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Original Research

Impact of Industrial Structure Rationalization and Upgrading on Well-Being Performance of Carbon Emissions- Empirical Analysis Based on Chinese Provincial Level

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Abstract

The rapid economic development has caused a continuous increase in carbon emissions, which has led to a series of problems such as environmental pollution and climate change, resulting in a decline in economic, ecological and social welfare. The increase in human well-being generated by each unit of carbon emissions can be expressed in terms of well-being performance of carbon emissions. Based on provincial panel data from 2005 to 2020 in China, this paper provides an in-depth exploration of the impact of the rationalization and upgrading of industrial structure on the well-being performance of carbon emissions by constructing a fixed-effect model. The conclusions of the study are as follows: (1) The rationalization of industrial structure at this stage has not yet had an impact on well-being performance of carbon emissions, and upgrading can significantly contribute to the improvement of well-being performance of carbon emissions. (2) the impact of industrial structure upgrading on well-being performance of carbon emissions is heterogeneous. Advancedization only significantly contributes to the well-being performance of carbon emissions of eastern regions, regions with low natural resource endowments, regions with high external dependence and regions with high environmental awareness. The conclusion of the paper provides an important reference for other countries to optimize the industrial structure to improve well-being performance.

Keywords: carbon emissions, well-being performance, well-being performance of carbon emissions, Super-SBM model, industrial structure

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Introduction

As the economy and society continue to rapidly develop, issues such as resource depletion, environmental pollution, and ecological degradation have become increasingly prominent, significantly constraining the sustainable development of the economy and society. According to the Earth Vitality Report 2008 released by WWF [1], human activities have exceeded the limits of the Earth's carrying capacity. The research literature on this subject can be divided into two main categories: the first category studies the impact of human activities on the environment; the second category studies the impact of environmental changes on humans [2]. Research in the first category of literature can offer robust theoretical support for policy formulation and provide crucial references for government departments to develop and modify policies. As for the second category of literature, the research mainly centers on the topic of sustainability study, which investigates the influence of environmental changes on human society. Due to the seriousness of environmental changes, more and more scholars are concerned about the impact of environmental changes on human beings. With increasing global temperatures and rising sea levels, the world is currently facing a serious threat of climate change, and causing a huge loss of human well-being. There is evidence that the frequency and severity of extreme weather is increasing due to climate change [3]. The main cause of climate change is the emission of greenhouse gases, especially carbon dioxide emissions from the burning of fossil fuels [4]. China's carbon emissions have ranked first in the world, facing enormous international pressure. Although China's carbon emission intensity decreased by more than 3% in 2021, reaching 0.45 kg/$. However, China's carbon emission intensity is still the highest among major economies. This is due to the dominant position of coal in China's energy structure and the high proportion of industry [5]. China's energy consumption is still dominated by fossil fuels such as coal, and the industrial structure that can drive energy consumption has become the breakthrough point for reducing carbon emissions [6].

There has been a growing focus on the significant rise in carbon emissions linked to the use of fossil fuels and its impact on human well-being. The relationship between carbon emissions and human well-being is referred to by some scholars as " well-being performance of carbon emissions" (WPCE) [7] or "carbon intensity of human well-being" (CIWB) [8, 9]. In the aforementioned context, how to achieve a win-win situation for both economy and well-being within the established carbon emission space, that is, how to maximize the WPCE, has become one of the urgent issues to be solved. The rationalization and upgrading of industrial structures can promote energy conservation and efficiency, as well as the development of clean energy industries, resulting in reduced energy consumption and carbon emissions [10-12]. Therefore, it is a feasible path to improve WPCE by optimizing and upgrading industrial structures. In addition, due to China's vast territory, there are large regional differences in natural conditions, resource endowments and economic foundations, so low-carbon emission reduction policies need to be formulated according to the region's own situation. Therefore, it is of great significance to study the evolution trend of the WPCE from the perspective of industrial structure at the provincial scale. On the one hand, it is helpful for provinces to take more targeted carbon emission reduction measures according to their own industrial structure characteristics and improve emission reduction efficiency; on the other hand, it also provides a new perspective for the analysis of the relationship between industrial structure and the WPCE, and enriches the existing research results.

The paper is organized as follows: Section 2 is the literature review. Section 3 presents the model setting, variable selection, and data sources. Section 4 analyzes the empirical results, including the baseline analysis and heterogeneity analysis. Section 5 is the discussion section. The last section presents the conclusions and recommendations of this study.

Literature Review

Well-Being Performance of Carbon Emissions

Individuals, businesses, and countries impact the environment by exploiting it to improve human well-being or raise living standards. Therefore, an efficient country is one that can provide maximum well-being with minimal environmental pressure. Over the past 20 years, scholars have aimed to estimate the environmental efficiency of the human well-being [2]. There are many scholars who have concretized this concept and applied it to the study of more specific issues [13, 14]. So, the concepts and computational methods of well-being performance of carbon emissions are also influenced by these efforts. Generally speaking, scholars define the ecological intensity of human well-being as the ratio of per capita ecological footprint to life expectancy [15]. Due to the increasingly severe issue of climate change, scholars have become increasingly concerned about carbon emissions. In the literature, scholars refer to the relationship between carbon dioxide emissions and human well-being as the carbon intensity of human well-being (CIWB) or well-being performance of carbon emissions" (WPCE) [8, 9]. Combined with the relevant literature, the WPCE constitutes an inverse relationship with the CIWB. In this paper, we uniformly use the concept of the WPCE. When the value of the WPCE is smaller, it indicates that the environmental pressure is higher and less sustainable. When the value of the WPCE is higher, it indicates that the environmental pressure is lower and more sustainable. From the existing literature, scholars have focused their research on the relationship between the WPCE and economic development. The results generally show that economic development decreases the WPCE in countries around the world and that in most countries, the negative impact of economic development on the WPCE is increasing over time, implying that the present development model is not sustainable [8]. Optimizing industrial structure is an important way to promote regional economic development, as it fully reflects the advantages of each industry and achieves coordinated development. However, at different stages of economic development, the impact of the rationalization and upgrading of industrial structure on economic growth varies [16]. Therefore, newer studies of the WPCE need to consider how industrial structure is associated with the WPCE.

