sustainability

Article

Industrial Structure Optimization and Low-Carbon Transformation of Chinese Industry Based on the Forcing Mechanism of CO_2 Emission Peak Target

Feng Wang [1], Changhai Gao [1,*], Wulin Zhang [2] and Danwen Huang [1]

[1] School of Economics and Finance, Xi'an Jiaotong University, Xi'an 710061, China; wangfeng123@xjtu.edu.cn (F.W.); huangdanwen1@163.com (D.H.)
[2] School of Management, Xi'an Jiaotong University, Xi'an 710061, China; zwlwoaiwojia1@163.com
* Correspondence: gychl1998@stu.xjtu.edu.cn

Abstract: The setting of a CO_2 emission peak target (CEPT) will have a profound impact on Chinese industry. An objective assessment of this impact is of great significance, both for understanding/applying the forcing mechanism of CEPT, and for promoting the optimization of China's industrial structure and the low-carbon transformation of Chinese industry at a lower cost. Based on analysis of the internal logic and operation of the forcing mechanism of CEPT, we employed the STIRPAT model. This enabled us to predict the peak path of China's CO_2 emissions, select the path values that would achieve the CEPT with the year 2030 as the constraint condition, construct a multi-objective and multi-constraint input/output optimization model, employ the genetic algorithm to solve the model, and explore the industrial structure optimization and low-carbon transformation of Chinese industry. The results showed that the setting of CEPT will have a significant suppression effect on high-carbon emission industries and a strong boosting effect on low-carbon emission industries. The intensity of the effect is positively correlated with the target intensity of the CO_2 emissions peak. Under the effect of the forcing mechanism of CEPT, Chinese industry can realize a low-carbon transition and the industrial structure can realize optimization. The CEPT is in line with sustainable development goals, but the setting of CEPT may risk causing excessive shrinkage of basic industries—which should be prevented.

Keywords: CO_2 emission peak target; industrial structure; forcing mechanism; low-carbon transition; sustainable development

Citation: Wang, F.; Gao, C.; Zhang, W.; Huang, D. Industrial Structure Optimization and Low-Carbon Transformation of Chinese Industry Based on the Forcing Mechanism of CO_2 Emission Peak Target. *Sustainability* **2021**, *13*, 4417. https://doi.org/10.3390/su13084417

Academic Editor: Ali Bahadori-Jahromi

Received: 24 March 2021
Accepted: 12 April 2021
Published: 15 April 2021

1. Introduction

At the general debate of the 75th session of the United Nations General Assembly, Chinese President Xi Jinping solemnly proposed that China would "aim to have CO_2 emissions peak before 2030 and achieve carbon neutrality before 2060". Can China achieve the CEPT (CO_2 emission peak target)? If so, how? This issue has been explored widely in existing literature [1–4]. It has been accepted that the key to achieving the CEPT is to reduce the use of fossil energy—but fossil energy is still the mainstay of China's energy structure. Although there is indeed a decoupling phenomenon between fossil energy and economic growth in many cases, the results of many studies have shown that, in China, the decoupling has mainly manifested as negative or weak [5–7]. Therefore, there is a positive correlation between economic growth and CO_2 emissions [8]. It can be expected that the implementation of CEPT will have a significant impact on Chinese industry, as the CO_2 emissions of China's industrial sector account for more than 80% of those of the country [9,10]. Industry is not only a major carbon emitter, but also the backbone of the country's economy. It is the key to achieving the CEPT, and is also the foundation for China to develop a well-off society and a strong modern country. Can the setting of CEPT force the low-carbon transformation of Chinese industries? How will Chinese industrial structure evolve? Is the CEPT compatible with—or deviating from—sustainable development goals? The United Nations Sustainable Development Summit established 17 global sustainable development goals (SDGs). In this paper, sustainable development goals refer to "urgent action to address climate change and its impacts in order to promote sustainable development of ecology and economic growth". Unless otherwise stated, the term refers to this meaning. In this key period of building China into a prosperous, strong, democratic, civilized, harmonious, and beautiful modern socialist country, the in-depth discussion of the above issues is of great practical significance.

In fact, the setting of CEPT must result in the use of a forcing mechanism to effect Chinese economic transition [11]. As a reverse operating economic governance mechanism, the forcing mechanism is often used to solve problems encountered in the process of China's reform and opening-up. Du [12] put forward the forcing mechanism of CEPT, but did not discuss the connotation, characteristics, internal logic, or operational mechanisms of which it consisted. In the retrieved literature, there was no study on the low-carbon transition of Chinese industry based on the forcing mechanism of CEPT. Understanding of the forcing mechanism of CEPT is still at an empirical level, and the internal logic and operating mechanisms remain to be explored. Few studies have explored the low-carbon transition of Chinese industries based on this forcing mechanism—which will prevent policymakers from weighing the pros and cons of setting the CEPT, failing to identify the risks, or making decisions based on uncertainties about whether the Chinese economy can achieve a smooth low-carbon transition. This will require policy makers to set aside the overall situation and focus on the CO_2 emissions peak, which may be dilemma.

In view of these factors, the present study analyzed the internal logic and operating mechanism of the forcing mechanism of CEPT, employed the STIRPAT model to predict the peak path of China's CO_2 emissions, selected the path values that would achieve the CEPT (with the year 2030 as the constraint condition), constructed a multiobjective and multiconstraint input-output optimization model, and employed the genetic algorithm to solve the model in three scenarios. Additionally, we incorporated the CEPT into the strategy of sustainable development, deduced the low-carbon transformation paths of Chinese subdivided industries, identified the risks associated with the process of low-carbon transformation, and examined compatibility between the CEPT and sustainable development goals.

The innovations of this paper are as follows: (1) This is the first study to explore the internal logic and operating mechanism of the forcing mechanism of CEPT. At present, the understanding of the forcing mechanism of CEPT is still at an empirical level, and its internal logic and operating mechanisms are still under exploration. Examining the internal logic and operating mechanisms of the forcing mechanism of CEPT is not only an extension of related research on the forcing mechanism, but also the basis for in-depth understanding and application of this mechanism. (2) The genetic algorithm was used innovatively to optimize the evolutionary path of Chinese industrial low-carbon transformation. The genetic algorithm is used to achieve global optimal solutions, and it is widely applied to optimization problems. Previous studies have used the genetic algorithm to solve the optimization problem of industrial structure, but until the present work, it had not yet been employed to optimize the path of Chinese industrial low-carbon transformation based on the forcing mechanism of CEPT (based on a review of retrieved literature). (3) We deduced the evolutionary trajectory of Chinese subdivided industries, and provided an early warning for the risk of excessive shrinkage of basic industries—a complication that may arise during the low-carbon transformation. Previous studies have mostly discussed the impact of environmental regulations on the Chinese economy and industrial structure from the perspective of so-called primary, secondary and tertiary industries. In contrast, we focused on the evolution of subdivided Chinese industries, such that the evolutionary path of the proportion of the added value of each subdivided industry accounted for that of the entire industry.

The structure of the rest of this paper is as follows: the second part contains a literature review and mechanism analysis; the third part goes over model construction; the fourth part covers data processing and parameter calculations; the fifth part details optimization results and analysis; the sixth part contains research conclusions and policy implications.

2. Literature Review and Mechanism Analysis

2.1. Literature Review

Since the CEPT was proposed, academics have conducted extensive discussions on how to achieve this target. Opinions in the existing literature generally agree that if certain emission reduction measures are taken, China could achieve the CEPT around 2030 [13–15]. Promoting technological progress [16–19], reducing CO_2 emission intensity [20], adjusting industrial structure [21,22] or energy structure [23–25], and establishing CO_2 emission trading mechanisms [26,27] are considered the main measures required to achieve the CEPT. In general, the logic of these researches is a line type positive thinking (as opposed to reverse thinking) that about what measures can be taken to achieve the CEPT. However, many studies failed to realize that the time frame in which the peak could be achieved was demonstrated before the CEPT was even proposed as a strategic target. Based on reverse thinking, it may be more urgent and necessary to examine the impact of CEPT on the future economy.

Current research on the impact of CEPT on the economy has mainly focused on environmental regulations. For example, Wang and Zou [28] showed that the average annual loss of gross domestic product (GDP) between 2013 and 2033 would amount to 5.92% and the average annual loss of employment would amount to 8.23% when China's CO_2 emissions peak in 2025. By constructing a Computable General Equilibrium modeling (CGE model), Wang et al. [29] assessed the impact of achieving the CEPT in 2025, 2030, and 2035, respectively, on Chinese economic growth. Their study showed that 2030 would be the best time for China's CO_2 emissions to reach their peak. The negative impact on the Chinese economy would be greater if CO_2 emissions peaked earlier; the earlier the peak, the greater the economic losses. CEPT can thus be considered a double-edged sword. Achieving the CEPT will come at a significant economic cost, in the short term. Regarding the issue that environmental regulations force the optimization and upgrading of industrial structures, the existing research has generally concluded that environmental regulations have a positive forcing effect on industrial structure adjustment [30,31]. The level of the forcing mechanism effect depends on economic differences between regions and the strength of environmental regulations [32,33]. However, the industrial structure that these literatures focused on mostly consisted of primary, secondary and tertiary industries, with little research on subdivided industries. More importantly, few studies focused on the compatibility between the CEPT and sustainable development goals—or the economic risk caused by the CEPT.

In fact, the setting of CEPT will facilitate policies to reduce emissions. These policies will inevitably create a forcing mechanism for Chinese low-carbon transformation. The forcing mechanism was first proposed by Zhong [34] in his book "Inflation Research of China". Zhong described it as a bottom-up money supply expansion process. On this basis, Ji [35], Yu and Sun [36] analyzed the reasons for formation and the countermeasures of the forcing mechanism in China's credit relations. After that, some scholars expanded the forcing mechanism to include the perspectives of logical reasoning [37], the governance of social contradictions [38,39], and population aging forcing economic transformation [40]. Wang and Yang [11] reviewed previous research on the forcing mechanism and concluded that the forcing mechanism was a reverse operating economic governance mechanism. This means that when dilemmas and contradictions emerge in the process of economic and social development, the government first sets reform targets, and then formulates a series of policies to change the external conditions of economic entities. These changes force microeconomic entities to adjust their preferences and action strategies, and choose the paths that are most favorable to their long-term development and society's interests as a whole. Du proposed the forcing mechanism of CEPT based on previous research [12], but did not discuss its connotation, characteristics, internal logic, or operating mechanisms. In the retrieved literature, there were few studies on the low-carbon transition of Chinese subdivided industries based on the forcing mechanism of CEPT.

Generally speaking, since the CEPT was proposed, academics have conducted extensive discussions on how to achieve this target. However, based on reverse thinking, it is necessary to conduct further in-depth research on the impact of the forcing mechanism of CEPT on the Chinese economy and the low-carbon transition of Chinese industry. In particular, the theory of the forcing mechanism of CEPT is still unexplored, and its connotations, characteristics, internal logic, and operating mechanisms need to be further elucidated and expanded.

2.2. Mechanism Analysis

2.2.1. Theoretical Basis of the Forcing Mechanism of CEPT

The Theory of Constraints and the Porter Hypothesis form the theoretical basis of the forcing mechanism of CEPT. It is well known that the negative externalities of enterprise production activities bring higher social costs. For example, air and water pollution—caused by enterprise production activities—seriously endangers human health and poses a serious threat to the natural environment on which human beings depend. In order to mitigate or compensate for this harm, society must pay a higher cost. Internalizing the negative externalities of enterprise production activities is one way to combat this problem. However, the Theory of Constraints and the Porter Hypothesis have fundamentally different views on the internalization of negative externalities of corporate production activities. According to the Theory of Constraints, the internalization of negative externalities in enterprises' production activities will have a negative impact on enterprise development under the influence of environmental regulations. Specifically, the setting of CEPT will subject companies to environmental regulatory policies, such as resource taxes, environmental taxes, technical standards, and tradable permits. These policies will cause higher production costs for enterprises, due to the increase in price of pollution-type production factors and the commensurate increase in pollution control costs. Therefore, the company's CO_2 emission reduction behavior will occupy the company's production resources—i.e., human, financial, and material resources—and the crowding out effect will restrict the company's expansion. According to the Theory of Constraints, the setting of CEPT will lead to a decline in the competitiveness of enterprises, and ultimately force high-carbon emission industries to transform, migrate, or withdraw. However, the Porter Hypothesis posits that the relationship between environmental regulation and corporate competitiveness is complementary rather than mutually exclusive. According to the hypothesis, appropriate environmental regulations will stimulate enterprises to carry out technological innovation, resource allocation, and optimization. These activities, in turn, will bring innovation compensation effects and the first mover advantage to enterprises. These advantages can partially or even completely offset the resources used, environmental costs, and pollution control costs. They can also lead enterprises to higher production efficiency and competitive advantages. According to the Porter Hypothesis, the setting of CEPT will force companies to carry out technological innovation, and ultimately achieve the optimization and upgrade of the production structure.

