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Research Article

Effect of Coal Consumption on the Upgrading of Industrial Structure

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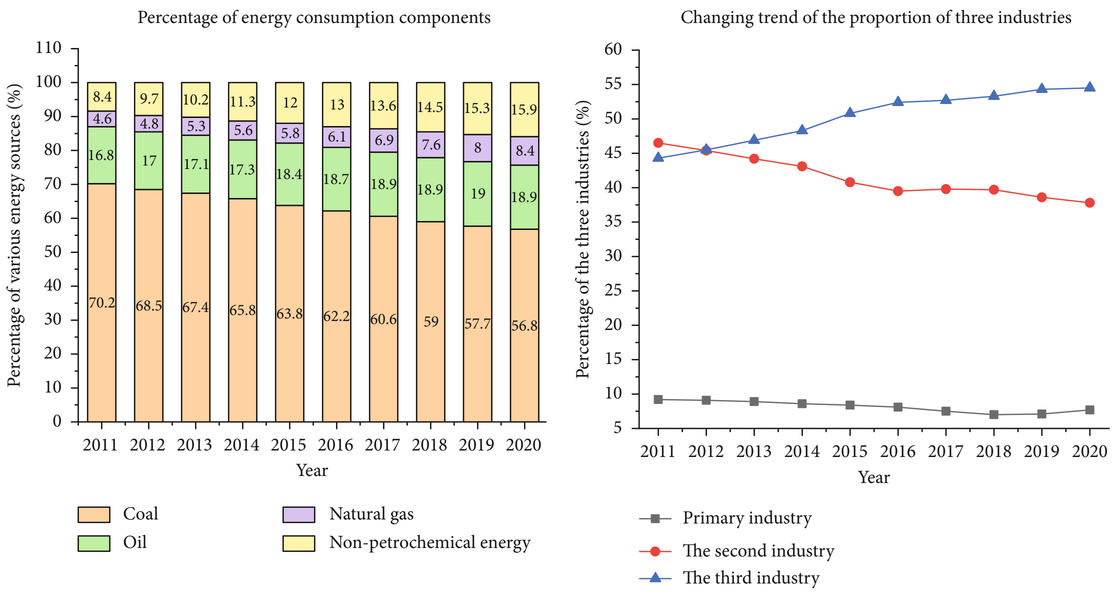
This paper attempts to study the effect of China's coal consumption on the upgrading of industrial structure based on the relevant data obtained from the China Statistical Yearbook (1992–2021). The results showed that (1) China's coal consumption has a downward trend, but it is still more than 56.8%. Similarly, the consumption of nonpetrochemical energy is not high, but the increase with respect to time is large. (2) Percentage of China's tertiary industry reached a maximum of 54.5% in 2020. However, there is a huge gap when compared to the global data. For example, the tertiary industries accounted for 77.4% in the US in 2017 and 71.3% in the UK in 2019. (3) In the short term, China's coal consumption will continue to promote the upgrading of industrial structure; in the long run, it is not obvious that China's coal consumption continues to drive the upgrading of industrial structure. (4) The intensity of the sustainable driving effect of China's coal consumption on the upgrading of industrial structure will gradually weaken from 0.0647 to 0.00102.

1. Introduction

According to the data from China's National Bureau of Statistics, the total energy consumption in 2021 was 5.24 billion tons of standard coal, an increase of about 5.2% over the previous year. China's coal consumption increased by 4.6%, crude oil consumption by 4.1%, natural gas consumption by 12.5%, and power consumption by 10.3%. Coal consumption accounted for 56% of the total energy consumption, down by 0.9 percentage points over the previous year. The total consumption of natural gas, hydropower, nuclear power, wind power, solar power, and other clean energy sources accounted for 25.5% of the total energy consumption, an increase of 1.2 percentage points over the previous year. The power and steel industries are still the sustainable driving factors of coal consumption in the high coal-consuming industrial sectors. China's coal consumption in building materials and chemical industries is equivalent to that in the same period last year. The above data show that it is very necessary to study China's coal consumption and its effect on the change of industrial structure.

