The Effect of China's Pilot Low-Carbon City Initiative on Enterprise Labor Structure

Xiaoyang Sun[1], Yuhua Zheng[2*], Chenyu Zhang[2], Xuelian Li[2] and Baosheng Wang[2]

[1]School of Economics and Management, China University of Labor Relations, Beijing, China, [2]Business School, Beijing Technology and Business University, Beijing, China

Based on the background of China's pilot low-carbon city initiative in 2010, 2012, and 2017, this article captures the exogenous change of enterprise labor structure based on A-share listed companies from 2007 to 2019 in Shenzhen and Shanghai Stock exchanges. With the integration of macro data on the city level and micro data on the enterprise level, adopting the time-varying difference-in-differences (DID) model, we found that 1) China's pilot low-carbon city initiative can significantly promote the upgrading of enterprise labor structure; 2) China's pilot low-carbon city initiative can significantly increase R&D investment of listed companies, suggesting that R&D investment is a channel for the impact of China's pilot low-carbon city initiative on enterprise labor structure in the pilot cities; 3) the heterogeneity analysis shows that the labor structure of the state-owned listed companies has been optimized significantly, while the labor structure of the non–state-owned listed companies is not significant. Meanwhile, the labor structure of the listed companies under high-quality government control has been optimized significantly, while the labor structure of the listed companies under low-quality government control is not significant. Overall, our study shows that the pilot low-carbon city initiative has played a governance role in China and optimized enterprise labor structure.

Keywords: China, low-carbon city, labor structure, R&D investment, difference-in-differences

INTRODUCTION

Global warming, as a result of excessive emissions of greenhouse gases, destroys the balance of the ecosystem, which in turn poses a great threat to human survival. Multiple countries have acted to cope with global climate change. The term "low carbon economy" first appeared in the field of economics (Kinzig and Kammen, 1998), and subsequently in official documents. In 2015, China announced the goal for peak carbon dioxide emissions by 2030 under the framework of the Paris Agreement (United Nations, 2015). In 2018, the Intergovernmental Panel on Climate Change (IPCC) issued a special report on the impacts of global warming of 1.5°C (IPCC, 2018), and that China will make a significant contribution to limiting the global temperature increase by 1.5°C compared with pre-industrial levels, responding to the agreement, and that China will promote low-carbon economic construction and incorporate the response to climate change into the national economic and social development plans. In 2021, "Carbon Peak" and "Carbon Neutral" were first included in the Chinese Government Work Report (The State Council, 2021), which fully demonstrates the Chinese government's determination to play its part as a major and responsible country.

TABLE 1 | List of pilot low-carbon cities.

Batch province	The first batch (July 2010)	The second batch (December 2012)	The third batch (January 2017)
Beijing		Beijing	
Tianjin	Tianjin		
Shanghai		Shanghai	
Chongqing	Chongqing		
Guangdong	Guangdong, Shenzhen	Guangzhou	Zhongshan
Liaoning	Liaoning		Shenyang, Dalian, Chaoyang
Hubei	Hubei	Wuhan	Changyang Tujia Autonomous County
Shaanxi	Shaanxi	Yan'An	Ankang
Yunnan	Yunnan	Kunming	Yuxi, Simao District (Pu'er City)
Fujian	Xiamen	Nanping	Sanming
Zhejiang	Hangzhou	Ningbo, Wenzhou	Jiaxing, Jinhua, Quzhou
Jiangxi	Nanchang	Jingdezhen, Ganzhou	Gongqingcheng, Ji'an, Fuzhou
Guizhou	Guiyang	Zunyi	
Hebei	Baoding	Shijiazhuang, Qinhuangdao	
Hainan		Hainan	Sanya, Qiongzhong Li and Miao Autonomous County
Shanxi		Jincheng	
Inner Mongolia		Hulunbuir	Wuhai
Jilin		Jilin	
Heilongjiang		Daxing'anling Prefecture	Xunke County
Jiangsu		Suzhou, Huai'an, Zhenjiang	Nanjing, Changzhou
Anhui		Chizhou	Hefei, Huaibei, Huangshan, Liu'an, Xuancheng
Shandong		Qingdao	Jinan, Yantai, Weifang
Henan		Jiyuan	
Guangxi		Guilin	Liuzhou
Sichuan		Guangyuan	Chengdu
Gansu		Jinchang	Lanzhou, Dunhuang
Xinjiang		Urumqi	Changji, Yining, Hetian
Hunan			Changsha, Zhuzhou, Xiangtan, Chenzhou
Tibet			Lhasa
Qinghai			Xining
Ningxia			Yinchuan, Wuzhong
Xinjiang Production and Construction Corps			Alar

China has implemented various carbon reduction policies and made efforts to continuously explore new paths for fulfilling China's commitment to the world. At the practical level, China has explored a series of policies, such as emission trading scheme (ETS) pilot policy, pilot low-carbon city initiative, carbon tax, etc. In the past 10 years, the National Development and Reform Commission of China has successively identified three batches of pilot areas in 2010, 2012, and 2017 (National Development and Reform Commission, 2010; National Development and Reform Commission, 2012; National Development and Reform Commission, 2017), including four municipalities, 71 prefecture-level cities, and 12 non-municipal districts (**Table 1**). The pilot areas actively explore low-carbon development paths in line with the actual condition.

Furthermore, environmental regulation also exerts a subtle influence on the labor structure. In July 2021, the Ministry of Education of the People's Republic of China issued the Action Plan for Carbon Neutralization and Technological Innovation in Higher Educational Institutions (The Chinese Ministry of Education, 2021), calling on colleges and universities to accelerate the construction of the carbon-neutral technological innovation system and talent training system, to focus on improving the ability of technological innovation and innovative talent training. As we all know, enterprises play an important role in urban construction and shoulder an important mission of promoting the construction of a low-carbon city. A series of decisions made by enterprises to reduce carbon emissions are actually fulfilled by their workforce. Therefore, low-carbon development inevitably leads to a higher demand for talents.

After nearly 10 years of exploration and development, at the macro-level, achievements have been made in the adjustment of industrial structure, optimization of energy mix, and the awakening of public awareness. Zheng et al. (2021b) previously research the impact of China's ETS pilot policy on enterprises, and prove that China's ETS pilot policy can significantly improve the carbon emission performance of listed companies in the pilot provinces. Meanwhile, Zheng et al. (2021b) also find that innovation is a channel for the impact of China's ETS pilot policy on carbon emission performance in the pilot provinces. Therefore, we continue to study the effect of the pilot low-carbon city initiative at the microlevel. What effect does the pilot low-carbon city initiative have on local enterprises? Does it have an impact on the upgrading of labor force structure? Is it a positive or negative effect? What mechanisms are in place to make an impact? Researchers have not drawn a clear and general conclusion on these questions yet. The study takes the release of the pilot low-

carbon city initiative as a quasi-natural experiment and employs the time-varying difference-in-differences (DID) to discuss the impact of low-carbon development of cities on enterprise labor structure. The study aims to respond to the above questions theoretically and tries to shed light on if and how the low-carbon city initiative can shape Chinese corporates' future development trajectory.

We present three main contributions in this article. 1) This article discusses the impact of China's pilot low-carbon city initiative on enterprise labor structure from a micro perspective, aiming to complement the literature in this area. 2) The study also has a certain empirical contribution. Based on China's pilot low-carbon city initiative launched in 2010, 2012, and 2017 as a quasi-natural experiment, this article uses the time-varying DID model to evaluate the impact of this initiative on enterprise labor structure. Furthermore, we set up various robustness tests to increase the validity of the conclusions. 3) The research also has certain policy implications. In recent years, China's economy has encountered mounting downward pressure. In this case, how to stabilize employment has become a focus of discussion from all walks of life. Based on the data of A-share listed companies in China, we found that the pilot low-carbon city initiative can effectively optimize the employment behavior of enterprises, which provides some empirical evidence for the government to optimize the labor structure through the pilot low-carbon city initiative. Furthermore, considering that the effect of China's pilot low-carbon city initiative is heterogeneous among different enterprises, the government should formulate different policies to comprehensively optimize the employment demand of enterprises in different regions, hence achieving the employment goal of emission reduction policies.

This article is structured as follows: Section "Literature Review and Research Gap" organizes the literature on the effect of pilot low-carbon city initiative, the effects of carbon policy and environmental regulation on labor, the relationship between pilot low-carbon city initiative and enterprise innovation, the relationship between enterprise innovation and labor structure, and then summarizes the research gap. Section "Theoretical Analysis and Hypotheses Development" provides the theoretical basis and hypotheses. Section "Research Design" presents the sample, model, variable, and descriptive statistics. Section "Empirical Results" presents the empirical results and discussions. Section "Conclusion" concludes the article and addresses the policy implications.