2.2.2. The Internal Logic and Operating Mechanism of the Forcing Mechanism of CEPT

CO_2 emission space has become a scarce commodity in production under the constraints of CEPT. The CO_2 emission rights derived from CO_2 emission space have become a tradable medium. The fluctuations in the price of CO_2 emission rights and changes in corporate pollution control costs directly determine the profitability of companies. The flow of CO_2 emission rights between industries has a significant inhibitive or expansive effect on industrial development. Based on this understanding, we explored the internal logic and operating mechanisms of the forcing mechanism of CEPT from three levels: the central government, local governments, and enterprises.

The central government proposed CEPT based on China's capacity for resources, ecological environment, and future economic development. On one hand, the CEPT is disbursed to local governments through an environmental assessment. On the other hand, GDP-based assessment methods of local governments are transformed, and the assessment of green development, environmental quality, and ecological protection are given relatively high weights. This transformation plays an important role in motivating and ensuring that local governments meet or exceed the established CO_2 emission reduction target.

Local governments establish their emission reduction plans based on tasks assigned by the central government in combination with their own capacity and economic conditions. Then, local governments comprehensively use administrative and economic means to change external conditions, such as resource and environmental costs. Changes in the external environment will force microeconomic entities to make adjustments in line with the developmental trends of industrial technology, changes in the structure of social demand, and changes in resource structure. At the same time, local governments revise the market exit and access mechanisms for incumbent and potential entrants, change the barriers to entry, and increase the difficulty of approval for high-carbon emission industries. A strict market exit mechanism can actively guide the orderly transfer or exit for high-carbon emission industries, and a reasonable market access mechanism can help promote the rationalization of regional industrial layout and the advancement of industrial structure.

The selective behavior of enterprises forms a micro-foundation for the low-carbon transformation of industries. As local governments adjust the cost of resources, the market exit mechanism, and the market access mechanism, the price of pollution-type production factors and pollution control costs will rise. This will squeeze the demand and profitability space of enterprises. With local governments increasing their pressure on environmental assessment, enterprises must adjust their production and operations to maximize their interests. This means adjusting production structures, optimizing investment directions, and increasing technological innovation. In the end, under the effects of the market and price mechanisms, the forcing mechanism of CEPT is gradually formed through the transformation, upgrading, migration, or exit of high-carbon emission enterprises—and the expansion or entry of low-carbon emission enterprises.

Based on the above analysis, the internal logic and action path of the forcing mechanism of CEPT are shown in Figure 1.

The forcing mechanism of CEPT is a reverse operating economic governance mechanism. That means, essentially, that the government proposes CEPT, then uses administrative and economic means—such as amending market exit and access mechanisms—to change the external conditions (e.g., resource and environmental costs) and industry access threshold. Ultimately, under the influence of the competition and price mechanisms, enterprises will realize that the industry will only allow the survival of the fittest (i.e., innovative and low-carbon) enterprises, and the industry will undergo a low-carbon transformation. A supporting point for the forcing mechanism of CEPT to exert its reversal effect is the adjustment of economic interests, and its basis is the change of profit margins. Its essence is to better play the decisive role of the market in resource allocation under indirect government regulation.

2.2.3. The Connotation and Characteristics of the Forcing Mechanism of CEPT

The forcing mechanism of CEPT has an obvious overall layout. It is results-oriented and based on survival of the fittest. The overall layout requires the CEPT to be determined based on the overall regional environmental capacity and CO_2 emission space. According to the CEPT, the government would formulate emission reduction policies, as well as market access and exit mechanisms, to ensure that economic activities can be carried out more rationally. Results-oriented denotes that the government should not be concerned with whether enterprises meet established emission reduction standards, but whether their total emissions in the specified space-time range meet the established target. If an enterprise fails to achieve its targets, it will be punished or shut down directly; the actual process of achieving the targets is not the focus. Survival of the fittest refers to the fact that even if the CO_2 emissions of an enterprise meet the requirements of environmental regulations, it may be forced out, due to the limited environmental capacity of the region it inhabits. Therefore, the forcing mechanism of CEPT also includes a competition mechanism, preferentially selecting the best enterprises.

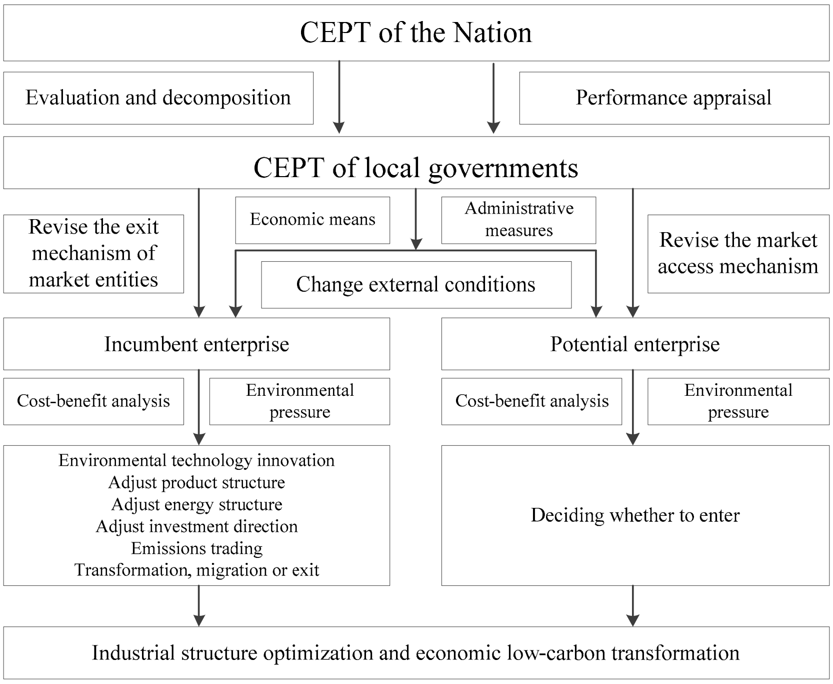

Figure 1. The internal logic and action path of the forcing mechanism of the CO_2 emission peak target (CEPT).

3. Modeling Building

3.1. Objective Function

In order to give consideration to the dual targets of economic growth and peak CO_2 emissions in the process of constructing the multiobjective and multiconstrained input-output optimization model, we set the goals of industrial structure optimization as: (i) maximizing industrial added value and (ii) minimizing CO_2 emissions.

3.1.1. Maximizing Industrial Added Value

Considering the fact that China is still a developing country, we took the maximization of annual industrial added value as the primary objective function and expressed it as:

$$\max G(x_t) = \sum_{j=1}^{n} x_{j,t}\left(1 - \sum_{i=1}^{n} a_{ij,t}\right) \tag{1}$$

Here, $G(x_t)$ is the accounting function of industrial added value in year t, $x_{j,t}$ is the total output of industry j in year t, $a_{ij,t}$ is the direct consumption coefficient of industry j in year t, and $x_{j,t}\left(1 - \sum_{i=1}^{n} a_{ij,t}\right)$ is the added value of industry j in year t.

3.1.2. Minimizing CO_2 Emissions

We discussed the optimization of industrial structure under the forcing mechanism of CEPT, so the minimization of annual industrial CO_2 emissions was taken as the second objective function and expressed as:

$$\min C(x_t) = \sum_{j=1}^{n} c_{j,t} x_{j,t} \left(1 - \sum_{i=1}^{n} a_{ij,t}\right) \tag{2}$$

Here, $C(x_t)$ represents the accounting function of the total CO_2 emissions of all industries in year t, and $c_{j,t}$ is the CO2 emissions per unit value-added of industry j in year t. We assume that the $c_{j,t}$ from 2017 to 2030 continues the trend of change from 2000 to 2016.

3.2. Constraints

3.2.1. Constraints on Industrial Production Capacity

Economic scale has a positive impact on CO_2 emissions. The larger the scale of industry output, the greater the CO_2 emissions. Therefore, the reduction of CO_2 emissions in industries will inevitably have a negative impact on the output levels if the energy structure cannot be greatly improved. For the sake of the stable growth of the Chinese economy, the industrial production capacity of industries should be kept within a stable range; effort should should be undertaken to avoid large fluctuations. Based on this, we set the constraints of the industrial production capacity of industries in t+1 as:

$$P_1 x_{j,t} \geq x_{j,t+1} \geq P_2 x_{j,t} \tag{3}$$

Here, $P_1 > 1 > P_2$, P_1 and P_2 represent the upper and lower limits of the production capacity growth rate. The related literature suggests that P_1 and P_2 are usually 1.2 and 0.8, respectively [41,42]. However, we believe that, under the strong constraints of CEPT, local governments will be more inclined to encourage high-tech and low-energy consumption industries—and likewise to restrict high-energy consumption and high-polluting industries. Therefore, the upper and lower limits are set at 1.1 and 0.85, respectively, for high-energy consuming industries (e.g., mining, quarrying, petroleum, steel, chemical, and power), 1.15 and 0.9, respectively, for light industry and manufacture of textile, and 1.25 and 0.95, respectively, for the electromechanical industry.

3.2.2. Constraints on Economic Growth

The expansion of economic scale is one of the main reasons for the growth of CO_2 emissions. Promoting the CEPT will have a certain impact on economic growth. In order to balance economic growth and CO_2 emission reduction targets, it will be necessary to limit the growth rate of added value of industry to ensure the stable development of the social economy. The constraints can be expressed as:

$$\sum_{j=1}^{n} x_{j,t} \left(1 - \sum_{i=1}^{n} a_{ij,t}\right) \geq (1 + r_t) \left[\sum_{j=1}^{n} x_{j,t-1} \left(1 - \sum_{i=1}^{n} a_{ij,t-1}\right)\right] \tag{4}$$

Here, r_t represents the growth rate of industrial added value in year t. According to the data released by the ministry of industry and information technology, the growth rate of Chinese industrial value-added in 2017 was 6.4%, while the growth rate in 2018 was 6.2%. Both of these were lower than the growth rate of GDP in the corresponding years. Bai et al. [43] believed that China's GDP growth rates would be 6.28%, 5.57%, and 4.82%, respectively, for each of the periods of 2016–2020, 2021–2025, and 2026–2030. Li et al. [44] thought that the GDP growth rates would be 6.4% in 2016–2020, 5.6% in 2021–2025, and 4.9% in 2025–2030. According to these estimates, we set the industrial value-added growth rates of the industrial sector as 6.2% in 2019–2020, 5.5% in 2021–2025, and 4.5% in 2026–2030.

3.2.3. CO_2 Emissions Constraints

The setting of CEPT in China will inevitably constrain economic activities. Meeting the target goals will require annual CO_2 emissions to be minimized as much as possible, but this value cannot exceed the value of predicted CO_2 emissions on the path to peak in 2030. Therefore, the constraints of annual CO_2 emissions can be set as:

$$\overline{C}_t \geq \sum_{j=1}^{n} c_{j,t} x_{j,t} \left(1 - \sum_{i=1}^{n} a_{ij,t}\right) \tag{5}$$

Here, $\overline{C}_t$ represents the upper limit of CO_2 emissions in year t, which is the value on the path of predicted CO_2 emissions peak.