Industrial Structure and Carbon Emissions

The optimization and upgrading of industrial structure includes two aspects, one is the rationalization of industrial structure and the other is the upgrading of industrial structure. Regarding the impact of industrial structure rationalization on carbon emissions, scholars generally hold a positive attitude that the rationalization of industrial structure can curb carbon emissions [10, 12, 17, 18] with a few subtle differences. Zhou et al. [19] used China's provincial panel data from 1995 to 2009 to analyze that the rationalization of industrial structure can reduce carbon emissions, but it has a lag. Feng and Wu [20] concluded that the rationalization and the upgrading of industrial structure can reduce carbon emissions, but the impact is weak. For the impact of industrial structure upgrading on carbon emissions, there are inhibition theory and inverted "V" relationship theory. Most scholars believe that the upgrading of industrial structure can inhibit carbon emissions [10-12, 17]. Based on the data of 16 districts in Beijing from 2009 to 2020, Shi et al. [21] pointed out that the upgrading of industrial structure has an inhibitory effect on the carbon emission intensity of the region and surrounding areas. However, there are some scholars that point out that this inhibitory effect is relatively weak, although it does exist. Based on the data of 29 provinces in China from 2000 to 2017, Li and Zhou [22] pointed out that the upgrading of industrial structure can help reduce carbon emissions, but the effect is limited. Yang et al. [18] concluded that the relationship between industrial structure upgrading and carbon emissions showed an inverted "V" shape based on provincial data from 2000 to 2017. As far as the relationship between industrial restructuring and carbon emissions is concerned, scholars have studied that industrial restructuring can help reduce carbon emissions, but the effect is relatively limited. Specifically, through the study of the Beijing-Tianjin-Hebei region from 2005 to 2014, Cheng et al. [23] believed that the decline in the proportion of the secondary industry will reduce carbon emissions, but the impact is not obvious.

Industrial Structure and Well-Being Performance

At present, the research on industrial structure and well-being performance focuses on two aspects. First, the impact of industrial structure on ecological well-being performance. Scholars have reached different conclusions on the impact of industrial structure on ecological well-being performance. From the current findings, scholars generally agree that the increase in the share of tertiary industry has a catalytic effect on ecological well-being performance [24]. Hu et al. [25], based on city-level data from 2001-2017 in the Yangtze River Delta region, showed that the optimization of industrial structure has a significantly positive effect on the improvement of ecological well-being performance. Hu et al. [26], based on city-level data from 2000-2017 in the Yangtze River Delta region, concluded that the upgrading of industrial structure promotes improved urban ecological well-being performance. Some scholars consider the effect of an increased share of the secondary sector on ecological well-being performance to be positive [27], but most of them consider it to be negative [19, 28]. Second, the impact of industrial structure on carbon emissions performance. The study of the impact of industrial structure on the carbon emissions performance has so far been relatively under-covered by academics. Specifically, Zhang et al. [29] have concluded that an increase in the share of the tertiary sector can contribute to the improvement of carbon emissions performance, but Han et al. [30] have also pointed out that this effect is not stable. Zha et al. [31] believe that the decline in the proportion of the secondary industry will improve carbon emissions performance.

Literature Comments

In summary, domestic and foreign scholars have achieved certain results in the construction of the WPCE indicators, the impact of industrial structure on carbon emission and the impact of industrial structure on well-being performance, which provide an important reference for this study. However, there are still the following shortcomings: First, in the measurement of the WPCE, scholars have chosen different indicators, and no unified and systematic measurement indicator has yet appeared. The differences in the choice of indicators among scholars make it difficult to compare their conclusions with each other and to accurately capture the changes and development trends of the WPCE, which makes it difficult for policy formulation and adjustment. Second, most of the studies on the WPCE are still focused on the national and regional level, and there are still few studies at the more micro level. To some extent, this overlooks the multi-dimensional variations in the WPCE across diverse industrial structures and natural conditions. Therefore, identifying the multi-dimensional differences in the WPCE in various regions, industrial structures, and natural conditions is crucial in revealing the impact of industrial structure adjustment on the WPCE in the context of carbon peak and carbon neutrality. Third, The research literature on the WPCE in China is relatively scarce. However, as a major emitter of carbon, China's carbon emission level are highly dependent on traditional energy sources such as coal, and the industries that dominate China's economic development also have their own distinct characteristics. Therefore, by focusing on Chinese provinces as the research objects, it is possible to reveal the changing patterns of the WPCE under different industrial structures, providing reference and guidance for other countries or regions, especially developing countries.

Therefore, the paper explores the impact of industrial structure on the WPCE, taking Chinese provinces as the research object. Firstly, the WPCE will be measured using the Super-SBM model. Based on the compilation and summarization of the literature on concepts and indicator systems related to the WPCE, we construct an evaluation indicator system that includes five measurement metrics. Our indicator system provides a concrete measurement of the development level of the WPCE in each province of China, overcoming the measurement bias caused by using a single indicator measurement and providing valuable guidance and direction for future studies on this topic. Then, considering the industrial development situation of each province, the impact of industrial structure optimization and upgrading on the WPCE will be analyzed. Finally, the industrial structure adjustment direction and policy recommendations are proposed. By research of the paper, we hope to give policy makers some new suggestions to achieve more sustainable development through industrial structure optimization and upgrading.

Materials and Methods

Variable Selection

Dependent Variable

There are two main methods used in constructing the WPCE indicators: ratio methods and data envelopment analysis methods [7, 8, 32]. When using the ratio method to calculate, due to the difference in the selection of indicators, it is easy to lead to biased results, and the research conclusions of various scholars are difficult to compare with each other. Based on this, this study uses a Super-SBM model to calculate the WPCE. This paper draws on the approach proposed by Tone [33] using a non-radial, non-angular, slack-based efficiency evaluation model. Because in the traditional SBM model, if there are multiple decision units that are all efficient, it is not possible to further compare who is more efficient. However, the Super-SBM can overcome this drawback, so this paper uses the Super-SBM model to measure the level of the WPCE, as shown in Equation (1). Suppose there are n decision making units, each of which contains three elements: input, desired output and undesired output, represented by the three vectors (X, Y, Z) respectively. $s^x \in R^m$, $s^z \in R^{s_2}$ denote the excess of inputs and undesired outputs, respectively. $s^y \in R^{s_1}$ represents the shortage of desired output. ρ denotes the efficiency value of the decision unit. m, s_1 and s_2 represent the number of variables for input, desired output and non-desired output. When $\rho \geq 1$, it means that the decision making units are valid; when $\rho < 1$, it means that decision making units are non-valid and there is room for improvement.