LITERATURE REVIEW AND RESEARCH GAP
Research on Effects of Pilot Low-Carbon City Initiative

In recent years, a large number of domestic and foreign scholars have continued to study the factors influencing CO_2 emissions (Li et al., 2017; Wen and Yan, 2018; Li and Hu, 2020; Dong et al., 2020b) and have focused on China's carbon reduction policies and approaches (Hunter et al., 2019;

Jiang and Kang, 2019; Dong et al., 2020a). The effect of pilot low-carbon city initiative has received a lot of attention. Related studies go from the national level, regional level, industry level, and gradually to the enterprise level. Most of the studies have focused on the national and regional levels, while relatively few studies have focused on the industry and enterprise levels.

On the national level, Khanna et al. (2014) adopt an ex ante comparative assessment of the low-carbon development plans and supporting measures and find that a lack of explicit definition for the low-carbon city, complexity and confusion resulting from several parallel programs, and insufficient supporting policies and market-based instruments, are the major factors in hindering the development of the low-carbon city. Li et al. (2018) set several indicators to analyze the progress of the implementation of low-carbon policies from the initial two batches and document that more constraints and incentives should be integrated into China's pilot low-carbon city initiative, a policy evaluation system should be establish, and good practices should be summarized to promote further development of policies. Qu and Liu (2017) establish a low-carbon development indicators system based on the driving force–pressure–state–impact–response model, which can quantify the level of low-carbon development, find that only five pilot cities' low-carbon development levels were positive, and present that measures, including legislation, economic means, improvement of renewable energy-saving technology, and low-carbon transportation can improve the low-carbon development level. Zheng et al. (2021a) research the positive impact of China's pilot low-carbon city initiative on the upgrading of the industrial structure, finding that technological innovation and reduction of high-carbon industries are the development path to promote the upgrading of the industrial structure. Under strong environmental law enforcement, the policies have a significant role in promoting the rationalization of the industrial structure. Using the logarithmic mean Divisia index method to decompose the factors of carbon emissions, Shen et al. (2018) find that industrial structure is the main factor in reducing carbon emissions and economic output is the top factor in increasing carbon emissions, based on analyzing various factors of carbon emissions. Yu and Zhang (2021) establish the general non-convex metafrontier data envelopment analysis model to measure the carbon emission efficiency. The analysis shows that China's pilot low-carbon city initiative increases the carbon emission efficiency by 1.7%, providing support for the implementation of China's pilot low-carbon city initiative.

On the regional level, Feng et al. (2021) study the impact of China's pilot low-carbon city initiative on carbon intensity on the city level and find that China's pilot low-carbon city initiative can increase carbon intensity in the short term. But after 3 years, the increase in carbon intensity decreases. Fu et al. (2021) analyze the effectiveness of China's pilot low-carbon city initiative on carbon emission reduction from the perspective of cost and benefit. The study shows that China's pilot low-carbon city initiative will not have a significant benefit on carbon emission reduction in the short term, but should evaluate its effectiveness from a long-term perspective, and points out that R&D investment is an effective path to improve efficiency. From the perspective of local

government policy implementation, Guo et al. (2021) show that local governments' lack of motivation for the implementation of China's pilot low-carbon city initiative makes the effect of China's pilot low-carbon city initiative fail in meeting the national expectations. Song et al. (2021) sort out and evaluate the policy innovations on the city level related to low-carbon pilot city development. They find that only one-third of cities implemented policy innovations, and nearly half of the cities are not applied policy innovations. Hong et al. (2021) show that China's pilot low-carbon city initiative can effectively reduce local energy intensity, especially for eastern cities, high economic development cities, and non-old industrial base cities. Its main mechanism is through technological innovation, not the optimization of the industrial structure. Wang et al. (2015) summarize the main low-carbon–related policies and use Zhejiang as an example to focus on key policy tools to understand the implementation of policies and provide advanced experience for reducing carbon emissions and reaching carbon peaks as soon as possible. Taking Shanghai as an example, Yang and Li (2018) establish a low-carbon economic development level evaluation model to analyze the city's low-carbon level and future development trends. In the end, it is discovered that although Shanghai is in a low-carbon economy and continues to develop, its investment in low-carbon construction and low-carbon technology is still relatively insufficient.

On the industry level, Tang et al. (2018) find that the pilot policy reduces land shifts in energy-intensive industries, but this effect diminishes rapidly over time. The role of the local secretary, namely the *de facto* "first-in-command" official of the local government, is also analyzed.

On the enterprise level, Chen et al. (2021) find that China's pilot low-carbon city initiative has a significant effect on the total factor productivity. Through analysis, it is pointed out that promoting technological innovation and optimizing resource allocation efficiency are important ways to improve total factor productivity, so as to achieve a win–win situation of reducing carbon emissions and high-quality development of enterprises.

Research on Effects of Carbon Policy and Environmental Regulation on Labor

The existing researches on the effects of carbon policy and environmental regulation on labor can be summarized in four levels, the national level, regional level, industry level, and enterprise level. Scholars have done a lot of research on the policy effects on labor demand, and they are gradually starting to focus on the enterprise level.

On the national level, Yamazaki (2017) examines the employment impact of British Columbia's revenue-neutral carbon tax and find that the British Columbia (BC) carbon tax generates an overall positive effect on the employment of labor. Zhong et al. (2021), using Cobb–Douglas production function and Dynamic Spatial Durbin Modeling, find that the proportion of high-skilled labor in China will increase with the intensification of environmental regulation while that of the low-skilled labor will show a U-shaped curve of first declining and then

rebounding. The results confirm that the proportions of high-skilled and low-skilled labor are influenced by the intensity of environmental regulations.

On the regional level, based on the generalized method of moments estimator, Cao et al. (2017) adopt a mediating model to examine the impact of environmental regulation in resource-based provinces in China on enterprise labor. It is found that the implementation of the environmental regulation in resource-based areas has direct positive impacts on labor and has positively mediating effect on labor by inducing industrial upgrades. Therefore, these findings provide policy suggestions to help the labor to adapt to the job changes brought about by technological innovation, by increasing the education of the labor force and improving the skills of the labor force.

On the industry level, Carbone et al. (2020), based on a computable general equilibrium model and quasi-natural experimental econometric model, compare ex ante estimates with ex post estimates of the employment effect of the BC carbon tax and find that carbon tax has a significant impact on the sectoral labor levels, and that sectoral labor levels with the highest carbon intensity decrease, while those with the lowest carbon intensity increase.

On the enterprise level, Anger and Oberndorfer (2008) take a large number of German enterprises covered by the European Union Emissions Trading System (EU ETS) as samples for quantitative analysis and research the relationship between the relative allowance allocation in the EU ETS and both the performance and labor force of the German enterprises. It is found that, within the first phase of EU ETS, the relative allowance allocation has no significant influence on the performance and labor force of the regulated German enterprises. Hanoteau and Talbot (2019), based on the DID model, find that the implementation of the Quebec carbon emission trading system (QC ETS) reduces greenhouse gas emissions but the regulated plants first and foremost scales down their investment activities to adapt to the implementation of the policy, resulting in labor demand reduction, and its employment effect is in contrast to the findings of similar studies on the early stages of EU ETS and BC carbon tax. The results promote the QC ETS to develop the ability to induce facilities to improve technology and innovation activities. Yu and Li (2021) research China's carbon emission trading pilot policy on labor demand from the perspective of micro enterprises and find that there are scale, substitution, and spatial spillover effects in the effect of carbon trading policy on the labor employment market, which refers to the fact that carbon emission trading policies increase labor demand by increasing enterprise production, promote enterprises to invest in environmental governance thus reducing labor demand, and force local enterprises to use clean technology thus improving the demand for labor. Using "China's sulfur dioxide (SO_2) emissions trading program" as a quasi-natural experiment, based on the DID model, Ren et al. (2020) find that the labor demand of regulated firms is significantly increased by the emissions trading program, and this positive employment effect is driven by scaling up production. Based on the moderating effect model, Li and Zhu (2019) present that the

direct impact of environmental regulation on enterprise labor employment and technological innovation is significantly positive. Furthermore, the effect of environmental regulation on the relationship between technological innovation and enterprise labor employment is negative, and there is significant heterogeneity that the negative impact of the environmental regulation on the employment creation of technological innovation in enterprises is smaller in private enterprises, clean industries, and high-tech industries.

