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Factor Analysis Method and Application of Energy Consumption Intensity Variation

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Abstract: The rapid growth of my country's economy has led to a continuous increase in energy consumption (EC). Although the growth rate of EC has declined in recent years, the problems of resource utilization and environmental pollution caused by high EC have not yet been identified. For a long time, China's economy has been balancing emission reductions between reducing EC and achieving sustainable economic growth. To this end, the text specifically analyzes the factors that lead to changes in EC and energy intensity (EI), and the corresponding method applications. This paper analyzes the factors that affect the intensity of EC, and uses the LMDI method to study the changes in EC by collecting industrial added value, EC and GDP in various sectors. If we analyze the experimental results, we can know that: in the overall economic situation, it is found that the contribution rate of economic activity is 182.25%, the contribution rate of EI is 77.83%, and the contribution rate of economic structure is 3.45%.

1. Introduction

In recent years, with the rapid development of the national economy in my country, the consumption of energy is also increasing. Now that the energy stock is decreasing day by day, the problem of energy use has become a situation that determines whether the economy can achieve sustainable development. The construction industry is a pillar industry of the national economy, and EC is also facing an increasing situation. Therefore, it is of great significance to study the EC of the construction industry and explore the evolution behind the EC of the construction industry to reduce the EC of the construction industry and improve the efficiency of EC [1-2].

In related studies, Aftab et al. believed that developing countries are facing the problem of environmental degradation [3]. The use of non-renewable EC to promote economic growth lays the foundation for environmental degradation, and its consequences cannot be ignored. Therefore, it is necessary to identify these determinants, build linkage models and explore feedback effects that may play a constructive role in mitigating environmental problems.

Jwa et al. found that due to differences in ecological environment, economic development and resources, the main influencing factors of natural gas consumption in different regions are different [4]. In order to fully understand this difference, the authors employed grey relational analysis (GRA) from gross domestic product (GDP), industrial structure, environmental protection mechanism, urbanization rate, population density, EC intensity and EC structure. Then, the intrinsic correlation between the three selected factors and regional gas consumption is analyzed.

Cheekatamarla studies the use of natural gas and hydrogen to support current and future building energy needs to offset total electricity demand while improving grid resilience and energy efficiency [5]. Demand-side energy management will play an important role in effectively managing available energy. The authors present performance evaluations of different power generation and energy management configurations. The development of solutions to address grid resilience by providing the ability to design suitable configurations to meet individual building energy needs is discussed.

The relationship between EC and EI was analyzed, and the study found that EI has a significant impact on EC and is a possible factor for national energy conservation and emission reduction; through scientific research in this field, we found that reducing intensity is a possibility to solve this contradiction One of the ways, but the development of energy conservation and emission reduction should continue from a global perspective, rather than just focusing on specific industries [6-7].

2. Design Research

2.1. Factors Affecting EC Intensity

There are many factors that affect the intensity of EC. Based on the existing literature and related policies at home and abroad, this paper mainly selects three influencing factors that describe the characteristics of the manufacturing industry, as well as the characteristics of the provinces, that is, the three factors that describe the external environment for the development of the manufacturing industry. Affecting factors [8-9]:

(1) Manufacturing Productivity (PRO). The production efficiency of the manufacturing industry is represented by the added value of the manufacturing industry brought by the average number of employment per manufacturing unit [10-11]. Theoretically, if the output per unit of labor is higher, on the one hand, it means the improvement of employee skills, high-tech personnel and skilled personnel can improve management efficiency and reduce EC intensity; on the other hand, it means that manufacturing-related enterprises are automated. The improvement of the level, although it will increase the output, may increase the consumption of electricity at the same time. Therefore, the impact of manufacturing productivity on its EI is uncertain.

(2) Manufacturing Structure (STR). In the past, most literatures studied the EI of the whole industry, and in these literatures, the proportion of a single industry in GDP was generally used to represent the industrial structure. Compared with the previous literature, the proportion of five high-energy-consuming manufacturing industries in the total manufacturing GDP is selected to represent the structure of the manufacturing industry.