3.2.4. Non-Negative Constraints

Decision variable X_t represents the output level of each industry—and these variables cannot be less than zero due to their economic significance, so they are set as constraints:

$$X_t \geq 0 \tag{6}$$

3.3. Genetic Algorithm

In this paper, we used a genetic algorithm to optimize the simulation of a multiobjective and multiconstrained input-output model. A genetic algorithm (GA) is a random searching algorithm based on natural selection and genetic theory. A GA achieves a global optimal solution by applying the adaptive rules of biological evolution and the random information exchange mechanism of chromosomes within the group. The principle of a genetic algorithm is to treat a feasible solution as an individual or chromosome in the group. Each individual is recorded and converted into a corresponding string. The artificial evolution means are employed to randomly and repeatedly simulate the biological evolution processes, e.g., replication, crossover, and mutation. After each iteration, the individuals are evaluated, selected, and eliminated by the preset target fitness function. Finally, a global parallel search method is used to find the optimal individual. The genetic algorithm solves the problem of vector minimization. If the objective function is to solve the maximum value, the objective function needs to be transformed into a minimization problem. Therefore, it is necessary to transform the objective function "maximizing industrial added value" into a minimization problem in this paper.

In the process of solving the multiobjective optimization model, if a certain solution is better than all other feasible solutions, it is called the optimal solution. If the optimal solution cannot be found to make each objective function reach the best result, the Pareto optimal solution is the best choice. Referring to the study of Niu and Jiang [45], we set the relevant parameters of the genetic algorithm, as shown in Table 1:

Table 1. The parameters and values of the genetic algorithm.

Parameters	Description	Value
Popsize	The size of the population	100
Maxgen	The maximum evaluation generation	80
p_c	The probability of crossover	0.9
n_c	The cross distribution parameter	20
p_m	The probability of mutation	0.1
n_m	The mutation distribution parameter	80

In order to better simulate policy decisions, we set three scenarios: economic growth as priority, CO_2 emission reduction as priority, and equal importance of these two objectives. The preference of policymakers was converted into the weight coefficient of the objective function, and the optimization path of the Chinese industrial structure was investigated. In order to explore the differences in the impact of different CO_2 emission target intensities on economy, we used the weight coefficient of minimization of CO_2 emissions to express the strength of the target. The weight settings of the three scenarios are shown in Table 2.

Table 2. Three scenarios division and objective function weight setting.

Scenarios	Preference Description	Ranking Rule	Weight (w_1,w_2)
A	Economic growth priority	$fit_1 \succ fit_2$	(0.75,0.25)
B	CO_2 emission reduction priority	$fit_2 \succ fit_1$	(0.25,0.75)
C	Equal important of the two objectives	$fit_1 \approx fit_2$	(0.5,0.5)

4. Data Processing and Parameter Calculation

4.1. Industry Classification

According to the *Classification of National Economic Industries (GB/T4754-2011)*, we referred to the classification method of previous studies, excluded support activities for mining, mining of other ores, other manufacture, utilization of waste resources, repair services of metal products, machinery and equipment, and divided the subindustry into eight representative industries. The detailed information of classification is summarized in Table 3.

Table 3. Detailed information on industry classification.

Industry	Sub-Industry
Mining and Quarrying	Mining and washing of Coal; Extraction of Petroleum and Natural Gas; Mining and Processing of Ferrous Metal Ores; Mining and Processing of Non-Ferrous Metal Ores; Mining and Processing of Nonmetal Ores
Light Industry	Processing of Food from Agricultural Products; Manufacture of Foods; Manufacture of Liquor, Beverages and Refined Tea; Manufacture of Tobacco; Processing of Timber, Manufacture of Wood, Bamboo, Rattan, Palm, and Straw Products; Manufacture of Furniture; Manufacture of Paper and paper Products; Printing and Reproduction of Recording Media; Manufacture of Articles for Culture, Education, Arts and Crafts, Sport and Entertainment Activities
Manufacture of Textile	Manufacture of Textile; Manufacture of Textile, Wearing Apparel and Accessories; Manufacture of Leather, Fur, Feather and Related Products and Footwear
Petroleum Industry	Processing of Petroleum, Coking and Processing of Nuclear Fuel
Chemical Industry	Manufacture of Raw Chemical Materials and Chemical Products; Manufacture of Medicines; Manufacture of Chemical Fibers; Manufacture of Rubber and Plastics Products; Manufacture of Non-metallic Mineral Products
Steel Industry	Smelting and Pressing of Ferrous Metals; Smelting and Pressing of Non-ferrous Metals; Manufacture of Metal Products
Electro-Mechanical Industry	Manufacture of General Purpose Machinery; Manufacture of Special Purpose Machinery; Manufacture of Automobiles; Manufacture of Railway, Ship, Aerospace and Other Transport Equipments; Manufacture of Electrical Machinery and Apparatus; Manufacture of Computers, Communication and Other Electronic Equipment; Manufacture of Measuring Instruments and Machinery
Power Industry	Production and Supply of Electric Power and Heat Power; Production and Supply of Gas; Production and Supply of Water

4.2. Data and Parameters

The input-output data used in this paper came from the Input-Output Tables of China. The industry energy consumption data came from the China Energy Statistical Yearbook, and the industrial value-added data came from the Statistical Yearbook of China and China Industrial Statistical Yearbook in corresponding years. Parts of the missing value-added data were based on the adjustment method of Chen [46]. The Input-Output Tables of China were updated to 2017. To verify the credibility of the RAS method, the direct consumption coefficient in the input-output table in 2017 should be compared with that in 2017, estimated by the RAS method and based on the direct consumption coefficient in input-output tables of 2010 and 2015. Therefore, we took the historical year range 2000–2016 and the forecast year range as 2017–2030. The value-added data over the years was adjusted to the constant price in 2000. In the process of solving the model, some parameters were regarded as known quantities, so these parameters needed to be determined first. We assumed that the technological progress from 2017 to 2030 would continue the trend of change from 2000 to 2016. The exogenous variables involved in the model were projected based on data from 2000 to 2016, including the CO_2 emissions per unit of value-added ($c_{j,t}$). As future demand was difficult to predict, we did not consider market demand and other nonquantifiable factors as independent variables or constraints in the optimization model. The basic assumptions of the input-output model were also valid in this paper. For example, we supposed that a sector produced specific homogeneous products and a constant return to scale. The meanings and the prediction methods of parameters are listed in Table 4.

Table 4. Parameter meanings and prediction methods.

Parameters	Meanings	Prediction Methods
A_t	Direct consumption coefficient matrix in year t	Based on the input-output tables for 2010 and 2015, the improved RAS method is used to estimate the direct consumption coefficient matrix for 2017–2030. According to this method, the average absolute error of direct consumption coefficient between the estimated and the real values in 2017 is 0.007. It is indicated that this method is acceptable. The direct consumption coefficients in 2030 can be found in Appendix A Table A1.
r_t	The growth rate of industrial added value in year t	It is assumed that the growth rates of industrial added value are 6.2% in 2019–2020, 5.5% in 2021–2025, and 4.5% in 2026–2030.
$c_{j,t}$	CO_2 emissions per unit value-added of industry j in year t	The CO_2 emissions of sub-industries are predicted by the STIRPAT model, the details can be referred to the Section 4.3 of this paper. The results can be seen in Appendix A Tables A2–A4. The industrial added value of subindustries are predicted by the GM (1,1) model, and the results can be found in Appendix A Table A5. $c_{j,t}$ can be calculated by dividing the CO_2 emissions by the added value of the corresponding industry in the corresponding year.
$\overline{C}_t$	The maximum industrial CO_2 emission in year t	These values are calculated in the Section 4.3 in this paper.

4.3. *Prediction for China's Maximum CO_2 Emissions*

According to the constraints of the multiobjective and multiconstrained input-output optimization model, it was necessary to predict the annual maximum CO_2 emissions $\overline{C}_t$ from 2017 to 2030. Although the Chinese government has proposed to achieve the CEPT around 2030, it has not set a clear CEPT for the industrial sector. Existing studies generally agree that the proportion of industrial CO_2 emissions to total national CO_2 emissions has been above 80% over the years [9,10,47]. It can thus be suggested that the achievement of CEPT in the industrial sector by around 2030 would directly determine the national achievement of CEPT. Therefore, in this paper, the peak path was predicted using the STIRPAT model for industrial CO_2 emissions—and this value was chosen as the maximum CO_2 emissions $\overline{C}_t$.

The STIRPAT model is based on the classical IPAT model and is widely used in the study of environmental and predictive problems. The advantage of this model is that it allows the coefficients of variables to be estimated as parameters, and also allows the variables to be properly decomposed and improved. Based on the existing studies on the influence factors of CO_2 emissions [8,48], we selected six variables—gross industrial output (*Gio*), square of GDP per capita ($Pgdp^2$), gross population at the end of one year (*Pop*), total energy consumption of industrial sector (*Itec*), efficiency of industrial energy consumption (*Eiec*), and total coal consumption of industrial sector (*Itcc*)—to forecast industrial CO_2 emissions (Ico_2).The period of variables was 2000–2016. The description of variables is shown in Table 5.

Table 5. Description of variables used.

Variables	Description	Unit	The Source of Datas
$Pgdp^2$	Square of GDP per capita based on price de-deseeds in 2000		China Statistics Yearbook, China Industrial Statistics Yearbook and China Energy Statistics Yearbook
Pop	Population size is indicated by the gross population at end of one year	100 Million People	
Gio	Real gross industrial output in terms of the industrial factory price index	100 Million RMB	
Itec	Total energy consumption of industrial sector	10 thousand tec	
Eiec	Real gross industrial output divided by the total amount industrial energy consumption	100 Million RMB/ 10 thousand tec	
Itcc	Total coal consumption of industrial sector	10 thousand tec	

The expressions of STIRPAT model can be expressed as:

$$\ln Ico_2 = \beta_1 \ln Pgdp^2 + \beta_2 \ln Pop + \beta_3 \ln Gio + \beta_4 \ln Itec + \beta_5 \ln Itcc + \beta_6 \ln Eiec + \ln e \quad (7)$$

In order to eliminate multicollinearity among the independent variables, we used ridge regression to estimate the coefficients of the STIRPAT model. According to Equation (7), the CO_2 emission in industrial sector needed to be calculated for 2000–2016. In this paper, the standard amount of end-use energy consumption in industries was used to calculate the CO_2 emissions, and the CO_2 emissions from energy consumption were divided into direct and indirect CO_2 emissions. Direct CO_2 emissions referred to the CO_2 emissions from the combustion of fossil fuels such as coal, coke, crude oil, gasoline, kerosene, diesel, fuel oil and natural gas. Indirect CO_2 emissions referred to emissions caused by electricity consumption. In this paper, the accounting method of energy consumption adopted was direct consumption, in which the consumption of energy such as coal, oil, or natural gas was accounted to the industry in which that energy was directly used. Therefore, the CO_2 emissions related to the generation of the electricity consumed were accounted for by the power industry. The standard coal conversion and CO_2 emission coefficients of primary fossil energy came from the *IPCC Guidelines for National Greenhouse Gas Inventories 2006* [49], and those of electricity consumption came from the calculation provided by Li et al. [50]. The evaluation expression is:

$$C = \frac{44}{12} \sum_i e_i \times emf_i \quad (8)$$

C represents CO_2 emissions, e_i represents the standard amount of energy i consumption, emf_i represents the CO_2 emission coefficient of energy i, and 44/12 represents the mass fraction of carbon elements in CO_2.

According to the change of R^2 with K in the ridge regression result, the optimal ridge regression was selected for CO_2 emission prediction. The ridge regression coefficient and model test results are shown in Table 6.

Table 6. The regression coefficient and model test results of industrial sector.

$Pgdp^2$	Pop	Itec	Itcc	Gio	Eiec	R2	F	Sig F
0.1433	0.1502	0.2265	0.1862	0.1345	−0.0926	0.974	101.66	0

Notes: The above variables are all significant at the 1% level.

Scenario analysis is a basic method for predicting and simulating the future. Based on previous research, we set up a benchmark scenario, low-carbon scenario and high-energy consumption scenario (the details of which can be seen the Appendix A Table A6) to predict China's industrial CO_2 emissions from 2017 to 2050. The peak path and peak value of CO_2 emissions in each scenario are shown in Table 7.

