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Can Carbon Emission Regulation Achieve a Dual Target of Low Carbon and Employment? An Empirical Analysis Based on China's Provincial Panel Data

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The Phillips curve of environment (EPC) and the environmental Kuznets curve of employment (EKCE) both indicate that the low-carbon economic transition can promote employment growth. Based on Chinese provincial dynamic panel data from 2005 to 2019, the GMM method is used to evaluate these two hypotheses. The results show that there is a remarkable U-shaped relationship between carbon emission regulation and employment, which means the EKCE is better than EPC to match the situation in China. So, a dual target of low carbon and employment can be achieved with the strengthening of environmental regulations. However, because of the difference in economic development, industrial structure, human capital, economic openness, wage of employees, and marketization, the significance level of the relationship between them varies substantially across regions. For the eastern and central regions, it can be characterized by EKCE, and for the western region, the EPC is more significant. Therefore, in order to realize the double dividend more effectively, it is necessary to accelerate the market-oriented reform of carbon emission while implementing differentiated carbon regulation policies and promoting the synergistic effect of administrative intervention mechanism and market mechanism.

Keywords: carbon emission regulation, Phillips curve of environment, environmental Kuznets curve, employment, China

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INTRODUCTION

Since the reform and opening-up, China's economy has developed rapidly. However, the traditional extensive mode of growth consumes resources excessively, and economic development hinders the bottleneck of the ecosystem. According to BP World Energy Statistical Yearbook, China's CO_2 emissions in 2020 were 9.899 billion tons, accounting for 30.7% of the world's total emissions. In order to solve the contradiction between China's economic development and the ecological environment, the Chinese government set binding targets for energy conservation and emission reduction in its 11th Five-Year-Plan in 2005, then the 18th National Congress of the Communist Party of China (CPC) put forward the concept of ecological progress, and the 19th CPC stressed that ecological progress is a major project that bears on the well-being of the people. In order to realize the transformation from industrial civilization to ecological civilization, we must attach great importance to environmental problems and ecological construction while developing the economy. In 2020, Chinese President Xi Jinping announced at the 75th Session of the United Nations General Assembly that China will adopt strong policies and measures to strive to peak carbon dioxide emissions by 2030 and achieve carbon neutrality by 2060. The Chinese government actively adopts both direct government intervention and gradually introduces market-oriented environmental regulation means in this low-carbon campaign. In 2011, pilot carbon emission trading schemes were launched in seven provinces and cities, including Beijing. In 2017, power generation became the first industry to trade carbon emissions across the country. The carbon emission trading policy has become an important measure to achieve energy conservation and emission reduction by market means in China. In 2021, China's national carbon emission trading market was officially launched. In its first implementation cycle, including 2,162 key emitters in the power generation industry, it covered more than 4.5 billion tons of carbon emissions annually, making it the largest carbon market covering greenhouse gas emissions in the world. From 2005 to 2020, China's carbon emission intensity had been 18.8 percent lower than that of 2015 and 48.4 percent lower than that of 2005.

How to achieve the dual carbon goal more effectively? According to the literature on environmental economics, economic growth and energy consumption are the main causes of high carbon dioxide emissions. In the process of industrialization and urbanization, China faces a "growth-carbon reduction" dilemma. On the one hand, high growth has led to the use of more carbon energy, such as crude oil, coal, and natural gas resources, and industrial production has emitted a large amount of carbon dioxide emissions. At the same time, consumers consume carbon-intensive goods, further driving higher levels of carbon emissions. In light of this dilemma, slowing carbon dioxide emissions could affect economic growth. Therefore, other determinants of CO_2 emissions need to be explored in order to reduce carbon emissions without affecting economic growth. Existing literature suggests drivers of carbon emissions, such as stages of economic growth (Grossman and Krueger, 1995), energy efficiency (Wolde-Rufael and Weldemeskel, 2020), energy prices (Anser et al., 2021a), natural resources (Wolde-Rufael and Weldemeskel, 2020), industrial structure (Yan et al., 2019), urbanization (Ali et al., 2019), technological progress (Xu Bin, 2018), financial development (Shoaib et al., 2020), trade (Haug and Ucal, 2019), demographics (Hashmi and Alam 2019), and globalization (Zaidi et al., 2019). The above-cited literature attempts to give paths of carbon emission reduction from different perspectives and proposes decarbonized economic growth. However, they focus more on low carbon and economic growth, while literature on the relationship between full employment and CO2 emissions is still lacking.

How to realize the double dividend of "employment and low-carbon"? Related scholars started from the perspective of adjustment of public and fiscal policies. For example, the dual distribution hypothesis (DDH) holds that whether the implementation of environmental tax can improve environmental quality and increase employment depends on the industry or stage of environmental tax collection (Degirmenci and Aydin, 2021). In fact, striking a balance between unemployment and carbon reduction requires special attention from all stakeholders. Therefore, to achieve greater employment in a low-carbon transition, appropriate policies or reforms must be implemented. Kashem and Rahman (2020) proposed the environmental Phillips curve (EPC) hypothesis for the first time by using panel data of OECD countries, arguing that there is a negative correlation between unemployment and carbon emissions. The validity is also demonstrated by Anser et al. (2021a) using BRICS data. EPC believes that high unemployment will lead to a decrease in willingness to improve environmental quality, and carbon emissions are expected to increase; that is, unemployment may degrade the quality of the environment, particularly in the context of the ongoing pandemic and increased uncertainties in the global economic environment, such as the war between Russia and Ukraine, there is an inherent tendency to undermine the SDGs in order to stabilize employment. Bhowmik et al. (2022) used a dynamic ARDL model to study the impact of monetary policy uncertainty (MU), fiscal policy uncertainty (FU), and trade policy uncertainty (TU) on carbon dioxide emissions and further explored the validity of the EPC hypothesis in the United States. Therefore, in the policy-making of carbon emission regulation, it is inevitable to empirically explore the specific relationship between employment and carbon emissions.

