Research on the Effect of Industrial Structure Upgrading on Energy Efficiency in Beijing-Tianjin-Hebei Region

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ABSTRACT
The transformation and upgrading of industrial structure in the Beijing-Tianjin-Hebei Region plays an important supporting role in improving energy efficiency. This study determined the selection of industrial variables and indicators in the Beijing-Tianjin-Hebei Region, and constructed a panel regression model to measure the impact of industrial structure upgrading on energy efficiency in the Beijing-Tianjin-Hebei Region. According to this study, the ratio of the added value of the tertiary industry to the added value of the secondary industry in the Beijing-Tianjin-Hebei Region increases by 1%, and the energy efficiency increased by 0.2339%. From an industrial perspective, the energy efficiency of the primary industry would be improved by 8.01% for every 1% increase in the ratio of the output value of planting industry to the output value of forestry, animal husbandry and fishery industry; the energy efficiency of the secondary industry would be improved by 1.609% for every 1% increase in the ratio of the output value of high-tech manufacturing to the total output value of the secondary industry; and the energy efficiency of the tertiary industry would be improved by 0.212% for every 1% increase in the ratio of the output value of the service sector to the output value of the circulation sector. Finally, according to the research results, against the background of "carbon dioxide peaking and carbon neutrality", further countermeasures and suggestions were put forward to promote the upgrading of the industrial structure and improve the energy efficiency in Beijing-Tianjin-Hebei Region.

Keywords: *Beijing-Tianjin-Hebei Region, Industrial structure upgrading, Energy efficiency, Effect, Return.*

1. INTRODUCTION

Since the 21st century, the transformation and upgrading of industrial structure and energy efficiency have attracted extensive attention from government departments and academic circles around the world. It has become a global consensus to promote the construction of an energy-saving society and achieve green growth. The Beijing-Tianjin-Hebei Region is one of the three most dynamic economic growth poles in China. In 2015, the "Beijing-Tianjin-Hebei Coordinated Development Plan" approved by the Political Bureau of the Central Committee of the Communist Party of China emphasized enhancing the resource and energy security capabilities of the Beijing-Tianjin-Hebei Region and taking industrial upgrading and transfer and ecological environmental protection as the key fields of Beijing-Tianjin-Hebei coordinated development. The Fifth Plenary Session of the 18th Central Committee of the Communist Party of China clearly proposed to implement the "dual control" action of total energy consumption and intensity. And the Beijing-Tianjin-Hebei Region should accelerate industrial upgrading and relocation to ensure energy conservation and emission reduction. Judging from the results of the fourth national economic census, the industrial structure of the Beijing-Tianjin-Hebei Region had been continuously optimized, and the tertiary industry had gradually become the leading industry in the Beijing-Tianjin-Hebei Region. The transformation and upgrading of the Beijing-Tianjin-Hebei industrial structure would be conducive to promoting the adjustment and optimization of the

energy structure and effectively improving the energy efficiency of the upstream and downstream of the industrial chain and related industries. Measuring the impact of Beijing-Tianjin-Hebei industrial structure upgrading on energy efficiency and putting forward targeted countermeasures and suggestions for further promoting the transformation and upgrading of Beijing-Tianjin-Hebei industrial structure and improving energy efficiency has become a research hotspot of academic attention.

