1.812* (3.49)	-2.192** (-1.82)	3.593*** (4.7)
<i>Observations</i>	9457	14286	693	15648	16492
<i>Adjusted R²</i>	0.746	0.811	0.788	0.93	0.855

Columns (1)–(3) of Table 7 show the regression results for different types of enterprises, which all pass the significance test at the 10% level. The coefficient values of private-owned enterprises are greater than those of state-owned enterprises and foreign-funded enterprises. The reasons for these results are as follows. First, the transmission pressure of environmental governance investment differs among enterprises of different ownership natures. Compared with private-owned enterprises, state-owned enterprises usually receive more government support and resources, and their agency costs are relatively low. Therefore, they have a stronger ability to cope with policy shocks and are less affected by negative impacts on employment. Second, there is a difference in the cost sensitivity of factor substitution effects. The policy prompts enterprises to replace some of their labour with capital and technology, resulting in a “factor substitution effect”. Private-owned enterprises, especially small and medium-sized enterprises, are more sensitive to costs and have stronger financing constraints. When facing transformation pressure, they are more likely to cope by reducing labour costs (rather than improving technology), resulting in a significant impact on employment. In contrast, foreign-funded enterprises may have more advantages in terms of green technology, management experience, and global resource mobilization and can adapt to new environmental regulations more quickly. Therefore, they may experience the least impact on employment from low-carbon transition policies, and some studies have even found that their labour income share is not significantly negatively affected.

Columns (4) and (5) of Table 7 show the regression results for enterprises of different ages, both of which pass the significance test at the 5% level. The coefficient values indicate that the pilot policy has a negative effect on old enterprises (-2.192) and a positive effect on new

enterprises (3.593). These regression results are consistent with the findings of Wang F (2022). The reason for the observed impact of China's low-carbon city pilot policy on employment can be explained by "abandoning the old for the new", and the main reason is that the market environment and cost constraints caused by the policy have undergone fundamental changes. For old enterprises that rely on high energy consumption and high sunk costs of equipment assets, the policy imposes strict environmental regulations and carbon emission costs, forcing them to compress the production scale or carry out capital transformation to reduce emissions. This directly restricts development funds and may lead to labour being replaced with machines, which have a negative effect on employment. In contrast, for new enterprises, the policy directly creates new markets and demand in the green and low-carbon field. These enterprises show high compatibility with the policy's guidance on the basis of their technological capabilities and flexibility, making it easier for them to obtain green finance and support from other sources, which creates new job opportunities during expansion and leads to positive effects on employment.

6. Conclusion

On the basis of macro data of Chinese cities and micro data of listed companies from 2008 to 2024, a multiple time point double difference model is used to test the impact of low-carbon city pilot policies on reducing urban carbon emissions and employment. The results show that at the urban level, the low-carbon city pilot policy significantly reduced carbon emissions and promoted employment in the pilot cities. Specifically, compared with nonpilot cities, this policy resulted in a reduction in carbon emissions of approximately 1.6% and an increase in employment of 6.6% for pilot cities. From the perspective of enterprises, compared with enterprises not located in pilot cities, enterprises located in low-carbon pilot cities have an average employment rate that is approximately 4.3% higher. The results of the mechanism test reveal that the pilot policy affects employment through output effects and factor substitution effects. However, the policy is beneficial for the employment of high-skilled personnel but detrimental to the employment of low-skilled personnel. The heterogeneity analysis was conducted according to industry and enterprise characteristics. The results of industry analysis reveal that the pilot policy has a greater promotion effect on employment in the tertiary industry than in the secondary industry and has a

negative effect on high-carbon industries but a positive effect on low-carbon industries. The results of enterprise analysis reveal that the pilot policy has a greater effect on private-owned enterprises than on state-owned enterprises and has a negative effect on old enterprises but a positive effect on new enterprises.

On this basis, this article proposes three policy recommendations.

(1) The collocation of low-carbon transformation policies and employment security policies should be strengthened. To strengthen the matching of the two policies, the most important thing is to build a forwards-looking and systematic “just transformation” framework. First, policymaking needs to be forwards looking by establishing an “employment impact assessment” mechanism to anticipate job trends in advance in high-carbon industries such as coal and steel. Second, precise vocational skills training and transformation support should be implemented; green skills retraining (such as in renewable energy, energy conservation, and environmental protection) should be implemented for affected workers; and job search assistance, cross-regional employment subsidies, and even transitional income compensation should be provided as a supplement. Moreover, new markets for green employment should be actively cultivated, vigorously supporting green industries such as renewable energy and the circular economy through industrial policies, fiscal subsidies, and tax incentives to create many high-quality job opportunities. Finally, social dialogue and multiparty collaboration should be strengthened to ensure the participation of the government, enterprises, trade unions, and workers in policy design; guarantee a fair and orderly transformation process; and ultimately achieve a win–win situation in terms of environmental benefits and employment stability.

(2) Low-carbon industries/enterprises should be vigorously cultivated. It is necessary to develop a comprehensive support system consisting of policy guidance, market drive, financial support, and technological innovation. The government should clarify the industrial orientation through top-level design; formulate strict carbon emission standards and long-term low-carbon development plans; and use fiscal and tax levers, such as providing subsidies, tax exemptions, and green procurement, to directly stimulate the research and application of low-carbon technologies and projects. The financial system needs to provide precise fund delivery; provide support to develop more financial instruments such as green credit, bonds, and funds; guide social capital to flow towards low-carbon areas; and solve the financing difficulties of enterprises. These processes

are crucial for stimulating innovation vitality; supporting the research and industrialization of key low-carbon technologies such as energy storage, hydrogen energy, and carbon capture; and protecting intellectual property rights. Moreover, it is necessary to actively cultivate market demand and create stable spaces for low-carbon products and services through the construction of carbon markets and the promotion of green electricity consumption certifications, which will ultimately result in a virtuous development pattern driven by policies, funds, technology, and markets to strengthen the growth of low-carbon enterprises.

(3) Low-carbon industry training should be promoted to workers. The key is to construct a lifelong vocational skills training system. First, the training content must be deeply aligned with industry demand; companies in the industry must collaborate with leading companies to dynamically predict skill requirements in emerging fields such as photovoltaics, wind power, energy storage, and energy management, and standardized and modular practical courses should be developed. Second, the training methods should be flexible and diverse, fully utilizing the resource advantages of vocational colleges, public training bases, and enterprises. Models such as “online theory + offline practical operation” and “school enterprise cooperation work alternation” should be promoted and flexible education systems and “credit banks” for in-service workers should be provided. Finally, it is necessary to strengthen policy incentives and employment guidance by providing training subsidies, skill certifications, and smooth green channels from training to employment to stimulate workers’ enthusiasm to participate in training, ensuring that they can not only learn new skills but also easily find high-quality jobs in the green economy, which will lead to synchronization between personal transformation and industrial upgrading.

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