$$\rho = \min \frac{1 + \frac{1}{m}\sum_{i=1}^{m}\frac{s_i^x}{x_{i0}}}{1 - \frac{1}{s_1 + s_2}\left(\sum_{k=1}^{s_1}\frac{s_k^y}{y_{k0}} + \sum_{l=1}^{s_2}\frac{s_l^z}{z_{l0}}\right)}$$

$$s.t.\begin{cases} x_{i0} \geq \sum_{j=1,\neq 0}^{n} \lambda_j x_j - s_i^x, \forall i; \\ y_{k0} \geq \sum_{j=1,\neq 0}^{n} \lambda_j y_j + s_k^y, \forall k; \\ z_{l0} \geq \sum_{j=1,\neq 0}^{n} \lambda_j z_j - s_l^z, \forall l; \\ 1 - \frac{1}{s_1 + s_2}\left(\sum_{k=1}^{s_1}\frac{s_k^y}{y_{k0}} + \sum_{l=1}^{s_2}\frac{s_l^z}{z_{l0}}\right) > 0; \\ s_i^x \geq 0, s_k^y \geq 0, s_l^z \geq 0, \lambda_j \geq 0, \sum_{j=1,\neq 0}^{n} \lambda_j = 1, \forall i, j, k, l. \end{cases} \quad (1)$$

Based on the literature summary and considering the data availability, this paper refers to Wang et al. [32] and Zhang et al. [27] to select the input and output indicators. In the measurement of the WPCE, we regard carbon emissions as the undesirable outputs. Given the input factors and technical structure, this method seeks to obtain more desirable outputs and less undesirable outputs with fewer inputs by maximizing the inclusion of desirable outputs and minimizing carbon emissions. Water, land and energy are required for production activities. The input of water resources, land resources and energy in a region can reflect to some extent the efficiency of water resources utilization, land utilization and energy utilization in a region. When these resource inputs are constant and more output is obtained or resource inputs are reduced and the same output is obtained, it indicates high resource utilization efficiency. And higher resource use efficiency can effectively reduce carbon emissions. Therefore, we choose water consumption, land resource consumption, and energy consumption as the three input indicators. We select human well-being to represent desired output. There are several characteristics of life expectancy that make it suitable as an indicator of well-being. First, it is a direct indicator of health and longevity. Second, life expectancy reflects the overall health of society, as it directly indicates the extension of life and the reduction

Table 1. The WPCE Indicators.

Input and Output	Selection Indicators	Specific Indicators Represent	Symbolic	Units
Input	Water consumption	Water consumption per capita	penergy	Cubic meters / person
	Land resource consumption	Per capita built-up area	pbua	Square meters / ten thousand people
	Energy consumption	Standard coal consumption per capita	pwater	Ton standard coal / person
Desired Output	Human well-being	Average life expectancy	lexp	Year
Non-Desired Output	Carbon dioxide emissions	Per capita carbon dioxide emissions	pco2	Tons / person

Source: Compiled by the authors.

of infant mortality, and indirectly reflects prenatal education, lifelong medical services, literacy rates, and education levels. Finally, life expectancy also has strong objectivity and comparability. The specific indicators are shown in Table 1.

Since the average life expectancy of each province is only available for 2000, 2010, and 2020, this paper follows the method of Xu et al. [34] to measure the average life expectancy of each province for the remaining years. Referring to the reference method provided in Chapter 6 of Volume 2 of the National Greenhouse Gas Inventory Guidelines, carbon dioxide emissions can be calculated. This emission can be obtained by summing the estimated amount of CO_2 emissions due to the consumption of various fossil energy fuels, and the CO_2 coefficient formula of various fossil energy emissions is as follows.

$$\phi_k = NCV_k * CEF_k * COF_k * \frac{44}{12}, K = 1,2,3,...8 \quad (2)$$

Where: NCV_k represents the average low-level heat generation, CEF_k represents the carbon emission factor, COF_k represents the carbon oxidation factor, 44 and 12 represent the molecular weight of CO_2 and C, respectively, and k is one of the 8 fossil fuels with high consumption, including coal, coke, crude oil, gasoline, kerosene, diesel, fuel oil and natural gas. In addition to the 8 fossil fuels, electricity energy consumption is also taken into account because of its high energy consumption. The calculation of carbon dioxide generated by electricity consumption refers to Hu et al. [35], and draws on the data in the "Provincial Greenhouse Gas Inventory Guidelines (Trial)" compiled by the National Development and Reform Commission in 2011 to calculate the carbon emissions generated by electricity consumption. Detailed descriptions are shown in Table 2.

Descriptive statistics regarding the WPCE input and output variables are shown in Table 3.

Independent Variables

Industrial structure rationalization: The existing literature on the calculation of industrial structure rationalization mainly uses the Thiel index proposed by Gan et al. [36]. This index makes up for the deficiencies

Table 2. Carbon Dioxide Calculation Index Generated by Power Consumption.

Power Grid Name	Covering Provinces and Municipalities	Carbon Dioxide Emissions (Kg/KW.H)
Northern China Region	Beijing, Tianjin, Hebei Province, Shanxi Province, Shandong Province, Western Inner Mongolia	1.246
Northeastern Region	Liaoning Province, Jilin Province, Heilongjiang Province, Eastern Inner Mongolia	1.096
Eastern China Region	Shanghai, Jiangsu Province, Zhejiang Province, Anhui Province, Fujian Province	0.928
Central China Region	Henan Province, Hubei Province, Hunan Province, Jiangxi Province, Sichuan Province, Chongqing	0.801
Northwestern Region	Shaanxi Province, Gansu Province, Qinghai Province, Ningxia Province, Xinjiang Province	0.977
Southern Region	Guangdong Province, Guangxi Province, Yunnan Province, Guizhou Province	0.714
Hainan	Hainan Province	0.917

Source: Compiled by the authors.

Table 3. Descriptive Statistics for the WPCE Sub-Indicators.

Variables	N	Mean	SD	Min	Max
penergy	480	3.4196	1.7734	0.9928	11.9026
pbua	480	0.3650	0.1474	0.0997	0.8435
pwater	480	508.1823	420.0492	164.6000	2657.4000
lexp	480	76.1328	2.8059	68.7154	82.9623
pco2	480	15.1592	10.6801	3.1053	72.2893

Source: calculations by the authors.

of the industrial structure deviation degree and maintains the economic meaning and theoretical basis of the industrial structure deviation degree. Therefore, this paper refers to Gan et al. [36] to calculate the industrial structure rationalization, which is expressed by tl. When the economy is in equilibrium, tl = 0. The more this indicator deviates from the equilibrium point 0, the more irrational the industrial structure is indicated. The specific calculation formula is

$$\mathrm{tl}=\sum_{i=1}^{n}\left(\frac{Y_i}{Y}\right)\ln\left(\frac{Y_i}{L_i}/\frac{Y}{L}\right) \tag{3}$$

Among them, Y represents output, L indicates employment, i represents the ith industrial sector.