Table 7. The peak path and peak value of CO_2 emissions in each scenario. (Unit: 1 billion CO_2).

Years	Benchmark Scenario	Low-Carbon Scenario	High-Energy Consumption Scenario	Years	Benchmark Scenario	Low-Carbon Scenario	High-Energy Consumption Scenario	Years	Benchmark Scenario	Low-Carbon Scenario	High-Energy Consumption Scenario
2017	8.07	8.03	8.06	2029	10.00	9.55	9.74	2041	9.00	7.83	11.89
2018	8.23	8.17	8.18	2030	10.14	9.48	9.92	2042	8.63	7.73	12.0
2019	8.38	8.32	8.33	2031	10.28	9.39	10.15	2043	8.38	7.62	12.00
2020	8.56	8.50	8.40	2032	10.40	9.28	10.32	2044	8.17	7.52	12.01 *
2021	8.73	8.65	8.50	2033	10.42 *	9.09	10.50	2045	7.96	7.42	11.94
2022	8.90	8.81	8.63	2034	10.40	8.86	10.69	2046	7.72	7.37	11.87
2023	9.09	8.99	8.85	2035	10.21	8.67	10.90	2047	7.50	7.22	11.63
2024	9.28	9.13	8.96	2036	10.06	8.50	11.03	2048	7.26	7.18	11.38
2025	9.41	9.26	9.09	2037	9.84	8.30	11.26	2049	6.98	7.10	11.06
2026	9.55	9.40	9.22	2038	9.66	8.19	11.48	2050	6.72	7.09	10.74
2027	9.70	9.50	9.39	2039	9.43	8.02	11.63				
2028	9.88	9.57 *	9.51	2040	9.21	7.93	11.77				

Note: The asterisk (*) represents peak CO_2 emission.

As shown in Table 7, only the low-carbon scenario achieved industrial CO_2 emissions (peaking at 9.57 billion tons of CO_2 by 2030). In order to verify the rationality of the predicted value, we employed the results provided by Chen [9] and Zhang et al. [10] that the CO_2 emissions of the industrial sector accounted for more than 80% of the total CO_2 emissions of China. Thus, 9.57 was converted to 11.97, which fell within the peak range (9–13 billion tons of CO_2) widely believed in academia [14,15]. In order to test the robustness of the model, the exogenous parameters in the low-carbon scenario (the details of which can be seen in Appendix A Table A6) were increased and decreased by 5%, respectively, to evaluate the impact of their fluctuations on CO_2 emission forecast results. The results showed that all the effects were within 5%, indicating that the model was relatively robust. Therefore, the CO_2 emission peak path predicted by the STIRPA model and the value on the path as a constraint both have strong credibility.

5. Optimization Results and Analysis

5.1. Optimization Result of Industrial Added Value

Based on the predicted values of parameters in Table 4 and the CO_2 emission path value of the low-carbon scenario in Table 7, we used the genetic algorithm toolbox in Matlab to solve the multiobjective and multiconstraint input-output optimization model, and obtained the optimization results of the industrial added value and CO_2 emissions in three scenarios in 2030 (as shown in Table 8). In each scenario, the total industrial added value of the eight industries in 2030 was much greater than in 2016. The average annual growth rates of industrial added value of all industries were positive in all scenarios, except for the mining, quarrying, and petroleum industries as calculated in the f CO_2 emission reduction priority scenario. The average annual growth rate of the industrial added value in low-carbon emission industries was generally higher than in high-carbon emission industries. For example, the electromechanical industry had the highest average annual growth rate, and the petroleum industry had the lowest. The CEPT had a significant suppressive effect on high-carbon emission industries and a strong boosting effect on low-carbon emission industries. This indicates that the CEPT was in line with the sustainable development goals. In terms of the specific scenarios, the total industrial added value of each industry was largest in the economic growth priority scenario and the smallest in the CO_2 emission reduction priority scenario. The average annual growth rate of industries in the economic growth priority scenario was generally higher than in other scenarios, and the annual growth rate in the CO_2 emission reduction priority scenario was generally the smallest. This indicates that the industrial added value rate of increase was negatively correlated with the intensity of CEPT; the greater the intensity of CEPT, the smaller the increase in the rate of industrial added value. Therefore, the setting of the intensities of CEPT should vary from place to place and industry to industry. It is not advisable to increase the intensity of CEPT layer by layer. Otherwise, the excessive intensity of CEPT will make localities and industries pay a higher economic cost.

Table 8. Industrial added value and CO_2 emissions in three scenarios in 2030.

Industry	Industrial Added Value in 2016	Industrial Added Value in 2030 (Unit: 1 Trillion Yuan)			CO_2 Emissions in 2030 (Unit: 1 Billion CO_2)			Average Annual Growth Rate of Industrial Added Value in 2016–2030 (%)		
		Scenarios			Scenarios			Scenarios		
		A	B	C	A	B	C	A	B	C
Mining and Quarrying	2.05	3.22	1.05	2.43	0.85	0.28	0.64	3.27	−4.64	1.22
Light Industry	3.95	10.21	9.91	9.72	0.53	0.51	0.5	7.02	6.8	6.65
Manufacture of Textile	1.65	3.49	3.68	3.26	0.22	0.24	0.21	5.48	5.87	4.97
Petroleum Industry	0.78	1.06	0.54	0.8	0.80	0.41	0.6	2.21	−2.64	0.22
Chemical Industry	4.61	9.43	7.28	8.26	3.40	2.63	2.98	5.24	3.31	4.25
Steel Industry	3.18	5.56	3.93	4.77	3.18	2.25	2.73	4.06	1.51	2.93
Electro-Mechanical Industry	6.88	30.79	32.5	31.56	0.48	0.50	0.49	11.3	11.73	11.5
Power Industry	1.47	2.91	2.25	2.71	1.45	1.12	1.35	5.02	3.11	4.48

Notes: Scenarios: A, economic growth priority; B, CO_2 emission reduction priority; and C, equal importance of the two objectives.

Specifically, across all industries, the average annual growth rate of industrial added value of the electromechanical industry was the highest in all three scenarios (all above 11%). Its growth rate under the CO_2 emission reduction priority scenario was the highest; it was lowest when economic growth was prioritized. This shows that under the action of the forcing mechanism, CEPT had a strong boosting effect on this industry, and that the effect was positively correlated with the target intensity. The situation in the manufacture of textile was similar to the electromechanical industry. With the exception of the CO_2 emission reduction priority scenario, the average annual growth rate of the petroleum industry was the smallest among all industries and scenarios, followed by mining and quarrying. This shows that the setting of CEPT limited the development of these two industries. In the CO_2 emission reduction priority scenario, the growth rates of industrial added value in these two industries were negative; the growth rate of the mining and quarrying industry was 2% lower than in the petroleum industry. This shows that in the CO_2 emission reduction priority scenario, the setting of CEPT had a significant suppressive effect on these two industries, and that the effect on the mining and quarrying industry was greater. The reasons for this can be explained as follows: First, Chinese mineral resources such as oil and natural gas rely mainly on imports. As the weight of CO_2 emission reduction increases, import substitution will have a greater impact on domestic mining and quarrying. Secondly, China is vigorously developing clean energy. It can be expected that when clean energy technology matures, it will have a greater impact on the petroleum industry.

5.2. Optimization Results of Industrial Structure

As seen in Figure 2, the proportion of high-carbon emission industries in the industrial structure tended to decline, and that of low-carbon emission industries tended to rise or fall, albeit to a lesser extent. The CO_2 emission reduction priority scenario had the most obvious effect on the optimization of Chinese industrial structure. Under this scenario, the proportion of the electromechanical industry in the industrial structure saw the largest increase; the manufacture of textile saw the smallest decline; the light industry changed from negative values (in other scenarios) to positive values (details can be seen in Appendix A Table A7); and high-carbon emission industries saw greater declines than in any other scenarios. Although the optimization of the economic growth priority scenario on Chinese industrial structure was also obvious, it had the smallest effect of the three scenarios. This shows that the setting of CEPT promoted the optimization of industrial structure and the low-carbon transformation of Chinese industries in any scenario.

The proportion of the electromechanical industry's share in the industrial structure rose in all three scenarios; the increase amplitude of the CO_2 emission reduction priority scenario was greater than that of the other two. This industry exhibits low CO_2 emissions and a high degree of technological innovation. Under the forcing mechanism of CEPT, governments at all levels will inevitably give priority to the development of the electromechanical industry, with its low CO_2 emissions and greater industrial added value, as well as its minimization of the impact on economic growth. If the CEPT is set at a higher intensity, governments will prioritize the development of low-carbon emission industries more obviously, and the substitution effect of low-carbon emission industries on high-carbon emission industries will likewise grow more apparent. As shown in Figure 2, in the CO_2 emission reduction priority scenario, the proportional role of the light industry in the greater industrial structure did not decline, but increased slightly. Additionally, the decreasing amplitude in the proportional role of textile manufacture the industrial structure was significantly lower than in the other two scenarios. The reasons for these effects on the two industries were similar to those for the electromechanical industry. High-carbon emission industries like petroleum, mining and-quarrying, and steel experienced a large decline in their proportions in the industrial structure (which together exceeded 35%), and the decline of these three industries in the CO_2 emission reduction priority scenario was significantly greater than in the other two scenarios. This shows that the setting of CEPT had a significant suppressive effect on high-carbon emission industries. Furthermore, the strength of that effect was positively correlated with the intensity of the CEPT. This conclusion is also valid for the chemical industry and power industry.

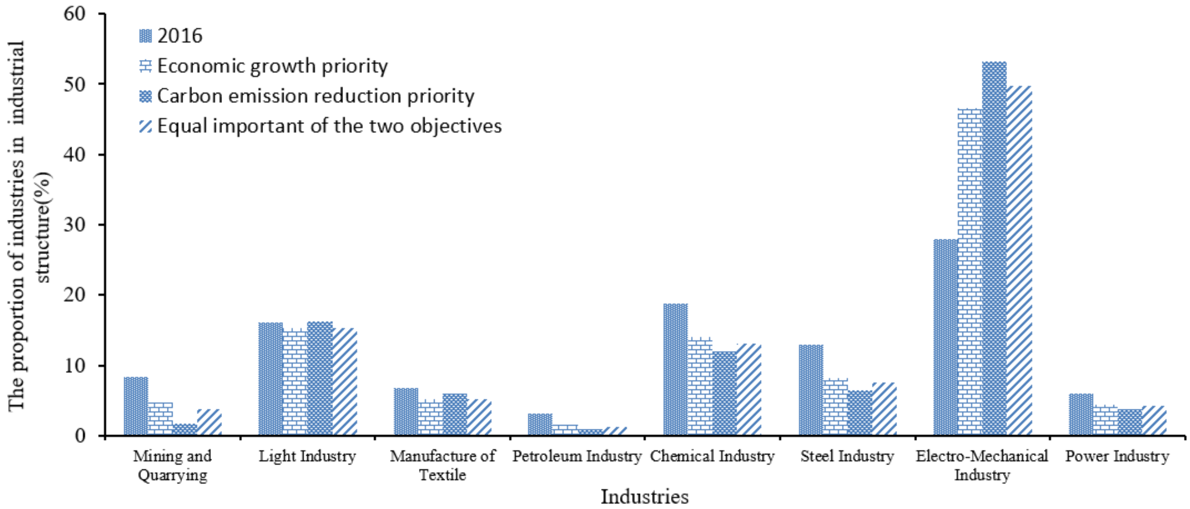

Figure 2. The changes of the proportion of industries in industrial structure (2016 vs. 2030).