2. LITERATURE REVIEW

Scholars at home and abroad have carried out a lot of research on the adjustment and upgrading of industrial structure and energy efficiency. However, due to different measurement methods, there were differences in sample selection and index construction, the research results were not the same, and two viewpoints were formed. The adjustment and upgrading of industrial structure could positively and significantly affect the improvement of energy efficiency. For example, Gao Zhenyu (2006) [1] calculated the energy productivity of various provinces in China and conducted cluster analysis, and concluded that the level of economic development, industrial structure, investment and energy prices were the main factors affecting energy productivity. Liu Hong (2016) [2], Shen Bing (2020) [3] measured the energy efficiency of provinces and cities in the central area of China, and found that technological progress, energy prices and industrial structure had a significant impact on the improvement of energy efficiency, among which the adjustment and upgrading of industrial structure had a significant impact. According to Ayres (2007) [4][5][6], under the premise that the industrial structure couldn't be properly adjusted, other ways of improving energy efficiency didn't work well. Yao S J (2012) [7] made it clear that if China didn't accelerate adjustment of industrial structure or improve energy efficiency, economic growth would seriously damage the global environment. Zhang Yong (2015) [8] used the dynamic panel method to empirically analyze the relationship between industrial structure changes and energy intensity based on the data of 6 major industries in 30 provinces in China, and concluded that industrial structure changes and upgrading could significantly reduce energy intensity. He (2011) [9] proposed that by adjusting the industrial structure and increasing the proportion of the tertiary industry, it could promote the flow of energy from low-productivity industries to high-productivity industries, thereby reducing energy consumption intensity. ② The adjustment and upgrading of industrial structure had little effect on the improvement of energy efficiency, and even had a negative effect. For example, Luo Chaoyang (2019) [10] used a non-dynamic panel threshold model to conclude that industrial restructuring and upgrading would significantly affect energy efficiency improvement only when technological progress reached a certain level. According to Ke Li (2014) [11], with the use of nonlinear approach, he concluded that there was a critical effect of industrial structure on energy efficiency, and industrial restructuring and upgrading could significantly reduce energy intensity when the share of the secondary industry in GDP was greater than the critical value. Liang Guanghua (2012) [12] argued that the crowding and free-rider effects generated in the process of industrial structure change could reduce the efficiency of energy allocation and use. Yu Binbin (2017) [13] clarified that the quality of industrial structure adjustment could significantly promote the improvement of energy efficiency, but the magnitude of industrial structure adjustment didn't have a significant impact on the improvement of energy efficiency.

Practice showed that the direction of industrial restructuring was divided into two categories: quantitative and technological progress, in which quantitative industrial restructuring might not significantly improve energy efficiency, while technological progress industrial restructuring could promote energy efficiency. [14] However, the role of technological innovation in improving energy efficiency was not direct and overnight. By promoting the upgrading of the industrial structure, the optimization of the structure of the energy industry could be realized, and the improvement of energy efficiency would be promoted steadily and effectively. In other words, the impact of industrial structure on energy efficiency was generalized from a single linear relationship to a nonlinear relationship. [15] In addition, some scholars analyzed the key influencing factors of energy efficiency. For example, Tian Shuai (2021) [16] believed that fixed asset investment factors would significantly affect regional energy economic efficiency. Wang Qian (2018) [17] proposed that changes in the RMB exchange rate would affect imports and exports, affecting carbon prices based on energy substitution and imports and exports, thereby affecting energy efficiency. According to the research on energy efficiency in Chongqing by

Guo Xiaoming (2017) [18], the increase in the export proportion of foreign-funded enterprises in Chongqing was not conducive to the improvement of energy efficiency.

According to literature review, there was still room for the research on the impact of industrial structure adjustment on energy efficiency improvement. First, from the perspective of the research area, most of the existing literature took the whole country or province as the research sample, and few literatures focused on the impact of industrial structure upgrading on energy efficiency in Beijing-Tianjin-Hebei Region. Secondly, from the perspective of research content, existing literature focused on analyzing the changes in the relative proportions of the three industries in the research on the impact of industrial structure upgrading on energy efficiency, and seldom literature involved the adjustment of the internal structure of the industry and changes in energy efficiency. To this end, this study took the impact of the industrial structure upgrading in the Beijing-Tianjin-Hebei Region on energy efficiency as the research theme, and analyzed the impact of the industrial structure upgrading in the Beijing-Tianjin-Hebei Region on its energy efficiency improvement from the regional and industrial levels. By clarifying the explained variables, explanatory variables and control variables of the impact of industrial structure upgrading in the Beijing-Tianjin-Hebei Region on energy efficiency and the selection of indicators, a panel regression model was constructed, and the stata measurement software was used to measure the significant effect of industrial structure upgrading in the Beijing-Tianjin-Hebei Region on its energy efficiency improvement. And countermeasures and suggestions were put forward to promote the transformation and upgrading of the industrial structure and improve energy efficiency in the Beijing-Tianjin-Hebei Region.

3. RESEARCH METHODS

In order to measure the impact of the industrial structure upgrading in the Beijing-Tianjin-Hebei Region on energy efficiency, the explained variables, explanatory variables, control variables and index selection at the industrial level in the Beijing-Tianjin-Hebei Region were determined, theoretical hypotheses were proposed, and a panel regression model was constructed.