With the development of economic globalization, energy strategy is at the heart of global economic development. The global primary energy demand is expected to continue to grow steadily, as it has over the last two decades. Human beings should learn to make the best possible use of the various energy sources available, including coal which is the most abundant and affordable fossil fuel [1–4]. Coal is an important fossil fuel and currently contributes to 41% of global electricity needs. However, the gradual depletion of coal has prompted researchers to explore a substitute for this fossil fuel [5]. Notwithstanding the environmental damage caused, coal remains an expanding low-price route to meeting energy needs and is forecasted to remain a major global resource in the future [6]. Although coal consumption can result in negative environmental impacts, coal remains a leading energy source to bring a notable change in the economic development of all countries [7]. Although China has abundant coal reserves, it is also a big coal consumer. Therefore, utmost attention should be paid to the coal imports and reserves [8]. It is important to note that China has relatively abundant coal reserves, but the oil and natural gas resources are scarce. Therefore, coal will dominate the energy consumption scenario for a long time in the future [9]. As basic energy and industrial raw material, coal provides an effective guarantee for China's economic development and national energy security [10]. In the process of analyzing China's energy consumption, it is found that coal consumption shows a downward trend, but it has still been at a high level (Figure 1(a)). At present, the major challenge to China's energy security is not the total amount of energy but the structural constraints [11]. Henceforth, China's energy consumption will face four major challenges: the population base and the scale of economic development governing that the total energy consumption are very large, rich coal reserves but insufficient oil and gas leading to an unreasonable energy structure, the rising external dependence on oil and gas dictating the unsafe energy supply, and the unconventional oil and gas endowment highlighting that using American model cannot achieve China's energy independence [12]. The unbalanced and insufficient development of the coal industry in China in terms of efficiency, technology, market, safety, and environment has become more noticeable and can no longer meet the new requirements for high-quality energy development and actively respond to climate change [13]. The global energy transformation and development provide a reference for energy reforms in China. The global energy transformation and development is led by two driving forces and one motive force. The spatial and regional imbalance in the global energy landscape is considered to be the internal driving force, whereas the gradual rise in the new energy competitiveness is the external driving force. Similarly, the scientific and technological revolution driven by scientific innovation and technological progress is also the sustainable driving force [14]. The major factors driving the future coal consumption in China include efficient power generation from coal; graded utilization, comprehensive treatment, and resource recovery of pollutants; generation of solid waste and biomass in coal-fired power generation; CO_2 capture, storage, conversion, and utilization; and smart energy [15]. At present, decapacity in the coal industry is the primary measure of the transformation of China's coal enterprises. The role of the decapacity policies is to promote the development of clean, low-carbon, efficient, and high-quality energy resources in China [16–19]. In addition, different studies have highlighted that the development of low-carbon technologies is also helping in reducing the environmental pollution caused by coal consumption. For example, Wang et al. pointed out that the development of clean coal technology is an important technique to overcome environmental pollution caused by coal utilization in China [20]. Coal-based carbon emissions constitute the most important part of total carbon emissions in China. Therefore, reduction in coal-based carbon emissions, in addition to efficient, clean, and low-carbon development and utilization of coal, is a major strategy to achieve the goal of carbon neutralization [21]. The empirical research by Xia and Wang showed that restricting coal consumption in terms of reduction in wastewater emissions is significantly better than the reduction in terms of waste gas and solid waste [22]. Chen et al. highlighted that carbon neutrality can be achieved in three stages: the initial stage (2020–2030), the critical stage (2030–2050), and the consolidation stage (2050–2060), and effective technical principles should be implemented at different stages. In addition, the dual strategies of energy savings, emission reduction, and increasing carbon sink should be considered [23].

