Mechanism Analysis of Industrial Structure Upgrading Promoting Energy Intensity Reduction

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Abstract

The 14th Five Year Plan period is a critical period for China to strive to reach its peak in carbon emissions before 2030. Inhibiting unreasonable energy consumption and strengthening energy intensity control are of great significance for achieving the goal of reaching its peak in carbon emissions before 2030. Based on the panel data of 30 provinces and cities in China from 2001 to 2020, this paper uses the panel fixed two-way effect model to empirically test the structural effect, technical effect, mesomeric effect and regulatory effect that promote the decline of energy intensity. The results show that the industrial structure upgrading contributes positively to the decline of energy intensity within the research interval, that is, the industrial structure upgrading promotes the decline of regional energy intensity. The impact coefficient of industrial structure upgrading in the eastern region on energy intensity is negative, but not significant. The contribution of industrial structure upgrading in the western region and the northeastern region to the decline of energy intensity is positive, and the industrial upgrading in the central region plays a negative role in the decline of energy intensity. Energy consumption structure has a partial mesomeric effect on the decline of regional energy intensity promoted by the upgrading of industrial structure. Energy technical efficiency, urbanization rate and scientific and technological level will weaken the impact of industrial structure upgrading on energy intensity. Therefore, the decline of energy intensity is an important factor in promoting economic development and decoupling energy consumption from carbon emissions. The government can speed up the realization of the goal of regional low-carbon transformation through the control of energy intensity indicators.

Keywords

Energy intensity, Industrial structure upgrading, Energy technical efficiency, Mesomeric effect, Regulatory effect.

1. INTRODUCTION

With the increasingly prominent energy shortage, how to achieve the transformation from energy consumption and extensive economic development to resource saving and environmentally friendly development has become a major theoretical and practical issue that urgently needs to be solved.Energy consumption is closely related to economic development and global climate change, and is a hot topic of concern for countries around the world today. It is also a global and strategic issue related to the sustainable development of China's social and economic development. Among them, the decline of energy intensity can effectively curb the growth of carbon emissions. The decline of energy intensity is an important factor in promoting economic development and decoupling energy consumption from carbon emissions. The government can speed up the realization of the goal of regional low-carbon transformation

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through the control of energy intensity indicators. The Fourteenth Five-Year Plan outlines "reducing energy consumption per unit of GDP by 13.5 percent" as one of the main binding indicators of economic and social development. Curbing unreasonable energy consumption and strengthening the control of energy consumption intensity are of great significance to the realization of the goal of carbon emissions peaking before 2030. Therefore, it is necessary to further analyze and study the driving factors and driving mechanisms that promote the decline of energy intensity. Therefore, based on the panel data of 30 provinces and cities in China from 2000 to 2020, this paper uses the panel fixed two-way effect model to empirically test the structural effect, technical effect, mesomeric effect and regulatory effect of promoting the decline of energy intensity

2. THEORETICAL ANALYSIS AND RESEARCH HYPOTHESIS

The concept of energy intensity was first proposed by Patterson in 1996. It is used to measure the energy consumption per unit output, thus reflecting the dependence of economic development of a country, region or industry on energy consumption (Patterson, 1996).Energy consumption intensity is usually referred to as energy intensity, which is generally measured by the comprehensive energy consumption per unit output. Regional energy intensity is mainly determined by the industrial structure in the region and the energy economic efficiency of various industries in the region, and also represents the trend of industrial structure upgrading and industrial energy economic efficiency (Chi Zhang, 2019).When a country or region has a high level of industrial structure and the energy efficiency of various industries, especially high energy consuming industries, is high, the energy consumption level per unit of economic output will be relatively low. Therefore, energy intensity comprehensively reflects the dependence of a country or region's production on energy and economic efficiency, and is an important indicator of the dependence of economic growth on energy (Ting Kong and Linyan Sun, 2008).

As for the index measurement of industrial structure change, the added value of three industries is generally used to construct the index. Part of the literature uses the proportion of the added value of the three industries in the regional GDP (Xiangyu Yu et al., 2019; Hua Zhang, 2020) or the ratio of the output value of the tertiary industry to the output value of the secondary industry(Mengqi Gong and Haiyun Liu, 2020)to the output value of the secondary industry to measure the upgrading of the industrial structure;Some scholars believe that with the continuous improvement of economic development level, the proportion of the output value of the primary industry in national economic development continues to decrease. Therefore, the ratio of the added value of the second and third industries to the gross domestic product is used to measure industrial structure upgrading (Zijing Wu et al., 2019; Jiayi Liu et al., 2014; Jun Dai and Yanming Fu, 2020); Some scholars also use the coefficient of industrial structure layers to measure industrial structure upgrading, that is $UIS = \sum_{i=1}^{3} w_i \times i = w_1 \times 1 + w_2 \times 2 + w_3 \times 3$, Where w_i is the proportion of the output value of the Industry i (Yingshi Liu et al., 2018).

