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Research on the Relationship between Industrial Structure Change and Carbon Emission in Major Developed Countries based on Improved Grey Correlation

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Abstract

Based on the data of three industries and carbon emissions from 2000 to 2018, this paper improved the grey correlation analysis model and combined with the analytic hierarchy Process to build an improved grey correlation analysis model to analyze the relationship between industrial structure change and carbon emissions in four major developed countries, the United States, Japan, The United Kingdom and Germany. The correlation between carbon emissions and three major industries in four countries was calculated. The results show that in developed countries as a whole, the secondary industry has the highest correlation with carbon emissions, followed by the tertiary industry, and the primary industry has the lowest correlation with carbon emissions. In addition, the development of the secondary industry is still the main contribution source of carbon emissions in developed countries, and as developed countries continue to shift the focus of industrial development to the tertiary industry, the "carbon reduction" attribute of the tertiary industry is fully manifested.

Keywords

Improved Grey Relational Analysis Model; Industrial Structure Change; Carbon Emissions.

1. Introduction

With the increasingly obvious trend of economic globalization, countries pay more and more attention to the economic benefits brought by industrial development, but ignore the environmental pollution caused by the imbalance of industrial structure. However, with the increasing global warming and energy crisis, countries in the world gradually realize that it is urgent to adjust the unreasonable industrial structure and low-carbon development path. The United States, Japan, the United Kingdom and other major developed countries took the lead in adjusting their industrial structure. By formulating industrial policies and increasing capital input, the proportion of the tertiary industry in the national economic system has been continuously expanded, and the industrial structure has been gradually tilted towards the tertiary industry. As a result, carbon emissions have been effectively controlled and shown a declining trend year by year. Therefore, the study of the relationship between industrial structure and carbon emissions in developed countries is of great practical significance to the industrial structure adjustment and low-carbon development of developed countries and even China in the future.

2. Literature Review

Industrial structure change is a dynamic evolution process with both time and space. The existing research mainly reflects on the influencing factors and effects of industrial structure

ISSN: 2688-9323

change. In terms of influencing factors, it is mainly related to technological innovation level, income level and economic growth. Specifically, in the process of industrial structure adjustment, technological innovation level plays a non-negligible role. Technological innovation promotes the adjustment and transformation of industrial structure by promoting industrial development, and promotes the optimization and upgrading of industrial structure (Gassmann et al.[1], 2012; Zuhdi et al.[2], 2014). In addition, the influence mechanism of income level on the change of industrial structure is mainly reflected in two aspects: On the one hand, when the income level of residents increases, people's demand for entertainment services increases correspondingly, which transfers the development focus of industrial structure to the tertiary industry, thus promoting the high-level development of industrial structure (Katsumoto & Watanabe[3], 2003). On the other hand, the increase of residents' income increases the production cost of producers. Driven by cost pressure, resources flow from high-cost sectors to low-cost sectors, thus realizing reasonable allocation of production factors and promoting the rational development of industrial structure (Alvarezcuadrado et al.[4], 2014). With the rapid development of economy and the continuous improvement of people's living standards, the informatization degree of industrial sectors is also getting higher and higher, thus promoting the overall industrial structure to constantly shift to knowledge and technical sectors and gradually optimizing the development pattern of industrial structure to "three, two and one" (Restuccia[5], 2010; Liu Quanliang[6], 2019).

In terms of effect, the optimization and upgrading of industrial structure will have a positive effect on economic growth, and the correctness of this conclusion has been verified in China and Russia (Zhao & Tang[7], 2017; Zhu & Shan[8], 2020). At the same time, the optimization and upgrading of industrial structure will promote the increase of employment opportunities, especially when the industrial structure shifts to public service, finance, real estate and other tertiary industries, it will have a positive effect on social employment (Yang Fan[9], 2019). Employment in different industries will have a greater impact on their income. The impact of industrial structure change on residents' income is reflected in many aspects: From the perspective of income level, when the proportion of the secondary industry is increasing and the industrialization degree of industrial structure is gradually deepening, it will promote residents' income level (Jacobs[10], 2014). From the perspective of income gap, the increase in the proportion of secondary industry and the advanced development of industrial structure will increase the urban-rural income gap, while the rationalization of industrial structure will narrow the urban-rural income gap (Li Chao[11], 2019). Finally, with the development of economic integration, international trade scale expands unceasingly, the adjustment of industrial structure effect is no longer limited to domestic, import and export products at the same time to value, the scale of import and export products, on some aspects, such as, in turn, increase the product competitiveness of foreign trade and trade strength, eventually to promote their country's foreign trade market prosperity (Haar[12], 2010; Zhai and Zhao [13], 2016).