The efficiency in the spatial flow of coal resources has a significant impact on the upgrading of industrial structure. This can be observed by the relationship between efficiency in the spatial flow of coal and the three dimensions of industrial structure. In other words, the coupling coordination degree is relatively high in areas with a high level of economic growth [24]. The improvement in energy efficiency is primarily contributed by the upgrading of industrial structure. The lack of the industrial structure upgrading significantly inhibits the energy efficiency, and the increase in the proportion of clean energy consumption has a positive effect on the energy efficiency [25]. Xue et al. found a relatively low state of coordinated development of the coal industry and environmental ecology in recent years, for example, the development of the coal industry over the years has caused more serious damage to the ecological environment [26]. Chiang studied on the impact of structural changes in the electric power industry, steel industry, and oil refinery on demand for maritime transport of bituminous coal and petroleum products. They highlighted the need to develop an active response plan such as the carbon neutrality policy by the government, proposing changes in the industrial structure, keeping a record of the status of ships owned by the national shipping companies, etc. [27]. Si and Mao found that the resource-based regions benefit from the resource bonus in the short term. However, as industries in these regions are prone to resource-dependent behavior, these regions have a crowding-out effect on other economic activities, resources, and the environment, which affects the long-term economic growth rate [28]. He et al. believed that while optimizing coal production capacity, the policy of coal productivity significantly affects the output of other energy industries and nonenergy industries with upstream and downstream linkages, which will inevitably affect the macroeconomy [29]. Xie et al. (2019) forecasted China's demand of the total energy consumption, and it was estimated that by 2025, China's energy consumption demand will be 5.5 ~ 5.6 billion tons of standard coal, and the coal consumption will reduce from 56% in 2021 to 50~52% in 2025 [30]. Xu and Xu concluded that the policy of providing energy subsidies has a positive role in promoting economy and partly improves the intensity of energy consumption. Coal subsidies can effectively reduce the cost of energy use and promote substantial economic growth; however, it is not conducive to a healthy environment [31]. Zhou et al. integrated mineral resources and eco-environmental factors into the Cobb-Douglas production function and proposed a comprehensive diagnosis method of resources. The results



(a) Percentage of energy consumption components

(b) Changing trend of the proportion of three industries

Figure 1: Distribution of China's energy consumption and the proportion of three industries.

showed that strengthening eco-environmental protection and governance and implementing dual control over the total amount and intensity of coal resources are important measures to crack the path-dependent of industrial sector development in resource-dependent cities [32–35].

Earlier literature on coal consumption mainly focused on the following two aspects: (1) for a long time, coal resources will remain an important strategic resource for the economic development in China, mainly for China's energy endowment and for overcoming structural contradictions and challenges. It is to be noted that the major challenge for the development of the coal industry is to deal with the environmental problems caused by coal consumption, and (2) the early literature studied the relationship between China's coal consumption and economic development, primarily including the relationship between industrial structure and coal flow efficiency; the coupling coordination degree between the coal industry and industrial structure; the measures undertaken for the comprehensive development of resources, environment, and economy; and the increasing economic dependency on resources available in the city. Only a few studies are focusing on the correlation between China's coal consumption and the upgrading of industrial structure. According to the existing literature, the factors influencing industrial structure upgrading mainly are the extent of new urbanization, environmental regulations, research and development activity, internet development, financial development, etc. [36–39]. In fact, the industries in China dependent on coal consumption include power, steel, building materials, chemical, and other industries, most of which belong to the secondary industrial sector [40, 41]. Undoubtedly, coal consumption is an important factor affecting the upgrading of industrial structure, and therefore, this study will focus on the impact of China's coal consumption on the upgrading of industrial structure.

2. Data and Methodology

2.1. Data and Variables. The data required for this study include the GDP of China (100 million yuan), the proportion of three industries in China (%), total energy consumption (100 million tons of standard coal), total coal consumption (100 million tons of standard coal), and other statistical data, which were all from China Statistical Yearbook (1992~2021) and sorted out. In this study, China's coal consumption (Tec) is considered an independent variable, and China's index of industrial structure upgrading (Index) is a dependent variable.