For China, the low-carbon transition will certainly have an impact on industrial structure, mode of production, and way of life, and then impact on employment goals. With the development of the carbon emission trading market, its impact on employment should not be underestimated. Employment concerns people's lives and the stability of the country. Employment has always been the top priority for the Chinese government to solve. The policy of prioritizing employment was further strengthened in the 14th Five-Year-Plan proposal. However, the "New Normal" has become a classic expression to describe the development stage of China's economy, namely the "New Normal" of economic growth rate, structural adjustment, and development momentum. In the future, China's economy will be in the "L-shaped" stage of the "New Normal" mode for a long time. In the stage of the "new normal" economy, a primary problem caused by multiple constraints such as the slowdown of economic growth is increasingly prominent employment problems. The problem of total employment still exists, but structural problems have become the main problem. In China's uncertain new normal, what is the impact of environmental regulation on employment, and what is the impact mechanism? Will the pursuit of low-carbon necessarily cost jobs? In the context of the proposed dual carbon target, can the "double dividend" hypothesis proposed by Pearce (1991) be realized? The "double dividend" hypothesis was first proposed by Pearce, which refers to more social employment and continuous growth of GDP formed when a carbon tax is levied, so that the first dividend of the carbon tax is to reduce carbon emissions and improve environmental quality, the second dividend is to reduce the distortion of the tax system, including increasing output and employment. The related research on the "double dividend debate" shows that employment increases when certain conditions are met while the environment improves (Schneider, 1997). As McEvoy et al. (2000) proposed that employment growth is the most likely outcome of emission reduction measures in the process of transition to the low-carbon economy when policy changes follow the economic cycle, which will lead to more jobs. On this basis, the 2009 World Labor Report proposed the "double dividend hypothesis" of employment, and Kahn and Mansur (2013) discussed the possible realization path of this hypothesis. Furthermore, CuiLizhi, ChangJifa (2018), Kashem and Rahman (2020), Bhowmik et al. (2022) and Anser, Apergis, Syed, and Alola (2021a) use the hypothesis of the environmental Phillips curve to describe "double dividend". Therefore, it is of great theoretical and practical significance to discuss the employment effect and its mechanism of economic low-carbon transition in China.

Based on the environmental Phillips curve hypothesis proposed by Kashem and Rahman (2020), this article discusses the validity of the EPC hypothesis in China and proposes a more advanced expression of EPC, which is the EKCE hypothesis, to carry out an empirical analysis on whether carbon regulation and policy achieve a dual low carbon and employment target. The marginal contribution of this study may be shown in three aspects. First, it is the first time to explore the validity of the EPC hypothesis in China by using Chinese provincial panel data. Second, due to the multi-tiered regional development in China, this article puts forward the ECKE hypothesis, which can better fit the carbon emission reduction and employment in the process of low-carbon transition in China. Third, different from the random effects panel adopted by Kashem and Rahman (2020), the PMG-ARDL model proposed by Anser et al. (2021A), and the ADRL proposed by Bhowmik et al. (2022), this study adopted a dynamic panel GMM analysis method. Due to a large number of influencing factors of low-carbon driving force and the large endogeneity among each factor, the GMM method can deal with the endogeneity problem, especially for the sample data set of "short time-long cross-section" in China, this method can present more reliable, efficient, and robust results.

LITERATURE REVIEW

Since the double dividend hypothesis was put forward by Pearce (1991), the academic circle has begun to re-examine the dilemma of "growth and environment". As for whether the goals of full employment and carbon emission reduction can be achieved at the same time, more and more scholars have discussed the constraints and possible paths. In some cases, the positive effect of regulations adopted by a low-carbon economy on employment may be greater than the negative effect. In this article, the basic literature on the relationship between low carbon and employment involves the employment effects of policies such as environmental regulation, low-carbon industrial development, renewable energy development and utilization, and low-carbon technological innovation.

Studies on Carbon Regulation Impact on Employment

Studies on the relationship between low carbonization and employment involve the impacts of environmental regulation, clean energy development and utilization, low-carbon technological innovation, and government environmental investment on employment or unemployment. Due to different research perspectives, conclusions are different. In the 1970s, with the increase of environmental regulation types and the strengthening of environmental regulation, many scholars turned to the employment effect of environmental regulation policies. As for the impact of environmental regulation on employment, the academic circle draws different conclusions due to different research methods and samples.

The first view is that environmental regulation can have a positive impact on employment. Kondoh (2012) investigated the relationship between emission tax and unemployment rate and concluded that environmental regulation promoted an increase in the employment rate. Shao (2017) used the GMM method to study the dual impact effect of China's industrial environmental regulation intensity and found that environmental regulation is conducive to realizing the double dividend of pollution reduction and labor demand, and there is significant dynamic continuity. Hafstead et al. (2018) pointed out that the government's pollution tax significantly increased the number of jobs in low-level pollution-intensive industries. Sun W. Y. and Xia F. (2019) verified that environmental regulation can optimize regional employment structure by using a spatial econometric model. Kashem MA and Rahman MM (2020) came up with a hypothesis of the environmental Phillips curve, which is supported by US data. Anser MK, Apergis N, Syed QR, and Alola AA (2021a) also proved this with the data of BRICS countries, which support EPC.

The second view is that environmental regulation has a negative impact on employment. Gray (2014) used the general equilibrium framework to construct the DID model and concluded that the Clean Act of the United States had a negative effect on employment. The inhibiting effect of carbon emission reduction policies on the employment market; Li Yuanlong (2011) used the CGE model to study the impact of energy and environment tax policies on employment, and his research results showed that the implementation of energy and environment tax policies inhibited the growth of employment. Zhang et al. (2017) and Yan et al. (2019) argue that the implementation of environmental policies has a significant negative impact on the employment scale of enterprises with high pollution emissions, thus reducing the overall employment level of the society.

The third view holds that there is a non-linear relationship between environmental regulation and employment. For example, Walker (2011) believes that the impact of environmental regulation on employment varies from industry to industry, and the influence coefficient between the two varies greatly with industry. Yan et al. (2012) believed that the positive effect of environmental regulation on employment exists as a threshold phenomenon. When environmental regulation is less than the threshold value, it promotes employment; when environmental regulation is greater than the threshold value, it restrains employment. Li (2016) found that employment in industries with heavy and moderate pollution was greatly affected by environmental regulations, while employment in industries with mild pollution was not significantly affected. Cui and Chang (2018) found a "U-shaped" relationship between environmental regulation policies and employment in high-pollution industries. Abbasi and Adedoyin (2021) believe that uncertainty makes the relationship between carbon reduction and employment non-linear.