5.3. Evolution Paths of Industries

The evolutionary path of the industrial added value in each industry in the planning year is shown in Figure 3, and the evolutionary path of the proportion of the added value in each subdivided industry to that of the entire industry is shown in Figure 4. On the whole, the industrial added value of industries generally showed an upward trend, and their proportion in industrial structure generally showed a downward trend. However, due to the nature of the industries, the forcing effects in different scenarios on industries varied greatly. Specifically, as shown in Figures 3a and 4a, the industrial added value of the mining and quarrying industry showed an upward trend under the economic growth priority scenario and a downward trend under the CO_2 emission reduction priority scenario. The proportion of the mining and quarrying industry in the industrial structure suffered the fastest decline trend in the CO_2 emission reduction priority scenario, reaching 79.38%. It showed the slowest decline trend in the economic growth priority scenario, about 43.41%. This shows that under the forcing mechanism, the setting of CEPT has a strong restrictive effect on the development of this industry, and the greater the intensity of CEPT, the more obvious that restrictive effect became. Mining and quarrying is a basic industry of the national economy, providing energy, industrial raw materials and agricultural production materials for other industries. However, against the backdrop of resource and environmental constraints, the forcing effects of CEPT and the scarcity of natural resources led to a gradual slowdown in the development of mining and quarrying and a gradual reduction in output. In fact, China has already begun to control the output of fossil energy such as coal and oil. The output of mining, washing of coal, extraction of petroleum, and natural gas has been declining for three consecutive years. At the same time, under the background of overcapacity in the steel industry, the output of mining and processing of ferrous metal ores is also declining. It can be seen that the above conclusions drawn in this paper are in line with expectations. As shown in Figures 3d and 4d, the industrial value-added of the oil industry and its share in the industrial structure were smaller than that of the extractive industry. The reason is that oil and gas are heavily dependent on foreign imports, and the setting of CEPT will further aggravate this situation. More importantly, on 12 December 2020, President Xi Jinping further announced at the Climate Ambition Summit that China would increase the proportion of nonfossil energy in primary energy consumption to about 25% by 2030. It is foreseeable that, as the proportion of clean energy in primary energy continues to rise, the growth rate of the petroleum industry's output will continue to decline, as will its proportion in the industrial structure.

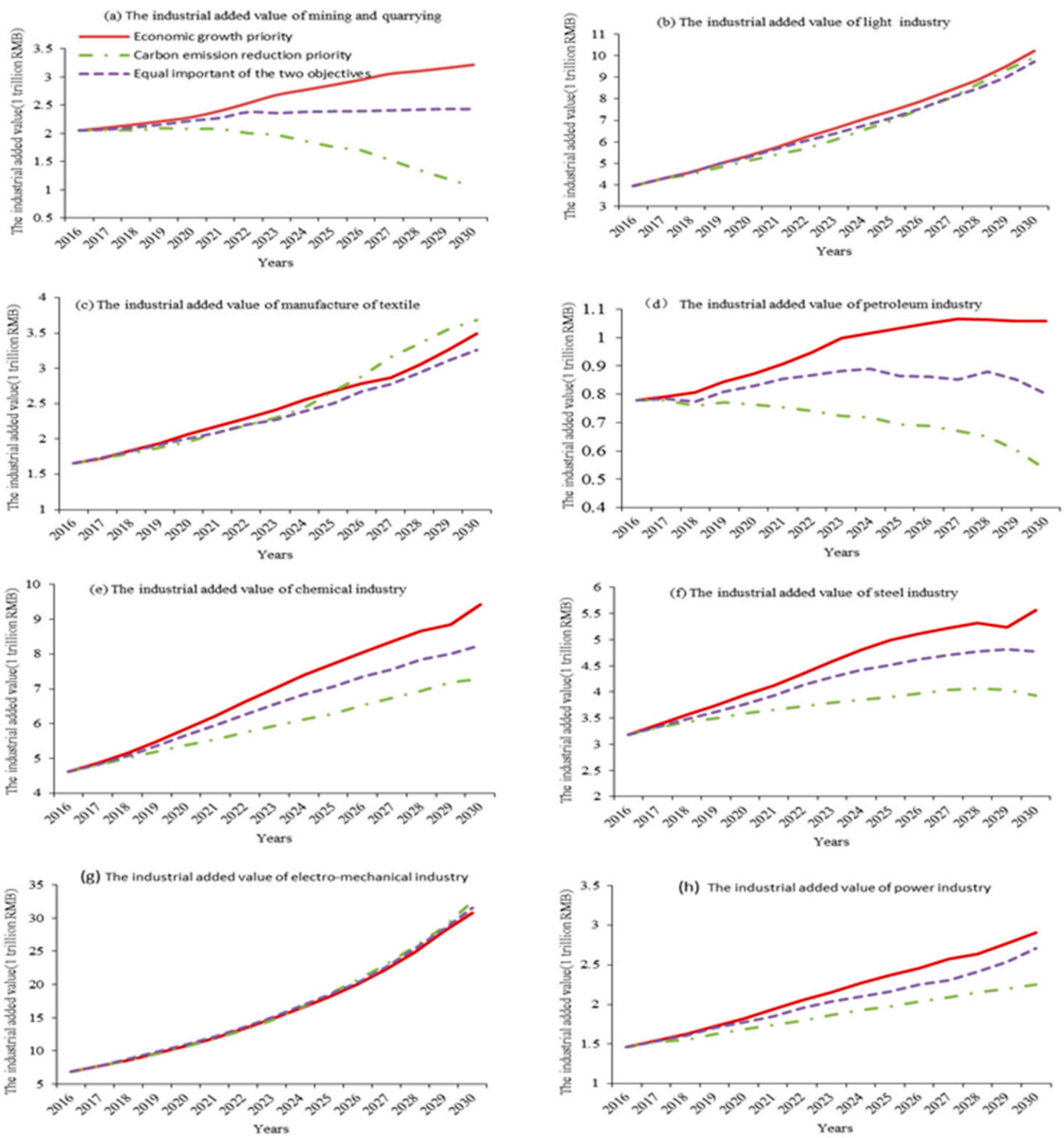

Figure 3. The evolutionary path of the industrial added value of each industry.

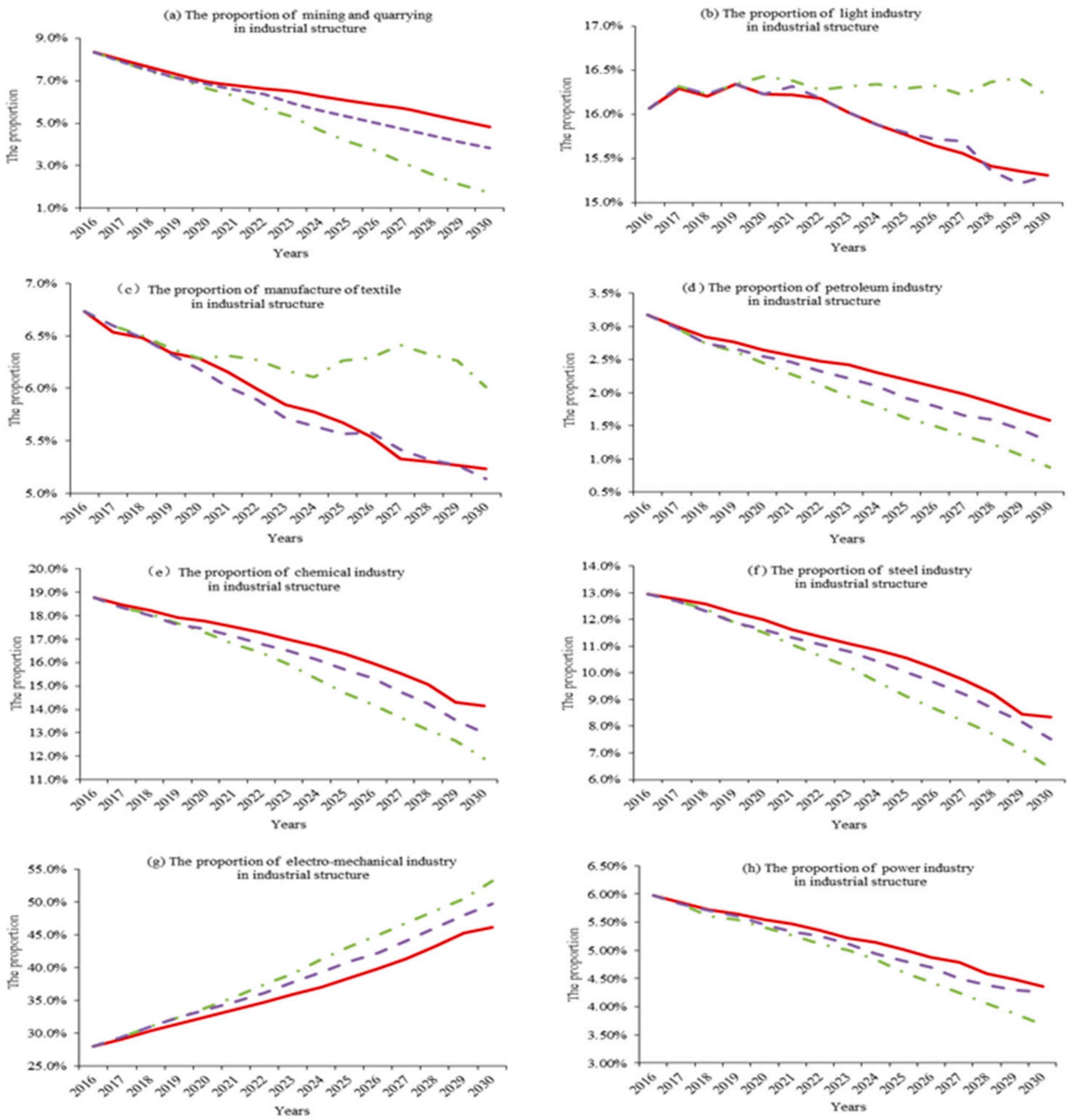

Figure 4. The evolutionary path of the proportion that the added value of each subdivided industry accounts for in the entire industrial sector.

For the light industry, as shown in Figures 3b and 4b, industrial added value rose under all three scenarios—and the speed of that growth across all scenarios did not differ greatly. Its proportion in the industrial structure showed a fluctuating trend in the CO_2 emission reduction priority scenario, but it showed a downward trend in the economic growth priority and equal weight scenarios. The reason for this is that the light industry is an important sector of the national economy and people's livelihood, with relatively small CO_2 emissions. However, it is closely related to people's lives. As people's living standards improve, the industrial added value of this industry will increase. However, under the CO_2 emission priority scenario, in order to ensure that the target of CO_2 emission reduction is achieved, local governments will vigorously restrict the development of high-carbon emission industries while relaxing the control of low-carbon emission industries or encouraging their development. Thus, the light industry's proportion in the industrial structure showed no obvious change. In the economic growth priority and equal importance scenarios, the CO_2 emission reduction was no longer the first target. Local governments will develop higher value-added industries or relax the control of high-carbon emission industries, which will lead to the suppression effect on the light industry. This will cause this industry share in the industrial structure to show a slight downward trend.

The evolution trajectory of the manufacture of textile is similar to that of light industry, as shown in Figures 3c and 4c. The difference is that the increase in industrial added value of this industry in the three scenarios is less than that of light industry, while its share in the industrial structure decreases more than light industry. The reason is that China is the world's largest producer and exporter in manufacture of textile. Although its CO_2 emissions are relatively small, its pollutants (COD, chemical oxygen demands) are more harmful to water quality. The stricter environmental supervision is bound to restrict the development of the industry. In addition, with the gradual disappearance of Chinese demographic dividend and the rising labor costs, many textile and apparel companies have moved their production bases to countries with lower labor costs such as Southeast Asia. This is another major reason for this phenomenon. Under the CO_2 emission reduction priority scenario, the growth rate in industrial added value of the manufacture of textile is greater than that of other scenarios, and its share of the industrial structure declines less than that of other scenarios. The reason is that the CO_2 emission reduction priority scenario has less restrictions on the manufacture of textile and greater restrictions on high-carbon emissions industry, while the economic growth priority scenario and the equal important of the two objectives scenario have smaller restrictions on all industries. Therefore, the manufacture of textile shows a boosting effect in the CO_2 emission reduction priority scenario, while it shows a suppression effect in other scenarios.