Considering the characteristics of China's GDP and actual coal consumption over the years, Tec is expressed as the actual coal consumption per-unit GDP. As the factor of production price is a measure of calculating the output value, the actual coal consumption per-unit GDP can be divided into energy consumption per-unit output value at the current price and energy consumption per-unit output value at the comparable price. During the study period, when the energy consumption per-unit output value changes, energy consumption per-unit output value at a comparable price can be adopted [42]. The output value at the comparable price can be calculated as follows:

$$\mathrm{GDP}_{t+1} = \frac{(\mathrm{GDP}_t \times I_{t+1})}{100}, \tag{1}$$

where I_{t+1} is the GDP index of the $(t+1)^{\text{th}}$ year (calculated by comparable prices, namely, by considering the GDP index of the previous year is equal to100).

Upgrading of China's industrial structure is characterized by the increasingly prominent position of the tertiary industry and the lesser importance of the primary industry. Therefore, the tertiary industry is given the highest weightage, and the primary industry is given the lowest weightage while calculating the Index. The following equation (2) for calculating Index is adopted based on the study by Yin and Chang [43]:

$$\text{Index} = \sum_{i=1}^{3} y_i \times i = y_1 \times 1 + y_2 \times 2 + y_3 \times 3, \quad (2)$$

where y_i represents the proportion of the i^{th} industry ($i = 1, 2, 3$), and the upper and lower limits of Index are 1 and 3, respectively. If Index is close to 1, it will indicate the lower level of industrial structure, staying at the initial level of industrialization; if Index is close to 3, it will indicate the higher level of industrial structure, reaching the level of developed countries; if Index is closer to 2, it will indicate that the level of industrial structure is between the first two, which is an industrialized economy, dominated by industry.

2.2. Methodology

2.2.1. Granger Causality Test. Sims introduced the variable autoregressive model (VAR model) in economics, which promoted the widespread application of dynamic analysis of the economic system [44]. VAR model was often used to predict interconnected time series systems and analyze the dynamic impact of random disturbances on variable systems. Another important application of the VAR model is to analyze the causal relationship between economic time series variables, Granger believed that whether variable X is the Granger cause of variable Y mainly depends on the extent to which current variable Y can be explained by past variable X, namely, whether adding some lag variable values of variable X can significantly improve the degree of interpretation to variable Y [45]. Thereafter, Sims proposed and proved a theorem convenient for the Granger causality test, which greatly promoted its wide application in economics [46]. Its regression equation is as follows:

$$Y_t = \sum_{i=1}^{m} \alpha_i X_{t-1} + \sum_{i=1}^{m} \beta_i Y_{t-1} + \mu_t. \quad (3)$$

According to the requirements of hypothesis test in statistics, two hypotheses are put forward, (1) null hypothesis: variable X is not the Granger cause of variable Y, namely, $\alpha_1, \alpha_2, \cdots \cdots, \alpha_m$ are all equal to 0; (2) alternative hypothesis: variable X is the Granger cause of variable Y, namely, α_1, $\alpha_2, \cdots \cdots \alpha_m$ are not all 0. The calculation formula of its F-statistic is shown in the following equation.

$$F = \frac{(\text{RSS}_R - \text{RSS}_U)/m}{\text{RSS}_U/(n-k)}, \quad (4)$$

where m is the number of lagging terms of variable X; n is the number of observations, and k is the number of parameters to be estimated in unconstrained regression. Make regression including and excluding the lag term of variable X in equation (3), and record the sum of squares of residuals (unconstrained regression) as RSS_U and the sum of squares of residuals (constrained regression) as RSS_R. If the calculated F-statistic is greater than the critical value $F_\alpha(m, n-k)$ at a given significance level α, the null hypothesis is rejected, which indicates that variable X is the Granger cause of variable Y. Similarly, we can study whether variable Y is the Granger cause of variable X. If variable X is the Granger cause of variable Y, we believe that the past behavior of variable X has a sustainable driving effect on variable Y [47].