Research on Pilot Low-Carbon City Initiative and Enterprise Innovation

Ma et al. (2021) analyze that China's pilot low-carbon city initiative has a positive effect on green technological innovation from multiple dimensions, especially in the eastern cities and the high carbon enterprises. Further studies show that tax breaks and the government subsidies are significant financial tools. Reducing financing difficulties of enterprises can effectively promote green technology innovation of enterprises. Xu and Cui (2020) demonstrate that China's pilot low-carbon city initiative promoted green technology innovation of enterprises. Further research find that command-and-control policy tools can effectively promote green technology innovation in pilot areas. Huang et al. (2021) find that environmental regulations promoted enterprises to increase R&D expenditure continuously, demonstrating the impact of environmental regulations on innovation activities. Based on Porter hypothesis, Xiong et al. (2020) find that China's pilot low-carbon city initiative has a significant effect on improving the level of green technology innovation of the high-carbon enterprises in the pilot city, especially in the green utility-model patents of enterprises. Zhong et al. (2020) find that China's pilot low-carbon city initiative induces green innovation among local firms, significantly increasing the absolute and relative levels of green innovation among firms, while further heterogeneity analysis is done. Li et al. (2019) confirm that the implementation of China's pilot low-carbon city initiative not only enhances the technological innovation capability of enterprises but also reduces the gap between the technological innovation levels of enterprises in cities of different grades.

Research on Enterprise Innovation and Labor Structure

Luo and Guo (2021) adopt the method of multidimensional fixed effect estimation and find that enterprise innovation input, through the effect of labor costs and labor productivity, has a two-way effect on employee employment. On the one hand, enterprise innovation input inhibits the employment of production personnel. On the other hand, it stimulates the employment of non–direct production personnel, including salesmen, technicians, managers. Zeng and Zhu (2014) find that the labor structure of R&D plays a key role in the development of high-tech industries and that enterprises should pay attention to the optimal allocation of the labor

force and capital investment to promote their long-term development. Based on the current situation of labor allocation in China's knowledge-intensive service industry, Li et al. (2021) find that there is a labor mismatch in China's knowledge-intensive service industry and further find that the mismatch of labor allocation inhibits the innovation performance of knowledge-intensive service enterprises, and heterogeneity exists in this inhibition.

Literature Gap

From the previous literature review, it can be found that a large number of scholars have studied the application effect of carbon emission reduction policies, such as the ETS pilot policy, pilot low-carbon city initiative, carbon tax, environmental regulation, etc. However, most scholars focus on the macro level, such as country, city, and industry. Limited literature focuses on enterprise at the microlevel, which is mainly limited to the impact on enterprise technological innovation, and there is relatively limited research on the integration with enterprise labor structure. A few scholars have studied the impact of R&D investment on the enterprise labor structure. Overall, the research on the impact and path of China's pilot low-carbon city initiative on enterprise labor structure is still relatively insufficient. This article will supplement research on the application effect of China's pilot low-carbon city initiative at the microlevel.

THEORETICAL ANALYSIS AND HYPOTHESES DEVELOPMENT

Basic Hypothesis

In the recent years, China's environmental pollution has been increasingly concerning the public, and it has become the inevitable choice of the Chinese government to intensify environmental regulations. Environmental regulations mean carbon emission trading, carbon tax, technical standards, etc., and forcing enterprises to redistribute resources such as labor and capital to reduce enterprise pollution (Ambec et al., 2013). Previous researches suggest that intensifying environmental regulations generate "compliance cost effect" and "innovation offset effect," which carries a double dividend of reducing pollution emissions and promoting employment for society (Yu and Li, 2021; Zhong et al., 2021).

As a comprehensive environmental policy under the interaction of the central and local governments, China's pilot low-carbon city initiative brings more preferential policies to the pilot areas, mainly in tax relief, financial subsidies, and talent incentives (Cao et al., 2017), which are the critical factors to promote the upgrading of enterprise labor structure. Furthermore, it has been shown that the pilot low-carbon city initiative promotes enterprises to increase R&D investment, and R&D investment can optimize enterprise labor structure (Yamazaki, 2017; Guo et al., 2018; Carbone et al., 2020; Huang et al., 2021). Thus, the following hypothesis 1 is proposed:

Hypothesis 1. China's pilot low-carbon city initiative can promote the upgrading of enterprise labor structure.
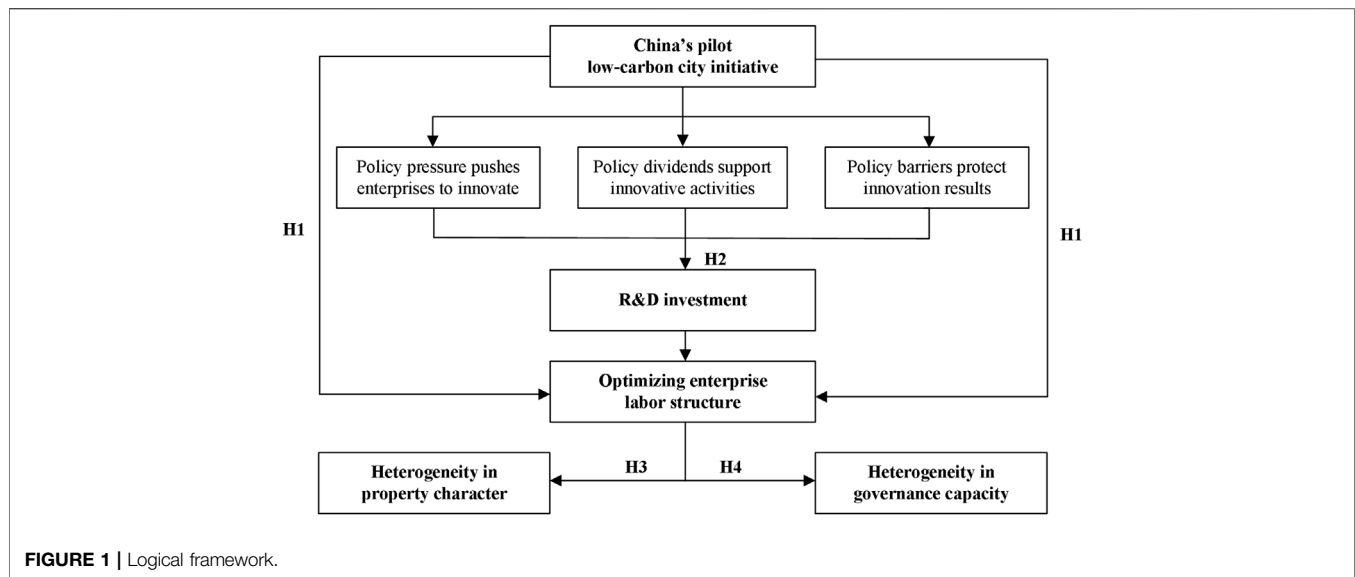
FIGURE 1 | Logical framework.

Mediation Hypothesis

Because enterprise innovation is characterized by high investment, long payback periods, and unstable earnings (Bansal and Hunter, 2003), it is difficult for enterprises to have the motivation to implement this highly risky business decision in the absence of external incentives (Borghesi et al., 2015).

There are three reasons that R&D investment can be used as mediating variable between the pilot low-carbon city initiative and the upgrading of enterprise labor structure: 1) the external pressures forcing enterprises to innovate have risen sharply. The pilot low-carbon city initiative, as a legal pressure, has also increased the pressure on enterprises to innovate and progress (Chen et al., 2017; Liao et al., 2018). In the game between increased carbon emission costs and reduced human resource costs, due to policy pressure, more enterprises tend to choose the latter, which will reduce the policy default cost by improving the enterprise labor structure and production technology. 2) Policy dividends to support innovation activities have been increased. The pilot low-carbon city initiative gives pilot cities tax incentives, talents motivation mechanism, and other multiple policy dividends, which play a key role in stimulating enterprises' innovation (Hall and Reenen, 2000; Lu and Li, 2021), thereby improving the overall quality of enterprise labor. 3) Policy barriers to protect innovation achievements have been strengthened. The low-carbon pilot city policy has given stronger protection to intellectual property rights in such high-tech sectors as clean energy, carbon emission reduction, etc., ensuring that the enterprises' innovation achievements can be smoothly transformed into internal income, breaking the illusion of stealing the intellectual property achievements of others (He et al., 2021; Zhuang et al., 2021) and in effectively increasing the demand and salary payments for technical talents. As a result, the enterprise labor structure is effectively improved. Based on the above discussions, we propose the following hypothesis 2:

Hypothesis 2. China's pilot low-carbon city initiative can promote the upgrading of enterprise labor structure through increasing R&D investment.

Heterogeneity Hypothesis
Property Character

Depending on whether the ultimate controller is the government or not, enterprises in China are divided into state-owned enterprises and non–state-owned enterprises, and they have great difference in policy implementation, corporate governance, and the role they play in the market.