The impact of industrial structure upgrading on energy intensity is mainly reflected in the following two aspects:

First, the upgrading of industrial structure has significantly promoted the decline of energy intensity (Adom, 2015). Reddy and Ray (2010) used the exponential decomposition model and found that the inhibitory effect of industrial structure on energy intensity was significantly greater than that of energy efficiency. He et al. (2011) used Cointegration Analysis and causality research methods to analyze the relationship between China's industrial structure and energy intensity from 2000 to 2006. The results show that the development of the secondary industry is the main factor leading to the increase of China's energy intensity, while the development of the tertiary industry has promoted the reduction of energy intensity. Shen Xiaobo et al. (2021)

used the Spatial Panel Model to analyze the impact of industrial structure distortion on energy intensity in China's provinces from 1978 to 2016. The results show that the distortion of industrial structure can significantly inhibit the decline of energy intensity.

Second, the upgrading of industrial structure cannot effectively promote the decline of energy intensity. Qiaosheng Wu and Jinhua Cheng (2006) discussed the driving factors of China's energy intensity from 1980 to 2003 based on the Index Decomposition Model. The study found that the industrial structure adjustment inhibited the decline of energy intensity. Boqiang Lin and Rui Duke (2014) analyzed the influencing factors of energy intensity in various regions of China from 2003 to 2010, and the results showed that changes in industrial structure hindered the decline of energy intensity in China. Yuting Li et al. (2016) used the Factor Decomposition Model to analyze the influencing factors of energy intensity in China and its provinces from 1980 to 2015. The results showed that the industrial structure adjustment had a negative impact on energy intensity after 1985.

In the 1940s, British economics proposed the famous Petty Clark Law, which states that as the economy develops and the level of national income gradually increases, labor will flow from the primary industry to the secondary and tertiary industries, thereby promoting the rationalization and advanced development of a nation's industrial structure. China’s industrial structure has changed significantly since 2000.The primary industry's share of output value has dropped dramatically from 14.67% in 2000 to 7.65% in 2020, and its employment share has dropped from 50% in 2000 to 23.6% in 2020; From 45.54% in 2000 to 37.82% in 2020, the secondary industry's share of the output value has decreased very modestly. From 22.5% in 2000 to 28.7% in 2020, the secondary industry's share of the labor force has grown. The share of output value in the tertiary industry has increased significantly, from 39.79% in 2000 to 54.52% in 2020. From 27.5% in 2000 to 47.7% in 2020, the tertiary industry's percentage of employment has expanded (see Figure 1).

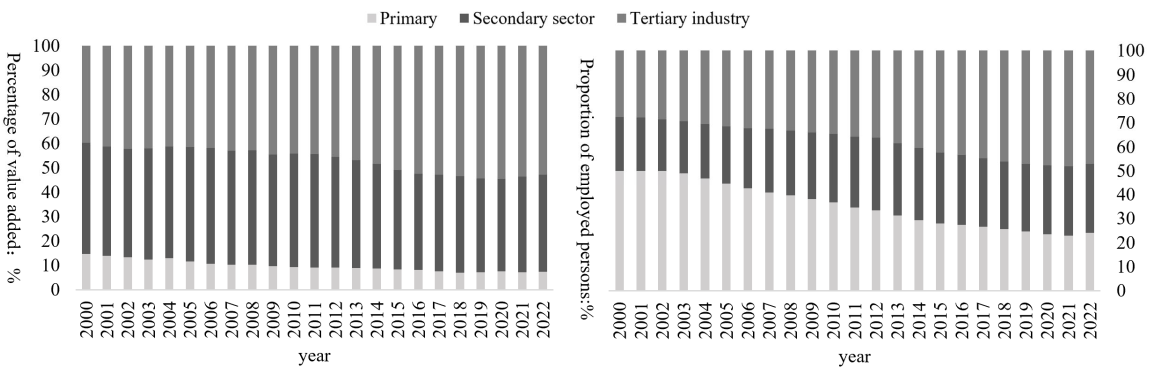

Figure 1:Output value share and employment share of China's three industries

In optimizing the industrial structure, China has consistently reduced emissions and conserved energy in recent years, and energy intensity has also greatly lowered.