2.2.2. Distributed Lag Model. The Granger causality test indicates the existence of a sustainable driving impact. However, the intensity of such a force needs to be evaluated. The distributed lag model is a novel method to evaluate the intensity of sustainable driving impact. The distributed lag model is expressed as

$$Y_t = \alpha + \beta_0 X_t + \beta_1 X_{t-1} + \beta_2 X_{t-3} + \cdots + \beta_m X_{t-m} + \mu_t. \quad (5)$$

In the distributed lag model (equation (5)), there is no lag explained variable, only the current explanatory variable X and its lag explanatory in several periods. Coefficient β_0 is short-run or impact multiplier, indicating the impact of one unit of change in variable X on the average value of variable Y in the current period. Coefficient $\beta_i (i = 1, 2 \cdots, m)$ is the dynamic multiplier or delay coefficient, which indicates the influence of the change of each lag-variable X on the average value of variable Y. If each coefficient value in the distributed lag model is statistically significant, the intensity of each lagged input of variable X on variable Y can be accurately calculated. Further study found that when the coefficients pass the significant level, the more lag items are designed, the more obvious the sustainable driving effect is.

3. Processing Data

3.1. Descriptive Statistics. According to the energy statistics obtained from the Statistical Yearbook (1992–2021) in China, the percentage distribution of various sources of energy consumption in China is shown in Figure 1(a). As shown in Figure 1(a), although coal consumption shows a downward trend, it still accounts for more than 56.8% of the total energy consumption, which indicates that China's energy consumption will still depend on coal in the coming years, whereas the oil consumption is significantly lower than that of coal, slightly increasing from 16.8% in 2011 to 18.9% in 2020. Although the consumption of natural gas is low, the increase in consumption from 4.6% in 2011 to 8.4% in 2020 is large. In addition, although the consumption of non-petrochemical energy is not high, a large increase is observed, i.e., from 8.4% in 2011 to 15.9% in 2020. The said researches show that China's robust energy reform strategies for promoting the clean and efficient utilization of coal, focusing on the development of noncoal energy sources, and forming a multiwheel-driven energy supply system of coal, oil, gas, nuclear energy, and renewable energy are proving to be rewarding.

According to the data form the World Statistical Yearbook, generally, the primary industries account for about

5% of GDP in the high-income countries, whereas the tertiary industries account for more than 60% in those countries. For example, the primary and tertiary industries accounted for 0.9% and 77.4% of GDP in the US in 2017. Similarly, the primary and tertiary industries accounted for 0.6% and 71.3% of GDP in the UK in 2019 (data from the World Statistical Yearbook 2020). From the industrial structure statistics provided by Statistical Yearbook (2012–2021) (Figure 1(b)) in China, a huge gap is observed in China when compared to the global data. The primary and tertiary industries accounted for 7.1% and 54.3% in 2019 in China. From 2011 to 2020, the primary industrial sector shows a downward trend, but it is still more than 7%, whereas the tertiary industrial sector shows a slow upward trend, reaching a maximum of 54.5% in 2020.

A negative correlation between Tec and Index is evident in Figure 2. From 1991 to 2020, Tec decreased from 3.83 in 1991 to 0.28 in 2020, i.e., a decrease of 92.7%. At the same time, Index increased from 2.105 in 1991 to 2.468 in 2020, i.e., an increase of 17.2%. The aforementioned study shows that steps have been undertaken to follow the concept of energy structure adjustment and power conversion, incorporated in the 13$^{\text{th}}$ five-year plan, which has led to high-quality development.