Firstly, the property character of state-owned enterprises leads them to bear many non-market burdens, such as strategic policy burdens and social policy burdens (Lin and Liu., 2001), which makes enterprises subject to greater government regulations and interventions and urges them to implement policies more vigorously and strictly. In addition, the government and state-owned enterprises hold a relationship of mutual assistance with Chinese characteristics—state-owned enterprises bear the policy burden and the government gives them preferential policies (Liao and Shen., 2014). Therefore, state-owned enterprises located in low-carbon cities will respond more strongly to the policy requirements of carbon emission reduction than non–state-owned enterprises and thereby having a higher demand for high-tech talents.

Secondly, state-owned enterprises are the backbone of national economic development and the pillar of socialism with Chinese characteristics, and the important strategic position makes state-owned enterprises have inherent political advantages, have easier access to policy and financial support (Li and Li., 2014; Li et al., 2016), and be frequently ahead of ordinary private enterprises in terms of enterprise strength, etc. Strong overall enterprise competitiveness and abundant funds provide support for state-owned enterprises to recruit talents.

Finally, state-owned enterprises face many challenges. Besides their own hard power such as production efficiency, the relationship between enterprises and society also forces them

TABLE 2 | Variable definition.

Variable	Definition and unites	Measurement
LDLJG	Labor structure (%)	The number of staff with bachelor degree and above/total number
DTShidian	Pilot low-carbon city initiative	Assigning it to 1 after the implementation, while assigning it to 0 before the implementation
Growth	Profit growth rate (%)	(Total profit of this year – total profit of the previous year)/total profit of the previous year
Size	Company size (-)	Ln (assets)
Lev	Leverage level (%)	Liabilities/total assets
ROA	Return on assets (%)	Net profit after tax/total assets
WXZCZB	Proportion of intangible assets (%)	Intangible assets/total assets
ZBLDB	Proportion of capital and labor (%)	Net value of fixed assets/number of employees
TOP1	Proportion of the largest shareholder (%)	Proportion of shares held by the shareholder with the most capital
Board	Board size (-)	Number of directors
Indd	Proportion of independent directors (%)	Number of independent directors/number of directors
GDP Growth	GDP growth rate (%)	(Total GDP of this year – total GDP of the previous year)/total GDP of the previous year

TABLE 3 | Descriptive statistics of variables.

Variable	Obs	Mean	SD	Min	Max	1st	5th	25th	50th	75th	95th	99th
LDLJG	22421	0.268	0.205	0.0214	0.874	0.0214	0.0467	0.113	0.203	0.370	0.715	0.874
DTShidian	22421	0.222	0.416	0	1	0	0	0	0	0	1	1
Growth	22421	0.220	0.584	−0.609	4.297	−0.609	−0.293	−0.0192	0.119	0.294	0.921	4.297
Size	22421	22.11	1.430	19.37	27.08	19.37	20.22	21.10	21.89	22.85	24.84	27.08
Lev	22421	0.454	0.222	0.0532	0.979	0.0532	0.110	0.276	0.448	0.618	0.829	0.979
ROA	22421	0.0351	0.0621	−0.273	0.200	−0.273	−0.0577	0.0125	0.0340	0.0633	0.125	0.200
WXZCZB	22421	0.0468	0.0546	0	0.338	0	0.000314	0.0143	0.0325	0.0577	0.145	0.338
ZBLDB	22421	0.533	0.900	0.0111	6.201	0.0111	0.0391	0.136	0.263	0.515	1.911	6.201
TOP1	22421	0.349	0.151	0.0850	0.746	0.0850	0.136	0.230	0.329	0.453	0.625	0.746
Board	22421	8.813	1.833	5	15	5	6	8	9	9	12	15
Indd	22421	0.372	0.0530	0.300	0.571	0.300	0.333	0.333	0.333	0.429	0.455	0.571
GDP Growth	22421	0.108	0.0495	0.00294	0.239	0.00294	0.0507	0.0783	0.0986	0.123	0.215	0.239

to pay more attention to the development of soft power, including corporate image and public reputation, etc. (Duan, 2014). Compared with non–state-owned enterprises, state-owned enterprises have more urgent needs for social image, and they are required to establish a good image in front of the public, respond to the policy vigorously, and show leadership for other private enterprises, which urges them to continuously introduce talents and optimize the labor structure. Based on the above comprehensive analysis, research hypothesis 3 can be put forward:

Hypothesis 3. Compared with non–state-owned enterprises, the labor structure of state-owned enterprises will be better optimized through China's pilot low-carbon city initiative.

Governance Capacity

As the main body of implementing China's pilot low-carbon city initiative, the governance capacity of the local governments has a significant impact on the efficiency and effectiveness of policy implementation. According to China's marketization index (Wang et al., 2021), this article divides governments into high-quality governments and low-quality governments. First of all, governments with stronger governance capacity will interpret policies more accurately and correctly to understand policy requirements. Implementing policies with policy requirements

as the standard is better at preventing mistakes (Feng, 2021); secondly, the government's competence relies on their capacities to regulate various economic entities within their region. The stronger the governance capacity, the better the regulation and institutional environment, and lesser the enterprises' rent-seeking behavior by establishing political affiliation (Wan and Chen, 2010). Based on the above comprehensive analysis, the research hypothesis 4 can be put forward:

Hypothesis 4. Compared with low-quality governments, the labor structure of listed companies under high-quality government control will be better optimized through China's pilot low-carbon city initiative.

Logical Framework

The logical relationship between the above theoretical analysis and research hypotheses are presented in **Figure 1**. Based on three aspects of policy effects, China's pilot low-carbon city initiative increases R&D investment and thereby has an impact on the micro–enterprise labor structure. Furthermore, analyzing the heterogeneity in property character and government governance capacity, we discuss differences of policy implementation effect, not only between state-owned and non–state-owned enterprises but also between high-quality and low-quality governments.

TABLE 4 | The impact of China's pilot low-carbon city initiative on enterprise labor structure.

	(1)	(2)	(3)	(4)	(5)	(6)
	LDLJG	LDLJG	LDLJG	LDLJG	LDLJG	LDLJG
	Basic regression	Basic regression	State-owned	Non–state-owned	High-quality	Low-quality
DTShidian	0.020***	0.020***	0.016**	0.013	0.021***	0.014
	(3.14)	(3.27)	(1.99)	(1.58)	(2.87)	(1.36)
Size		0.004	0.000	0.008**	0.004	0.003
		(1.53)	(0.12)	(2.20)	(1.06)	(0.65)
Lev		−0.024	0.006	−0.061***	−0.007	−0.045**
		(−1.60)	(0.25)	(−3.22)	(−0.38)	(−2.00)
ROA		0.134***	0.184***	0.103**	0.213***	0.020
		(3.85)	(3.27)	(2.45)	(4.65)	(0.38)
Growth		0.015***	0.015***	0.015***	0.016***	0.013***
		(5.50)	(3.82)	(4.22)	(4.44)	(3.26)
WXZCZB		−0.413***	−0.360***	−0.404***	−0.416***	−0.389***
		(−9.14)	(−5.32)	(−6.67)	(−7.64)	(−5.96)
ZBLDB		0.029***	0.035***	0.014*	0.032***	0.025***
		(8.47)	(8.82)	(1.95)	(7.75)	(4.47)
TOP1		−0.076***	0.035	−0.147***	−0.077***	−0.053*
		(−3.94)	(1.13)	(−6.34)	(−3.24)	(−1.76)
Board		−0.001	−0.002	0.002	0.001	−0.003
		(−0.59)	(−0.97)	(0.59)	(0.48)	(−1.24)
Indd		0.042	0.026	0.101	0.085	0.018
		(0.87)	(0.39)	(1.47)	(1.44)	(0.23)
GDP Growth		0.072	0.115*	−0.020	0.143	0.091
		(1.55)	(1.93)	(−0.28)	(1.60)	(1.52)
_cons	0.175***	0.095	0.100	0.058	0.070	0.148
	(6.48)	(1.58)	(1.13)	(0.65)	(0.87)	(1.43)
Year	Yes	Yes	Yes	Yes	Yes	Yes
Industry	Yes	Yes	Yes	Yes	Yes	Yes
Province	Yes	Yes	Yes	Yes	Yes	Yes
Obs	22421	22421	9388.000	13033	13798	8623.000
Adj. R^2	0.347	0.378	0.400	0.402	0.346	0.441

Standard errors are in parentheses. The _cons represents the intercept term.

*, **, and *** denote significance at the 10, 5, and 1% levels, respectively.

RESEARCH DESIGN

Sample Selection

Our sample is composed of A-share listed companies on the Shanghai Stock Exchange and Shenzhen Stock Exchange in 293 prefecture-level cities in China from the China Stock Market and Accounting Research system over the period from 2007 to 2019. The city-level data comes from the China City Statistical Yearbook.