3.1 Selection of Variables and Indicators

At the regional level, energy efficiency was selected as the explained variable, industrial structure upgrading was selected as the explanatory variable, and fixed asset investment, RMB exchange rate and export volume were selected as control variables. According to the existing literature [17][18], the selection of variables and indicators could be expressed as:

- Variables to be explained: select "the ratio of GDP to energy consumption" as the energy efficiency indicator, which was expressed with ee.
- Explanatory variables: select "the ratio of the added value of the tertiary industry to the added value of the secondary industry" as an indicator of industrial structure upgrading, and express it with isa.
- Control variable: select "fixed asset investment, RMB exchange rate and export value" as the corresponding index of the control variable.

Among them, fixed asset investment was expressed with k, and the unit was 100 million yuan. RMB exchange rate was represented with $rmbrate$. The variable export value was expressed by $\exp ort$, and the unit was ten thousand US dollars.

At the industrial level, the explained variables, explanatory variables, control variables and the indicators for the impact of the industrial structure upgrading of the three industries in the Beijing-Tianjin-Hebei Region on energy efficiency were determined.

- Explained variable

The ratio of GDP of the primary, secondary and tertiary industries to their industrial energy consumption was selected as the energy efficiency index of the three industries, which was expressed with ee_1, ee_2, ee_3 respectively.

- Explanatory variables

It selected "the ratio of the output value of the planting industry to the output value of forestry, animal husbandry and fishery in the primary industry" (expressed with zl) [19], "the proportion of the output value of the high-tech manufacturing industry in the total output value of the secondary industry" (expressed with gx) [20], "the ratio of

the output value of the service sector to the output value of the circulation sector" (expressed with fl) [21] as the industrial structure upgrading indicators of the three industries.

- Control variable

For the primary industry, it selected "the ratio of the investment in the primary industry to the total investment" (expressed by tz_1) as the capital indicator, and "the ratio of the employment population in the primary industry to the total employed population" (ld_1) as the labor force index; for the secondary industry, it selected "the number of patent applications accepted" (expressed by js) as the technical indicator, and "the ratio of the employed population in the secondary industry to the total employed population" (expressed by ld_2) as the labor force Indicator; for the tertiary industry, it selected "the ratio of the employed population in the tertiary industry to the total employed population" (expressed by ld_3) as the labor force indicator.

3.2 Theoretical Hypothesis

In order to analyze the impact of the industrial structure upgrading in the Beijing-Tianjin-Hebei Region on energy efficiency, the following assumptions were put forward:

H1: The upgrading of the industrial structure in the Beijing-Tianjin-Hebei Region could generally promote the improvement of energy efficiency.

H2: Increasing the ratio of the output value of planting to forestry, animal husbandry and fishery could promote the energy efficiency of the primary industry and reduce the energy consumption per unit of GDP in the primary industry.

H3: Increasing the proportion of the output value of high-tech manufacturing in the total output value of the secondary industry could promote the improvement of the energy efficiency of the secondary industry and reduce the energy consumption per unit of GDP in the secondary industry.

H4: Increasing the ratio of the output value of the service sector to the output value of the circulation department could promote the energy efficiency of the tertiary industry and reduce the energy consumption per unit of GDP in the tertiary industry.

3.3 The Construction of Panel Regression Model

The study aimed to study the impact of the industrial structure upgrading in the Beijing-Tianjin-Hebei Region on energy efficiency, that is, whether industrial structure upgrading could really improve energy efficiency and the degree of improvement. To this end, referring to the basic econometric model of the literature, [22] this study constructed a panel regression model of the impact of industrial structure upgrading in the Beijing-Tianjin-Hebei Region on energy efficiency, which could be expressed as

$$ee_{it} = c + a \cdot isa_{it} + b_i \cdot \sum u_{it} + \varepsilon_{it} \quad (1)$$

In formula (1), ee_{it} represented the energy efficiency of i in the year of t, that is, the ratio of GDP to energy consumption; isa_{it} represented the upgrading of the industrial structure of i in the year of t, namely, the ratio of the added value of the tertiary industry to the added value of the secondary industry; $\sum u_{it}$ represented the aggregated value of the control variables of i in the year of t, including fixed asset investment (k), RMB exchange rate ($rmbrate$) and exports amount ($\exp ort$); a and b represented coefficients, c represented intercept terms, and ε_{it} represented random error terms in the region of i in the year of t.