In 2020, the energy intensity decreased by 41.98% compared to 2005, equivalent to saving 3.507 billion tons of standard coal. During the "12th Five Year Plan" and "13th Five Year Plan" periods, China's GDP grew at a rate of about 7%, while the growth in energy consumption was only about 3%. From the perspective of the three industries, the secondary industry with the highest energy consumption has relatively low energy consumption in the primary and tertiary industries. When a country starts the early stage of industrialization from the agricultural-based economic model, it may appear that the energy intensity increases with the change of industrial structure. When industrialization has progressed to a certain stage, the scale effect and technological effect will promote the regional energy intensity to decrease through the

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improvement of energy efficiency of the industry. With the continuous transfer of industries and employment to the tertiary industry, the proportion of high energy intensity industries will decrease again, the proportion of low energy intensity services will increase, and the regional energy intensity will further decrease. For the impact of industrial structure change on regional energy intensity, different time periods and different regions will have different effects, but on the general trend, regional energy intensity will decrease with the change of industrial structure upgrade. Therefore, hypothesis 1 is presented.

Hypothesis 1: There is a negative correlation between industrial structure upgrading and energy intensity.

The change of industrial structure is a process of transferring output and employment share between departments. When a regional industrial change and upgrading, the output share of each industry also changes. The main path is the transfer of primary industry employees to the secondary and tertiary industries, with the first and secondary industries shrinking and the tertiary industry expanding. That is, the share of the secondary industry with high energy consumption intensity decreases, while the share of the tertiary industry with low energy consumption intensity increases, which can directly promote the reduction of energy consumption intensity in a region. When the industrial structure of a region changes, its energy consumption structure will also change. The upgrading of the industrial structure plays a certain role in promoting the optimization of the energy structure, and thus the optimization of the energy structure will also play a certain role in reducing the regional energy intensity. Therefore, hypothesis 2 is proposed.

Hypothesis 2: Energy consumption structure plays a mesomeric role in the impact of industrial structure on energy intensity.

Because energy intensity is affected by multiple factors such as industrial structure, energy consumption structure, and economic development level, energy intensity and energy efficiency are not necessarily fully linked. The internal energy intensity of each industry mainly reflects the technical efficiency of energy, but the technical efficiency of energy and energy intensity are not consistent. When the industrial structure of a region remains unchanged, the decline of energy intensity within each industry, that is, the improvement of comprehensive energy technical efficiency within the region, can promote the decline of regional energy intensity. However, when there is a significant change in the industrial structure within the region, that is, when the share of output in high energy consuming industries within the region changes significantly, even if the energy efficiency of high energy consuming industries improves, the regional energy intensity may still rise. Referring to the method of (Ke Wang et al., 2021), this paper introduces regional comprehensive energy efficiency and studies its impact on regional energy intensity under the interaction between it and industrial structure. When comprehensive energy efficiency increases to a very high level, the energy intensity of various industries will decrease, and the difference in energy consumption per unit output of various industries will narrow, which will weaken the contribution of industrial structure upgrading to the reduction of energy intensity. Conversely, when the industrial structure is upgraded to an advanced state, the regional energy intensity will decrease to a lower state, which will also weaken the contribution of energy efficiency improvement to the reduction of regional energy intensity. Therefore, hypothesis 3 is proposed.

Hypothesis 3: Energy efficiency has a negative regulatory role in the transmission of the impact of industrial structure on energy intensity.

The upgrading and transformation of industrial structure is not only the change of industrial share among departments, but also the flow of employees among departments. The flow of agricultural workers to industry and service industries has promoted the upgrading and transformation of industrial structure, while also promoting the urbanization rate. The original

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driving force behind the transfer of the agricultural workforce to industry and services comes from the income differences between agriculture, industry, and services. Progress in science and technology is the main reason for the formation of income differences between departments, and has a significant positive impact on the improvement of energy efficiency. Therefore, progress in science and technology has a positive contribution to the decline in regional energy intensity. When the level of technology and urbanization increases, energy intensity will decrease, thereby weakening the impact of industrial structure on energy intensity to a certain extent. Therefore, hypothesis 4 is proposed.

Hypothesis 4: Urbanization rate and technological level have a reverse regulatory effect on the transmission of the impact of industrial structure on energy intensity.

3. EMPIRICAL RESEARCH DESIGN

3.1. Variable selection and data source

(1)variable selection

Selection of interpreted variables. Energy intensity (EI): Energy intensity refers to the energy consumption per unit of GDP. Here, unit GDP refers to the unit GDP converted at constant prices in 2000. The total energy consumption is converted into standard coal using the calorific value method. The specific calculation formula is shown in Equation (1):

$$EI_i = \frac{\sum_j E_{ij} \times \eta_j}{G_{i,2000}} \tag{1}$$

In Equation (1), EI_i is the energy intensity of i province and city, E_{ij} is the consumption of energy of type j in province i, $G_{i,2000}$ is the fixed price GDP of province i based on the year 2000, η_j is the conversion coefficient of j energy sources into standard coal.