Since China's pilot low-carbon city initiatives were implemented in July 2010, December 2012, and January 2017 respectively, the years 2011, 2013, and 2017 will be taken as the time points for external policy shocks. Listed companies registered in the pilot cities are set as the experimental group, and listed companies registered in the non–pilot cities are set as the control group. In order to ensure the validity of the data processing results, this article screens the samples as follows, before the analysis: 1) exclude non-municipalities and non–prefecture-level cities; 2) exclude financial listed companies; 3) exclude ST or *ST companies; and 4) exclude companies with incomplete data or abnormal financial data. Based on winsorizing continuous variables on 1% quantile, 22,421 unbalanced panel data are constructed finally.

Model

The DID model is the most widely used measure for estimating treatment effects and is originally proposed by medical scientist Snow (1855) in his study of the cholera epidemic in London and is introduced into economics by Obenauer and Nienburg (1915) in their study of the effects of the minimum wage method. In estimating treatment effects, the synthetic control method is used if the experimental group has only one treated subject. If the experimental group has more than one treated object, the DID method is used. If the treated time is the same point in time, the traditional DID is used; if the treated time is different, the time-varying DID is used.

The implementation of China's pilot low-carbon city initiative is equivalent to a "quasi-natural experiment." Firstly, the initiative is equal to an exogenous event for the enterprises located in the pilot city and is not determined by the enterprises' characteristics, thereby meeting the external conditions of a quasi-natural experiment (Pan and Dong, 2021). Secondly, the construction of the low-carbon pilot city not only produces a certain efficiency in attracting talents but also provides necessary financial support. From this perspective, it also meets the relevant requirements between the explanatory and explained variables, providing the feasibility for using the DID quantitative model. Due to different regions implementing the pilot low-carbon city initiative at

TABLE 5 | The impact of China's pilot low-carbon city initiative on innovation.

	(1)	(2)
	R&D	**R&D**
	R&D/sales revenue	**R&D/total assets**
DTShidian	0.002**	0.493**
	(2.22)	(2.18)
Size	−0.002***	0.670***
	(−4.39)	(7.75)
Lev	−0.042***	−4.957***
	(−14.85)	(−10.10)
ROA	−0.018**	4.028***
	(−2.42)	(3.80)
Growth	−0.001***	−0.315***
	(−3.30)	(−3.45)
WXZCZB	−0.004	1.226
	(−0.52)	(0.73)
ZBLDB	−0.001**	−0.492***
	(−2.57)	(−3.97)
TOP1	−0.017***	0.440
	(−5.27)	(−0.74)
Board	0.000	0.052
	(0.40)	(0.95)
Indd	0.019**	0.964
	(2.31)	(0.66)
GDP Growth	0.014	−5.902***
	(1.40)	(−2.66)
_cons	0.048***	−10.111***
	(5.36)	(−5.19)
Year	Yes	Yes
Industry	Yes	Yes
Province	Yes	Yes
Obs	22421	22421
Adj. R^2	0.392	0.506

Note: Standard errors are in parentheses.

*, **, and *** denote significance at the 10, 5, and 1% levels, respectively.

different times, this article chooses the time-varying DID method to identify the impact of China's pilot low-carbon city initiative on the enterprise labor structure.

This article regards the impact of China's pilot low-carbon city initiative in 2011, 2013, and 2017 as a quasi-natural experiment and uses the time-varying DID model to compare the enterprise labor structure and the R&D investment of listed companies in the experimental and control groups before and after the implementation of the policy, so as to present the policy effect more intuitively. Therefore, the benchmark panel time-varying DID model is constructed as follows:

$$Y = \beta_0 + \beta_1 Treat \times T + \sum Control + year + industry$$
$$+ province + \varepsilon \qquad (1)$$

Enterprise labor structure and R&D investment are used as the explained variables, denoted by LDLJG and R&D (Ting et al., 2021), respectively. $Treat$ is a regional dummy variable that equals 1 if the city is in the experimental group; otherwise, it is 0. T equals 1 if the pilot low-carbon city initiative is implemented; otherwise, it is 0. The interaction term, the core explanatory variable, is denoted by $Treat \times T$, and it tests whether China's pilot low-carbon city initiative can bring double dividends of the enterprise labor structure and

R&D investment. $Control$ represents the control variables, including macro and micro control variables. $year$, $industry$, and $province$ represent the time fixed, industry fixed, and province fixed effects, respectively. ε is the error term.

Variable Definitions and Measurement
Explained Variable
The existing literatures have not yet provided a unified measure for measuring the labor structure of enterprises. In this article, we refer to the research results of Zhu and Li (2018) and consider bachelor's degree and above as higher education and construct the index "The number of staff with bachelor degree and above/ total number of workers" to portray the optimization level of the labor structure (LDLJG).

Explanatory Variable
Whether or not to implement China's pilot low-carbon city initiative is used as a policy dumb variable, and the experimental and control groups are divided by regions. The experimental group contains the municipalities and prefectures in **Table 1**, which are equal to 1, while the control group contains the other municipalities and prefectures, which are equal to 0. We define the next year of the first and second batches and the year of the third batch of the pilot low-carbon city initiative as the event year. The event year and subsequent years are equal to 1, and the years before the event year are equal to 0. Above all, if the enterprise registration place belongs to the experimental group city and the time is after the event year, it is regarded as the group adopting China's pilot low-carbon city initiative, which is equal to 1.

Control Variable
Considering that the explained variable is the micro data of enterprises while the policy dummy variable has macro characteristics, on the basis of previous research results (He and Tian, 2013; Bel and Joseph, 2018; Tang et al., 2018; Huang et al., 2019; Hu et al., 2020; Wen et al., 2020; Liu and Sun, 2021; Lv and Bai, 2021; Ting et al., 2021; Yu et al., 2021), this article selects control variables from macro (city) and micro (enterprise) dimensions. Here are control variables of enterprises: "Growth" represents the profitability rate of the company; "Size" represents the company size; "Lev" represents leverage level of the company; "ROA" represents the return on assets; "WXZCZB" represents proportion of intangible assets; "ZBLDB" represents proportion of capital and labor; "TOP1" represents proportion of the largest shareholder; "Board" represents the size of the board; and "Indd" represents proportion of independent directors. As a macro control variable, "GDP Growth" represents GDP growth rate of cities in the experimental and control groups.

In summary, the detailed variable definitions are presented in **Table 2**.

Descriptive Statistics
Table 3 reporting the descriptive statistics of the variables shows that the mean value of the enterprise labor structure is 0.268 and

TABLE 6 | Robustness test results.

	(1)	(2)	(3)	(4)
	LDLJG	LDLJG	LDLJG	LDLJG
	Regarding the policy year as the event year	Regarding postgraduate degree or above as a higher degree	Adopting PSM model	Excluding samples from the four municipalities
DTShidian	0.020***	0.008***	0.020***	0.022***
	(3.49)	(4.62)	(3.12)	(3.35)
Size	0.004	0.001	0.003	0.007**
	(1.54)	(1.46)	(0.75)	(2.30)
Lev	−0.024	−0.007*	−0.015	−0.033**
	(−1.61)	(−1.72)	(−0.85)	(−2.08)
ROA	0.134***	0.024**	0.155***	0.070*
	(3.86)	(2.51)	(3.46)	(1.86)
Growth	0.015***	0.003***	0.008**	0.016***
	(5.48)	(4.11)	(2.26)	(5.26)
WXZCZB	−0.413***	−0.058***	−0.381***	−0.347***
	(−9.13)	(−4.75)	(−7.18)	(−7.26)
ZBLDB	0.029***	0.005***	0.037***	0.027***
	(8.47)	(3.43)	(9.81)	(6.76)
TOP1	−0.076***	−0.009*	−0.056**	−0.064***
	(−3.96)	(−1.66)	(−2.15)	(−3.10)
Board	−0.001	−0.001	−0.002	0.001
	(−0.59)	(−0.98)	(−0.90)	(0.49)
Indd	0.042	−0.017	−0.042	0.027
	(0.87)	(−1.27)	(−0.67)	(0.53)
GDP Growth	0.083*	−0.008	0.082	−0.010
	(1.77)	(−0.52)	(1.06)	(−0.19)
_cons	0.092	0.014	0.138*	−0.019
	(1.52)	(0.70)	(1.80)	(−0.24)
Year	Yes	Yes	Yes	Yes
Industry	Yes	Yes	Yes	Yes
Province	Yes	Yes	Yes	Yes
Obs.	22421	22421	8711	17933
Adj. R^2	0.378	0.200	0.355	0.329

Standard errors are in parentheses
*, **, and *** denote significance at the 10, 5, and 1% levels, respectively.

the standard deviation is 0.205, indicating that the labor structure of the surveyed companies has relatively small differences. The mean value of DTShidian is 0.222, indicating that 22.2 percent of companies in the sample interval are regulated by China's pilot low-carbon city initiative. Basic statistics of control variables are varied within a reasonable range.