At the same time, in order to explore the impact of internal structural adjustment and upgrading of various industries in Beijing-Tianjin-Hebei Region on energy efficiency, referring to the basic econometric model [21], a panel regression model of the impact of industrial structure adjustment on energy efficiency in the Beijing-Tianjin-Hebei Region was constructed, which could be expressed as follows:

$$\begin{cases} ee_{i1t} = c_1 + a_1 \cdot zl_{it} + b_1 \cdot \sum u_{i1t} + \varepsilon_{i1t} \\ ee_{i2t} = c_2 + a_2 \cdot gx_{it} + b_2 \cdot \sum u_{i2t} + \varepsilon_{i2t} \\ ee_{i3t} = c_3 + a_3 \cdot fl_{it} + b_3 \cdot \sum u_{i3t} + \varepsilon_{i3t} \end{cases} \quad (2)$$

In formula (2), ee_{i1t}, ee_{i2t}, ee_{i3t} represented the energy efficiency of the primary industry, secondary industry and tertiary industry in the region of i in the year of t; zl_{it}, gx_{it}, fl_{it} represented the industrial structure adjustment of the primary industry, secondary industry and tertiary industry in the region of i in the year of t, that is, the ratio of the output value of the planting industry to the output value of forestry, animal husbandry and fishery, the proportion of the output value of high-tech manufacturing to the total output value of the secondary industry, the output value of the service sector to the output value of the circulation sector. $\sum u_{i1t}$ $\sum u_{i2t}$ and $\sum u_{i3t}$ respectively represented the aggregated value of the control variables of the primary, secondary and tertiary industries in the region of i in the year of t. Among them, the control variables of primary industry included the ratio of the investment in the primary industry to the total investment (tz_1), the ratio of the employed population in the primary industry to the total employed population (ld_1); the control variables of the secondary industry were the number of patent applications accepted in the secondary industry (js), and the ratio of the employed population in the secondary industry to the total employed population; and the control variable of the tertiary industry was the proportion of the employed population in the tertiary industry to the total employed population (ld_3). a_1 a_2, a_3, b_1, b_2, b_3 were coefficients; c_1, c_2, c_3 were intercept terms; ε_{i1t}, ε_{i2t}, ε_{i3t} represented stochastic error terms of the primary industry, secondary industry and tertiary industry in the region of i in the year of t.

4. EMPIRICAL RESEARCH

The data in this study were mainly from the "Beijing Statistical Yearbook", "Tianjin Statistical Yearbook" and "Hebei Statistical Yearbook", and the sample range was in Beijing, Tianjin and Hebei Province. From the perspective of data availability, the time span of 2000-2018 was selected to study the impact of industrial structure upgrading on energy efficiency in Beijing-Tianjin-Hebei Region at the regional level. At the industrial level, the impact of structure upgrading of the primary industry in Beijing-Tianjin-Hebei Region on its energy efficiency was studied, and the data from 2008 to 2017 was selected; the impact of structure upgrading of the secondary industry on energy efficiency in Beijing, Tianjin and Hebei was studied, and the data from 2010 to 2017 were selected; and the impact of structure upgrading of the tertiary industry on energy efficiency in Beijing, Tianjin and Hebei was studied, and the data from 2010 to 2017 were selected. Taking 2000 as the base period, the GDP, fixed asset investment (k) and exports (export) were deflated by the GDP deflator, so as to eliminate price changes and conduct inter-period comparisons.

4.1 Analysis on the Effect of Industrial Structure Upgrading on Energy Efficiency in the Beijing-Tianjin-Hebei Region

Using the constructed panel regression model (1), this study firstly tested the stationarity results of all variables to ensure the validity of the estimated results. Through the LLC test, the results showed that the original variable and the first-order difference of the industrial structure upgrading had passed the stationarity test, and the first-order difference of energy efficiency had also passed the stationarity test, but the original variable of energy efficiency hadn't passed the stationarity test. Therefore, follow-up econometric analysis could be carried out. After the Hausman test, the fixed utility model was finally chosen instead of the random model. The measurement results obtained by the benchmark regression were shown in "Table 1".