(3) Manufacturing Investment (INV). Since the reform and opening up, industry has become the backbone of China's economic development, and China has continuously strengthened the scale of investment in fixed assets in industry and manufacturing. On the one hand, the accumulation of

fixed assets can bring economies of scale, thereby reducing costs and EC intensity. In addition, fixed asset investment has a guiding role and a resource supplementary role in the optimization of the manufacturing industry structure, such as updating and more efficient production technology and purchasing new equipment, so as to achieve energy efficiency improvements. In this paper, the investment in manufacturing fixed assets is used to represent the investment intensity [12-13].

(4) Provincial level of economic development (GDP). For industrialized countries, rapid economic growth can lead to a dramatic increase in EC. In addition, the process of economic development is often accompanied by technological progress and industrial structure optimization, which plays an important role in reducing EI.

(5) Provincial Urbanization Level (URB). At present, China's urbanization process is still accelerating. Compared with rural residents, urban residents have greater needs for infrastructure and transportation equipment, such as high-rise buildings, transportation, water supply, sewage treatment systems, sanitation and drainage systems, etc. Large-scale urban infrastructure has facilitated the expansion of energy-intensive manufacturing industries such as steel, cement, aluminum and glass used as building materials, leading directly to the consumption of fossil fuels. On the other hand, compact city theory argues that a high-density urban land use development model can exploit economies of scale in cities by reducing reliance on automobiles, optimizing driving distances, power supply transmission and distribution losses, etc., i.e., vertical urban expansion (increase in urban population) has a greater opportunity to promote economies of scale than horizontal expansion (addition of new cities), resulting in a reduction in energy demand. These mechanisms make the impact of urbanization on EI more difficult to predict objectively [14-15].

(6) Provincial openness level (OPE). This paper uses the province's foreign import and export trade volume to represent the level of openness, which represents the external development environment of a province's manufacturing industry. While foreign trade drives economic growth, it also greatly increases China's demand for energy. With the deepening of the international division of labor, China, as the "world's factory", bears the demand for products from other countries in the world, exports a large number of industrial supplies to the world, and at the same time bears the burden of huge EC. At the same time, the opening up of developing countries has also promoted the inflow of advanced technology and management experience, which may have a positive impact on energy conservation and emission reduction [16-17].

2.2. Lamin Index Decomposition Method

The basic idea of the Laplace index method is to expand the variability of each information variable. In the calculation, one information variable is used as a frequency and the other is used as a variable, and each independent variable is changed by considering the variable value of the variable to exert a defined effect [18-19].

Decomposition principle:

$$dZ = XdY + YdX \tag{1}$$

$$\Delta Z = \int_{y_0}^{y_t} XdY + \int_{x_0}^{x_t} YdX \tag{2}$$

According to the approximate calculation formula;

$$\Delta Z_x = (X_t - X_0)Y_0 \tag{3}$$

$$\Delta Z_y = (Y_t - Y_0)X_0 \tag{4}$$

$$\Delta Z = \Delta Z_x + \Delta Z_y + R \tag{5}$$

In the formula, ΔZ represents the change of Z, ΔZx and ΔZy are the changes of Z caused by the changes of X and Y, and R represents the residual value of decomposition.

3. Experimental Study

3.1. Model Introduction

This paper uses the LMDI method to study the change of EC by collecting the industrial added value, EC and GDP of each sector. From the analysis results, the factors affecting the change of EC are studied.

In this paper, the EC equation constructed by B.W.Ang [20] is:

$$E = \sum_i E_i \times \sum_i GDP \times \frac{GDP_i}{GDP} \times \frac{E_i}{GDP_i} = \sum_i GDP \times S_i \times I_i \tag{6}$$

The subscript i represents the relevant industrial sector, Ei is the total consumption, and GDPi is the total production value.