3.2. Results of Granger Causality Test. In order to avoid pseudo regression, the stationary of time series data must be tested by unit root. If the time series data are of the same order stable, regression can be carried out. Augmented Dickey-Fuller (ADF) test results showed that the two original sequences of Tec and Index are unstable, but their first-order difference sequences are stable. Granger causality test was performed by *Eviews* 6.0 software to examine the relationship between Tec and Index. After repeated trial calculation, when the lag period is greater than 8, Tec is not the Granger cause Index, and Index is not the Granger cause Tec. Therefore, the maximum lag period of Granger causality test is 8.

As shown in Table 1, with a significance level of 5%, Tec is Granger reason of Index for the lag of 2 to 5. Tec is not Granger reason of Index for the lag period of 6 to 8. In addition, for the lag period of 2, 3, and 5, Index is Granger cause of Tec. Index is not Granger cause of Tec for the lag of 4, 7, and 8. The above results clearly indicate that (1) China's coal consumption is a sustainable driving force to promote the upgrading of industrial structure in the short term; (2) in the long run, China needs to upgrade the industrial structure to drive sustainable coal consumption. Whether in the short term or long term, China's industrial structure upgrading has a definite role in promoting coal consumption, but it does not show strong sustainability.

3.3. Regression Results of Distributed Lag Model. As the transmission of economic policies needs to be considered in time series data, economic interaction and penetration need specific time intervals to materialize. The values of these variables are usually determined by variables on their own lags or the lags of other variables. Therefore, the lag relationship of variables should always be considered (equation (5)). If the characteristics of China's coal consumption are considered as variables in the distributed lag model, the multicollinearity between these multiple lagged variables should be objective. If *OLS* is directly used to estimate the parameters, the influence of each lagged variable on the dependent variable cannot be accurately calculated. This makes it necessary to estimate the values by an alternate method, and the commonly used method in such cases is the *Almon* method. The number times of *Almon* polynomial are generally 2 or 3 for all practical applications. After repeated trials, this study believes that it is more appropriate to consider the number times of *Almon* polynomial as 2. At the same time, considering that the lag period of Granger causality test is 8. Therefore, the lag period of distributed lag model is also 8. The corresponding results obtained by using Eviews 6.0 software are shown in Table 2. F-statistics, goodness of fit (R^2), and adjusted R^2 are equal to 221.133, 0.973584, and 0.969181, respectively, which clearly indicate a good fit of the equation and statistical significance. Except for the absolute values of the t-statistic of coefficients β_5, β_6, β_7, and β_8 (i.e., less than 2), the absolute values of the t-statistic of other coefficients are greater than 2 and statistically significant. The above results imply that the regression results of the distributed lag model in Table 2 need to be further improved.

With the increase in the number of lagged terms, the estimated coefficient value of the above regression is close to 0. Therefore, based on the condition that the number times of *Almon* polynomial is 2, the number of lagged terms is still 8, and the distal constraint is applied for reestimation (Table 3). In this case, F-statistics, goodness of fit (R^2), and adjusted R^2 are equal to 349.9884, 0.973574, and 0.970792, respectively, implying that the equation has a good fit and the values are statistically significant. Except for the absolute value of the t-statistic of coefficient β_8 (i.e., less than 2), the absolute values of t statistic of other coefficients are greater than 2 and statistically significant. When the distal constraint is applied to distributed lag model, marked improvements in statistically significant results are observed.