Table 1. Empirical results of benchmark regression

Variable	Regression model (1)	Regression model (2)	Regression model (3)
C (constant)	0.4292***	0.7581*	1.7705***
isa	0.3426***		0.2339***
k		-0.00003***	-0.0003***
rmbrate		-0.1379	-0.1782***
export		0.0036***	0.0013***
F	224.99	48.62	159.03
R-squared	0.8036	0.7335	0.9244
obs	57	57	57

a Note: *** showed p<0.01; ** showed p<0.05; * showed p<0.1; and obs showed the number of observed individuals. Model (1) only considered the relationship between the explanatory variable and the explained variable; Model (2) only considered the relationship between the control variable and the explained variable, and Model (3) considered the addition of the control variable on the basis of Model (1). .

In "Table 1", the regression model (1) was used to analyze the impact of industrial structure upgrading on energy efficiency, considering explanatory variables and without control variables. The results showed that the industrial structure upgrading index increased by 1%, and the energy efficiency increased by 0.3426%, that is, the impact of industrial structure upgrading on energy efficiency was positive and significant, indicating that the tertiary industry could improve energy efficiency more than the secondary industry. The R-squared value of regression model (1) was 0.8036, and the result was significant.

In "Table 1", control variables were added instead of explanatory variables, and the regression model (2) was used to analyze the relationship between control variables and energy efficiency. The results showed that for every 1% increase in export volume, energy efficiency increased by 0.0036%, and the result was significant; for every 1% increase in fixed asset investment, energy efficiency decreased by 0.00003%, and the result was significant; and for every 1% increase in the RMB exchange rate, energy efficiency decreased by 0.1379%, but the result was not significant.

In "Table 1", explanatory variables were considered, control variables were added, and the regression model (3) was used to analyze the impact of industrial structure upgrading on energy efficiency. The results showed that the R-squared value increased to 0.9244, the industrial structure upgrading index increased by 1%, the energy efficiency increased by 0.2339%, and the results were significant.

The research showed that the industrial structure upgrading in the Beijing-Tianjin-Hebei Region could generally positively promote the improvement of energy efficiency, which supported the theoretical hypothesis H1. In the process of optimizing and upgrading the industrial structure of the Beijing-Tianjin-Hebei economy in the post-industrialization period, the factors of production had gradually shifted from "low productivity sectors" to "high productivity sectors", driving the overall Beijing-Tianjin-Hebei economy. The scale effect and structural dividend formed in the process could effectively promote the economic growth of the Beijing-Tianjin-Hebei Region, thereby further promoting the optimization and upgrading of the industrial structure. And the upgrading of the industrial structure further reduced the economic dependence on energy, which was conducive to reducing the energy consumption intensity of the economic system, alleviating the pressure on the ecological environment, and improving the production efficiency.

4.2 Analysis on the Regression Results of the Impact of the Structure Upgrading of the Primary Industry on Energy Efficiency in the Beijing-Tianjin-Hebei Region

According to the explained variables, explanatory variables, control variables and their indicators of the primary industry at the industrial level of Beijing-Tianjin-Hebei Region, the regression results of the impact of the structure upgrading of the primary industry in the Beijing-Tianjin-Hebei Region on energy efficiency were determined. The operation results of Stata were shown in "Table 2".

Table 2. Regression results of the impact of structure upgrading of the primary industry on energy efficiency in the Beijing-Tianjin-Hebei Region

	Model (1)	Model (2)	Model (3)
Variable	ee	ee	ee
zl	3.167	6.113**	8.010***
	(2.041)	(2.666)	(2.298)
tz_1		49.33	60.57**
		(30.45)	(25.45)
ld_1			8.989**
			(3.095)
Constant	-1.158	-3.552*	-5.988***
	(1.398)	(1.992)	(1.847)
Observations	30	30	30
R-squared	0.910	0.923	0.951

a t-statistics in parentheses

b *** p<0.01, ** p<0.05, * p<0.1

c Note: zl represented the ratio of the output value of planting to the output value of forestry, animal husbandry and fishery, and tz1 and ld1 were shown in "Table 1". Model (1) only considered the relationship between the explanatory variable and the explained variable. Model (2) and Model (3) were based on Model (1), adding control variables in turn.