In general, the analysis of the effect of industrial structure change is mainly reflected in its impact on economic growth, social employment and foreign trade, while few scholars have studied the impact of industrial structure change on carbon emissions. Based on this, this paper analyzes the impact of industrial structure change on carbon emission relationship according to the current situation of global environment and the goal of realizing sustainable development of economy, environment and society, and lays a foundation for realizing the goal of “dual carbon”.

ISSN: 2688-9323

3. Theoretical Hypothesis

In the era when economy leads social progress, the characteristics of industrial structure largely determine the type and quantity of energy consumption, which will lead to a large number of emissions of greenhouse gases such as carbon dioxide. Therefore, the change of industrial structure has a significant impact on carbon dioxide emissions.

In the industrial structure, the primary industry mainly influences carbon emissions from two aspects: On the one hand, the division of the three industries shows that the primary industry includes agriculture, forestry, animal husbandry and fishery, and most of them are closely related to plant cultivation, which makes the primary industry itself have a certain carbon sequestration function and can absorb carbon dioxide in the atmosphere and reduce carbon dioxide emissions. On the other hand, the development of primary industry is inevitably accompanied by the use of pesticides and fertilizers, agricultural equipment and deforestation, which to some extent increases carbon dioxide emissions or reduces carbon dioxide absorption. However, with the acceleration of the pace of industrial restructuring, the proportion of the primary industry in the national economic system is gradually shrinking, so its promotion or suppression effect on carbon emissions is also weakening. The total amount of resources and energy consumed by the development of the secondary industry is large, especially the high carbon sectors such as petroleum, coal, materials and paper, which consume a lot of energy, leading to a high carbon emission intensity. Secondly, the impact of intermediate sectors such as food, textile and tobacco processing on carbon emissions cannot be ignored. The tertiary industry belongs to the service industry, and its operation is not accompanied by material production activities, which consumes less energy. Among them, the tertiary industry, such as water conservancy and public facilities management, also effectively reduces carbon dioxide emissions. Therefore, the tertiary industry has a relatively obvious inhibitory effect on carbon emissions.

Therefore, the evolution of primary industry to secondary industry will lead to the increase of carbon emissions, and the evolution of secondary industry to tertiary industry, especially when tertiary industry occupies a dominant position, carbon dioxide emissions will be effectively suppressed. Based on this, the change of industrial structure will have a significant impact on carbon emission level.

4. Empirical Analysis

4.1. Sample Selection and Data Sources

So far, a total of 31 of the developed countries in the world, in the process of empirical research, if the calculation and analysis, the focus on each of the 31 countries involved in the data is too big and not easy to collect, display, measuring process and therefore appear multifarious the inconvenience but also prone to caused by error of calculation result is not consistent with actual situation. In view of this, this paper selects four major developed countries, the United States, Japan, the United Kingdom and Germany, as representatives, based on the proportion of output value of tertiary industries in GDP and total carbon emissions data from 2000 to 2018, and uses the improved grey correlation analysis model to study the correlation between tertiary industries and carbon emissions in these four countries from 2000 to 2018.

In this paper, the industrial share data of GDP of four major developed countries from 2000 to 2018 come from the website of the National Bureau of Statistics, the World Bank WDI database and the 2019 International Statistical Yearbook. The total carbon emission data comes from the World Bank WDI database, Environmental Indicators Data from 1960 to 2018. Some hard-to-find data were calculated and sorted out through relevant literatures, journals and reports.

ISSN: 2688-9323

4.2. Variable Description

In this paper, the total amount of carbon emissions is selected as the index to measure the level of carbon emissions, and the industrial composition of GDP, namely, the proportion of the output value of the primary, secondary and tertiary industries in GDP, is used as the index to measure the industrial structure. In basic grey correlation analysis model, the carbon emissions as a dependent variable, Y included in the reference sequence, the first industrial output value accounted for the proportion of gross national product (GNP), the second industry output value accounted for the proportion of gross national product (GNP) and the tertiary industry output value accounted for the proportion of gross national product (GNP) as the independent variable, respectively on comparative sequence X1, X2, X3; In the analytic hierarchy Process, the total carbon emission is determined as the affected factor, which is taken as the evaluation objective A, and the proportion of the output value of the first, second and tertiary industries in the GROSS national product is taken as the influencing factor, which is taken as the evaluation samples U1, U2 and U3. Table 1:

Table 1. The index system

Research object	Measure	Basic grey relational analysis model	Analytic hierarchy process
Industrial structure	The proportion of output value of primary industry in GDP	Compare sequence X_1	Evaluation of the sample U_1
	The proportion of the output value of the secondary industry in GDP	Compare sequence X_2	Evaluation of the sample U_2
	The proportion of output value of tertiary industry in GDP	Compare sequence X_3	Evaluation of the sample U_3
Carbon emission level	Total carbon emission	Reference sequence Y	Evaluation target A

4.3. Model Construction

According to existing studies, when the industrial structure continues to tilt toward the tertiary industry, carbon dioxide emissions will also show a downward trend, that is, there is some correlation between the change of the proportion of the tertiary industry and carbon emissions. Therefore, this paper will adopt the improved grey correlation model to calculate the correlation between the change of the proportion of output value in GDP of the tertiary industries and carbon emissions, and study the relationship between the change of industrial structure and carbon emissions in major developed countries.

(1) Construction of basic grey correlation analysis model

①Determine the reference sequence and comparison sequence

Establish the reference sequence, that is, the system feature sequence, denoted as $Y : Y = \{Y(1), Y(2), Y(3), \ldots, Y(n)\}$; Establish the comparison sequence, that is, the sequence of relevant factors, denoted as, $X_i : X_i = \{X_i(1), X_i(2), X_i(3), \ldots, X_i(n)\}$.

②Dimensionless processing of sequence

Since the dimensions of reference sequence and comparison sequence in the system are different, direct comparative analysis may lead to inaccurate measurement results. Therefore, it is necessary to conduct dimensionless processing for the original data of reference sequence and comparison sequence. In this paper, the initial method is adopted for dimensionless processing to obtain the dimensionless sequence:

ISSN: 2688-9323

$$X_i^{'} = \{X_i(1)/X_i(1), X_i(2)/X_i(1), X_i(3)/X_i(1), ..., X_i(n)/X_i(1)\} \tag{1}$$

③Obtain the absolute value sequence of the difference

According to the dimensionless sequence obtained, the value of each period of the comparison sequence is subtracted from the corresponding period of the reference sequence, and the absolute value is taken to obtain the absolute value sequence of the difference value:

$$\Delta_i(n) = \left|X_0^{'}(n) - X_i^{'}(n)\right| \tag{2}$$

④Calculate the correlation coefficient

In the sequence of difference $\Delta_i(n)$, Take the maximum value of each group $\Delta_i(\max)$, The minimum value $\Delta_i(\min)$. In Group I, take out the maximum $\Delta_i(\max)$ and minimum $\Delta_i(\min)$.

$$\Delta(\max) = \{\Delta_1(\max), \Delta_2(\max), \Delta_3(\max), ..., \Delta_i(\max)\} \tag{3}$$

$$\Delta(\min) = \{\Delta_1(\min), \Delta_2(\min), \Delta_3(\min), ..., \Delta_i(\min)\} \tag{4}$$

Then, the correlation coefficient between the ith comparison sequence and the reference sequence at the NTH period can be expressed as:

$$N_i(n) = \frac{\Delta(\min) + \rho\Delta(\max)}{\Delta_i(n) + \rho\Delta(\max)} \tag{5}$$

Where, ρ represents the standardized coefficient, and the value range is (0,1). $\rho = 0.5$.

⑤Calculate the correlation degree

The correlation degree can be obtained by averaging the correlation coefficients $N_i(n)$ of the comparison sequence and reference sequence in each period R_i :

$$R_i = \frac{1}{n}\sum N_i(n) \tag{6}$$

(2) On this basis, the analytic hierarchy Process is introduced

When calculating the correlation degree by formula (6), the weight of each influencing factor is not specified, but the average weight is adopted. However, there are errors in the results obtained by this method. In order to make the calculation result more accurate, the analytic hierarchy process is introduced to give weight to each influencing factor. The specific steps of ahp to calculate the weight are as follows:

①Determine the objective of evaluation and the sample set U of evaluation

②Construct the judgment matrix

A represents the evaluation target, and U_k represents the evaluation sample ($U_k \in U$, $k = 1,2,3,...,n$). U_{kj} Relative importance with ($k = 1,2,3,...,n$; $j = 1,2,3,...,n$) The value of U_{kj} is determined by comparing samples U_k ($k = 1,2,3,...,n$)and U_j ($j = 1,2,3,...,n$), and the value standard is shown in Table 2:

ISSN: 2688-9323

Table 2. The meaning of each value scale

Scale values	Meaning
1	Sample U_k and sample U_j are of equal importance
3	So sample U_k is slightly more important than sample U_j
5	Sample U_k and comparison U_j are significantly more important than each other
7	Sample U_k is more important than sample U_j
9	Sample A is more important than sample B
2,4,6,8	2, 4, 6, 8 are the intermediate values of adjacent judgments respectively
Bottom	Represents the judgment obtained by comparing sample U_k and U_j, then U_j and U_k can be judged by comparing

The judgment matrix is constructed according to Table 2:

$$P=\begin{pmatrix} U_{11} & \cdots & U_{1n} \\ \vdots & \ddots & \vdots \\ U_{n1} & \cdots & U_{nn} \end{pmatrix}$$

The matrix P is called the judgment matrix A-U.

③Calculate weight vector

Firstly, MATLAB software is used to calculate the maximum eigenvalue of the judgment matrix A-U and its corresponding eigenvector, namely the weight vector, which is expressed as: $W=[W_1,W_2,\dots,W_n]^T$.

Secondly, the consistency test method is used to judge the feasibility of the matrix, which proves that the weight calculated by analytic hierarchy process is effective.

(3) Construct and improve the grey correlation degree calculation formula

Combining the weight Wi ($i=1,2,3,\dots,n$) calculated by analytic hierarchy process with the correlation degree calculation formula (5) of the basic grey correlation analysis model, the improved correlation degree calculation formula (7) is obtained:

$$R_i=\frac{1}{n}\sum W_i N_i(n) \tag{7}$$

According to Formula (7), the comprehensive correlation degree between the comparison sequence and the reference sequence is obtained and sorted according to the magnitude to judge the influence degree of the comparison sequence on the reference sequence.

4.4. Empirical Analysis

(1) Grey correlation analysis

ISSN: 2688-9323

The correlation coefficient is determined according to the calculation steps of the basic grey correlation analysis model, and the specific process is as follows:

Comparison sequence X_1, X_2, X_3 and reference sequence Y are dimensionless processed to obtain dimensionless sequence $X_i^{'}$ ($i = 0,1,2,3$), as shown in table 3.

Table 3. Dimensionless sequence

	The United States				Japan				Britain				Germany			
Year	$X_0^{'}$	$X_1^{'}$	$X_2^{'}$	$X_3^{'}$	$X_0^{'}$	$X_1^{'}$	$X_2^{'}$	$X_3^{'}$	$X_0^{'}$	$X_1^{'}$	$X_2^{'}$	$X_3^{'}$	$X_0^{'}$	$X_1^{'}$	$X_2^{'}$	$X_3^{'}$
2000	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2001	0.98	1.00	0.95	1.01	0.99	0.93	0.95	1.03	1.01	0.89	0.95	1.02	1.03	1.09	0.97	1.01
2002	0.99	0.83	0.92	1.03	1.00	0.93	0.93	1.04	0.98	0.89	0.94	1.02	1.00	0.82	0.95	1.03
2003	1.00	1.00	0.92	1.02	1.02	0.87	0.93	1.04	1.00	0.89	0.90	1.04	0.99	0.82	0.95	1,03
2004	1.01	1.08	0.94	1.02	1.04	0.87	0.92	1.04	1.00	1.00	0.87	1.05	0.98	0.91	0.96	1.02
2005	1.02	1.00	0.94	1.02	1.01	0.80	0.92	1.05	1.00	0.67	0.88	1.05	0.96	0.73	0.95	1.03
2006	1.00	0.92	0.96	1.01	1.01	0.73	0.91	1.05	1.00	0.67	0.88	1.05	0.98	0.73	0.98	1.02
2007	1.02	0.92	0.96	1.01	1.03	0.73	0.91	1.05	0.98	0.67	0.86	1.05	0.94	0.73	0.99	1.01
2008	0.99	1.00	0.93	1.02	0.99	0.73	0.88	1.06	0.96	0.78	0.84	1.06	0.94	0.82	0.97	1.01
2009	0.92	0.92	0.87	1.04	0.90	0.73	0.83	1.08	0.87	0.67	0.80	1.08	0.87	0.64	0.89	1.05
2010	0.95	1.00	0.88	1.04	0.96	0.73	0.87	1.06	0.91	0.78	0.80	1.07	0.91	0.64	0.97	1.02
2011	0.93	1.17	0.89	1.03	0.98	0.73	0.82	1.08	0.83	0.78	0.80	1.07	0.88	0.73	0.99	1.01
2012	0.90	1.00	0.88	1.03	1.01	0.80	0.81	1.08	0.86	0.78	0.80	1.07	0.89	0.73	0.99	1.01
2013	0.91	1.25	0.89	1.03	1.02	0.73	0.82	1.08	0.85	0.78	0.81	1.07	0.91	0.82	0.97	1.01
2014	0.92	1.08	0.89	1.03	0.99	0.73	0.84	1.07	0.77	0.78	0.79	1.07	0.87	0.73	0.98	1.01
2015	0.91	0.83	0.80	1.06	0.93	0.73	0.88	1.02	0.73	0.78	0.79	1.08	1.01	0.55	0.99	1.01
2016	0.90	0.75	0.78	1.07	0.93	0.80	0.88	1.02	0.70	0.67	0.78	1.11	1.02	0.64	0.99	1.06
2017	0.90	0.75	0.78	1.07	0.85	0.80	0.89	1.02	0.68	0.78	0.78	1.11	1.09	0.73	0.98	1.06
2018	0.92	1.33	0.88	1.03	0.82	0.73	0.84	1.04	0.67	0.67	0.78	1.11	1.05	0.73	0.99	1.05