As shown in Table 3, except for the constant term, all the coefficient values are negative, implying that a continuous reduction in China's coal consumption (cost-effective index) promotes upgrading of industrial structure (benefit index). In Table 3, the coefficient values of each lag period of Tec also have a clear meaning. For example, the coefficient value of lag period 5 of Tec is -0.01334, which indicates that when other conditions remain unchanged, the intensity of Tec acting on Index increases by 0.01334 units for every change of 1 unit in lag phase 5 of Tec. It is interesting to note that with the extension of the lag period, the continuous driving effect of China's coal consumption on the industrial structure upgrading gradually weakened from 0.06470 to 0.00102. In fact, the coefficient β_i ($i = 1, 2, 3, 4, 5, 6, 7, 8$) indicates the effect intensity of the i^{th} Tec on the dependent variable (index) under the condition that other conditions remain unchanged. It is obvious that the effect intensity of Tec must weaken with the change of time. The most likely explanation for the failure of coefficient β_8 to pass the significance test is that as a time node,

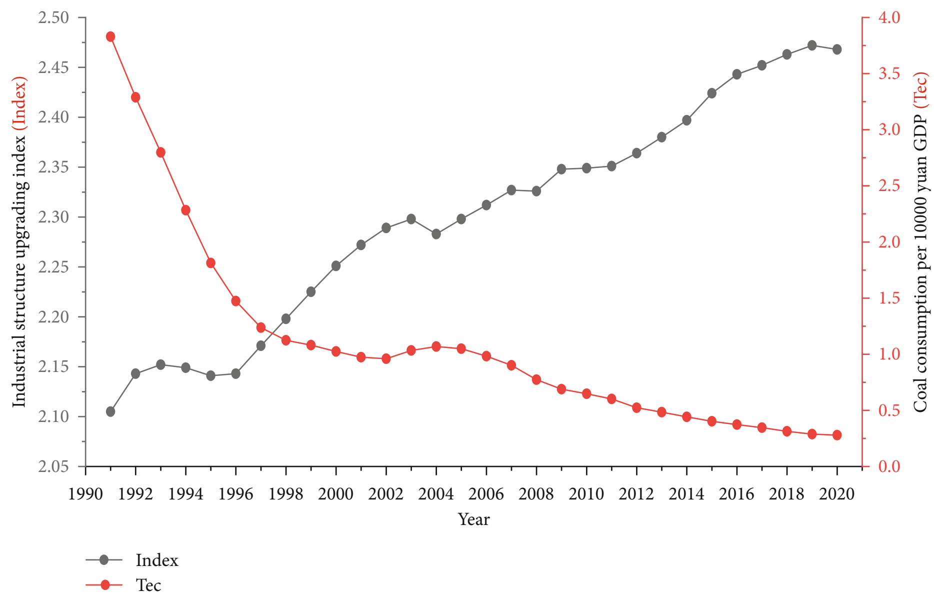


Figure 2: Comparison between China's coal consumption and industrial structure index.

Table 1: Granger causality test between Tec and Index.

Null hypothesis	Lags	F-statistic	P-value	Results
Tec does not Granger cause Index	1	0.69502	0.4121	Not rejected
Index does not Granger cause Tec		1.16003	0.2914	Not rejected
Tec does not Granger cause Index	2	5.88936	0.0086	Rejected
Index does not Granger cause Tec		8.56336	0.0017	Rejected
Tec does not Granger cause Index	3	5.35953	0.0071	Rejected
Index does not Granger cause Tec		3.82947	0.0257	Rejected
Tec does not Granger cause Index	4	6.94820	0.0017	Rejected
Index does not Granger cause Tec		1.28503	0.3148	Not rejected
Tec does not Granger cause Index	5	3.61947	0.0261	Rejected
Index does not Granger cause Tec		3.23140	0.0380	Rejected
Tec does not Granger cause Index	6	2.76928	0.0682	Rejected
Index does not Granger cause Tec		2.32941	0.1064	Not rejected
Tec does not Granger cause Index	7	1.81634	0.2105	Not rejected
Index does not Granger cause Tec		3.32026	0.0572	Not rejected
Tec does not Granger cause Index	8	1.81634	0.4184	Not rejected
Index does not Granger cause Tec		3.32026	0.0674	Not rejected

Table 2: Regression results of the distributed lag model without distal constraint.