Industrial structure upgrading: The upgrading of industrial structure refers to the change of industrial proportion and the improvement of labor productivity. This connotation includes two aspects: first, the change of industrial structure, such as the transformation from labor-intensive to capital-intensive to knowledge and technology-intensive industries; second, the upgrading of industrial structure can be achieved by constantly upgrading and innovating the production technology of traditional industries or improving the technical content of products. In order to quantitatively analyze the advanced industrial structure, the proportional relationship of each industry is commonly used in the academic community to measure [36]. Also, the degree of advancedization can be assessed by the product of the output share of each industrial sector and labor productivity [37]. This paper refers to Gan et al. [36] for calculation, and is expressed by the ratio of the added value of the tertiary industry to the added value of the secondary industry, which is recorded as ind. The larger the value, the more advanced the industrial structure.

Control Variables

Referring to Zhang et al. [29] and Wang et al. [38], this paper selects economic growth, urbanization rate, environmental governance, foreign investment utilization, energy efficiency and fixed assets rate as control variables.

(1) Economic growth

This study uses the logarithm of real GDP to represent economic growth. The environmental Kuznets curve believes that with the continuous development of the economy, the environmental situation will first deteriorate and then improve [39]. Therefore, this paper also controls the square term of economic growth.

(2) Urbanization rate

Some scholars have shown that urbanization has a positive effect on the WPCE, but different degrees of urbanization have different effects on the WPCE [40]. In this paper, the urbanization rate is expressed by the ratio of urban population to total population.

(3) Environmental governance

The more the local government invests in environmental governance, the better the governance of the environment, and then the higher the well-being level, so this paper also controls for environmental governance. The completed investment in industrial pollution control is taken as logarithm to represent the regional environmental governance.

(4) Utilization of foreign capital

A considerable amount of literature has examined the correlation between foreign investment and environmental pollution [41, 42]. The spillover effects of knowledge and technology resulting from foreign investment can facilitate domestic producers in enhancing their equipment and increasing their investment in technological research and development. This, in turn, can help to decrease carbon intensity and energy consumption. However, the entry of foreign capital may also bring about the transfer of foreign polluting industries, thus aggravating domestic environmental pollution. Hence, this paper takes into consideration the foreign investment profile. The real foreign direct investment, represented as a percentage of GDP, is used as an indicator of foreign investment utilization.

(5) Energy efficiency

The higher the energy efficiency, the lower the carbon emissions per unit of energy. Therefore, improving energy efficiency can reduce carbon emissions, reduce negative impacts on the environment, and improve human well-being. Energy efficiency is expressed using the ratio of total energy consumption to real GDP. This indicator is a negative indicator, the larger the indicator,

Table 4. Variable Definitions.

Type	Variable Name	Symbols	Calculation Methods	Units	Data Sources
Dependent Variable	Well-being performance of carbon emissions	WPCE	Super-SBM model	\	China Statistical Yearbook
Independent Variables	Rationalization of industrial structure	tl	$\text{tl}=\sum_{i=1}^{n}(\frac{Y_i}{Y})\ln(\frac{Y_i}{L_i}/\frac{Y}{L})$	\	China Statistical Yearbook
	Advanced industrial structure	ind	Ratio of added value of tertiary sector to added value of secondary sector	\	China Statistical Yearbook
Control Variables	Economic growth	lnrgdp	Real GDP taken as natural logarithm	100 million	China Statistical Yearbook
		lnrgdp2	The square of the natural logarithm of real GDP	$(100 \text{ million})^2$	China Statistical Yearbook
	Urbanization rate	ur	The ratio of urban population to total population	\	China Statistical Yearbook
	Environmental Governance	engov	Completed investment in industrial pollution control is taken as logarithm	Ten thousand yuan	China Statistical Yearbook
	Utilization of foreign capital	fdi	Actual foreign direct investment taken as natural logarithm	\	China Statistical Yearbook, Statistical Yearbook of Provinces
	Energy efficiency	eff	Ratio of total energy consumption to real GDP	ton of standard coal /million yuan	China Statistical Yearbook
	Fixed assets rate	fixar	Ratio of fixed asset investment to annual gross domestic product	\	Statistical Yearbook of the Chinese Investment in Fixed Assets, China Statistical Yearbook

Source: Compiled by the authors.

the lower the energy efficiency; the smaller the indicator, the higher the energy efficiency.

(6) Fixed assets rate

The social fixed asset investment of each province and the annual GDP of each province are used to measure the supply degree of local government public goods, which is expressed by fixar [43]. Investment in fixed assets is an important part of economic development. Investment in fixed assets can adjust the regional distribution of economic structure and productivity, but also drive employment, increase residents' income, improve people's quality of life, and thus improve the well-being level of the region.

Data Sources

This paper is based on 30 provinces and municipalities in China. Hong Kong, Macau, Taiwan and Tibet in China are excluded from this study due to the reason that data is difficult to obtain or seriously missing. The data of the above indicators are obtained from the China Statistical Yearbook, provincial statistical yearbooks, China Population and Employment Statistical Yearbook, China Energy Statistical Yearbook, China Environmental Statistical Yearbook, China Urban Construction Statistical Yearbook, Statistical Yearbook of the Chinese Investment in Fixed Assets and the statistical bulletins on national economic and social development of provinces in each year. The descriptive statistics of the variables are shown in Table 5.

Model Settings

This paper employed the panel fixed effects model to estimate the impact of industrial structure on the WPCE. The panel fixed effects model can reduce the error caused by time instability by controlling the inherent time-invariant factors between individuals. It also helps to reduce the bias and variance caused by missing variables, thereby improving the accuracy and reliability of the estimates. The following benchmark model is developed in this paper.

$$Y_{it}=\alpha_0+\alpha_1 tl_{it}+\alpha_2 ind_{it}+\alpha_3 C_{it}+u_i+v_t+\sigma_{it} \quad (4)$$

Table 5. Statistical description of variables.

Variable	N	Mean	Sd	Min	Max
WPCE	480	0.6059	0.2259	0.1627	1.0966
tl	480	0.2094	0.1579	-0.9759	0.8147
ind	480	1.2021	0.6696	0.5271	5.2440
lnrgdp	480	8.6536	0.8742	6.2134	10.3241
lnrgdp2	480	75.6472	14.7221	38.6064	106.5878
urbrate	480	0.5517	0.1401	0.2686	0.8958
engov	480	10.9996	1.1210	4.8195	13.3251
fdi	480	13.5679	1.7444	6.7108	16.3499
eff	480	2.1745	1.2446	0.6045	8.1415
fixar	480	0.7513	0.2808	0.2109	1.5965

Source: calculations by the authors.

Where: i denotes province or municipality; t denotes year; Y_{it} represents the dependent variable, that is, well-being performance of carbon emissions (WPCE); tl_{it} denotes industrial structure rationalization; ind_{it} denotes industrial structure advanced; C_{it} denotes a series of control variables; u_i denotes individual effect; v_t denotes time effect; σ_{it} represents the random error term.