EMPIRICAL RESULTS

Basic Analysis of the DID Regression Results

Based on the benchmark regression analysis, we apply the time-varying DID method to investigate the average treatment effect of enterprise labor structure of listed companies in the pilot cities. The results for the enterprise labor structure as the explained variables are reported in **Table 4**.

The basic regression results in the first and second columns show that the coefficient of $Treat \times T$ is significantly positive at the 1% level ($\beta_1 = 0.020$, $p < 0.01$), indicating that no matter whether control variables are added or not, China's pilot low-carbon city initiative significantly promotes the upgrading

of enterprise labor structure, which is consistent with Hypothesis 1.

Based on the basic regression analysis, heterogeneity analysis is also conducted. On the basis of distinguishing corporate property rights by the standards of state-owned companies and non–state-owned companies, we evaluate the similarities and differences in the labor structure optimization from different enterprises with different property rights by China's pilot low-carbon city initiative. The third and fourth columns of **Table 4** show that the labor structure of state-owned listed companies has been optimized significantly, but not of non–state-owned listed companies, which is consistent with Hypothesis 3.

Otherwise, according to China's marketization index (Wang et al., 2021), municipal governments can be divided into high-quality and low-quality governments, then we should assess the different impacts of China's pilot low-carbon city initiative on the different types of governments. The fifth and sixth columns of **Table 4** show that the labor structure of listed companies under high-quality government control has been optimized significantly, but not under low-quality government control, which is consistent with Hypothesis 4. It can be seen that the

stronger the governance capacity of municipal government, the more obvious the effect of the pilot low-carbon city initiative.

Mechanism Analysis

Enterprise's R&D investment (R&D), as the mediating variable, is measured by two indicators. The first indicator is "R&D to sales revenue" and the other is "R&D to total assets." The test results of **Eq. 1** for R&D investment as the explained variable are reported in **Table 5**.

The regression results in the first and second columns show that the two coefficients of $Treat \times T$ are both significantly positive at the 5% level ($\beta_1 = 0.002$, $p < 0.05$; $\beta_1 = 0.493$, $p < 0.05$), indicating that China's pilot low-carbon city initiative can significantly increase R&D investment of listed companies, suggesting that R&D investment is a channel for the impact of China's pilot low-carbon city initiative on enterprise labor structure in the pilot cities, which is consistent with Hypothesis 2.

Robustness Tests

Through the basic regression analysis, it is known that China's pilot low-carbon city initiative significantly promotes the upgrading of enterprise labor structure. In order to reduce the error of time-varying DID estimation and ensure the reliability of the conclusion, we use four different methods to conduct the robustness tests. The results are shown in **Table 6**.

Method 1: Regarding the policy year as the event year. Three batches of pilot low-carbon city initiatives were promulgated in 2010, 2012, and 2017, respectively. The first column of **Table 6** shows the regression results. It can be seen intuitively that the coefficient of $Treat \times T$ is significantly positive at the 1% level ($\beta_1 = 0.020$, $p < 0.01$), indicating that China's pilot low-carbon city initiative can significantly promote the upgrading of enterprise labor structure.

Method 2: Regarding postgraduate degree or above as a higher degree. On the basis of measuring the variable LDLJG by "Number of employees with postgraduate degree or above/total number of employees," the second column of **Table 6** shows the regression results. It can be seen intuitively that the coefficient of $Treat \times T$ is significantly positive at the 1% level ($\beta_1 = 0.008$, $p < 0.01$), indicating that China's pilot low-carbon city initiative can significantly promote the upgrading of enterprise labor structure.

Method 3: Adopting propensity score matching (PSM) model. To reduce systematic errors and estimation bias in the time-varying DID method, based on the principle that the company size and leverage level are as similar as possible to the experimental group before the policy occurs, we match the experimental group with a more similar control group in the non-pilot region. The third column of **Table 6** shows the regression results. It can be seen intuitively that the coefficient of $Treat \times T$ is significantly positive at the 1% level ($\beta_1 = 0.020$, $p < 0.01$), indicating that China's pilot low-carbon city initiative can significantly promote the upgrading of enterprise labor structure.

Method 4: Excluding samples from the four municipalities. The fourth column of **Table 6** shows the regression results. It can be seen intuitively that the coefficient of $Treat \times T$ is significantly

positive at the 1% level ($\beta_1 = 0.022$, $p < 0.01$), indicating that China's pilot low-carbon city initiative can significantly promote the upgrading of enterprise labor structure.

In **Table 6**, we find that the estimated coefficients of $Treat \times T$ are still significant, which indicates that the conclusion is robust.

CONCLUSION

In this study, using panel data based on municipalities and prefecture-level cities in the pilot low-carbon cities and A-share listed companies in Shanghai and Shenzhen from 2007 to 2019, we explore whether China's pilot low-carbon city initiative can significantly promote the upgrading of enterprise labor structure by using the time-varying DID model. Our study finds that: 1) China's pilot low-carbon city initiative can significantly optimize enterprise labor structure. 2) China's pilot low-carbon city initiative can significantly increase R&D investment of listed companies, suggesting that R&D investment is a channel for the impact of China's pilot low-carbon city initiative on enterprise labor structure in the pilot cities. 3) Furthermore, the heterogeneity analysis shows that the labor structure of state-owned listed companies has been optimized significantly, but not of non–state-owned listed companies. Meanwhile, the labor structure of listed companies under high-quality government control has been optimized significantly, but not under low-quality government control.

Based on the above findings, several policy recommendations are provided as follows: 1) The effect of China's pilot low-carbon city initiative is heterogeneous in different regions. The government should formulate differentiated policies to optimize the employment demand of enterprises in different regions, thus achieving the goal of optimizing the labor structure. 2) Under the guidance of the government's dual carbon strategic goals, cities in China should formulate emission reduction plans, improve assessment and incentive mechanisms, and practically implement carbon emission action plans. 3) With the increasing pressure of enterprise emission reduction, technological innovation has become the only way out. Looking ahead, Enterprises should increase R&D investment, optimize labor structure, improve talent quality, strengthen innovation, and seek long-term development. 4) Higher education institutions shoulder the important responsibility of providing talent support for dual carbon strategic goals. They should take social demand as the guide, strengthen social requirement investigation, vigorously develop talent training programs and teaching materials in the field of carbon neutrality, and integrate the concept and practice of carbon neutrality into the talent training system.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

AUTHOR CONTRIBUTIONS

XS: conceptualization, resources, writing—review, proofreading language, and supervising. YZ: conceptualization, investigation, resources, writing—original draft, writing—review, and editing. CZ: validation, investigation, methodology, software, data curation, writing—original draft, and funding acquisition. XL: literature and data collection. BW: literature and data collection. All authors contributed to the article and approved the submitted version.

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REFERENCES

Ambec, S., Cohen, M. A., Elgie, S., and Lanoie, P. (2013). The porter hypothesis at 20: Can environmental regulation enhance innovation and competitiveness? *Review of Environmental Economics and Policy* 7 (1), 2–22. doi:10.1093/reep/res016

Anger, N., and Oberndorfer, U. (2008). Firm performance and employment in the EU emissions trading scheme: An empirical assessment for Germany. *Energy Policy* 36, 12–22. doi:10.1016/j.enpol.2007.09.007

Bansal, P., and Hunter, T. (2003). Strategic explanations for the early adoption of ISO 14001. *Eournal of Business Ethics* 46 (3), 289–299. doi:10.1023/A:1025536731830

Bel, G., and Joseph, S. (2018). Policy stringency under the European Union Emission trading system and its impact on technological change in the energy sector. *Energy Policy* 117, 434–444. doi:10.1016/j.enpol.2018.03.041

Borghesi, S., Cainelli, G., and Mazzanti, M. (2015). Linking emission trading to environmental innovation: evidence from the Italian manufacturing industry. *Research Policy* 44 (3), 669–683. doi:10.1016/j.respol.2014.10.014

Cao, W., Wang, H., and Ying, H. (2017). The Effect of Environmental Regulation on Employment in Resource-Based Areas of China-An Empirical Research Based on the Mediating Effect Model. *International Journal of Environmental Research and Public Health* 14 (12), 1598. doi:10.3390/ijerph14121598

Carbone, J. C., Rivers, N., Yamazaki, A., and Yonezawa, H. (2020). Comparing applied general equilibrium and econometric estimates of the effect of an environmental policy shock. *Journal of the Association of Environmental and Resource Economists* 7 (4), 687–719. doi:10.1086/708734

Chen, Z., Li, X., and Cao, H. (2017). Research on the influence of institutional pressures on green innovation strategy. *IOP Conf. Ser.: Earth Environ. Sci.* 94, 012162. doi:10.1088/1755-1315/94/1/012162