Research on Employment Effect of Green Technology Innovation

Low-carbon transformation requires technological innovation, and the improvement of technological level will crowd out the labor force, which is not conducive to employment, while the development of a low-carbon economy will give birth to emerging industries and create new jobs. Among them, the employment effect of clean energy and renewable energy is an important research direction. Wei et al. (2010) used the employment creation model to predict the net employment effect of clean energy programs in the United States. Mirasgedis et al. (2014) used an input–output approach to estimate the direct, indirect and resulting employment effects in the Greek electricity sector related to renewable energy technologies. Lehr (2012) used the economy–energy–environment model PANTA RHEI to analyze the impact of large-scale investment in renewable energy on the labor market in Germany and evaluate the impact of total employment and net employment under different scenarios. Markaki et al. (2013) used the input–output analysis method to measure the direct, indirect, and induced output effect and employment effect caused by measures such as the promotion of renewable energy in Greece. Malik et al. (2014) studied the important role of bio-energy in mitigating climate change and creating employment. Simas and Pacca (2014) estimated the jobs created by the wind industry. Markandya et al. (2016) and Allan et al. (2020) studied the impact of renewable energy on regional employment.

Studies on Employment Effects of Energy and Environmental Policies

Some scholars have discussed the impact of low-carbon development on employment from the perspective of energy and environmental policies. Bosello et al. (2001) studied the impact of the energy tax on labor employment. Yong-sheng (2010) quantitatively analyzed the impact of different low-carbon development modes of the three industries on employment from the perspectives of increasing carbon sinks and improving energy efficiency. The Ilo and the Research team of the Institute of Urban and Environmental Studies of the Chinese Academy of Social Sciences (2010) adopted the methods of model analysis and industry survey to analyze the impact of energy conservation and emission reduction policies on employment in industrial sectors, and calculated the direct and indirect employment effects of some industries. Cai and Cai (2011) investigated the relationship between a low-carbon economy and employment and proposed that employment costs should be considered in the implementation of emission reduction to avoid impact on the labor market. Yi (2013) used employment data to investigate whether state and local climate and clean energy policies in the United States affected the distribution pattern of green jobs in metropolitan areas. Lu (2011) studied the impact of green policies on emission reduction and employment from the perspective of double dividend.

Research on Employment Effect of Low-Carbon of Industrial Structure

Some researchers have discussed how to guarantee full employment while adjusting industrial structure. Xiaodi (2014) adopted the multi-objective optimization model to study the industrial structure adjustment scheme under the multiple constraints of low carbon, economic growth, and employment. Yu et al. (2018) proposed a new optimization multi-objective model, taking employment as one of the objective functions of industrial structure optimization and studied the path of industrial structure adjustment to achieve peak carbon emissions in China. Wang H. J. and Chen X. K. (2014) Quantified the impact of industrial structure changes in different energy consumption sectors on non-agricultural employment in China by using the input-occupancy output model. Sun Wei et al. (2016) calculated the optimization degree of China's industrial structure under the constraints of energy conservation and employment based on the linear programming function and multi-region input-output model, providing a scientific basis for structural adjustment. Zhu and Li (2019) used a social accounting matrix (SAM) to measure the total employment effect of unit output changes and quantified the impact of low-carbon industrial structure transformation on employment by constructing a sacrifice coefficient index.

Research on Double Dividend Hypothesis

Bezdek et al. (2008), Marx (2010), and other studies indicated that a win–win situation could be achieved between employment and the environment. Krause et al. (2003) proposed the comprehensive lowest cost policy measures for the United States to implement the Kyoto Protocol, including a carbon tax of 50 dollars per ton and creating tens of thousands of jobs for the United States. Low carbon economic policies and measures can cause income effect, price effect, and then affect international competitiveness, product demand, and compensatory tax cuts. Environmental protection policies and measures will have a negative impact on GDP, disposable income, and employment. Holstet al. (2009) believe that integrated energy and climate policies and carbon emission reduction policies can promote market efficiency in energy demand, development of alternative and renewable energy technologies in energy supply, economic growth, and job creation. Their results show that by 2020, the United States could create between 918,000 and 19 million jobs through comprehensive energy and climate policies. They argue that the tougher the federal government's climate policies, the greater the economic rewards. Kondoh and Yabuuchi (2003) believe that the impact of environmental policy on employment is reflected in the substitution effect, circular effect, and multiplier effect, and whether the dual dividend of environment and employment can be realized depends on the following factors: environmental expenditure levels and consistency, and the overall economic environment, the unemployment rate and the type of unemployment, human resources, environmental policy direction, the nature of the implementation of the measures, spending type, investment and technology, the kinds of financing channels and the influence on lending and tax, import leakage degree, environmental policy influence scope, and industry competitiveness. Kashem and Rahman (2020), Bhowmik et al. (2022), and Anser, Apergis, Syed, and Alola (2021a) use the hypothesis of the environmental Phillips curve to describe the "double dividend".

In general, the abovementioned researches provide a reference for further analysis of the standard, but there are several problems. First, studies on employment effects of environmental policies in existing literature mainly focus on developed countries, such as the EU and the US, and pay insufficient attention to developing countries, especially China, which is a big carbon emitter. Second, literature on the employment effect of carbon trading mechanism usually uses industry or industry panel data, lacking observation at the regional level. Third, the methods used in the abovementioned studies on employment effects can be summarized into two categories. The first category is research based on survey and analysis, which is generally measured by changes in the number of jobs, usually directly created jobs, such as discussing the direct impact of specific technology or energy and environment policies on industrial employment. The second is to use input–output technology to analyze the comprehensive impact of the change of unit final demand on the employment of the whole economy from the perspective of final demand. There are few literatures discussing the statistical relationship between them from the whole level. Finally, the research on the impact of low-carbon on employment is still in its infancy in China. Its impact on employment mainly focuses on the impact of low-carbon economic efficiency or restrictive incentive low-carbon policies on employment and is mainly discussed at the national level. This article uses provincial data to analyze the impact mechanism of low-carbon transition on employment and tries to explain the employment effect of low-carbon transition in a more comprehensive and in-depth way. In particular, there is a lack of empirical literature based on the "double dividend" hypothesis of low-carbon and employment targets at the provincial level in China.