Results

Baseline Regression Results

Before conducting the empirical analysis, unit root tests were conducted on the panel data to avoid pseudo-regression problems. Three tests, LLC method, IPS method and ADF-Fisher method, were used to conduct the unit root test, and the results are shown in Table 6.

In this paper, F test, LM test and Hausman test are used to select the appropriate panel data regression model, and the results are shown in Table 7. From the test results, F test, LM test and Hausman test all reject the original hypothesis, so the fixed effect model should be selected for empirical analysis.

Table 8 presents the results of panel regression of model (4). The main independent variables are industrial structure rationalization and industrial structure advancement. The first column of Table 8 does not add any control variables, and only controls the provincial fixed effect. The second column of Table 8 does not add control variables, control provinces and time fixed effect. Column 3 of Table 8 adds all control variables and only controls the provincial fixed effect. Column 4 of Table 8 adds all control variables and controls the provincial and time fixed effect. It can be seen from the regression results that: First, the impact of rationalization on the WPCE has not yet emerged at this

Table 6. Results of Unit Root Test.

Variables	LLC-P value	IPS-P value	ADF-Fisher-P value	Test results
WPCE	0.0000	0.0000	0.0000	Stable
tl	0.0106	0.0000	0.0000	Stable
ind	0.0000	0.0366	0.0000	Stable
lnrgdp	0.0000	0.0131	0.0000	Stable
lnrgdp2	0.0000	0.0286	0.0000	Stable
urbrate	0.0000	0.0109	0.0000	Stable
engov	0.0038	0.0000	0.0000	Stable
fdi	0.0000	0.0074	0.0000	Stable
eff	0.0000	0.0102	0.0000	Stable
fixar	0.0000	0.9017	0.0000	Stable

Source: calculations by the authors.

Table 7. F Test, LM Test and Hausman Test.

Type of inspection	Statistical quantities	P value
F test	38.4800	0.0000
LM test	1175.2118	0.0000
Hausman test	11.5754	0.2383
Robust Hausman test	14.4608	0.0000

Source: calculations by the authors.

stage. From the fourth column of Table 8, the regression coefficient of industrial structure rationalization is positive, which shows the reverse relationship between industrial structure rationalization and the WPCE. The reason may be that the rationalization level of industrial structure at this stage does not adapt to the change of the WPCE. Second, the upgrading of industrial structure has a positive impact on the WPCE. From the fourth column of Table 8, the advanced regression coefficient is positive and significant at the 10 % statistical level. In terms of economic significance, for every unit increase in the upgrading of industrial structure, the WPCE increases by 0.1241 units on average. This suggests that the higher the degree of advancedization, the higher the WPCE. The connotation of advanced industrial structure includes two aspects. The first is the change of industrial structure, which evolves from the dominance of primary industry to the dominance of tertiary industry, and from labor-intensive to capital-intensive to technology-intensive. This industrial evolution can improve production efficiency, reduce carbon emissions and enhance well-being.

Table 8. Baseline Regression.

Variables	(1)	(2)	(3)	(4)
tl	0.3406**	0.2269	0.1812**	0.1509*
	(-2.2907)	(-1.6981)	(-2.1738)	(-1.7397)
ind	0.1376***	0.1934***	0.1852***	0.1241*
	(-3.3128)	(-2.9570)	(-4.4661)	(-1.9105)
lnrgdp			-1.5472*	-1.6408*
			(-2.0124)	(-2.0117)
lnrgdp2			0.0778*	0.0934*
			(-1.7346)	(-1.9196)
urbrate			-0.2663	-0.8917*
			(-0.7635)	(-1.9470)
engov			0.0082	0.0006
			(-1.0609)	(-0.0561)
fdi			-0.0259***	-0.0186***
			(-3.6200)	(-2.8674)
eff			0.0012	0.0146
			(-0.0615)	(-0.6624)
fixar			-0.0250	-0.0004
			(-0.4794)	(-0.0064)
_cons	0.3692***	0.4502***	8.2688**	8.2892**
	(-5.1962)	(-5.4931)	(-2.4474)	(-2.3281)
Provincial fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	No	Yes	No	Yes
N	480	480	480	480
R^2	0.1389	0.2769	0.3192	0.3581
Adjusted R^2	0.1352	0.2503	0.3062	0.3242

Note: ***, **, * denote significance levels 1%, 5% and 10%; t-values in parentheses are based on clustering under robust standard errors, as below.

The second is the change of products, from low-end products to high-end products. Both the increase in the share of knowledge- and technology-intensive industries and the high technology and high value-added of each industry itself can have beneficial effects on local energy conservation, emission reduction and environmental protection. In terms of control variables, The regression coefficient of the real GDP is significantly negative, and the regression coefficient of the squared term of real GDP is significantly positive, indicating that the WPCE deteriorates and then improves with economic growth. The regression coefficient of urbanization rate is significantly negative at the 10% level, indicating that the higher the urbanization rate, the lower the WPCE. The reason may be that the more people congregate in cities and towns, the greater the traffic congestion and ecological stress, which will lead to a decrease in well-being performance. The regression coefficient for real foreign capital use is significantly negative at the 1% level, indicating that the level of well-being decreases further as foreign capital use increases. This may be due to the fact that the entry of foreign capital brings about the transfer of foreign polluting industries, which reduces the level of well-being. The other control variables are not significant.

Heterogeneity Analysis

The above has confirmed the impact of rationalization and upgrading of industrial structure on the WPCE, but for regions with different characteristics, is there heterogeneity in the effect? The research on this issue is helpful to understand the asymmetric impact of industrial structure on the WPCE, so as to provide a useful reference for the optimization and upgrading of industrial structure. On this basis, this paper further explores the heterogeneity of industrial structure and the WPCE in terms of region, natural resource endowment, external dependence and environmental awareness.

Different Regions[1]

Due to the different levels of development in various regions, the distribution of industries is also different.

Table 9. Heterogeneity Analysis-Investigation based on Different Regions.