According to Formula (2), the absolute value of the difference between the comparison sequence and the reference sequence is calculated, and the absolute value sequence of the difference is obtained: $\triangle_i(n)$ (i=1,2,3;n=1,2,...,19), See Table 4.

Table 4. Difference absolute value sequence

	The United States			Japan			Britain			Germany		
Year	Δ_1	Δ_2	Δ_3	Δ_1	Δ_2	Δ_3	Δ_1	Δ_2	Δ_3	Δ_1	Δ_2	Δ_3
2000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2001	0.02	0.03	0.03	0.06	0.04	0.04	0.12	0.06	0.01	0.06	0.06	0.02
2002	0.16	0.07	0.04	0.07	0.07	0.04	0.09	0.04	0.04	0.18	0.05	0.03
2003	0.00	0.08	0.02	0.15	0.09	0.02	0.11	0.10	0.04	0.17	0.04	0.04
2004	0.07	0.07	0.01	0.17	0.12	0.00	0.00	0.13	0.05	0.07	0.02	0.04
2005	0.02	0.08	0.00	0.21	0.09	0.04	0.33	0.12	0.05	0.23	0.01	0.07
2006	0.08	0.04	0.01	0.28	0.10	0.04	0.33	0.12	0.05	0.25	0.00	0.04
2007	0.10	0.06	0.01	0.30	0.12	0.02	0.31	0.12	0.07	0.21	0.05	0.07
2008	0.01	0.06	0.03	0.26	0.11	0.07	0.18	0.12	0.10	0.12	0.03	0.07
2009	0.00	0.05	0.12	0.17	0.07	0.18	0.20	0.07	0.21	0.23	0.02	0.18
2010	0.05	0.07	0.09	0.23	0.09	0.10	0.13	0.11	0.16	0.27	0.06	0.11
2011	0.24	0.04	0.10	0.25	0.16	0.10	0.05	0.03	0.24	0.15	0.11	0.13
2012	0.10	0.02	0.13	0.21	0.20	0.07	0.08	0.06	0.21	0.16	0.10	0.12
2013	0.34	0.02	0.12	0.29	0.20	0.06	0.07	0.04	0.22	0.09	0.06	0.10
2014	0.16	0.03	0.11	0.26	0.15	0.08	0.01	0.02	0.30	0.14	0.11	0.14
2015	0.08	0.11	0.15	0.20	0.05	0.09	0.05	0.06	0.35	0.46	0.02	0.00
2016	0.15	0.12	0.17	0.13	0.05	0.09	0.03	0.08	0.41	0.38	0.03	0.04
2017	0.15	0.12	0.17	0.05	0.04	0.17	0.10	0.10	0.43	0.36	0.11	0.03
2018	0.41	0.04	0.11	0.09	0.02	0.22	0.00	0.11	0.44	0.32	0.06	0.00

According to formula (5, the correlation coefficient between the comparison sequence and the reference sequence is calculated from the absolute value sequence of the difference. △(Max)=0.30, △(min)=0 in Japan; △(Max)=0.33 and △(min)=0 in the U.K. △(Max)=0.25, △(min)=0) in Germany, as shown in Table 5.