THEORETICAL BACKGROUND AND MODEL DESIGN

EPC and EKCE

The environmental Kuznitz curve (EKC) (Grossman and Krueger, 1995) has been used to observe the relationship between carbon emissions and economic growth, and has been extensively studied on how to promote "growth and carbon decoupling". Although the form of EKC varies in different countries, it has been confirmed that it exists significantly under certain conditions. However, when employment becomes the primary goal, can the "double welfare" of low-carbon economic transformation and employment be achieved at the same time? In this regard, Kashem and Rahman (2020) proposed the environmental Phillips curve (EPC) hypothesis, describing the negative correlation between unemployment and environmental degradation. Low-carbon transformation can be achieved through five aspects of input and output dimensions. The input dimension is reflected in the intensity of environmental regulation, popularization of the low-carbon concept, and improvement of the green rate. The output dimension reflects the advanced industrial structure and low carbon production capacity. The abovementioned five aspects of low-carbon transition are not independent of each other, but intrinsically related. The intensity of environmental regulation and the greening reflect the low carbon input from the end and the source, respectively. Environmental regulation can promote a reduction of carbon source, while greening can provide an increase in carbon sink. The popularization of the low-carbon concept is the synthesis of the two so that low carbon permeates into all aspects of production and life. In the process of low-carbon, the industrial structure is gradually changing. The development of the low-carbon industry inevitably needs the support of low-carbon technology. The increase in green investment and the development of advanced technology improve the low-carbon productivity constantly, and the development is guaranteed to be sustainable. These factors act together, cause and effect each other, and have direct or indirect effects on the employment scale and employment structure. The following is a detailed explanation of the impact mechanism of low-carbon economic transition on employment from these five aspects.

First, as the implementation of low carbon policy, stricter environmental regulations could lead to higher costs to the enterprise, highly polluting enterprises transfer or close to reduce employment, environmental regulation potter effect, which, on the other hand, may make enterprises to carry out technical innovation, can increase the income of the enterprise carbon emissions, increase the profit of the enterprise so as to increase employment; At the same time, it also helps to develop new products and win market advantages. In order to meet market demand, it can increase the employment of the labor force, and it also helps to promote the division of specialization so as to generate more new jobs and improve the employment level. In a word, low-carbon environmental regulation can have different impacts on employment through industrial structure upgrading and technological innovation. Second, low carbon concept spread of low carbon life, low carbon society with low carbon idea thorough popular feeling, which changes the original concept of consumption and economic and social values, to effectively motivate people preference to the products of low carbon consumption, promote the growing demand for low carbon markets, bring new green technology innovation and the development of emerging green industries, thus creating new jobs. Third, the improvement of the greening rate is one of the most effective ways to achieve "carbon neutrality". The expansion of investment in public environment construction can effectively increase carbon sink. In order to effectively improve the greening rate, it is necessary to strengthen desertification control, forest coverage, road construction, river regulation, and afforestation in urban construction. In addition, from the planning and design of green space construction, greening management, and supervision to the treatment of domestic waste, all have generated the resulting demand for greening work. Fourth, the adjustment of industrial structure is the result of low carbon, and in turn, the upgrading of industrial structure will promote the realization of low carbon goals. As one aspect of high-quality development required by low-carbon economy, the upgrading path of industrial structure will be gradually upgraded to the pattern of "three two one". The tertiary industry is considered to have a high elasticity coefficient of employment (Dong Zhiqing et al., 2019), so the upgrading of industrial structure means the improvement of economic employment absorption capacity. Fifth, low-carbon production capacity reflects the carbon emission efficiency of low-carbon regions. The improvement of low-carbon production capacity is reflected in the gradual adjustment of more traditional energy sources with high carbon emissions to new energy sources, that is, the adjustment of the ecological industrial structure of high-carbon industries. This change has a direct impact on employment in related industries; Meanwhile, as the reason for the improvement of low-carbon production capacity, the innovation of low-carbon technology and the increase of various green investments will indirectly promote the increase of employment demand.

Therefore, based on the environmental Kuznitz curve (EKC) and environmental Phillips curve (EPC), this article further proposes the environmental Kuznets of employment hypothesis (EKCE), which can explicate carbon emission regulation can achieve the "double welfare" of low-carbon economic transition and employment growth, that is, with the tightening of carbon emission regulation, there is a "U-shaped" relationship between carbon emission reduction and employment.

Description of Models and Variables

Arellano and Bond (1991) respectively, proposed the idea of generalized moment SYS-GMM estimation. Based on the assumption that the random error term is not correlated with a set of instrumental variables, SYS-GMM selects the parameter estimator whose correlation between the random error term and the set of instrumental variables is 0 as far as possible, and the correlation moment estimator is the so-called criterion function. This function can make GMM estimation robust even in the case of autocorrelation and unknown heteroscedasticity by selecting an appropriate weighting matrix. In this regard, the basic model of panel estimation is established as follows:

$$y_{i,t} = \alpha_{\mathrm{it}} + \beta_{it}' x_{i,t} + \mu_{i,t} \tag{1}$$

where I = 1...,N; T = 1,... T; $y_{i,t}$ is the explanatory variable vector, $x_{i,t}$ is the explanatory variable matrix, and $\mu_{i,t}$ is the T* 1-dimensional disturbance vector. Dynamic factor is added to the basic model of **Eq. 1**, that is, an autoregressive expression, $\sum_{k=1}^{p} \alpha_k y_{i,t-k}$, is added, as shown in Eq. 2:

$$y_{i,t} = \sum_{k=1}^{p} \alpha_k y_{i,t-k} + \beta_{it}' X_{i,t} + \gamma_{i,t} CV_{i,t} + \eta_i + \varepsilon_{i,t} \tag{2}$$

where $X_{i,t}$ is the endogenous variable, $CV_{i,t}$ is the exogenous control variable, η_i is the dummy variable, and $\varepsilon_{i,t}$ is the random disturbance term. When performing GMM estimation, the dimension of parameter vector to be estimated should be at most the same as the number of selected tool variable Z. However, when the model has overidentification problem, that is, when the dimension of parameter vector is smaller than the number of sample moment conditions, the following moment conditions can be obtained:

$$E\left[Z' u(y, \phi, X)\right] = 0 \tag{3}$$

Eq. 3 cannot satisfy all parameter estimates; Arellano and Bover (1991) believed that the theoretical moment estimation condition could be replaced by the sample moment estimation condition, which could be processed by constructing the following criterion function to minimize:

$$\sum_{i=1}^{T} \left[Z' u(y, \phi, X)\right]' B \left[Z' u(y, \phi, X)\right] \tag{4}$$

Eq. 4 can be used to measure the distance between the sample moment and the extent to which it approaches 0. Here, B is a weighted matrix. If B is positive definite, the estimation of parameters ϕ is consistent with this method. The core idea of SYS-GMM estimation is to obtain the corresponding moment condition estimation equation by means of instrumental variables. Then, the dynamic SYS-GMM model of the relationship between carbon emissions and employment can be constructed based on the EPC model, Okun's Law, and ECK effect model.