Variables	(1) East	(2) Central	(3) West
tl	0.0842*	0.2700	0.1806
	(-1.9773)	(-0.6222)	(-1.4904)
ind	0.2143*	0.2309	-0.1026
	(-2.1236)	(-1.3012)	(-0.9123)
Control Variables	Yes	Yes	Yes
Provincial fixed effects	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes
N	176	128	176
R^2	0.4653	0.7142	0.5560
Adjusted R^2	0.3803	0.6476	0.4854

Therefore, it is necessary to analyze each region separately (see Table 9). Columns 1-3 of Table 9 show the regression results of rationalization and upgrading of industrial structure on the WPCE. From the regression results, only the industrial structure upgrading in the eastern region has a significant positive impact on the WPCE. The rationalization of industrial structure in the eastern, central and western regions has a negative impact on the WPCE, but it is not significant in the central and western regions. The high WPCE level of the eastern region may be due to its higher proportion of high-tech industries, that is, the high proportion of modern service industry in the tertiary industry. In contrast, the development of modern service industries in the central and western regions is relatively lagging. Furthermore, the good coordination between the optimization and upgrading of industrial structure, energy conservation and emission reduction, and well-being improvement in the eastern region has achieved balanced development among these three aspects, which is also a key reason for the higher WPCE level in the eastern region.

Natural Resource Endowment

The natural resource endowments of different regions are different, and the absorption capacity of carbon emissions will also be quite different, so the WPCE will also be different. This paper uses the logarithm of forest volume to represent the natural resource endowment of a region. According to the mean value of natural resource endowment, the total sample is divided into "high natural resource endowment area" and "low natural resource endowment area". Columns 1-2 of Table 10 show the regression result of rationalization and upgrading of industrial structure on the WPCE. From the regression results, the effect of rationalization of industrial structure on the WPCE is negative but still insignificant. The effect of upgrading

[1] The regions in this paper are divided as follows. The eastern region includes Beijing Municipality, Tianjin Municipality, Hebei Province, Liaoning Province, Shanghai Municipality, Jiangsu Province, Zhejiang Province, Fujian Province, Shandong Province, Guangdong Province, and Hainan Province. The central region includes Shanxi Province, Jilin Province, Heilongjiang Province, Anhui Province, Jiangxi Province, Henan Province, Hubei Province, and Hunan Province. Western region including Inner Mongolia Autonomous Region, Guangxi Zhuang Autonomous Region, Chongqing Municipality, Sichuan Province, Guizhou Province, Yunnan Province, Shaanxi Province, Gansu Province, Qinghai Province, Ningxia Hui Autonomous Region, Xinjiang Uygur Autonomous Region.

Table 10. Heterogeneity Analysis-based on natural resource endowment, external dependence and years of education.

Variables	Natural resource endowment		External dependence		Environmental awareness	
	(1) High	(2) Low	(3) High	(4) Low	(5) High	(6) Low
tl	0.0369	0.0699	0.0840*	0.3229*	0.0986	0.0756
	(-0.3415)	(-0.7546)	(-1.9492)	(-1.7850)	(-0.6054)	(-0.9709)
ind	-0.0637	0.2060*	0.1502**	-0.0433	0.1810***	0.0486
	(-1.2048)	(-1.7656)	(-2.3704)	(-0.5514)	(-3.6542)	(-0.4217)
Control Variables	Yes	Yes	Yes	Yes	Yes	Yes
Provincial fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
N	242	238	240	240	240	240
R^2	0.5907	0.3142	0.4374	0.5708	0.5002	0.6048
Adjusted R^2	0.5455	0.2370	0.3746	0.5229	0.4444	0.5606

of industrial structure on the WPCE in low natural resource endowment areas is positive and significant at the 10% statistical level, while the effect on high natural resource endowment areas is negative but insignificant. The reason may be that some regions with poor natural resource endowments are under greater pressure from local governments to meet policy targets after the introduction of the dual carbon target. As a result, local governments focus more on upgrading the local industrial structure with a view to bringing about better carbon reduction effects and well-being enhancement effects.

External Dependence

Different foreign trade structures determine different industrial structures and production methods in each region. This results in different levels of carbon emissions and therefore a certain degree of difference in the level of the WPCE. In this paper, the ratio of total imports and exports to GDP in the location of operating units is used to express the degree of foreign dependence. Based on the mean value of external dependence, the total sample is divided into two groups of "high external dependence regions" and "low external dependence regions". Columns 3-4 of Table 10 show the regression results of rationalization and upgrading of industrial structure on the WPCE. From the regression results, the effect of rationalization of industrial structure on the WPCE is negative, and significant at the 10% statistical level. The reason for this may be that China currently has a relatively large share of high energy consumption and high emission industries. The level of development of low carbon economy is relatively low, and the development of new energy, energy conservation and environmental protection fields has not yet been able to completely replace traditional energy-intensive industries. Therefore, although the industrial structure is becoming more rationalized, the WPCE has not been improved. The upgrading of industrial structure has played a significant role in promoting the WPCE in regions with high external dependence, and the impact on regions with low external dependence is negative, but not significant. The reason may be that regions with high external dependence mainly sell products to foreign markets and face competitive pressures from domestic and international markets. This competitive pressure forces the local industrial structure to upgrade to enhance its competitiveness in the international market. At the same time, more exposure to foreign markets will also introduce new foreign technologies. These factors objectively promote the improvement of local production efficiency, thus promoting the improvement of well-being level.

Environmental Awareness

People with high environmental awareness will pay more attention to environmental protection and low-carbon consumption, driving demand for low-carbon products and services and promoting low-carbon production methods. They will be more active in environmental protection activities and offer environmental opinions and suggestions to push the government to formulate and implement stricter environmental protection policies, impose stricter carbon emission limits and regulations on companies, and improve the WPCE. People with longer years of education usually have higher levels of knowledge and better understanding of environmental issues, and thus a stronger awareness of environmental protection. In light of this, in this paper, the years of education are used to express environmental awareness. Based on the mean value of years of education, the total sample is divided into two groups of "longer years of education regions" and "shorter years of education regions". Columns 5-6 of Table 10 show the regression results of rationalization and upgrading of industrial structure on the WPCE.

From the regression results, in areas with higher environmental awareness, the upgrading of industrial structure can have a positive impact on the WPCE.

Robustness Test

Endogenous Treatment

Although this paper controls for factors affecting the WPCE as much as possible, the level of well-being performance may also be influenced by factors such as religious beliefs, behavior manners, and customs, and there is the problem of omitted variables. In addition, there may be a two-way causal relationship between industrial structure and the WPCE. On the one hand, the rationalization and advanced industrial structure can promote carbon dioxide emission reduction and improve environmental quality, thus having a higher level of the WPCE. On the other hand, regions with higher WPCE are likely to have a better ecological environment and developed tourism, so that tertiary industries dominate the overall industry and thus the degree of industrial upgrading is high. Based on this, this paper chooses the lag first-order variable of industrial structure rationalization and advancement as the instrumental variable of IV-2SLS regression, and the regression results are shown in Table 11. From the regression results, the effectiveness of instrumental variables has been verified. After considering the endogenous problem, the coefficient direction of industrial structure rationalization and upgrading has not changed, so the impact of industrial structure optimization and upgrading on the WPCE is robust.