Coefficient	Coefficient value	t-statistic	Coefficient	Coefficient value	t-statistic
α	2.537195	296.8817	β_4	-0.02115	-2.76838
β_0	-0.06377	-4.77463	β_5	-0.01391	-1.94422
β_1	-0.05106	-8.94406	β_6	-0.00804	-1.72570
β_2	-0.03973	-11.3937	β_7	-0.00353	-1.87612
β_3	-0.02976	-4.84225	β_8	-0.00039	-0.05082

Table 3: Regression results of the distributed lag model with distal constraint.

Coefficient	Coefficient value	t-statistic	Coefficient	Coefficient value	t-statistic
α	2.536892	336.9178	β_4	-0.02052	-17.4207
β_0	-0.06470	-9.15953	β_5	-0.01334	-7.84668
β_1	-0.05134	-11.4023	β_6	-0.00769	-3.99488
β_2	-0.03953	-16.0575	β_7	-0.00358	-2.07088
β_3	-0.02926	-25.4961	β_8	-0.00102	-0.93506

the energy policy eight years ago may not meet the current development requirements, and it is of utmost necessity to bring deepening energy reforms hereafter to pursue high-quality development.

4. Discussions

There are the following limitations while evaluating the sustainable driving effect by the Granger causality test: (1) it can evaluate whether variable X has a sustainable driving effect on variable Y under a certain lag period, but its intensity cannot be evaluated. Similar to the statistically significant multivariable regression model, it can only determine the joint influence of the explanatory variable on the explained variable; (2) Granger causality test of bivariate series also does not consider the possible influence of other variable sequences. In addition, it does not consider the nonlinear causality.

Although we can evaluate the intensity of the continuous driving effect of China's coal consumption on the upgrading of industrial structure, there is great uncertainty in the determination of the number times and lagged terms of *Almon* polynomial.

When the Granger causality test has 7 or 8 lags, Tec is no longer the Granger reason for Index. However, the regression results of the distributed lag model showed that the values of coefficient β_7 are statistically significant, while the values of coefficient β_8 do not pass the significance test. Hence, these results need further evaluation. Briefly speaking, on the one hand, from equations (3) and (5), it can be judged that the Granger causality test does not consider the current impact of Tec, while the distributed lag model considers the current impact of Tec; on the other hand, equations (3) and (5) study on the influence of independent variables on dependent variables from different aspects, and some differences are inevitable. It is important to state that any economic phenomenon such as industrial structure upgrading is the result of many factors. However, this study only considers coal consumption as an independent variable, and other variables are assumed to be control variables. Therefore, the results obtained in this study may have certain limitations.

5. Conclusions

The emphasis of this study is the impact of China's coal consumption on the upgrading of industrial structure. On the one hand, the concept of the sustainable driving effect is explained by applying the Granger causality test. On the other hand, because the transmission of economic policy, the interaction, and penetration of economic action in the economic system all need a certain time, distributed lag model can be used to study on the intensity of sustainable driving effect in a time series data.

The coal consumption in China shows a downward trend, but the proportion is still more than 56.8%. Similarly, the consumption of nonpetrochemical energy is not high, but the increase with respect to time is large. China's tertiary industry reached a maximum of 54.5% in 2020, but there is a huge gap when compared to the global data. For example, the tertiary industries in the United States accounted for 77.4% in 2017 and 71.3% in the UK in 2019.

Granger causality test showed that in the short term, China's coal consumption will continuously promote the upgrading of industrial structure. However, the continuous promotion of China's coal consumption on the upgrading of industrial structure is not obvious in the long run. The regression results of distributed lag model highlighted that with the extension of the lag period, the intensity of the sustainable driving effect of China's coal consumption on the industrial structure upgrading will gradually weaken from 0.0647 to 0.00102.

Data Availability

The datasets generated during the current study are available from the corresponding author on reasonable request.

Conflicts of Interest

No conflict of interest exists in the submission of this manuscript.

Authors' Contributions

The manuscript is approved by all authors for publication.

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