Based on the EPC model proposed by Kashem and Rahman (2020), the equation of the relationship between low carbonization and employment can be expressed as follows:

$$\begin{aligned} \mathrm{CO2} = {} & \mathrm{g} - \mathrm{hU or}\ InCO2_{it} \\ & = \alpha_0 + \alpha_1 U_{1it} + \beta_1 Y + \beta_2 Y^2 + \kappa CV_{it} + \eta_i + \varepsilon_{it} \end{aligned} \tag{5}$$

where U is the unemployment rate, CO2 is carbon emission, Y is per capita GDP, and Y^2 measures the ECK effect. By reviewing existing literature and sorting out the theoretical mechanism of the impact of low-carbon transition on employment, the employment effect of carbon emission regulation may show a linear positive correlation or U-shaped relationship between low-carbon and employment. Therefore, combining Okun's Law (Okun, 1995) and ECK effect model (Kacprzyk and Kuchta, 2020), Okun's law can transform unemployment into employment, and ECK indicates the inverted U relationship of carbon emissions in the economic growth. In combination with

Eq. 2, the dynamic panel should be considered with exogenous variables, and the following basic model can be constructed by econometric empirical study:

$$InEmploy_{it} = \alpha_0 + \sum_{k=1}^{p}\alpha_k InEmploy_{i,t-k} + \beta_1 InEr_{it} + \beta_2 InEr_{it}^2 + \kappa CV_{it} + \eta_i + \varepsilon_{it} \quad (6)$$

where employment is the explained variable, indicating the regional employment level; Er represents the intensity of carbon emission regulation, while ε is a random disturbance term with independent homo distribution and finite variance. It is worth noting that the relevant factors with low impact on employment may be omitted, and the estimation bias caused by insufficient information on the proxy index for carbon regulation measurement. Endogeneity is a problem that the above-given regression model may not be able to avoid. Exogenous instrumental variables are difficult to deal with due to the consistency of the samples' environment, macroeconomic policies, and institutions. Therefore, in accordance with the ideas of Brown and Petersen (2011), the employment variable was regarded as an endogenous variable, and the system-generalized moment method (SYS-GMM) was used to estimate the parameters. The corresponding lag term is selected as the instrumental variable of the difference equation.

The first concern is the lag of the explained variable, which introduces dynamics into the estimate, which is regarded as the initial state of the employment level. Second, low carbon regulation or the coefficient of this variable is what we are most interested in. To observe whether it is significantly positive is used to observe the Phillips effect of the environment. The square term of low-carbon regulation is used to determine whether there is a U-shape phenomenon of Kuznets effect of environmental employment between employment and low-carbon regulation and is expressed as follows:

$$A0: \left\{\begin{array}{l}\beta_1 > 0, \beta_2 = 0 \Rightarrow \text{linear relationship with positive correlation} \Rightarrow \text{EPC} \\ \beta_1 < 0, \beta_2 = 0 \Rightarrow \text{U}-\text{shape} \Rightarrow \text{EKCE}\end{array}\right\}$$

The abovementioned formula is the judgment formula of whether the environmental Phillips effect (EPC) and the environmental Kuznets effect (EKCE) of employment are established. Regarding the relationship between carbon regulation and low carbon, we need further clarification. According to the existing literature, the reciprocal of carbon emission intensity had been used to measure carbon emission regulation (Zhao et al., 2017 and Bhowmik et al., 2022). In this article, we also used the reciprocal of carbon emission intensity to measure carbon emission regulation. The carbon emission intensity is expressed by carbon dioxide emission per unit of GDP. Therefore, there is a negative correlation between carbon regulation and employment, which means that employment growth is accompanied by carbon emission reduction. So, a dual target of low carbon and employment can achieve if the EPC and ECKE assumptions hold.

In addition, vectors containing a list of variables are called instrumental variables. Following the example of Kashem and Rahman (2020), Bhowmik et al. (2022), and Anser, Apergis, Syed, and Alola (2021a), we resorted to some other control variables like income following Rahman (2017), Kashem and Rahman (2019); income following Rahman (2020), Islam and Shahbaz (2012); and InOpen following Hossain (2012) and Rahman et al. (2017). lnWage following (Wang, 2013), lnZF following (Lu Y, 2011), lnModern following (Kacprzyk and Kuchta, 2020), lnHuman following (Shao Shuai, Yang Zhenbing, 2017), and lnPRC following (Zhao Liange et al., 2016). Some other variables were also used by the researchers for carbon-emission analysis. However, we did not include them, as they were not significant for this study. Our control variables were selected by trial-and-error method to finalize the model. And the related variables involved in the model and their interpretations are shown in **Table 1**.

EMPIRICAL RESULTS AND ANALYSIS

Data Sources

This article selects the data composition analysis sample of China's provincial administrative regions from 2005 to 2019. Why did this study choose 2005 as the starting point? is the turning point of China's carbon reduction. For the first time, the Chinese government set binding targets for energy conservation and emission reduction in its 11th Five-Year-Plan and set a target of reducing energy consumption per unit of GDP by 20% in 2010 from 2005 levels. Since then, this binding target has become a regular guiding principle for all provinces and cities. Due to data availability and comparability, this study includes 30 provinces, which are as follows: Beijing, Tianjin, Hebei, Shanxi, Inner Mongolia, Liaoning, Jilin, Heilongjiang, Shanghai, Jiangsu, Zhejiang, Anhui, Fujian, Jiangxi, Shandong, Henan, Hubei, Hunan, Guangdong, Guangxi, Hainan, Chongqing, Sichuan, Guizhou, Xizang, Shaanxi, Gansu, Qinghai, Ningxia, and Xinjiang. In this article, the data are from the China labor statistical yearbook, China's population and employment statistics yearbook and China statistical yearbook, China energy statistical yearbook and statistical yearbook, various provinces and cities each of the variables in the estimate is obtained by the abovementioned provinces and index on the basis of the data processing and statistical description of the variables shown in **Table 2**.