As shown in Figures 3e,f,h and 4e,f,h, the evolution paths of the chemical industry, steel industry and power industry are similar. In the three scenarios, the industrial added values of the three industries are on the rise. The increase amplitude in the economic growth priority scenario is the largest, and the one in the CO_2 emission reduction priority scenario is the smallest. The proportions of the three industries in industrial structure all show a downward trend, the economic growth priority scenario has the smallest decrease amplitude, and the CO_2 emission reduction priority scenario has the largest decrease amplitude. It can be seen from Table 8 that the average annual growth rate of the industrial added value of these three industries is chemical industry, power industry and steel industry in descending order. The reason is that these three industries are the basic industries of the national economy, which provide raw materials and power for economic development. Under the economic growth priority scenario, it will inevitably have a greater pulling effect on these three industries, which will lead to a larger increase amplitude in industrial added value and a smaller decrease amplitude that the proportion of them in the industrial structure. In the CO_2 emission reduction priority scenario, the development of these three industries will inevitably be restricted under the effect of the forcing mechanism, which will lead to a smaller increase amplitude in industrial added value and a larger increase amplitude that the proportion of them in the industrial structure. Specifically, the chemical industry is a key industry for CO_2 emission control and an important source of pollutants such as sulfur dioxide, nitrogen oxides, and chemical oxygen demand. With the setting of CEPT and the increase of citizens' awareness of green environmental protection, it will be inevitable that the industrial added value of this industry will slow down and its proportion in the industrial structure will tend to decline. For the steel industry, its overcapacity problem has become increasingly prominent as China enters the post-industrial era. Especially in the context of the current supply-side reform, the production capacity of this industry will be controlled. Therefore, under the forcing mechanism of CEPT, the development of the steel industry will be subject to a greater impact. For power industry, the power supply in the past mainly relied on fossil fuels such as coal, which had relatively large CO_2 emissions. Due to the constraints of the CEPT and the reduction of coal supply, the growth rate of its industrial added value and its share in industrial structure will tend to decline.

According to Figures 3g and 4g, under those three scenarios, the industrial added value of the electro-mechanical industry tends to rise and the rising speed has an increasing trend. Although the growth rate of the three scenarios is similar, the rate of increase in the CO_2 emission reduction priority scenario is greater than that of the other two scenarios. Its proportion of that in industrial structure is also rising in those three scenarios, and the CO_2 emission reduction priority scenario is on the fastest rise. The reason is this industry covers almost all the high-tech industries. According to the ten-year national plan Made in China 2025, China is striving to move into the ranks of manufacturing powerhouses. Under the strategy of innovation-driven development, the electro-mechanical industry will take up the important task of Chinese industrial technological innovation and become the engine of industrial economic growth. It is foreseeable that under the forcing mechanism of CEPT, this industry will become the key development objects of governments at all levels. The greater the intensity setting by the CEPT, the greater the motivation for this preference of governments at all levels and the more obvious forcing effect caused by the preference.

6. Discussion

6.1. Be Wary of the Risk of the "Basic Industries Excessive Shrinkage"

"Rapid deindustrialization" refers to the phenomenon that the absolute value and relative scale of industry have fallen too quickly beyond the normal trajectory of economic structure evolution and economic development stages, thereby affecting the role of industry as an engine and support for the growth of the national economy, and the judgment criterion is whether the average annual decline in the proportion of industrial value-added to total value-added exceeds the rate of 1.3% [51]. We analyzed C, the more realistic scenario—in which the objectives were of equal importance—and found that the average annual decline of the industrial added value of the mining and quarrying industry was 1.3% in 2016–2030, while that of the petroleum industry was 1.31%. When we considered the CO_2 emission reduction priority scenario, the situation looked even worse. The average annual decline of the mining and quarrying and petroleum industries were 1.34% and 1.33%, respectively. The situation was similar for the steel industry, chemical industry and power industry, all of which are basic industries. It can thus be seen that the risk of excessive shrinkage in basic industries was realistic, and existed for each planning year.

The first problem caused by basic industries' excessive shrinkage is a reduction in employment. Although basic industries such as mining and quarrying and the petroleum industry have high CO_2 emissions, they have also absorbed a large amount of labor. Excessive shrinkage of these industries could easily lead to structural unemployment and wage polarization caused by labor transfer, which will reduce the socioeconomic growth rate and increase the risk of China falling into the middle-income trap—at least to a certain extent [52]. The second problem caused by basic industries' excessive shrinkage is resource security. These basic resource industries are both part of the foundation of China's national economic development. Under the effects of the forcing mechanism of CEPT, import substitution will become an inevitable choice. However, in the context of the deglobalization trend, it is worth pondering whether excessive dependence on imported resources is reliable. The third problem caused by the excessive shrinkage of basic industries is the hollowing out of those industries. Although the average annual rate of decrease in the proportion of the industrial added value in the steel, chemical, and power industries accounted for less than 1.3% of the total industrial added value, they were all above 1.25%. If these basic industries underwent excessive shrinkage, it would inevitably lead to an increase in the prices of production factors such as resources and raw materials. This would further squeeze the profit margins of enterprises, and accelerate the removal of manufacturing industries with relatively low added value from China, thus hollowing out those industries. In promoting CEPT, we must not be caught in the dilemma of setting aside the overall situation and focusing solely on the CO_2 emissions peak target. We must take into account sustainable development and avoid the risks of excessive shrinkage.

The key to avoiding that risk lies in improving the utilization efficiency of fossil energy and increasing the amount of clean energy. The national level should start at the macro level. On one hand, they should promote clean energy infrastructure and basic research at a national level. They should develop clean energy—solar energy, wind energy, and so on—and provide guarantees for clean energy substitution. On the other hand, they should establish a clear and comprehensive carbon accounting system, determine the total amount of carbon emission reduction, establish a national carbon emission trading market, and promote carbon emission reduction of basic industries according to their actual conditions under the established scenarios of total carbon emissions. Furthermore, they should promote technological innovation—especially green technology innovation—and promote the transformation of innovation and the reduction of carbon emissions in industries that have to use fossil energy. For local governments, they must first implement the central government's emission reduction policies and supervise the implementation of clean energy substitution in these basic industries. Secondly, they should guide the upgrading of outdated technologies and equipment in basic industries. Thirdly, they should increase the supervision of local basic industries, increase the penalties for companies that violate regulations, and use the profit space to guide enterprises to balance the interests of output value and emissions. Therefore, under the premise of improving the efficiency of fossil energy and increasing the use of clean energy, preventing the excessive shrinkage of basic industries will have a limited impact on climate change. This is in line with the CEPT and sustainable development goals.

6.2. Reindustrialization and Climate Change

Due to the influence of COVID-19 and trade protectionism, some countries promote the pursuit unilateral trade protectionism policies. Their policies mainly include: (i) withdrawing from the Trans-Pacific Partnership Agreement; (ii) raising trade barriers; (iii) adopting tax policies in the hope that enterprises will return to their home countries. The ultimate goal of these policies is to realize the goal of reindustrialization in their home country and establish their basic industrial system by promoting deglobalization. Trade protectionist policies—and the trend of deglobalization and reindustrialization—will have a greater negative impact on reducing GHG (Greenhouse Gas) emissions globally. The reasons for this can be attributed to the following points: first, trade protectionist policies and the trend of deglobalization have split the theory of comparative advantage in international trade. It will break the previous advantage of intensive resource utilization, relying on comparative advantage for mass production, which will increase GHG emissions globally. Second, reindustrialization will stimulate the rise of basic industries, such as the steel, mining and quarrying, petroleum, and chemical industries. A distinctive character of basic industries is that they cause high energy consumption and high emissions. This will inevitably lead to an increase in GHG emissions globally.

6.3. The CEPT and Climate Change

The CEPT is a very necessary tool to address the climate crisis. First, the time schedule and the target task of the CEPT are very clear and highly maneuverable. Second, it is conducive to achieving a crucial target: controlling the global average temperature rise within 2 °C (while striving to control it within 1.5 °C) during this century. If the current overall situation and business-as-usual practices continue, the consequence will be that climate change will continue at its current rate. According to the IPCC Special Report on Global Warming of 1.5 °C, if climate warming continues at the current rate, global temperatures are expected to rise by 1.5 °C from 2030 to 2052 compared to preindustrial levels. Experts say that if this is the case, the global average temperature will rise by 0.2 °C every 10 years. By 2100, the global sea level will rise by 26 cm to 77 cm. In this century, the Arctic will be ice-free in summer, and 70% to 80% of existing coral reefs will disappear.

In this global climate crisis, smooth transitions are a very necessary choice. Economic development and ecological environment are the two fundamentals of human survival. The global climate crisis is an ecological imbalance caused by human activities; since the industrial revolution, human beings have continuously accumulated material wealth from the ecosystem. If we take the reins of governance and give up economic development in favor of the environment, the materials required for human development and survival will no longer exist. This will be catastrophic and unsustainable. Similarly, abandoning the environment for material foundations and letting go of the global climate crisis would be disastrous. Climate warming would cause a series of changes in the human living environment, and the blow to human existence would be devastating. Therefore, in response to the global climate crisis, we must adhere to the principle of equal emphasis on adaptation and mitigation, and seek a smooth transition. Improving the efficiency of fossil energy, increasing the rate of replacement of fossil energy with clean energy, and preventing the excessive shrinkage of basic industries are extremely important in a smooth transition route. National and local governments must promote the use of clean energy and advanced technologies at their respective levels. This would not only reduce carbon emissions and climate change, but it would avoid the harm that shrinkage of basic industries would do to the industrial sector.

Of course, setting CEPT is not the only way to achieve GHG reduction targets. The Chinese government has been making continuous efforts to achieve GHG emission reduction targets and has been trying some fast, effective ways—for example: releasing and setting the Total Energy Consumption Control Target, Carbon Intensity Control Target, Energy Intensity Control Target, and Promoting the Construction of Ecological Civilization Construction. These have achieved good results in reducing climate change and carbon emissions. However, even compared with these, CEPT remains a necessary tool to deal with the climate crisis.

7. Conclusions and Policy Implications

On the basis of existing research, we explored the internal logic and operating mechanism of the forcing mechanism of CEPT. Subsequently, based on the predicted value of the CO_2 emission peaking path, we constructed a multiobjective and multiconstrained input-output optimization model. We then used the genetic algorithm to solve this model, exploring the influence of setting CEPT on industrial structure optimization and industry low-carbon transformation. Finally, we deduced the evolutionary trajectory of Chinese subdivided industries and identified the risks that Chinese industries may encounter during the low-carbon transformation. The main conclusions are as follows:

First: the setting of CEPT promoted the optimization of industrial structures and the low-carbon transformation of industries. From 2017 to 2030, the proportion of high-carbon emission industries in the industrial structure tended to decline, and that of low-carbon emission industries tended to rise. The CO_2 emission reduction priority scenario had the most obvious effect on the optimization of Chinese industrial structures. Although the optimization effect of the economic growth priority scenario on Chinese industrial structure was also obvious, it had the the smallest effect of all three scenarios. Therefore, the CEPT is in line with the sustainable development goal.

Second: the setting of CEPT had a great impact on subdivided industries. For high CO_2 emission industries, such as the mining and quarrying, petroleum, steel, power and chemical industries, the impact of the CEPT mainly manifested as a suppressive effect. For low CO_2 emission industries, such as the electromechanical industry, the impact mainly manifested as a strong boosting effect. For light industry and manufacture of textiles, the boosting effect only appeared in the CO_2 emission reduction priority scenario. On the whole, the strength of the suppressive effect and the boosting effect were positively correlated with the intensity of the CEPT, whether for high-carbon or low-carbon emission industries.

Third: excessive shrinkage of basic industries should be prevented. Unfortunately, in the present study, such shrinkage did exist between 2016–2030. This coul lead to a series of social problems, e.g., structural unemployment and wage polarization, dangers in resource security caused by excessive dependence on imports, and the hollowing out of industries induced by rising prices of production factors. Therefore, while achieving the CEPT, we should give consideration to sustainable development and be wary of the hazards of rapid deindustrialization.