In "Table 2", from the point of view of Model (1), without control variables, the ratio of the output value of planting industry to that of forestry, animal husbandry and fishery increased by 1%, and the energy efficiency of primary industry increased by 3.167%. The R-squared of model (1) was 0.91, which was highly significant.

In "Table 2", control variables were added to Model (2) and Model (3) respectively. The results showed that both investment and labor input would positively promote the improvement of energy efficiency, the results were significant, and the model fitting degree was good. Among them, the ratio of the output value of planting to that of forestry, animal husbandry and fishery increased by 1%, and the energy efficiency of the primary industry increased by 8.01%, which supported the theoretical hypothesis H2.

4.3 Analysis on the Regression Results of the Impact of Secondary Industrial Structure Upgrading on Energy Efficiency in the Beijing-Tianjin-Hebei Region

Based on the explained variables, explanatory variables, control variables and their indicators of the secondary industry in the Beijing-Tianjin-Hebei Region at the industrial level, the regression results of the impact of the secondary industrial structure upgrading in the Beijing-Tianjin-Hebei Region on energy efficiency were determined. The operation results of Stata were shown in "Table 3".

In "Table 3", from the perspective of model (1), without control variables, the proportion of the output value of high-tech manufacturing to the total output value of the secondary industry increased by 1%, and the energy efficiency of the secondary industry increased by 2.314%. Therefore, the relationship between these two was significantly positive.

Table 3. Regression results of the impact of structure upgrading of the the secondary industry on energy efficiency in the Beijing-Tianjin-Hebei Region

	Model (1)	Model (2)	Model (3)
Variable	ee	ee	ee
gx	2.314***	1.923***	1.609***
	(9.35)	(3.99)	(3.61)
ld_2		-1.543	-8.509**
		(-0.94)	(-2.76)
js_2			2.068**
			(2.56)
Constant	0.259**	0.774	1.731**
	(2.14)	(1.39)	(2.79)
Observations	24	24	24
R-squared	0.799	0.807	0.855

a t-statistics in parentheses

b *** p<0.01, ** p<0.05, * p<0.1

c Note: gx represented the proportion of the output value of high-tech manufacturing to the total output value of the secondary industry, and variable indicators such as ld2 and js2 were shown in "Table 1". Model (1) only considered the relationship between the explanatory variable and the explained variable. Models (2) and (3) were based on model (1), adding control variables in turn.

In "Table 3", control variables were added to model (2) and model (3) respectively. The results showed that the investment in technology could positively promote the improvement of energy efficiency, that is, the proportion of the output value of high-tech manufacturing to the total output value of the secondary industry increased by 1 %, the energy efficiency of the secondary industry increased by 1.609%, and the model fitting degree was 0.855, which was highly significant and supported the theoretical hypothesis H3.

4.4 Analysis on the Regression Results of the Impact of the Tertiary Industrial Structure Upgrading on Energy Efficiency in the Beijing-Tianjin-Hebei Region

According to the explained variables, explanatory variables, control variables and their indicators of the tertiary industry in the Beijing-Tianjin-Hebei Region at the industrial level, the regression results of the impact of the structure upgrading of the tertiary industry in Beijing-Tianjin-Hebei Region on energy efficiency were determined. The operation results of Stata were shown in "Table 4".

Table 4. Regression results of the impact of the structure upgrading of the tertiary industry on energy efficiency in Beijing-Tianjin-Hebei Region

	Model (1)	Model (2)
Variable	ee	ee
fl	0.113***	0.212***
	(3.54)	(4.11)
ld3		-2.942*
		(-2.21)
Constant	4.669***	6.575***
	(44.91)	(7.59)
Observations	16	16
R-squared	0.641	0.802

a t-statistics in parentheses

b *** p<0.01, ** p<0.05, * p<0.1

c Note: fl represented the ratio of the output value of the service sector to the output value of the circulation sector, and the ld3 variable indicator was shown in "Table 1". Model (1) only considered the relationship between the explanatory variable and the explained variable, and Model (2) added control variables on the basis of Model (1).