Table 2 below shows the statistical description of each variable. Among them, the average value of labor employment in 30 provinces and cities is 7.622, the maximum value is 8.322, and the minimum value is 5.124. The average value of environmental regulation intensity is 1.296, the maximum value is 2.811, and the minimum value is 0.812. It can be found that during the sample study period, the dispersion degree of each variable is relatively high, indicating that there are certain differences in environmental regulation and employment among provinces and cities in China. From the perspective of JB statistics, the p values of all variables are greater

TABLE 1 | Variables involved in the model and their interpretation.

Indicator type	Indicator description	Data source
Explanatory variables: In $Employ_{i,t}$	The total number of employed persons at the end of each province is used to represent the employment level	China Labor Statistics Yearbook
Carbon-emission Regulation: InEr	In previous literatures, it has been used as a reciprocal of carbon emission intensity to measure carbon emission regulation. In this study, the reciprocal of carbon emission intensity is also used to measure carbon emission regulation. Among them, carbon emission intensity is expressed by carbon dioxide emission per unit of GDP. Carbon emissions are calculated by referring to the measurement method of Zhao et al., 2017 and Bhowmik et al. (2022)	China Energy Statistical Yearbook
Control variable$CV_{i,t}$	Fixed asset investment/GDP (InPRC): proxy variable reflecting the investment status of the real economy; Total import and export trade/GDP (InOpen): reflects the degree of local economic openness; Government expenditure/GDP (InZF): reflects the degree of government interference to the economy, as a substitute indicator to reflect the degree of marketization; Human capital (InHuman): reflects the differences of Human capital between regions, represented by average years of education; Third industry added value/GDP (InModern): Show the economic structure of each province and its degree of modernization; Iny: represents the per capita income level; InWage is the average real wage of employees in urban units as a measure of human cost	China Statistical Yearbook and provincial statistical yearbook
η_i	Non-observable fixed effect variables in each province	
$\varepsilon_{i,t}$	Random error	

TABLE 2 | Statistical characteristics of variables.

Variables	InEmployment	InEr	Iny	InOpen	InWage	InZF	InModern	InHuman	InPRC
Mean	7.622	1.296	10.083	16.123	10.352	1.483	0.445	2.325	0.436
Median	0.820	0.725	0.755	1.671	0.533	0.285	0.235	0.184	0.172
Maximum	5.124	0.812	8.284	11.752	9.237	0.675	0.386	1.782	0.216
Minimum	7.965	2.021	10.215	14.661	10.423	1.306	0.468	2.101	1.623
Std. Dev	8.322	2.811	12.152	18.610	11.714	2.019	0.668	2.629	2.415
Skewness	2.156	0.154	−0.365	−0.107	0.095	0.248	−0.107	−0.365	−0.106
Kurtosis	10.335	1.943	2.824	2.684	1.964	2.767	2.684	2.824	1.943
Jarque–Bera	1.541	1.010	1.871	1.518	1.508	1.104	1.918	0.871	1.807
Probability	0.501	0.562	0.453	0.568	0.503	0.610	0.368	0.653	0.392
Obs	450	450	450	450	450	450	450	450	450

TABLE 3 | GMM estimation of the employment effect of carbon emission regulation. (Explained variable: InEmploy; SYS-GMM, estimation).

Var	Model-1	Model-2	Model-3	Model-4
L.InEmploy	0.7251*** (0.0122)	0.5101*** (0.0142)	0.6536*** (0.0112)	0.6036*** (0.0153)
InEr	0.0417 (0.0353)	0.0328 (0.0258)	−0.0297** (0.0152)	−0.0272*** (0.0118)
LnEr2			0.0432*** (0.0183)	0.0318*** (0.0125)
Iny		0.3291*** (0.1612)		0.3172*** (0.1124)
InOpen		0.0327** (0.0171)		0.0361** (0.0194)
InWage		0.3328*** (0.0562)		0.3024*** (0.0685)
InZF		−0.0168** (0.0882)		−0.0151*** (0.0533)
InPRC		−0.2172*** (0.0748)		−0.2255*** (0.0821)
InModern		−0.1692*** (0.0528)		−0.1255*** (0.0512)
InHuman		0.0164*** (0.0077)		0.0184*** (0.0089)
_cons	−0.37468*** (0.121)	−0.43284** (0.0298)	−0.37757** (0.1556)	−0.33753** (0.0255)
Wald test		0.0000		0.0000
AR (1)		0.0021		0.0019
AR (2)		0.5053		0.5290
Sargan test		0.8502		0.8865
Observations	450	450	450	450

*Note: *, **, and *** represent the significance at the level of 1, 5, and 10% respectively; Wald test, AR (1), AR (2) and Sargan test give corresponding* p *values of statistics, respectively; The values in brackets represent the standard deviation.*

than 0.35. Therefore, it can be considered that all samples of variables are from the normal distribution population.

RESULTS

Table 3 is the GMM estimation of the dynamic panel Model of the employment effect of carbon emission regulation. Model-1 and Model-2 are respectively the test of EPC without control variables and with control variables; Model-3 and Model-4 are, respectively, the tests of EKCE without control variables and with control variables. Due to the focus on EPC and EKCE coefficients, the estimated results for related control variables are not listed. **Table 3** shows that the Wald test rejects the null hypothesis that the coefficient of each explanatory variable is zero at the significance level of 1%, indicating that the model is robust on the whole. AR (1) statistics show that it accepts the assumption that the residual term of the original sequence has autocorrelation, but AR (2) indicates that it rejects the assumption that the residual of the first-order difference equation has second-order autocorrelation, which meets the requirements of the GMM estimation. Sargan test statistics cannot reject the null hypothesis that there is no overidentification, indicating that instrumental variables are valid.