Based on these conclusions, the policy implications are as follows:

The role of the government in the forcing mechanism of CEPT should be comprehensively understood and reasonably used. As the maker of CEPT and the leader of the macroeconomic target, the central government should formulate the corresponding policies and regulations and establish the CO_2 emission trading markets at the national level in order to to create a sound environment for the orderly promotion of CEPT. On the other hand, it is necessary to change the assessment method of local governments, and assign higher priority to the assessment of green development, environmental quality and ecological protection, thereby encouraging local governments to meet or exceed the CEPT. Local government should have a clear understanding and orientation of their resource environment, location advantages and industrial development, and construct the industrial planning in line with the long-term development interests of the local area. They should also comprehensively use administrative and economic means to change external conditions, revise the market exit and access mechanisms, guide enterprises to exit and enter in an orderly manner, and promote the rationalization of regional industrial layout and the advancement of industrial structure. The setting of the intensity of CEPT should not be added layer-upon-layer by local governments. Otherwise, excessive intensity could lead to higher economic costs.

The importance of enterprises in the forcing mechanism of CEPT should be given full attention. Enterprises are the main participants in economic activity. Their production and business activities not only determine the vitality of economic activities, but also determine the progress of low-carbon transformation. Therefore, under the effect of the forcing mechanism of CEPT, enterprises should actively fulfill their new social responsibilities (low-carbon and environmental protection). Enterprises should establish their own CO_2 emission management systems by setting up management agencies and establishing CO_2 emission reduction regulations. Additionally, enterprises should actively explore the path of low-carbon transformation by improving the effectiveness of their direct emission reduction, improving energy efficiency, increasing technological innovation, and broadening the scope of clean energy substitution. Lastly, enterprises should adjust their development strategies, including adjusting production structure, optimizing investment directions, and transforming, upgrading or relocating according to the regulations of the industries and regions in which they operate.

Excessive shrinkage of basic industries should be prevented, and the smooth transition of the Chinese economy during the low-carbon transformation should be promoted. Basic industry excessive shrinkage is partly attributable to their being perceived as inferior by some local governments and people, due to their high energy consumption and high pollution characteristics. It is also the result of the promotion of industrial upgrading. Under the current deglobalization/reindustrialization trend in Europe and America, excessive basic industrial shrinkage will inevitably damage the competitive advantage of the Chinese manufacturing industry. Therefore, we should get rid of the idea that promoting the CEPT requires us to allow basic industries to shrink, and focus instead on optimizing and upgrading their industrial structure. Whether it is to promote the CEPT or optimize and upgrade the industrial structure, success will be based on the continuation of existing technologies in basic industries and the orderly succession of new and old sources of momentum in Chinese economic growth. Additionally, we should use the forcing mechanism of CEPT to promote optimization and upgrading strategies within the industrial structure that suit the actual situation in a given region (according to differences in resource endowments and industrial advantages of eastern, central and western China). We should build a deep industrial system that can cover the whole industrial chain, and promote the long-term sustainable development of the Chinese economy. We should also be actively developing clean energy, increasing the proportion of clean energy used in basic industries, and promoting the replacement of fossil energy by clean energy in an orderly manner. All of this may ensure a smooth transition for the Chinese economy during the low-carbon transformation.

However, this study did have certain limitations. One is that we did not consider technological breakthroughs, such as carbon neutrality, or CO_2 capture and storage (CCS). Breakthroughs in key technologies will have a certain impact on the peak time or path of CO_2 emissions, and may affect the evolutionary path of industrial structures and our industrial low-carbon transformation. Therefore, incorporating carbon neutrality and CCS into the research framework is a future research direction. Another limitation is that employment is not included in this study. The setting of CEPT has promoted the industrial structure optimization and low-carbon transformation of industries. This change will inevitably have a greater impact on employees who depend on high-carbon emission industries. Under the effects of the forcing mechanism of CEPT, determining how to realize the orderly flow of labor in the industrial low-carbon transformation may be an important area for future research.

Author Contributions: Conceptualization, F.W.; Data curation, C.G. and W.Z.; Funding acquisition, F.W.; Investigation, D.H.; Methodology, F.W.; Software, C.G. and W.Z.; Writing—original draft, C.G.; Writing—review & editing, F.W. and C.G. All authors have read and agreed to the published version of the manuscript.

Funding: This work was supported by the National Natural Science Foundation of China under Grant number 71673217.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Direct consumption coefficients (A_t) in 2030.

Industry's Code	S1	S2	S3	S4	S5	S6	S7	S8
S1	0.1064	0.0030	0.0023	0.6067	0.0506	0.1335	0.0019	0.1289
S2	0.0243	0.3039	0.0529	0.0123	0.0576	0.0610	0.0321	0.0090
S3	0.0062	0.0174	0.4523	0.0008	0.0093	0.0035	0.0060	0.0044
S4	0.0522	0.0043	0.0044	0.1050	0.0653	0.0462	0.0065	0.0339
S5	0.0762	0.0615	0.0867	0.0340	0.3904	0.0446	0.0739	0.0077
S6	0.0703	0.0237	0.0037	0.0059	0.0313	0.3855	0.1811	0.0084
S7	0.1477	0.0160	0.0149	0.0279	0.0330	0.0595	0.4286	0.0932
S8	0.1238	0.0177	0.0166	0.0322	0.0622	0.0696	0.0180	0.4183

Table A2. The regression coefficient and model test results of the sub-industries.

Industries	$Pgdp^2$	Pop	Itec	Itcc	Gio	Eiec	R^2	F	Sig.F
Mining and Quarrying	0.0225	0.0846	0.6878	0.0447	0.1868	−0.186	0.963	70.5	0
Light Industry	0.0805	0.1026	0.6935	0.0352	0.0835	−0.231	0.948	49.96	0
Manufacture of Textile	0.0795	0.1057	0.3923	0.3811	0.0714	−0.11	0.978	123.28	0
Petroleum Industry	0.0128	0.0194	0.0382	0.0185	0.0163	−0.024	0.987	219.82	0
Chemical Industry	0.2013	0.1571	0.2622	0.1038	0.1986	−0.04	0.945	46.99	0
Steel Industry	0.1157	0.1689	0.2124	0.2127	0.1402	0.1316	0.989	244.94	0
Electro-Mechanical Industry	0.1211	0.0893	0.2709	0.3037	0.1416	0.0283	0.968	83.07	0
Power Industry	0.0343	0.1724	0.2665	0.2647	0.1268	0.0881	0.971	92.45	0

Notes: The above variables are all significant at the 1% level.

Table A3. The peak path and peak value of CO_2 emissions in the subindustries (Unit: 1 billion CO_2).

Industries	Benchmark Scenario		Low-Carbon Scenario		High-Energy Consumption Scenario	
	Peak Value	Peak Year.	Peak Value	Peak Year.	Peak Value	Peak Year.
Mining and Quarrying	0.85	2031	0.67	2026	0.82	2039
Light Industry	0.52	2029	0.55	2027	0.79	2042
Manufacture of Textile	0.29	2032	0.27	2025	0.34	2043
Petroleum Industry	0.72	2028	0.68	2022	0.81	2038
Chemical Industry	3.20	2033	2.98	2028	3.70	2042
Steel Industry	3.08	2032	2.75	2028	3.39	2038
Electro-Mechanical Industry	0.59	2034	0.55	2022	0.74	2045
Power Industry	1.27	2036	1.36	2031	1.49	2040

Notes: Only the low-carbon scenario can achieve the CEPT by 2030.

Table A4. CO_2 emission forecasts of the subindustries in the low-carbon scenario. (Unit: 1 billion CO_2).

Years	Mining and Quarrying	Light Industry	Manufacture of Textile	Petroleum Industry	Chemical Industry	Steel Industry	Electro-Mechanical Industry	Power Industry
2017	0.54	0.39	0.23	0.64	2.53	2.45	0.48	0.78
2018	0.56	0.39	0.23	0.65	2.57	2.49	0.50	0.79
2019	0.58	0.40	0.23	0.66	2.62	2.52	0.52	0.81
2020	0.60	0.41	0.24	0.67	2.67	2.56	0.53	0.83
2021	0.61	0.43	0.24	0.67	2.72	2.60	0.55	0.86
2022	0.63	0.45	0.25	0.68 *	2.77	2.63	0.55 *	0.89
2023	0.64	0.46	0.26	0.68	2.83	2.67	0.55	0.92
2024	0.66	0.48	0.27	0.66	2.88	2.69	0.54	0.96
2025	0.67	0.51	0.27 *	0.65	2.92	2.72	0.53	1.02
2026	0.67 *	0.54	0.27	0.63	2.94	2.73	0.52	1.09
2027	0.67	0.55 *	0.26	0.62	2.96	2.74	0.51	1.18
2028	0.67	0.55	0.25	0.62	2.98 *	2.75 *	0.50	1.26
2029	0.66	0.53	0.23	0.61	2.98	2.74	0.50	1.31
2030	0.64	0.50	0.21	0.60	2.98	2.73	0.49	1.35
2031	0.63	0.47	0.20	0.60	2.96	2.71	0.49	1.36 *
2032	0.61	0.44	0.19	0.59	2.93	2.68	0.48	1.32
2033	0.59	0.42	0.19	0.59	2.90	2.65	0.48	1.24
2034	0.58	0.39	0.19	0.59	2.83	2.63	0.48	1.17
2035	0.56	0.37	0.18	0.58	2.77	2.61	0.47	1.10

Notes: The mark * represents the peak carbon emission.

Table A5. The predicted industrial added value of the subindustries (Unit: 1 trillion RMB).

Years	Mining and Quarrying	Light Industry	Manufacture of Textile	Petroleum Industry	Chemical Industry	Steel Industry	Electro-Mechanical Industry	Power Industry
2017	2.07	4.29	1.73	0.78	4.82	3.33	7.71	1.53
2018	2.11	4.58	1.83	0.77	5.08	3.48	8.76	1.61
2019	2.16	4.97	1.92	0.81	5.36	3.62	9.87	1.71
2020	2.22	5.27	2.01	0.83	5.66	3.77	10.94	1.77
2021	2.27	5.66	2.09	0.86	5.95	3.93	12.09	1.85
2022	2.38	6.04	2.20	0.87	6.26	4.13	13.48	1.96
2023	2.36	6.37	2.27	0.88	6.55	4.29	14.99	2.03
2024	2.38	6.74	2.39	0.89	6.84	4.42	16.67	2.10
2025	2.39	7.11	2.50	0.86	7.07	4.51	18.40	2.17
2026	2.39	7.55	2.68	0.86	7.36	4.62	20.28	2.25
2027	2.41	8.05	2.78	0.85	7.56	4.71	22.60	2.31
2028	2.42	8.47	2.93	0.88	7.85	4.78	25.38	2.42
2029	2.43	8.99	3.11	0.85	8.00	4.81	28.33	2.54
2030	2.43	9.72	3.26	0.80	8.26	4.77	31.56	2.71

Table A6. The setting of the growth rate in various variables under each scenario from 2017 to 2030 (%).

Scenarios	Pgdp	Pop	Iener	Icoal	Ieff
benchmark scenario	6	1	2	−3	14
low-carbon scenario	4	0	−3	−5	21
high-energy consumption scenario	6	1	7	5	7

Table A7. The Chinese industrial structure and its variations in each scenario from 2016 to 2030 (unit: %).

Industry	Industrial Structure in 2016	2030					
		A		B		C	
		Industrial Structure	Variation	Industrial Structure	Variation	Industrial Structure	Variation
Mining and Quarrying	8.34	4.72	−43.41	1.72	−79.38	3.82	−54.20
Light Industry	16.07	15.31	−4.73	16.21	0.87	15.31	−4.73
Manufacture of Textile	6.73	5.24	−22.14	6.02	−10.55	5.14	−23.63
Petroleum Industry	3.17	1.59	−49.84	0.88	−72.24	1.26	−60.25
Chemical Industry	18.78	14.02	−25.35	11.91	−36.58	13.01	−30.72
Steel Industry	12.96	8.12	−37.35	6.43	−50.39	7.51	−42.05
Electro-Mechanical Industry	27.99	46.64	66.63	53.16	89.92	49.68	77.49
Power Industry	5.97	4.36	−26.97	3.68	−38.36	4.26	−28.64

Notes: A, B and C, respectively, stand for economic growth priority scenario, CO_2 emission reduction priority scenario, and equal importance of the two objectives, respectively.