(2) Analytic hierarchy process to calculate the weight

The analytic hierarchy process (AHP) is used to calculate the influence weight of the proportion of output value of three industries in GNP on carbon emissions. The specific calculation is as follows:

Table 5. Correlation coefficient

	The United States			Japan			Britain			Germany		
Year	N_1	N_2	N_3	N_1	N_2	N_3	N_1	N_2	N_3	N_1	N_2	N_3
2000	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2001	0.8	0.73	0.73	0.71	0.79	0.79	0.58	0.73	0.94	0.68	0.68	0.86
2002	0.33	0.53	0.67	0.68	0.68	0.79	0.65	0.80	0.80	0.41	0.71	0.81
2003	1.00	0.50	0.80	0.50	0.63	0.88	0.60	0.62	0.80	0.42	0.76	0.76
2004	0.53	0.53	0.89	0.47	0.56	1.00	1.00	0.56	0.77	0.64	0.86	0.76
2005	0.80	0.50	1.00	0.42	0.63	0.79	0.33	0.58	0.77	0.35	0.93	0.64
2006	0.50	0.67	0.89	0.35	0.60	0.79	0.33	0.58	0.77	0.33	1.00	0.76
2007	0.44	0.57	0.89	0.33	0.56	0.88	0.35	0.58	0.70	0.37	0.71	0.64
2008	0.89	0.57	0.73	0.37	0.58	0.68	0.48	0.58	0.62	0.51	0.81	0.64
2009	1.00	0.62	0.40	0.47	0.68	0.45	0.45	0.70	0.44	0.35	0.86	0.41
2010	0.62	0.53	0.47	0.39	0.63	0.60	0.56	0.60	0.51	0.32	0.68	0.53
2011	0.25	0.67	0.44	0.38	0.48	0.60	0.77	0.85	0.41	0.45	0.53	0.49
2012	0.44	0.80	0.38	0.42	0.43	0.68	0.67	0.73	0.44	0.44	0.56	0.51
2013	0.19	0.80	0.40	0.34	0.43	0.71	0.70	0.80	0.43	0.58	0.68	0.56
2014	0.33	0.73	0.42	0.37	0.50	0.65	0.94	0.89	0.35	0.47	0.53	0.47
2015	0.50	0.42	0.35	0.43	0.75	0.63	0.77	0.73	0.32	0.21	0.86	1.00
2016	0.35	0.40	0.32	0.54	0.75	0.63	0.85	0.67	0.29	0.25	0.81	0.76
2017	0.35	0.40	0.32	0.75	0.79	0.47	0.62	0.62	0.28	0.26	0.53	0.81
2018	0.16	0.67	0.42	0.63	0.88	0.41	1.00	0.60	0.27	0.28	0.68	1.00

Table 6. Judgment matrix

	The United States			Japan			Britain			Germany		
A	U_1	U_2	U_3	U_1	U_2	U_3	U_1	U_2	U_3	U_1	U_2	U_3
U_1	1	1/9	1/3	1	1/3	1/9	1	1/2	3	1	1/9	1/3
U_2	9	1	2	3	1	1/2	2	1	9	9	1	2
U_3	3	1/2	1	9	2	1	1/3	1/9	1	3	1/2	1

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According to Table 2, the evaluation samples U1, U2 and U3 were compared in pairs to construct the judgment matrix, as shown in Table 6.

MATLAB software is used to calculate the feature vector of the above judgment matrix, namely the weight vector, and the weight is obtained:

The United States $W_i=(W_1,W_2,W_3)=(0.08,0.64,0.28)$;

Japan $W_i=(W_1,W_2,W_3)=(0.08,0.28,0.64)$;

Britain $W_i=(W_1,W_2,W_3)=(0.28,0.64,0.08)$;

Germany $W_i=(W_1,W_2,W_3)=(0.08,0.64,0.28)$;

Consistency test is used to test the validity of weight:

The results show that each judgment matrix is feasible, that is, the weight calculated by ANALYTIC hierarchy process is effective.