$$\Delta E = E^T - E^O = \Delta E_{act} + \Delta E_{str} + \Delta E_{\text{int}} \tag{7}$$

$$D = \frac{E^T}{E^O} = D_{act} D_{str} D_{\text{int}} \tag{8}$$

In equations (2) and (3), ET and EO represent the total EC in periods T and O; the subscripts act, str and int represent the impact of overall economic activities, the impact of economic structure, and the energy efficiency of each sector. Using the LMDI decomposition, these effects can be calculated by the following equations for the additive decomposition method:

$$\Delta E_{act} = \begin{cases} 0, & if \quad E_i^O \times E_i^T = 0 \\ \sum_i L(E_i^O, E_i^T) In(\frac{GDP^T}{GDP^O}), if & E_i^O \times E_i^T \neq 0 \end{cases} \tag{9}$$

$$\Delta E_{act} = \begin{cases} 0, & if \quad E_i^O \times E_i^T = 0 \\ \sum_i L(E_i^O, E_i^T) In(\frac{S_i^T}{S_i^O}), if & E_i^O \times E_i^T \neq 0 \end{cases} \tag{10}$$

$$\Delta E_{act} = \begin{cases} 0, & if \quad E_i^O \times E_i^T = 0 \\ \sum_i L(E_i^O, E_i^T) In(\frac{I_i^T}{I_i^O}), if & E_i^O \times E_i^T \neq 0 \end{cases} \tag{11}$$

in,,. Similarly, using the multiplicative factorization method, relative estimators of these effects can be obtained:

$$D_{act} = \exp(\sum_i \frac{(E_i^T - E_i^O)/(In(E_i^T) - In(E_i^O))}{(E^T - E^O)/(In(E^T) - In(E^O))} In(\frac{GDP^T}{GDP^O})) \quad (12)$$

$$D_{act} = \exp(\sum_i \frac{(E_i^T - E_i^O)/(In(E_i^T) - In(E_i^O))}{(E^T - E^O)/(In(E^T) - In(E^O))} In(\frac{S_i^T}{S_i^O})) \quad (13)$$

$$D_{act} = \exp(\sum_i \frac{(E_i^T - E_i^O)/(In(E_i^T) - In(E_i^O))}{(E^T - E^O)/(In(E^T) - In(E^O))} In(\frac{I_i^T}{I_i^O})) \quad (14)$$

3.2. LMDI Decomposition of Energy Change

In the process of analyzing the change of total EC, this paper adopts the LMDI analysis method, in which equations (7), (9), (10), (11) are used for additive decomposition, and equations (8), (12), (13), (14) are used for multiplication decomposition. The results are shown in Table 1.

Table 1. EC LMDI decomposition results

	Additive decomposition	Multiplication factorization
Gross EC	193654.12	2.2546
Economic activity	349887.31	4.3578
economic structure	-8497.69	1.0023
EI	-150123.31	0.4958