Chen, H., Guo, W., Feng, X., Wei, W., Liu, H., Feng, Y., and Gong, W. (2021). The impact of low-carbon city pilot policy on the total factor productivity of listed enterprises in china. *Resources, Conservation and Recycling* 169 (2), 105457. doi:10.1016/j.resconrec.2021.105457

Dong, K., Dong, X., and Ren, X. (2020a). Can expanding natural gas infrastructure mitigate CO$_2$ emissions? Analysis of heterogeneous and mediation effects for China. *Energy Economics* 90, 104830. doi:10.1016/j.eneco.2020.104830

Dong, K., Hochman, G., and Timilsina, G. R. (2020b). Do drivers of CO$_2$ emission growth alter overtime and by the stage of economic development? *Energy Policy* 140, 111420. doi:10.1016/j.enpol.2020.111420

Duan, P. (2014). Analysis of the existing problems and countermeasures of the image of large state-owned enterprises—A state-owned enterprise as an example. *Modern Communication (Journal of Communication University of China)* 36 (07), 27–33. doi:10.3969/j.issn.1007-8770.2014.07.007

Feng, M. (2021). Innovation degree and implementation difference of local governance policies. *Academia Bimestrie* 2021 (03), 120–127. doi:10.16091/j.cnki.cn32-1308/c.2021.03.014

Feng, T., Lin, Z., Du, H., Qiu, Y., and Zuo, J. (2021). Does low-carbon pilot city program reduce carbon intensity? Evidence from chinese cities. *Research in International Business and Finance* 58 (1), 101450. doi:10.1016/j.ribaf.2021.101450

Fu, Y., He, C., and Luo, L. (2021). Does the low-carbon city policy make a difference? Empirical evidence of the pilot scheme in china with dea and psm-did. *Ecological Indicators* 122, 107238. doi:10.1016/j.ecolind.2020.107238

Guo, S., Song, Q., and Qi, Y. (2021). Innovation or implementation? Local response to low-carbon policy experimentation in China. *Rev Policy Res* 38 (5), 555–569. doi:10.1111/ROPR.12436

Guo, Y., Xia, X., Zhang, S., and Zhang, D. (2018). Environmental Regulation, Government R&D Funding and Green Technology Innovation: Evidence from China Provincial Data. *Sustainability* 10, 940. doi:10.3390/su10040940

Hall, B., and Reenen, J. (2000). How effective are fiscal incentives for R&D? A review of the evidence. *Research Policy* 29 (4), 449–469. doi:10.1016/S0048-7333(99)00085-2

Hanoteau, J., and Talbot, D. (2019). Impacts of the Québec carbon emissions trading scheme on plant-level performance and employment. *Carbon Management* 10 (3), 287–298. doi:10.1080/17583004.2019.1595154

He, J., and Tian, X. (2013). The dark side of analyst coverage: The case of innovation. *Journal of Financial Economics* 109, 856–878. doi:10.1016/j.jfineco.2013.04.001

He, L., Liu, H., and Xu, K. (2021). Impact of intellectual property protection on innovation investment of high-tech enterprises: Mediating role of new technologies and new products. *Science and Technology Management Research* 41 (15), 170–177. doi:10.3969/j.issn.1000-7695.2021.15.022

Hong, M., Chen, S., and Zhang, K. (2021). Impact of the "Low-Carbon City Pilot" Policy on Energy Intensity Based on the Empirical Evidence of Chinese Cities. *Front. Environ. Sci.* 9, 717737. doi:10.3389/fenvs.2021.717737

Hu, J., Pan, X., and Huang, Q. (2020). Quantity or quality? The impacts of environmental regulation on firms' innovation-Quasi-natural experiment based on China's carbon emissions trading pilot. *Technological Forecasting and Social Change* 158, 120122. doi:10.1016/j.techfore.2020.120122

Huang, J., Zhao, J., and Cao, J. (2021). Environmental regulation and corporate R&D investment-evidence from a quasi-natural experiment. *International Review of Economics and Finance* 72, 154–174. doi:10.1016/j.iref.2020.11.018

Huang, Q., Yu, Y., and Zhang, S. (2019). Internet development and productivity growth in manufacturing industry: Internal mechanism and China experiences. *China Industrial Economics* (08), 5–23. doi:10.19581/j.cnki.ciejournal.2019.08.001

Hunter, G. W., Sagoe, G., Vettorato, D., and Ding, J. (2019). Sustainability of low carbon city initiatives in China: A comprehensive literature review. *Sustainability* 11 (16), 4342. doi:10.3390/su11164342

IPCC (2018). Special report on global warming of 1.5°C. Available online at: https://www.ipcc.ch/sr15/ (Accessed October 06, 2018).

Jiang, W., and Kang, W. (2019). A Review on the low-carbon city study: Development and trends. *Chn. J. Urb. Environ.Stud* 07 (2), 1950006. doi:10.1142/S2345748119500064

Khanna, N., Fridley, D., and Hong, L. (2014). China's pilot low-carbon city initiative: A comparative assessment of national goals and local plans. *Sustainable Cities and Society* 12, 110–121. doi:10.1016/j.scs.2014.03.005

Kinzig, A. P., and Kammen, D. M. (1998). National trajectories of carbon emissions: analysis of proposals to foster the transition to low-carbon economies. *Global Environmental Change* 8 (3), 183–208. doi:10.1016/S0959-3780(98)00013-2

Li, D., and Zhu, J. (2019). The role of environmental regulation and technological innovation in the employment of manufacturing enterprises: Evidence from China. *Sustainability* 11, 2982. doi:10.3390/su11102982

Li, H., Wang, J., Yang, X., Wang, Y., and Wu, T. (2018). A holistic overview of the progress of China's low-carbon city pilots. *Sustainable Cities and Society* 42, 289–300. doi:10.1016/j.scs.2018.07.019

Li, L., Wang, J., and Xu, Y. (2019). The influence of pilot policy of low-carbon city on enterprise technology innovation: An empirical research based on difference-in-different model. *Ecological Economy* 35 (11), 48–54. Available online at: https://kns.cnki.net/kcms/detail/detail.aspx?FileName=STJJ201911011&DbName=DKFX2019.

Li, J., Zhang, B., and Shi, J. (2017). Combining a genetic Algorithm and support vector machine to study the f influencing CO_2 emissions in Beijing with scenario snalysis. *Energies* 10, 1520. doi:10.3390/en10101520

Li, W., and Li, Y. (2014). Does industrial policy promote corporate investment. *China Industrial Economics* 13 (5), 122–134. doi:10.19581/j.cnki.ciejournal.2014.05.010

Li, X., Guo, Y., Hou, J., and Liu, J. (2021). Human capital allocation and enterprise innovation performance: An example of China's Knowledge-Intensive service industry. *Research in International Business and Finance* 58, 101429. doi:10.1016/j.ribaf.2021.101429

Li, Y., Holgado, M., and Evans, S. (2016). "Business model innovation in state-owned and private-owned enterprises in China," in *Advances in Production Management Systems. Initiatives for a Sustainable World. APMS 2016. IFIP Advances in Information and Communication Technology.* Editors I. Nääs, O. Vendrametto, J. M. Reis, R. F. Gonçalves, M. T. Silva, G. von Cieminski, and D Kiritsis (Cham: Springer) 488, 528–535. doi:10.1007/978-3-319-51133-7_63

Li, Y., and Hu, H. (2020). Influential Factor Analysis and Projection of Industrial CO2 Emissions in China Based on Extreme Learning Machine Improved by Genetic Algorithm. *Polish Journal of Environmental Studies* 29(3), 2259–2271. doi:10.15244/pjoes/110973

Liao, G., and Shen, H. (2014). Policy burdens of state-owned enterprises: Reason, consequence and governance. *China Industrial Economics* 13, 96–108. doi:10.19581/j.cnki.ciejournal.2014.05.010

Liao, Z., Xu, C.-k., Cheng, H., and Dong, J. (2018). What drives environmental innovation? A content analysis of listed companies in china. *Journal of Cleaner Production* 198, 1567–1573. doi:10.1016/j.jclepro.2018.07.156

Lin, Y., and Liu, P. (2001). Self-generating capacity and SOE reform. *Economic Research Journal* 11, 60–70. Available online at: https://kns.cnki.net/kcms/detail/detail.aspx?FileName=JJYJ200109007&DbName=CJFQ2001.