In "Table 4", from the perspective of model (1), without control variables, the ratio of the output value of the service sector to the output value of the circulation sector increased by 1%, and the energy efficiency of the tertiary industry increased by 0.113%. The relationship between the two was significantly positive. Adding control variables to Model (2), the results showed that labor input would reduce energy efficiency, the ratio of the output value of the service sector to the output value of the circulation sector would increase by 1%, the energy efficiency of the tertiary industry would increase by 0.212%, and the model fitting

degree would improve. This supported the theoretical hypothesis H4.

5. CONCLUSION AND SUGGESTION

Research showed that the upgrading of the industrial structure in the Beijing-Tianjin-Hebei region could generally promote the improvement of energy efficiency. Increasing the ratio of the output value of planting to forestry, animal husbandry and fishery could promote the energy efficiency of the primary industry and reduce the energy consumption per unit of GDP in the primary industry. Increasing the proportion of the output value of high-tech manufacturing in the total output value of the secondary industry could promote the improvement of the energy efficiency of the secondary industry and reduce the energy consumption per unit of GDP in the secondary industry. Increasing the ratio of the output value of the service sector to the output value of the circulation department could promote the energy efficiency of the tertiary industry and reduce the energy consumption per unit of GDP in the tertiary industry.

In order to accelerate the industrial structure upgrading and improve the energy efficiency of the Beijing-Tianjin-Hebei Region, the following countermeasures and suggestions are proposed:

It is suggested to accelerate the optimization and upgrading of the industrial structure in the Beijing-Tianjin-Hebei Region, and promote the high-quality coordinated economic development of the Beijing-Tianjin-Hebei Region. It is required to increase the ratio of the added value of the tertiary industry to the added value of the secondary industry in the Beijing-Tianjin-Hebei Region, and gradually realize the transformation from resource-labor-intensive to capital-technology-intensive industries in the Beijing-Tianjin-Hebei Region. It is better to further promote Tianjin and Hebei to undertake the function of "non-capital function evacuation", expand the economic growth of Tianjin and Hebei, promote the upgrading of industrial structure through economies of scale, further improve energy efficiency, and achieve high-quality coordinated development of Beijing-Tianjin-Hebei economy.

It is necessary to optimize the industrial structure and energy structure of the Beijing-Tianjin-Hebei Region under the hard constraints "carbon peaking and carbon neutrality". It is suggested to reduce the proportion of manufacturing industries with high energy consumption, especially heavy industry, and increases the proportion of services and light industries with low energy intensity; It is necessary to reduce the proportion of fossil energy consumption such as coal and oil with high carbon content, and increase the consumption proportion of zero-carbon renewable energy and low-carbon natural gas and other clean energy consumption; It is required to enhance the technological innovation capability of the Beijing-Tianjin-Hebei Region, reduce waste in energy production, transportation and consumption, and further improve energy utilization efficiency.

It is better to accelerate the optimization and upgrading of the industrial structure of the three industries in Beijing-Tianjin-Hebei Region. For the primary industry, it is better to adjust and optimize the proportional relationship between planting and forestry, animal husbandry and fishery in Beijing, Tianjin and Hebei, and increase capital investment in agriculture and animal husbandry to improve labor productivity. For the secondary industry, it is required to strengthen the proportion of investment in energy, power and high-tech industries in the Beijing-Tianjin-Hebei Region, alleviate the problems of high proportion of heavy industrialization, high resource and energy consumption, and overcapacity in the past, fundamentally promote the upgrading of the industrial structure of Beijing-Tianjin-Hebei Region, and improve the competitiveness of the manufacturing industry in the Beijing-Tianjin-Hebei Region. For the tertiary industry, it is necessary to adjust and optimize the ratio of the industrial structure of service sector to that of the circulation sector in the Beijing-Tianjin-Hebei Region, and increase the proportion of high-level service sectors. Since the distribution services provided by labor-intensive industrial sectors would increase the intensity of carbon emissions, the development mode of the transportation industry should be transformed to use clean energy and new vehicles. In the future, it is also necessary to increase investment in the production service industry of high-tech, knowledge and human capital. At the same time, it is required to increase capital investment in information transmission, computer services and software industries, and promote the coordinated development of the tertiary industry.

AUTHORS' CONTRIBUTIONS

Dan Wu is responsible for experimental design and writing the manuscript, Mengyao Liu responsible for research collection and writing the manuscript.

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