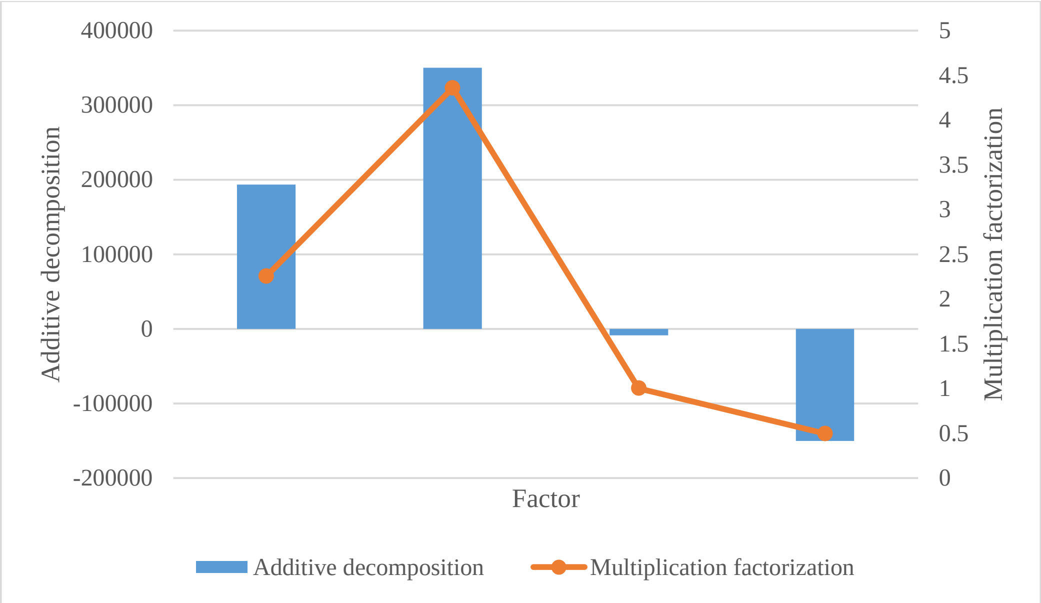

Figure 1. Analysis of EC LMDI decomposition results

According to the decomposition results, we can know that: from the overall economic situation, it is found that the economic activity has the greatest impact on EC with a contribution rate of 182.25%, followed by the EI contribution rate of 77.83%, and finally the economic structure contribution rate of 3.45%.

4. Experiment Analysis

4.1. Industry EC

Table 2 breaks down the EC from an industry perspective.

Table 2. EC by sector

	Years	1	5	10	15	20	21	22
EC by sector/ton	Total	98703	131176	146964	261369	360648	402138	416913
	Agriculture, forestry, animal husbandry and fishery, water conservancy	4852	5505	4233	6860	7266	7804	8055
	Industry	67578	96191	103014	187914	261377	284712	291131
	Construction industry	1213	1335	2207	3486	5533	6337	7017
	Transportation, warehousing, postal industry	4541	5863	11447	19136	27102	32561	34819
	Wholesale, retail and accommodation, catering	1247	2018	3251	5917	7847	10012	10598
	Other industry	3473	4519	6118	10484	15052	18407	19763
	Living consumption	15799	15745	16695	27573	36470	42306	45531
	Industry's share of the total	68.47%	73.33%	70.09%	71.90%	72.47%	70.80%	69.83%

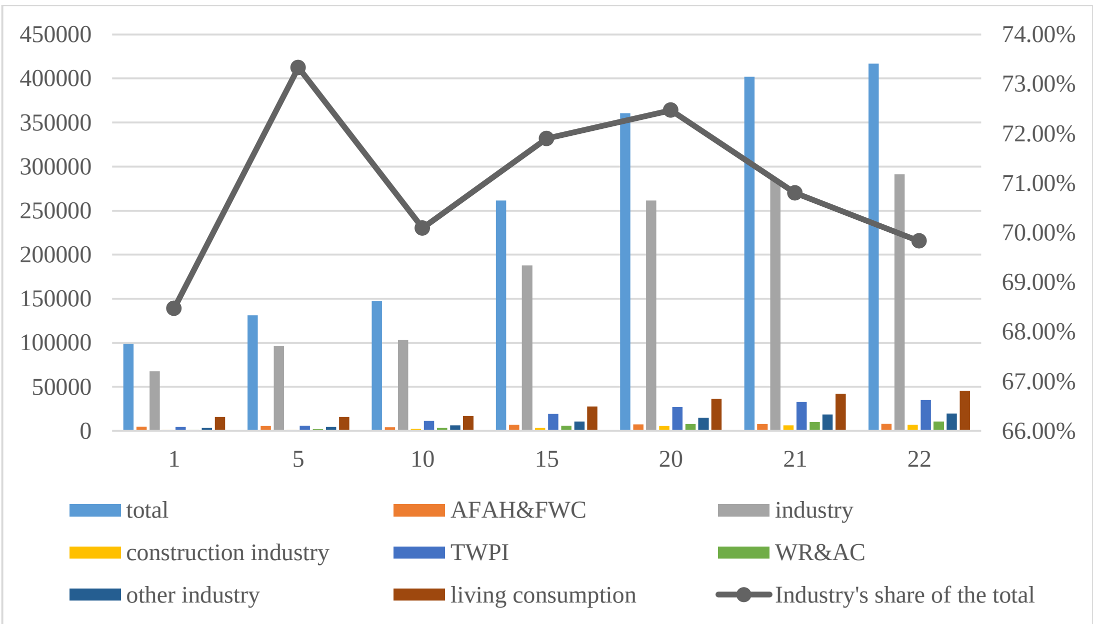

Figure 2. Analysis of EC by sector

From the decomposition results, it can be seen that industry accounts for about 70% of EC. As we all know, the average industrial EC accounts for more than 60% of China's total EC. Reducing industrial EC can reduce China's total EC to a certain extent. As can be seen in Figure 2, the total EC of various industries generally increases every year, but in the 21st year, the total EC of the black metal mining and dressing industry has decreased compared with 20 years. In the past two years, there has been an upward trend.