Liu, Z., and Sun, H. (2021). Assessing the impact of emissions trading scheme on low-carbon technological innovation: Evidence from China. *Environmental Impact Assessment Review* 89, 106589. doi:10.1016/j.eiar.2021.106589

Lu, X., and Li, L. (2021). Influencing factors and the mechanisms of enterprise innovation: A literature review and prospects. *Theories* 32 (07), 55–62. doi:10.16158/j.cnki.51-1312/f.2021.07.006

Luo, R., and Guo, Y. (2021). Enterprise innovation investment, employee demand scale and employee internal composition. *Journal of Shanxi University of Finance and Economics* 43 (4), 47–62. doi:10.13781/j.cnki.1007-9556.2021.04.004

Lv, M., and Bai, M. (2021). Evaluation of China's carbon emission trading policy from corporate innovation. *Finance Research Letters* 39, 101565. doi:10.1016/j.frl.2020.101565

Ma, J., Hu, Q., Shen, W., and Wei, X. (2021). Does the low-carbon city pilot policy promote green technology innovation? Based on green patent data of Chinese A-share listed companies. *Int. J. Environ. Res. Public Health* 18 (7), 3695. doi:10.3390/ijerph18073695

National Development and Reform Commission (2010). Circular of the National Development and Reform Commission on carrying out pilot work of low carbon provinces, regions and cities. Available online at: https://www.ndrc.gov.cn/xxgk/zcfb/tz/201008/t20100810_964674.html (Accessed July 19, 2010).

National Development and Reform Commission (2012). Circular of the National Development and Reform Commission on carrying out pilot work of the second batch of national low carbon provinces, regions and cities. Available online at: https://www.ndrc.gov.cn/xxgk/jianyitianfuwen/qgzxwytafwgk/202107/t20210708_1288699.html?code=&state=123 (Accessed November 26, 2012).

National Development and Reform Commission (2017). Circular of the National Development and Reform Commission on carrying out the third batch of national low carbon cities pilot work. Available online at: https://www.ndrc.gov.cn/xxgk/zcfb/tz/201701/t20170124_962888.html (Accessed January 01, 2020).

Obenauer, M. L., and Nienburg, B. V. D. (1915). Effect of minimum-wage determination in oregon. *Monthly Review of the U.S. Bureau of Labor Statistics* 1 (3), 5–8. doi:10.2307/41823870

Pan, L., and Dong, Z. (2021). Tax incentives and corporate employment: A quasi-natural experiment from payroll tax policy. *Statistical Research* 38 (7), 100–111. doi:10.19343/j.cnki.11-1302/c.2021.07.008

Qu, Y., and Liu, Y. (2017). Evaluating the low-carbon development of urban china. *Environ Dev Sustain* 19 (3), 939–953. doi:10.1007/s10668-016-9777-8

Ren, S., Liu, D., Li, B., Wang, Y., and Chen, X. (2020). Does emissions trading affect labor demand? Evidence from the mining and manufacturing industries in China. *Journal of Environmental Management* 254, 109789. doi:10.1016/j.jenvman.2019.109789

Shen, L., Wu, Y., Lou, Y., Zeng, D., Shuai, C., and Song, X. (2018). What drives the carbon emission in the Chinese cities?-A case of pilot low carbon city of Beijing. *Journal of Cleaner Production* 174, 343–354. doi:10.1016/j.jclepro.2017.10.333

Snow, J. (1855). On the comparative mortality of large towns and rural districts, and the causes by which it is influenced. *Journal of Public Health, and Sanitary Review* 1 (4), 16–24. Available online at: https://www.webofscience.com/wos/alldb/full-record/MEDLINE:30378870 (Accessed January 10, 2010).

Song, Q., Liu, T., and Qi, Y. (2021). Policy innovation in low carbon pilot cities: lessons learned from China. *Urban Climate* 39, 100936. doi:10.1016/J.UCLIM.2021.100936

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

The Chinese Ministry of Education (2021). Action plan for carbon neutral scientific and technological innovation in colleges and universities. Available online at: http://www.gov.cn/zhengce/zhengceku/2021-07/29/content_5628172.htm (Accessed July 12, 2021).

The State Council (2021). The Government Work Report. Available online at: http://www.gov.cn/zhengce/2021-10/24/content_5644613.htm (Accessed September 22, 2021).

Ting, H.-I., Wang, M.-C., Yang, J. J., and Tuan, K.-W. (2021). Technical expert CEOs and corporate innovation. *Pacific-Basin Finance Journal* 68, 101603. doi:10.1016/j.pacfin.2021.101603

United Nations (2015). The Paris Agreement. Available online at: https://newsroom.unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement (Accessed December 12, 2015).

Wan, H., and Chen, X. (2010). Governance environment rent-seeking and transaction cost: Evidence from the non-productive expenditures of Chinese firms. *China Economic Quarterly* 9 (1), 553–570. doi:10.1382/j.Cnki.ceq.2010.02.018

Wang, X., Hu, L., and Fan, G. (2021). *Marketization index of China's provinces*. Beijing: Social Sciences Academic Press.

Wang, Y., Song, Q., He, J., and Qi, Y. (2015). Developing low-carbon cities through pilots. *Climate Policy* 15, S81–S103. doi:10.1080/14693062.2015.1050347

Wen, L., and Yan, F. (2018). Regional differences and influencing factors in the CO_2 emissions of China's power industry based on the panel data models considering power-consuming efficiency factor. *Environ Dev Sustain* 20, 1987–2007. doi:10.1007/s10668-017-9973-1

Wen, Y., Hu, P., Li, J., Liu, Q., Shi, L., Ewing, J., and Ma, Z. (2020). Does China's carbon emissions trading scheme really work? A case study of the hubei pilot. *Journal of Cleaner Production* 277, 124151. doi:10.1016/j.jclepro.2020.124151

Xiong, G., Shi, D., and Li, M. (2020). The effect of low-carbon pilot cities on the green technology innovation of enterprises. *Science Research Management* 41 (12), 93–102. doi:10.19571/j.cnki.1000-2995.2020.12.008

Xu, J., and Cui, J. (2020). Low-carbon cities and firms' green technological innovation. *China Industrial Economics* 12, 178–196. doi:10.3969/j.issn.1006-480X.2020.12.016

Yamazaki, A. (2017). Jobs and climate policy: Evidence from British Columbia's revenue-neutral carbon tax. *Journal of Environmental Economics and Management* 83, 197–216. doi:10.1016/j.jeem.2017.03.003

Yang, X., and Li, R. (2018). Investigating low-carbon city: Empirical study of Shanghai. *Sustainability* 10 (4), 1054. doi:10.3390/su10041054

Yu, D.-J., and Li, J. (2021). Evaluating the employment effect of china's carbon emission trading policy: Based on the perspective of spatial spillover. *Journal of Cleaner Production* 292 (490), 126052. doi:10.1016/j.jclepro.2021.126052

Yu, P., Cai, Z., and Sun, Y. (2021). Does the emissions trading system in developing countries accelerate carbon leakage through OFDI? Evidence from China. *Energy Economics* 101, 105397. doi:10.1016/j.eneco.2021.105397

Yu, Y., and Zhang, N. (2021). Low-carbon city pilot and carbon emission efficiency: Quasi-experimental evidence from china. *Energy Economics* 96 (2), 105125. doi:10.1016/j.eneco.2021.105125

Zeng, J., and Zhu, H. (2014). "R&D human capital allocation in high-tech industries and its economic effects," in 2014 Seventh International Joint Conference on Computational Sciences and Optimization, Beijing, China, 4-6 July 2014, 218–222. doi:10.1109/CSO.2014.47

Zheng, J., Shao, X., Liu, W., Kong, J., and Zuo, G. (2021a). The impact of the pilot program on industrial structure upgrading in low-carbon cities. *Journal of Cleaner Production* 290, 125868. doi:10.1016/J.JCLEPRO.2021.125868

Zheng, Y., Sun, X., Zhang, C., Wang, D., and Mao, J. (2021b). Can emission trading scheme improve carbon emission performance? Evidence from China. *Front. Energy Res.* 9, 759572. doi:10.3389/fenrg.2021.759572

Zhong, C., Hu, D., and Huang, Y. (2020). Evaluation of Green innovation effect of low carbon pilot policy — An empirical study based on the data of listed firms in China. *Science and Technology Progress and Policy* 37 (19), 113–122. doi:10.6049/kjjbydc.2020050667

Zhong, S., Xiong, Y., and Xiang, G. (2021). Environmental regulation benefits for whom? Heterogeneous effects of the intensity of the environmental regulation on employment in China. *Journal of Environmental Management* 281 (69), 111877. doi:10.1016/j.jenvman.2020.111877

Zhu, Q., and Li, M. (2018). A study on artificial intelligence, technological progress and the optimization countermeasures of labor structure. *Science and Technology Progress and Policy* 35 (6), 36–41. doi:10.6049/kjjbydc.2017090391

Zhuang, Z., Jia, H., and Li, X. (2021). Research on the impact of intellectual property rights protection on firm innovation—Based on the perspective of firm heterogeneity. *Nankai Business Review* 29, 1–22. Available online at: http://kns.cnki.net/kcms/detail/12.1288.f.20210923.1037.002.html.