Replacement Variables and Model Methods

(1) Replace Dependent Variables

The regression results of the model may also be affected by the measurement of variables, so this paper uses the ratio method to re-measure the dependent variable. This study uses the data of China's provincial emission inventory published by CEADs (https://www.ceads.net.cn/data/province/). Since the latest is only published until 2019, the period of research data is 2005-2019. In order to eliminate the impact of population, the carbon emission data is divided by the population to obtain the per capita carbon emission data. Referring to the calculation method of Jorgenson [8], the CIWB is constructed as the explained variable. The CIWB is a negative indicator. The larger the value, the lower the well-being level. The smaller the value, the higher the well-being level. Specifically, we use the ratio method to calculate the CIWB, and the calculation formula is the CIWB = carbon emission/well-being level. Here, we use per capita carbon emissions (perceaco2) to represent the level of carbon emissions, and the well-being level is expressed by the average life expectancy (lexp). There is a problem when the ratio method is used for measurement. That is, when the coefficient of variation of the numerator and denominator are different, the whole ratio will be affected by the party with the larger coefficient of variation. In order to solve this problem, we refer to the method of Dietz et al. [15] and Jorgenson [8], and add a constant to the mean of the party with large coefficient of variation to make its coefficient of variation equal. In this paper, the standard deviation of per capita carbon emissions is 4.7184, the mean is 7.3735, and the coefficient of variation is 0.6399. The standard deviation of average life expectancy was 2.8059, the mean was 76.1328, and the coefficient of variation was 0.0369. Therefore, it can be seen that the coefficient of variation of the molecule is much larger than the denominator. In this paper, a constant 120.6514 is added to the mean value of the molecule, so that the coefficient of variation of the denominator is equal. The specific calculation formula is as follows.

$$CIWB = \frac{\text{perceaco2}+120.6514}{\text{lexp}} * 100 \tag{5}$$

The regression results are shown in column 1 of Table 12. It can be seen that the rationalization of industrial structure has a positive but not significant impact on the CIWB, which is similar to the previous regression results. The upgrading of industrial structure has a significant negative impact on the CIWB, which is the same as the previous regression results.

(2) Replace Independent Variables

The regression results of the model may also be affected by the measurement of variables, so this paper further replaces the measurement of core independent variables. The calculation method of industrial structure rationalization is calculated by referring to Han et al. [44], which is recorded as ia. where ia = 1/sr. The calculation formula of sr is as follows.

$$sr = \sum_{i=1}^{n} (\frac{Y_i}{Y}) \left| (\frac{Y_i}{L_i}) / (\frac{Y}{L}) - 1 \right| \tag{6}$$

Among them, Y represents output, L represents labor input, i represents the ith industrial sector, and n is the total number of industrial sectors. The larger the value, the more reasonable the industrial structure, the smaller the value, the more unreasonable the industrial structure.

The regression results after replacing the independent variable are shown in column 2 of Table 12. It can be seen that rationalization of industrial structure has a negative effect on the CIWB at the 10% level of significance. Advanced industrial structure has a significant negative effect on the CIWB, similar to the results of the previous regression.

(3) Transformation Model Approach

Since the minimum value of the dependent variable WPCE level in this paper is 0.1627 and the maximum value does not exceed 1.5. The dependent variable is

Table 11. Endogenous Test.

Variables	(1) First Stage	(2) Second Stage	(3) First Stage	(4) Second Stage
L.tl	0.4256**			
	(-2.0778)			
L.ind			0.8752***	
			(-32.3094)	
tl		0.2823***	-0.0432**	0.1385**
		(-3.0748)	(-2.0188)	(-2.2829)
ind	-0.0809***	0.1247***		0.1224***
	(-2.8660)	(-3.2984)		(-2.7281)
Control Variables	Yes	Yes	Yes	Yes
Provincial fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
K-P LM		28.378***		63.941***
		(0.0000)		(0.0000)
C-D Wald F		92.478		1498.848
N	450	450	450	450
R^2		0.2820		0.2960

Table 12. Robustness Test.

Variables	(1)	(2)	(3)	(4)	(5)
tl	-0.6659		0.1509*	0.1509***	0.1509***
	(-0.3588)		(-1.7850)	(-3.0474)	(-3.0474)
ia		-0.1679*			
		(-1.8216)			
ind	-3.3255**	-2.7945*	0.1241*	0.1241***	0.1241***
	(-2.1589)	(-1.9569)	(-1.9602)	(-3.8357)	(-3.8357)
Control Variables	Yes	Yes	Yes	Yes	Yes
Provincial fixed effects	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes
N	450	450	480	480	480
R^2	0.6506	0.6582			
Adjusted R^2	0.6317	0.6397			

restricted and has the characteristics of truncated data. Therefore, this paper uses tobit model for estimation. Also because the research data in this paper are panel data, the regression results of the panel tobit model are also presented together. The regression results are shown in Table 12. Column 3 of Table 12 shows the results of the pooled tobit model regression, column 4 the results of the panel tobit model regression, and column 5 the coefficients of the panel tobit model regression. From the regression results, the advanced industrial structure plays a significant role in improving the WPCE, while the rationalization of industrial structure decreases the WPCE. Similar to the previous conclusion. This indicates that the findings of this paper are robust.

Discussion

As the biggest developing country, China already ranks first in the world in carbon emissions.

This situation has seriously affected the construction of a regional ecological civilization and the sustainability of the country. Studying China's experience and practices has reference significance for other countries to conduct similar research and formulate policies. In general, the promotion of the WPCE needs to be supported by a certain industrial structure optimization and upgrading. The impact of the rationalization and upgrading of industrial structure on the WPCE is reflected in two main aspects: First, the rationalization and upgrading of industrial structure makes resources can be effectively utilized with less carbon emissions. Second, as the industrial structure continues to be rationalized and upgraded, the level of technology and management in the industry will continue to improve, which will promote rapid economic development and, in turn, improve people's income levels and quality of life.

The study's findings are consistent with previous research that indicates the positive impact of the rationalization and upgrading of industrial structure on carbon emissions [10, 12, 18]. The paper confirmed that the upgrading of industrial structure have a promotion effect on the WPCE, which is similar to the conclusion drawn by Hu et al. [25]. Hu et al. [25] suggests that industrial structure upgrading has a significant positive driving effect on ecological well-being performance. In contrast to the existing studies, first, this study uses the Super-SBM model to compute the WPCE index, avoiding the inadequacy of a single index system, and giving a comprehensive understanding of the index. Second, this paper mainly explores the impact of the rationalization and upgrading of industrial structure on the WPCE from the perspective of heterogeneity analysis, which expands the research depth of the WPCE and enriches the existing research content of the WPCE. The study's identification of the heterogeneous impact of industrial structure upgrading on the WPCE in different regions, natural resource endowments, external dependence, and environmental awareness highlights the need for policymakers and business leaders to develop tailored policies to promote sustainable economic development. Third, it is helpful to deepen the understanding of the evolution mechanisms of the WPCE to examine the rationalization and upgrading of industrial structure on the WPCE.