4.2. LMDI Decomposition Results

Table 3 shows the LMDI decomposition results for each industry.

Table 3. LMDI decomposition results of various industries in China

	Gross EC	Economic activity	Economic structure	EI
Overall	192149.06	350200.28	-8509.75	-149541.47
Agriculture, Forestry, Animal Husbandry, Fishery and Water Conservancy	2870.666	8638.786	-1968.87	-3799.25
Industry	148689	276877.8	-8123.77	-120065
Construction industry	3988.844	6345.841	785.6825	-3142.68
Transportation, Warehousing and Postal Industry	20283.12	32564.77	-5282.93	-6998.72
Wholesale, retail, accommodation, catering industry	5498.228	8828.055	550.1926	-3880.02
Other industry	10819.17	16945.03	5529.94	-11655.8

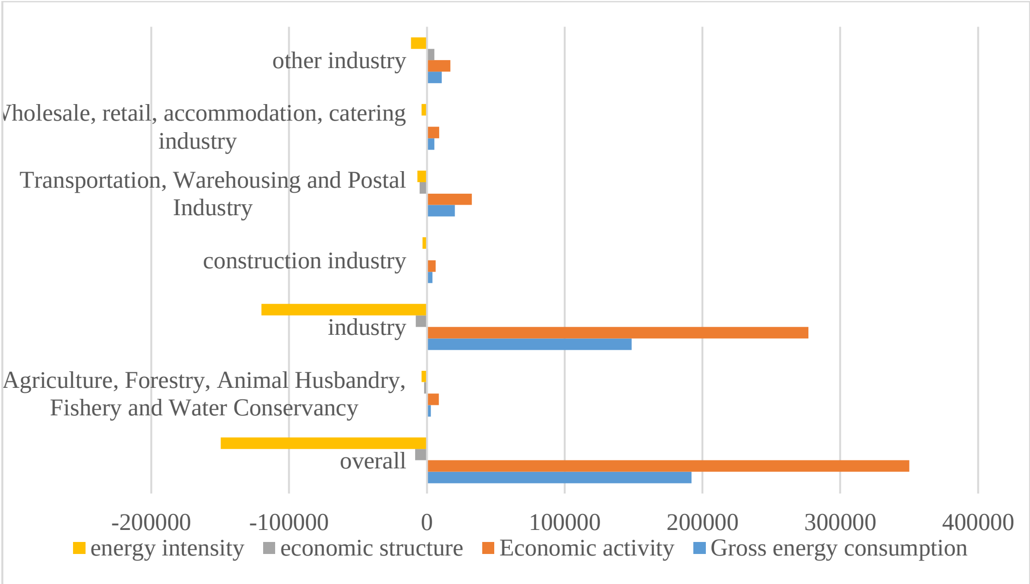

Figure 3. Analysis of LMDI decomposition results by industry

During this period, the total EC increased by 192,149.06, and the total industrial EC increased by 148,689 at most, accounting for 77.38% of the total economic EC, followed by transportation, warehousing, and postal industry 10.56% (20183.12), other Industry 5.63% (10819.17), wholesale, retail, accommodation, catering 2.86% (5498.228), construction 2.08% (3988.844), agriculture, forestry, animal husbandry, fishery and water conservancy 1.49% (2870.666). The average contribution rate of economic activities is 187.33% (8638.786 for agriculture, forestry, animal husbandry, fishery and water conservancy, 276877.8 for industry, 16945.03 for other industries), and the average contribution rate of economic structure is -3.21% (-1968.87 for agriculture, forestry, animal husbandry, fishery and water conservancy, -8123.77 for industry, Other industries 5529.94), the contribution rate of EI is -84.11% (-3799.25 for agriculture, forestry, animal husbandry, fishery and water conservancy, -120065 for industry, and -11655.8 for other industries). It is not difficult to conclude that, from the perspective of various industries, it is the influence of economic activities (expansion of economic scale) that promotes EC, while both economic structure and EI have an inhibitory effect on total EC. That is to say, the reduction of economic scale, the downward adjustment of economic structure and the decline of EI will restrain the growth of EC.