The estimation results show that: no matter whether control variables are added or not, the estimation coefficient of EPC is not significant, indicating that the linear relationship between low-carbon regulation and employment in China is not obvious. However, the EKCE coefficient shows that with the enhancement of low-carbon regulations, the two are negatively correlated at the beginning, and then turn into a positive correlation after reaching a certain stage, that is, there is a u-shaped curve between carbon emissions and employment. In general, EKCE can better describe the dynamic relationship between carbon emission reduction and employment under China's dual carbon targets. The main reasons may be as follows: First, in order to achieve the carbon emission target, the local competition mechanism makes local governments adopt the carbon emission regulation policy of campaign, which makes employment suffer a great negative impact in the short term. Second, after 2007, China adopted supply-side structural reform. In the process of economic transformation, enterprises with high emissions were eliminated or actively transformed, which further squeezed employment. However, in the long run, with the continuous improvement of low-carbon regulation intensity, especially after the implementation of the carbon emission trading system in 2011, the prices of production factors such as raw materials of enterprises rise, while the relative prices of labor factors decline, thus, increasing the demand for labor and improving the employment level.

L. Lemploy coefficient is significantly positive, indicating that the lag period of employment has a significant impact on the current employment, indicating that there is inertia in employment. As Sun et al., 2020 believe that employment indicators have a strong positive cyclical nature. The level of economic development represented by LNY is significantly positive, indicating that economic development in a region promotes employment in the region. The Openness coefficient is significant, indicating that import and export trade is an important driving force to promote employment growth in China's export-oriented economy. The coefficient of human capital (lnHuman) is significantly positive, indicating that the accumulation of human capital as measured by educational development contributes to the increase of local employment. The coefficient of lnWage is significantly positive, indicating that the increase in wage level will increase employment in this region. The conclusion that economic development, openness to the outside world, marketization, and human capital can effectively promote employment is consistent with existing literature. The marketization degree coefficient represented by lnZF is significantly negative, and the proportion of fiscal expenditure to GDP reflects the market intervention of local governments. Therefore, the smaller the coefficient is, the higher the local marketization will be, and the more conducive to the development of small and medium-sized enterprises and the promotion of employment. The employment effect of lnModern industrial structure is significantly negative, indicating that service of industrial structure squeezes out employment. The coefficient of fixed asset investment (lnPRC) is significantly negative, which is caused by the increasing trend of capital replacing labor with China's technological progress and industrial structure upgrading, which makes it difficult for new investment to play an effective role in driving employment.

Further, to analyze the impact of environmental regulations on employment in different regions or income levels, this study divides 30 provincial administrative regions into three groups: eastern region, central region, and western region, as shown in **Table 4**. The results show that the environmental regulation in the western region improves employment level, the environmental regulation in the income region in the middle region has no significant impact on employment, and the environmental regulation in the eastern region has a u-shaped impact on employment. In other words, the eastern region conforms to the EKCE curve hypothesis, while the western region conforms to the EPC hypothesis. The low-carbon transition in the eastern and western regions has achieved a win-win situation of carbon emission reduction and employment. From the comparison of the significance and sensitivity of the estimated coefficients of control variables in the eastern and western regions, it can be seen that the impact of human capital and openness on employment decreases from the eastern to the western regions, while the marketization has a significant impact on employment in the eastern regions, which is only significant at the level of 10% in the eastern and western regions. The reason why the relationship between carbon emission reduction and employment shows different characteristics across regions. The main reason is that the strengthening of environmental regulations in the eastern region will promote enterprises to major in the central and western regions, which will reduce employment in the short term. After the "dual transfer strategy", which is also named vacating cage to change bird, is a strategic measure in the process of economic development in China. It is to transfer the existing traditional manufacturing industry out of the industrial base and then transfer the "advanced productivity" so as to achieve the goal of economic transformation and industrial

TABLE 4 | Analysis of state heterogeneity of employment effect of carbon emission regulation (Explained variable: lnEmploy; SYS-GMM estimation).

Var	Model-5 (Eastern region)	Model-6 (Central region)	Model-7 (Western region)
L.lnEmploy	0.5254*** (0.2215)	0.6118*** (0.1568)	0.6745*** (0.1252)
lnEr	−0.0413*** (0.0112)	−0.02874 (0.0254)	0.0581** (0.0305)
LnEr2	0.0645*** (0.0088)	0.01818 (0.0156)	0.01553 (0.0175)
lny	0.3112*** (0.1011)	0.3349*** (0.161)	0.4225*** (0.161)
lnOpen	0.0388*** (0.0155)	0.0311** (0.0160)	0.0285** (0.0149)
lnWage	0.2152*** (0.0882)	0.3624*** (0.0756)	0.3882*** (0.0455)
lnZF	−0.0125*** (0.0061)	−0.0156* (0.0792)	−0.0198* (0.0098)
lnPRC	−0.1157*** (0.0589)	0.2241*** (0.0674)	0.2878*** (0.0764)
lnModern	-0.0859*** (0.0355)	−0.128*** (0.0482)	−0.225*** (0.0667)
lnHuman	0.0202*** (0.0095)	0.0113*** (0.0072)	0.0124*** (0.0045)
_cons	−0.3746*** (0.0525)	−0.3284*** (0.0458)	−0.3753*** (0.0657)
Wald test	0.0003	0.0001	0.0002
AR (1)	0.0000	0.0001	0.0022
AR (2)	0.6432	0.4394	0.5052
Sargan test	0.9633	0.9052	0.8502
Observations	165	150	135

*Note: *, **, and *** represent significance at the level of 1, 5, and 10%, respectively; The values in brackets represent the standard deviation.*

upgrading. After the relocation in the eastern region, the economic development conditions become better and better, like the quality of human resources and the degree of marketization is higher. The low-carbon regulations can promote the upgrading of industrial structure, accelerate technological innovation, and, thus, promote the increase in employment. On the one hand, the central region has advantages in labor costs, and on the other hand, it has taken over the transfer of polluting industries from high-level regions. In the face of the increase in low-carbon regulation intensity, the cost of enterprises will rise and the scale of enterprises will be reduced, so the overall net effect is not significant. In the western region, due to the relatively backward economic development, the labor cost presents an absolute advantage, prompting enterprises to use more labor to replace other factors of production, thus increasing employment.