Admittedly, there are still some shortcomings in this study. Firstly, The study of the WPCE did not consider how social and economic conditions outside of economic development affect the WPCE. Identifying other social and economic conditions that may affect the WPCE may lead to more comprehensive and effective policies, promote social change, and steer humanity towards a more sustainable direction. Secondly, it should be noted that the study only utilized data from 30 provinces in China, thus limiting its representativeness for the entire country. Furthermore, there could be region-specific or province-specific factors that were not accounted for in the study. Future research could benefit from using a larger sample size and more comprehensive data to address these limitations. In addition to the study of the WPCE and industrial structure, future research will consider how other factors, such as national regulatory conditions, the form of global economic integration, and gender inequality, affect the WPCE. Nevertheless, optimizing industrial structure can increase the WPCE, providing a pathway to enhance sustainability.

Conclusions and Recommendations

For a long time, the relationship between economic activities and the environment has been researchers' concern. Currently, this relationship is attracting more attention due to the increasingly serious issue of climate change. As industrial development is closely related to economic activities, considering the relationship between industrial development and the environment is crucial for achieving sustainable development goals. Literature reports a large number of studies on sustainable economics. Unfortunately, as a carbon emitting country, the investigation of the relationship between changes in China's industrial structure and the WPCE has not received due attention. Therefore, this paper attempts to explore the impact of China's rationalization and upgrading of industrial structure on the WPCE. This paper aims to enhance our comprehension of the relationship between the rationalization and upgrading of industrial structures and human well-being.

In this paper, based on provincial panel data from 2005 to 2020 in China, we construct a Super-SBM model to compute the WPCE index and use a fixed effect panel model to examine the impact of the rationalization and upgrading of industrial structure on the WPCE. The overall findings expose the positive fact that the performance of Chinese provinces is encouraging from a sustainability perspective. The conclusions are as follows: (1) The rationalization of industrial structure at this stage has not yet had a significant impact on the WPCE, and even has a negative effect. (2) The upgrading of industrial structure can significantly promote the WPCE. In terms of economic significance, for each unit increase in the upgrading of industrial structure, the WPCE increases by 0.1241 units on average. (3) The impact of upgrading of industrial structure on the WPCE is heterogeneous in different regions, different natural resource endowments, different external dependence and different environmental awareness. Upgrading only plays a significant role in promoting the WPCE in the eastern region, low natural resource endowment regions, high external dependence regions and high environmental awareness regions.

Based on the research conclusions of this paper, the following suggestions are put forward:

(1) Provinces should vigorously improve the level of industrial rationalization and upgrading, and promote the improvement of regional WPCE. From the empirical results, the upgrading of industrial structure

plays a significant role in promoting the WPCE, so it is necessary to speed up the pace of upgrading of industrial structure in various provinces. On this basis, we should pay attention to the proportion of industries within and between industries, and realize the coordination and cooperation between the rationalization and upgrading of industrial structure, so as to give full play to the effect of carbon emission reduction and energy saving. At the same time, the government should also strengthen the guidance and support of companies, so as to promote the high-quality development of local industries.

(2) Different regions should combine the situation of their own industrial development and formulate industrial optimization and upgrading policies suitable for their own development characteristics. The industrial development in the eastern region is relatively mature, with a high proportion of high-tech industries. Therefore, it should actively engage in independent innovation, research and develop new clean technologies and promote their use. On the other hand, the economy in the central and western regions is relatively backward, and it should learn to play to its strengths and avoid weaknesses. The region should actively introduce new technologies, learn more from the eastern region, and strengthen cooperation with technologically advanced companies. The government can encourage the development of environmentally friendly and low-carbon industries through tax breaks, government subsidies, or creating a favorable investment environment and market mechanisms. At the same time, it can gradually phase out high-energy-consuming and highly-polluting industries. In addition, the government can strengthen cross-regional coordination in industrial structure development. Through inter-regional industrial coordination, it can optimize resource allocation, promote the upgrading and transformation of industrial structure, reduce carbon emissions and improve the WPCE.

(3) From the perspective of rationalization and upgrading of industrial structure, for regions with good natural resource endowments, the WPCE can be improved by strengthening the development of low-carbon industries. For example, the government can implement policies to support the development of new energy industries such as solar, wind, and hydropower, and encourage companies to adopt energy-saving and environmentally friendly technologies to reduce carbon emissions. This not only improves the WPCE but also promotes sustainable economic development in the local area. For regions with poor natural resource endowments, the WPCE can be improved through the upgrading of industrial structure. For example, regions can develop tourism and cultural and creative industries with local characteristics based on their unique geographical, ecological, and cultural resources. They can gradually reduce the proportion of high-energy-consuming and highly-polluting industries, improve the rationalization level of the industrial structure, reduce carbon emissions, and ultimately enhance the WPCE.

(4) In order to better cope with market competition, regions with high external dependence also need to strengthen the cultivation and development of the region's special industries and improve the added value and brand value of the industries. At the same time, companies should improve quality and efficiency in the export-oriented economy and actively learn external advanced technologies and systems. Regions with low external dependence should also actively learn from the experience of advanced regions and optimize and upgrade their own industrial structures to gain greater competitive advantages. Meanwhile, regions with low external dependence can increase external exchanges and cooperation, thus gaining access to high-quality resources, technical support and market development opportunities, and accelerate their industrial upgrading to improve the WPCE.

(5) From an educational standpoint, for regions with shorter education periods, the government can improve the WPCE by promoting education, providing more public services, and encouraging and supporting local businesses to implement energy-saving and emission-reduction measures. For example, by increasing support for promoting energy-saving and environmentally friendly high-quality products in the local market to drive the transformation and upgrading of local industries; providing technical support and training for local companies to improve their environmental awareness and technical level. For regions with longer education years, their residents generally have higher cultural literacy and pay more attention to environmental protection and sustainable development. Therefore, the WPCE can be improved by introducing more advanced, green, and low-carbon new technologies and industries. For example, the government can attract foreign investment and high-quality talents through policies and tax incentives to promote the rapid development of high-tech, high-value-added, and low-carbon industries. They can also strengthen the construction of smart environmental protection and green development think tanks, especially in collaboration with higher education institutions, to promote well-being enhancement.

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Conflict of Interest

The authors declare no conflict of interest.

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