(3) Grey correlation degree calculation based on analytic hierarchy Process

Integrate the correlation coefficient obtained by (1) with the weight obtained by (2), and calculate the correlation between the share of output value of the first, second and third industries and carbon emissions according to Formula (7). The results are shown in Table 7:

Table 7. Correlation and ranking

Countries	The first industry	The second industry	The third industry	Correlation rank
The United States	0.04	0.39	0.17	two, three, one
Japan	0.04	0.08	0.45	three, two, one
Britain	0.19	0.45	0.05	Two, one, three
Germany	0.04	0.48	0.20	two, three, one

4.5. Result Analysis

According to the calculation results of the above improved grey correlation model, among the four major developed countries, the proportion of output value of the secondary industry in the United States, The United Kingdom and Germany has the greatest correlation with carbon emissions. In the United States and Germany, the proportion of output value of the tertiary industry is only second to that of the secondary industry. The proportion of the output value of primary industry in the United States, Japan and Germany has the least impact on carbon emissions. The following is a specific analysis of the correlation between the proportion of output value of the three industries and carbon emissions in different countries:

(1) from the United States three times industry output value proportion and correlation of the carbon emissions, the first, second, third industry output value proportion and the correlation of the carbon emissions were 0.04, 0.39, 0.17, namely the second industry output value proportion and correlation of the carbon emissions, the largest of the third industry, the first industry output value proportion and the correlation of the carbon emissions is minimal. In other words, the development of the secondary industry is the main reason for the growth of carbon emissions, while the tertiary industry contributes less to carbon emissions than the secondary industry, and the primary industry has the weakest impact on carbon emissions.

(2) three times from Japan's industrial output value accounted for and the correlation of the carbon emissions, the first, second, third industry output value proportion and the correlation of the carbon emissions were 0.04, 0.08, 0.45, and the tertiary industry output value proportion and correlation of the carbon emissions is the largest, the second industry, the first industry output value proportion and the correlation of the carbon emissions is minimal. In other words, the tertiary industry has the largest contribution to carbon emissions, the secondary industry has a relatively small impact on carbon emissions, and the primary industry has the weakest effect on carbon emissions.

(3) three times from Britain's industrial output value accounted for and the correlation of the carbon emissions, the first, second, third industry output value proportion and the correlation of the carbon emissions were 0.19, 0.45, 0.05, is the second largest industry output value proportion and the correlation of the carbon emissions, the first industrial times, the tertiary industry output value proportion and the correlation of the carbon emissions. In other words, the secondary industry is the main source of carbon emissions, the primary industry has a relatively weak contribution to carbon emissions, and the tertiary industry has the least impact on carbon emissions.

(4) Three times from Germany's industrial output value accounted for and the correlation of the carbon emissions, the first, second, third industry output value proportion and the correlation of the carbon emissions were 0.04, 0.48, 0.20, namely the second industry output value proportion and correlation of the carbon emissions, the largest of the third industry, the first industry output value proportion and the correlation of the carbon emissions is minimal. In general, the development of the secondary industry contributes the most to carbon emissions, while the tertiary industry contributes less to carbon emissions than the secondary industry, and the development of the primary industry has the least impact on carbon emissions.

5. Enlightenment

Based on the correlation between the three industries and carbon emissions in four major developed countries, the secondary industry has the greatest impact on carbon emissions in developed countries as a whole, followed by the tertiary industry, and the primary industry has the least impact on carbon emissions. In this view, if developed countries want to realize low-carbon economy and low-carbon development path, they must start from the rectification and adjustment of the secondary industry, increase investment in industrial low-carbon technology research and development, vigorously promote the development of green industry, and realize the transformation from traditional industry to low-carbon industry. At the same time, the third industry has a large carbon reduction potential, the developed countries should continue to maintain the leading position of the third industry in promoting economic growth, and further increase its proportion in the industrial structure and optimizing for the internal structure of the tertiary industry, maximize the tertiary industry on the inhibition effect of carbon emissions, to make it better service to the energy conservation and emissions reduction targets of developed countries. Finally, to make full use of the first industry inhibitory effect on carbon emissions, according to the "carbon reduction" attribute of the first industry, set up the mechanism of related industries, vigorously develop agriculture, promote the industry to absorb carbon dioxide, to achieve its unique "carbon sink" function, change the traditional pattern of agricultural development actively, promote green, organic farming, achieving industry internal carbon emissions reduction.

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