4.3. Status Quo Analysis of EC Intensity in Manufacturing Industry

The mathematical expression of the EI of manufacturing is the total amount of energy consumed by the manufacturing industry or the final EC divided by the value added of the manufacturing industry in the corresponding time period. Below is an analysis of the manufacturing EI data:

Table 4. EI of my country's manufacturing industry and all industries in the past 15 years

Years	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Manufacturing ei	2.8	2.6	2.6	2.5	2.4	2.1	2.2	2.1	2.0	1.8	1.7	1.6	1.5	1.3	1.3
National ei	1.6	1.6	1.5	1.4	1.3	1.4	1.3	1.3	1.2	1.1	0.9	0.9	0.8	0.7	0.7

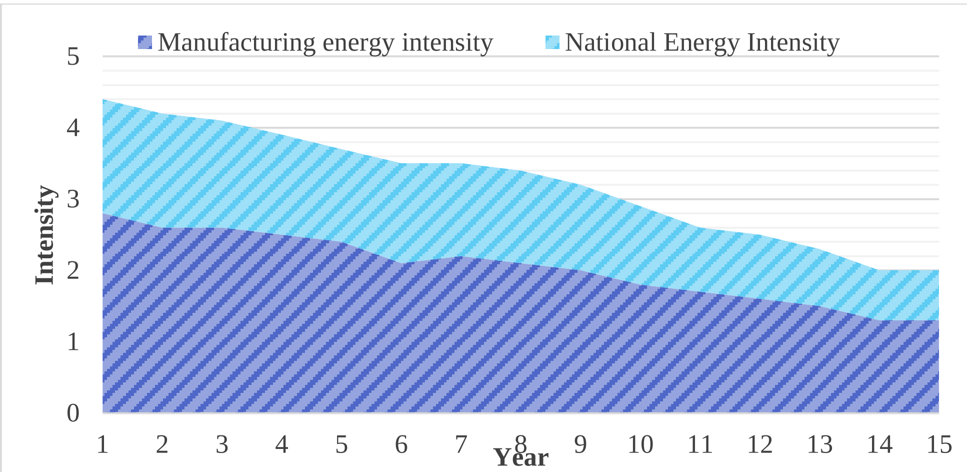

Figure 4. Analysis of EI of my country's manufacturing industry and all industries in the past 15 years

From the data in Figure 4, it can be seen that the EI value of China's manufacturing industry gradually decreases with the increase of the year. From the highest level of 28,000 tons of standard coal/yuan in the first year to 13,000 tons of standard coal/100 million yuan in the fifteenth year, the decline reached 54.6%. In terms of national EI, the overall EI also showed a downward trend, from 16,000 tons of standard coal/100 million yuan in the first year to 7,000 tons of standard coal/100 million yuan in the fifteenth year, a decline of 56.5%, the decline is greater than the decline in EI of the manufacturing industry, indicating that the level of energy conservation and emission reduction in the manufacturing industry is lower than the national average level, and there is still much room for improvement in the task of reducing EC in the manufacturing industry.

5. Conclusion

In recent years, with the rapid development of the global economy, EC has also increased, causing many problems such as resource scarcity and climate change. As a measure of general energy use, the intensity of EC reflects the economic system's dependence on the economy and the system benefits of energy use. This paper examines the key factors affecting energy efficiency and analyzes the relationship between EI changes and carbon emissions, which helps to improve energy efficiency, thereby reducing EC and promoting efficient and low-carbon construction. Finally, the EC intensity of the industry will also be affected by other factors such as industry R&D investment, labor employment rate, industry age, and other alternative energy prices and other industry heterogeneity factors. These factors are also unavoidable when the industry conducts energy conservation and emission reduction. . This will be explored in future further research.

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Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

Conflict of Interest

The author states that this article has no conflict of interest.

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