ROBUSTNESS CHECKS

Since China's carbon emission trading policy was officially implemented at the end of 2012, as a market-oriented policy in carbon regulation, this policy has a great impact on carbon emissions and employment targets. The low-carbon region pilot policy includes two batches of low-carbon provinces and cities. The first batch of pilot programs was based on the circular on pilot programs of low-carbon provinces and cities issued by the National Development and Reform Commission in October 2010, and the second batch of pilot programs was based on the circular on pilot programs of low-carbon provinces and regions and low-carbon cities issued by the National Development and Reform Commission in December 2012. In order to further illustrate the reliability of the regression results of the above model, this section conducts two robustness tests based on the benchmark model. First, the regression of the benchmark model is based on the data from 2005 to 2019, and the sample period is changed to two phases from 2005 to 2012 and from 2013 to 2019. Second, the sample is divided into pilot areas (Tianjin, Beijing, Shanghai, Guangdong, Hubei, Chongqing, and Hainan) and non-pilot areas according to whether they are pilot or not. The results of the robustness test are shown in **Table 5**. The regression results show that the pilot policy does not change the conclusion that China complies with EKCE as a whole. In contrast, the implementation of a carbon emission trading policy greatly improves the coefficient of EKCE, indicating that a low-carbon policy can more effectively promote the

TABLE 5 | Robustness test of employment effect of carbon emission regulation (Explained variable: lnEmploy; SYS-GMM).

Var	Model-8 (2005–2012)	Model-9 (2013–2019)	Model-10 (Pilot area)	Model-10 (Non-pilot area)
L.lnEmploy	0.5568*** (0.1812)	0.5604*** (0.2065)	0.4985*** (0.1546)	0.6255*** (0.2850)
lnEr	−0.0295*** (0.0108)	−0.0226*** (0.0088)	−0.0201*** (0.0115)	−0.0276*** (0.0148)
LnEr2	0.0325*** (0.0085)	0.03815*** (0.0174)	0.03708*** (0.0105)	0.03813*** (0.0115)
CV	yes	yes	yes	yes
Wald test	0.000	0.000	0.000	0.000
AR (1)	0.000	0.000	0.001	0.001
AR (2)	0.6885	0.5687	0.5504	0.6212
Sargan test	0.9055	0.9012	0.8810	0.8950
Observations	240	210	105	345

*Note: *, **, and *** represent significance at the level of 1, 5, and 10%, respectively; The values in brackets represent the standard deviation. Pilot areas, including Tianjin, Beijing, Shanghai, Guangdong, Hubei, Chongqing, and Hainan, where carbon emission trading policy was implemented at the end of 2012.*

realization of the "double dividend" of low-carbon and employment growth goals.

CONCLUSION AND POLICY RECOMMENDATIONS

Ecological economic development has become a global consensus. China's economic development has entered the stage of low-carbon transition, and the intensity of national low-carbon regulation has been constantly improving, including input and output. In order to investigate the employment effect of low-carbon transition and whether the dual benefits of "low carbon" and "employment" can be achieved, this study verifies the adaptability of the environmental Phillips curve (EPC) and the environmental Kuznets curve of employment (EKCE) in China and makes an empirical analysis using Chinese provincial panel data from 2005 to 2019. The results show that in the long run, China's low-carbon environmental regulations promote the improvement of employment. In terms of the dynamic relationship between carbon emission reduction and employment growth, there is a significant u-shaped characteristic, and the EKCE effect of employment is more obvious than EPC. However, the validity of the hypothesis depends on the degree of regional marketization, human capital and industrial structure. The EKCE can be observed more in regions with rapid market-oriented reform, abundant human capital, and more advanced industrial structure, that is, the employment effect of low-carbon economic transition is greater. Due to the difference in development, EKCE is more significant in the eastern and central regions. The characteristics of EPC in western China are more significant. Therefore, in order to realize the double dividend more effectively, it is necessary to promote the accumulation of human capital and accelerate the market-oriented reform of carbon emission right trading while implementing differentiated low-carbon rules and policies so as to form the synergistic effect between government intervention mechanism and market mechanism of carbon regulation.

In this regard, the enlightenment and suggestions obtained in this article are as follows. First, this article concludes that there is a statistically significant U-shaped relationship between China's carbon emission regulation and employment growth, which plays an important guiding role for the Chinese government to adhere to the low-carbon economic transformation strategy of dual carbon targets in the new normal economic growth stage under the dilemma of weak employment growth. Furthermore, it can strengthen the confidence that the double dividend of employment can be realized, which will help all regions accelerate the process of economic low-carbon and play a better demonstration effect for global carbon emission reduction.

Second, the research shows that low carbon and employment goals are not mutually exclusive, but to form the synergy of goals, differentiated carbon regulation policies should be implemented according to the economic growth characteristics of each region. For the eastern region, it has already passed the U-shaped inflection point, and it is suitable to adopt the market-based carbon emission trading mode. In the west, more carbon taxes are needed.

Third, In the high-income eastern region, measures such as further opening up, modernizing the industrial structure and investing in human capital have actively promoted the development of emerging strategic industries and modern service industries. Middle-income central regions should step up low-carbon regulation gradually to prevent excessive low-carbon regulation from "slowing down" the local economy. Through fiscal and tax policies, enterprises are encouraged to purchase and use environmental protection equipment to help them transform and upgrade. Low-income western regions should prevent local governments from introducing high-emission and high-pollution industries in pursuit of economic growth, and explore clean and efficient leading industries according to local resource endowment and social characteristics. In the process of industrial transformation, create more jobs.

Of course, there are two main limitations of this study. First, from the perspective of the time span of the research data, the time span of this study is relatively short because China's carbon emission target policy was put forward late. Second, although this article studies the relationship between carbon regulation policies and employment at the provincial level, it fails to evaluate the effect value of the policies on the industry level and individual enterprises. Third, from the choice of variables, this article only measures the employment level by the number of employment in each province without further analyzing the employment structure of each province. Fourth is the lack of specific quantitative analysis of the impact of carbon trading policies on employment. All these are areas for further research and improvement in the future.

DATA AVAILABILITY STATEMENT

Publicly available datasets were analyzed in this study. These data can be found in China labor statistical yearbook, China's population and employment statistics yearbook, and China energy statistical yearbook.

AUTHOR CONTRIBUTIONS

PX is mainly responsible for empirical analysis of measurement, and LS is mainly responsible for literature review and mechanism analysis.

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