References

1. Wen, Z.; Zhang, X.; Chen, J.; Tan, Q.; Zhang, X. Forecasting CO_2 mitigation and policy options for China's key sectors in 2010–2030. *Energy Environ.* **2014**, *25*, 635–659. [CrossRef]
2. Yang, X.; Teng, F. Air quality benefit of China's mitigation target to peak its emission by 2030. *Clim. Policy* **2017**, *18*, 1–12. [CrossRef]
3. Niu, D.; Wang, K.; Wu, J.; Sun, L.; Liang, Y.; Xu, X.; Yang, X. Can China achieve its 2030 carbon emissions commitment? Scenario analysis based on an improved general regression neural network. *J. Clean. Prod.* **2020**, *243*, 1–14. [CrossRef]
4. Zhang, L.; Jiang, Z.; Liu, R.; Tang, M.; Wu, F. Can China achieve its CO_2 emission mitigation target in 2030: A system dynamics perspective? *Pol. J. Environ. Stud.* **2018**, *27*, 2861–2871. [CrossRef]
5. Gao, C.; Ge, H.; Lu, Y.; Wang, W.; Zhang, Y. Decoupling of provincial energy-related CO_2 emissions from economic growth in China and its convergence from 1995 to 2017. *J. Clean. Prod.* **2021**, *297*, 126627. [CrossRef]
6. Haberl, H.; Wiedenhofer, D.; Virág, D.; Kalt, G.; Plank, B.; Brockway, P.; Fishman, T.; Hausknost, D.; Krausmann, F.; Leon-Gruchalski, B.; et al. A systematic review of the evidence on decoupling of GDP, resource use and GHG emissions, part II: Synthesizing the insights. *Environ. Res. Lett.* **2020**, *15*, 065003. [CrossRef]
7. Yu, J.; Shao, C.; Xue, C.; Hu, H. China's aircraft-related CO_2 emissions: Decomposition analysis, decoupling status, and future trends. *Energy Policy* **2020**, *138*, 111215. [CrossRef]
8. Wang, F.; Wu, L.H.; Yang, C. Driving factors for growth of carbon dioxide emissions during economic development in China. *Econ. Res. J.* **2010**, *45*, 123–136. (In Chinese)
9. Chen, S.Y. Energy-save and emission-abate activity with its impact on industrial win-win development in China: 2009–2049. *Econ. Res. J.* **2010**, *45*, 129–143. (In Chinese)
10. Zhang, Y.; Liu, C.; Chen, L.; Wang, X.; Song, X.; Li, K. Energy-related CO_2 emission peaking target and pathways for China's city: A case study of Baoding City. *J. Clean Prod.* **2019**, *226*, 471–481. [CrossRef]
11. Wang, F.; Yang, F. A review of research on China's carbon emission peak and its forcing mechanism. *Chin. J. Popul. Res. Environ.* **2018**, *16*, 49–58. [CrossRef]
12. Du, X.W. Need to Establish a Forcing Mechanism for a Steady Declining Trend of Energy Consumption. 2012. (In Chinese). Available online: http://www.escn.com.cn/news/show-28620.html (accessed on 9 December 2020).
13. Elzen, M.D.; Fekete, H.; Höhne, N.; Admiraal, A.; Forsell, N.; Hof, A.F.; Oliver, J.G.; Roelfsema, M.; van Soest, H. Greenhouse gas emissions from current and enhanced policies of China until 2030: Can emissions peak before 2030? *Energy Policy* **2016**, *89*, 224–236. [CrossRef]
14. Fang, K.; Tang, Y.Q.; Zhang, Q.; Song, J.; Wen, Q.; Sun, H.; Ji, H.; Xu, A. Will China peak its energy-related carbon emissions by 2030? Lessons from 30 Chinese provinces. *Appl. Energy* **2019**, *255*, 113852. [CrossRef]

15. Su, K.; Lee, C.M. When will China achieve its carbon emission peak? A scenario analysis based on optimal control and the STIRPAT model. *Ecol. Indic.* **2020**, *112*, 106–138. [CrossRef]
16. Chen, H.; Wang, L.; Chen, W. Modeling on building sector's carbon mitigation in China to achieve the 1.5 °C climate target. *Energy Effic.* **2019**, *12*, 483–496. [CrossRef]
17. Tang, B.; Li, R.; Yu, B.; An, R.; Wei, Y.-M. How to peak carbon emissions in China's power sector: A regional perspective. *Energy Policy* **2018**, *120*, 365–381. [CrossRef]
18. Wang, D.; He, W.; Shi, R. How to achieve the dual-control targets of China's CO_2 emission reduction in 2030? Future trends and prospective decomposition. *J. Clean. Prod.* **2019**, *213*, 1251–1263. [CrossRef]
19. Liu, J.; Yang, Q.; Zhang, Y.; Sun, W.; Xu, Y. Analysis of CO_2 emissions in China's manufacturing industry based on extended logarithmic mean division index decomposition. *Sustainability* **2019**, *11*, 226. [CrossRef]
20. Meng, M.; Shang, W.; Wang, X.; Pang, T. When will China fulfill its carbon-related intended nationally determined contributions? An in-depth environmental Kuznets curve analysis. *Greenh. Gases Sci. Technol.* **2020**, *10*, 1039–1049. [CrossRef]
21. Yu, S.; Zheng, S.; Li, X.; Li, L. China can peak its energy-related carbon emissions before 2025: Evidence from industry restructuring. *Energy Econ.* **2018**, *73*, 91–107. [CrossRef]
22. Yu, S.; Hu, X.; Zhang, X.; Li, Z. Convergence of per capita carbon emissions in the Yangtze River economic Belt, China. *Energy Environ.* **2019**, *30*, 776–799. [CrossRef]
23. Peng, J.; Sun, Y.; Song, J.; Yang, W. Exploring potential pathways toward energy-related carbon emission reduction in heavy industrial regions of China: An input–output approach. *Sustainability* **2020**, *12*, 2148. [CrossRef]
24. Yan, Q.; Wang, Y.; Li, Z.; Baležentis, T.; Streimikiene, D. Coordinated development of thermal power generation in Beijing-Tianjin-Hebei region: Evidence from decomposition and scenario analysis for carbon dioxide emission. *J. Clean. Prod.* **2019**, *232*, 1402–1417. [CrossRef]
25. Zhao, F.; Liu, F.; Hao, H.; Liu, Z. Carbon emission reduction strategy for energy users in China. *Sustainability* **2020**, *12*, 6498. [CrossRef]
26. Hu, Y.; Ren, S.; Wang, Y.; Chen, X. Can carbon emission trading scheme achieve energy conservation and emission reduction? Evidence from the industrial sector in China. *Energy Econ.* **2020**, *85*, 104590. [CrossRef]
27. Zhang, H.; Zhang, R.; Li, G.; Li, W.; Choi, Y. Sustainable feasibility of carbon trading policy on heterogenetic economic and industrial development. *Sustainability* **2019**, *11*, 6869. [CrossRef]
28. Wang, Y.; Zou, L.L. The economic impact of emission peaking control policies and China's sustainable development. *Adv. Clim. Chang. Res.* **2014**, *5*, 162–168. [CrossRef]
29. Wang, Y.; Wang, E.D.; Bi, Y. Impact of a peak in carbon emissions on China's economy in different situations: Analysis based on CGE model. *Resour. Sci.* **2017**, *39*, 1896–1908. (In Chinese) [CrossRef]
30. He, S.B.; Tan, Q.; Zhou, H.R. Measurement of the effect of pollution reduction on the adjustment of industrial structure—Based on the perspective of input and output. *Stat. Inf. Forum* **2015**, *30*, 15–23. (In Chinese)
31. Zhang, B.B.; Tian, X.; Zhu, J. Environmental pollution control, marketization and energy efficiency: A theoretical and empirical analysis. *Nanjing Soc. Sci.* **2017**, 39–46. (In Chinese) [CrossRef]
32. Zheng, J.M. Effect and path of environmental regulation on Chinese industrial dynamics. *Financ. Trade Res.* **2018**, *29*, 21–29. (In Chinese) [CrossRef]
33. Yuan, Y.J.; Xie, R.H. Research on the effect of environmental regulation on industrial structure—Empirical test based on provincial panel data of China. *China Ind. Econ.* **2014**, 57–69. (In Chinese) [CrossRef]
34. Zhong, P.R. *Study on China's Inflation*; Jiangxi People's Publishing House: Nanchang, China, 1990. (In Chinese)
35. Ji, R.P. A discussion on the mechanism of forcing credit funds. *Soc. Sci.* **1993**, *1*, 16–19. (In Chinese)
36. Yu, Q.H.; Sun, S.H. Research on the forced mechanism and countermeasures in China's credit Relationship. *J. Shandong Univ. Financ. Econ.* **1996**, *2*, 29–31. (In Chinese)
37. Zhang, W. Forcing mechanism: Plausible reasoning as practical logic. *J. Cent. South. Univ. (Soc. Sci. Ed.)* **2012**, *18*, 59–62. (In Chinese)
38. Wu, Z.M. An analysis of the mechanism of social contradictions forcing reform and development. *Chin. Soc. Sci.* **2015**, *5*, 4–20, 203. (In Chinese)
39. Zhu, L.; Shao, Y. The new turn of social governance mechanism: Things forced prevent beforehand. *Soc. Sci. Res.* **2017**, *4*, 93–98. (In Chinese)
40. Zhang, Z.J.; Ban, L.; Yuan, X.L. Market shocks, assets allocation and debt financing decisions: Also on "stabilizing leverage" in the context of manufacturing recovery during the post-epidemic period. *Mod. Econ. Sci.* **2018**, *40*, 113–123, 128. (In Chinese)
41. Fei, L.; Dong, S.; Xue, L. Energy consumption-economic growth relationship and carbon dioxide emissions in China. *Energy Policy* **2011**, *39*, 568–574. [CrossRef]
42. Yu, S.; Zheng, S.; Ba, G.; Wei, Y.-M. Can China realise its energy-savings goal by adjusting its industrial structure? *Econ. Syst. Res.* **2016**, *28*, 1–21. [CrossRef]
43. Bai, C.E.; Zhang, Q. Prediction of China's economic growth potential: A supply-side analysis considering transnational productivity convergence and the characteristics of China's labor force. *China J. Econ.* **2017**, *4*, 1–27. (In Chinese) [CrossRef]
44. Li, P.; Lou, F.; Wang, H.W. Analysis and forecast of China's economic aggregate and its structure from 2016 to 2035. *Eng. Sci. China* **2017**, *19*, 13–20. (In Chinese) [CrossRef]

45. Niu, H.L.; Jiang, K.S. Measurement of low-carbon effect of industrial structure adjustment—Based on NSGA-II genetic algorith. *Ind. Econ. Res.* **2012**, *1*, 62–69, 94. (In Chinese)
46. Chen, S.Y. Reconstruction of sub-industrial statistical data in China (1980–2008). *China Econ. Q.* **2011**, *3*, 735–776. (In Chinese) [CrossRef]
47. Zhang, Y.; Wang, Y.; Hou, X. Carbon mitigation for industrial sectors in the Jing-Jin-Ji urban agglomeration, China. *Sustainability* **2019**, *11*, 6383. [CrossRef]
48. Zhao, Q.Z.; Yan, Q.Y. Driving factors analysis of carbon dioxide emissions in China based on STIRPAT model. *Adv. Mater. Res.* **2013**, 734–737. [CrossRef]
49. Intergovernmental Panel on Climate Change (IPCC). IPCC Guidelines for National Greenhouse Gas Inventories. 2006. Available online: https://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html (accessed on 20 September 2020).
50. Li, X.Y.; Wu, X.M.; Ma, Q.Q. The measure of China's Industry carbon emission and the structural decomposition analysis of influcing factors. *Statal Res.* **2014**, *31*, 56–62. (In Chinese)
51. Wei, H.K.; Wang, S.J. Analysis and theoretical reflection on China's "excessive deindustrialization" phenomenon. *China Ind. Econ.* **2019**, *1*, 5–22. (In Chinese) [CrossRef]
52. Huang, Q.H.; Huang, Y.H.; He, J.; Jiang, F.T. A study of an industrialization strategy for China's upper-middle income stage. *Soc. Sci. China* **2017**, *12*, 94–116, 207. (In Chinese)