Selection of core explanatory variables. Industrial structure upgrading (ISU) refers to the method adopted by Yingshi Liu et al. (2018) to measure the industrial structure upgrading coefficient. The specific calculation formula is shown in Equation (2):

$$r = \sum_{i=1}^{3} y_i \times i \tag{2}$$

In Equation (2), it is the proportion of added value of the tertiary industry; $r \in [1,3]$, The higher the value, the faster the upgrading of the industrial structure. Referring to the experience and practice of Jun Dai and Yanming Fu (2020), the "(added value of the tertiary industry in each province+added value of the secondary industry in each province)/total GDP in each province" was used to replace the industrial structure upgrade for robustness testing. Control the selection of variables. This article controls other factors that affect energy intensity, including:

①Energy efficiency (eef), referring to the method of (Ke Wang et al., 2021), this paper first measures the energy technical efficiency index of the five sectors of agriculture, industry, construction, transportation and services in various provinces and cities. The energy technical efficiency index of each sector uses the reciprocal of energy intensity, that is, the added value of the unit end-user energy consumption, as its energy technical efficiency index, The energy technical efficiency index of each department is aggregated into the energy efficiency of each

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province and city by using the proportion of the added value of the five departments after standardization. The specific calculation formula is shown in Formula (3):

$$eef_i = \sum_{j}^{5} \omega_{ij} \times eef_{ij} \tag{3}$$

In formula (3), eef_i is the energy efficiency index of province i; eef_{ij} is the energy efficiency index of the provincial sector; ω_{ij} is the proportion of added value of standardized provincial departments. The specific calculation formula for sector energy efficiency index eef_{ij} is shown in Equation(4):

$$eef_{ij} = \frac{G_{ij,2000}}{E_{ij}} \tag{4}$$

In Equation (4), $G_{ij,2000}$ is the fixed price GDP of the provincial sector with the base period of 2000, E_{ij} is the terminal energy consumption of department j in province i The terminal energy consumption here is the sum of various energy consumption amounts converted into standard coal. Due to significant differences in factors such as the level of economic development, energy consumption structure, and industrial structure among provinces and cities, as well as significant differences in the energy consumption structure of various departments, there may be significant gaps in sectoral energy technical efficiency indexes. To avoid the impact of extreme values and maintain the relative stability of the energy technical efficiency index, when calculating the sectoral energy technical efficiency index, this paper adopts the logarithmic power function method to standardize the relevant data. The improvement of energy technical efficiency in any department will reduce the energy consumption per unit of added value of that department, so the improvement of energy technical efficiency in each province and city will inevitably reduce the energy intensity of the region. Therefore, the expected regression result of energy efficiency in the analysis of energy intensity drivers is negative.

②Economic development level ($vGDP$). GDP per capita is used as the proxy variable, adjusted over the base period of 2000, and logarithmic. When the economy reaches a certain stage of development, the dependence of economic growth on energy consumption will gradually decrease. According to the environmental Kuznets hypothesis, when the economy reaches a certain level, the environment will gradually improve with economic growth. Environmental improvement means a reduction in energy consumption, that is, a reduction in energy consumption per unit of GDP. Therefore, the regression result of the expected economic development level in the analysis of energy intensity drivers is negative.

③Energy consumption (VEC). Measured by logarithmic per capita energy consumption. Currently, China has a coal based energy consumption structure, with an increase in per capita energy consumption, probably due to the new production of high energy consuming devices with large capacity in the region. Therefore, there is a positive correlation between per capita energy consumption and energy intensity. Therefore, the expected regression result is positive.

④Environmental regulation ($lnpcp$). Referring to the treatment method of Xiangyu Yu et al. (2019), the amount of investment in environmental pollution control is used and measured logarithmically. Under the role of environmental regulation, promoting enterprises and lower

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level governments to increase investment in environmental governance and maintenance can promote the effective control of unreasonable energy consumption in the energy field, and pay more attention to the use of low-carbon and efficient energy, thereby playing a positive role in the reduction of energy intensity in the region. Therefore, the expected regression result is negative.

⑤Economic Openness($open$). According to the practice of Shenghua Yu and Tingting Wang (2021), the total import and export volume/GDP is used to measure. Countries and regions with open economies have more choices in the introduction of industries and products, and choose some production equipment with low energy consumption, enterprises with high output value and advanced production technology to improve their energy efficiency, thereby reducing energy intensity; At the same time, in order to improve their competitiveness in the international market, countries and regions continue to improve the level of technological innovation and energy efficiency, thereby reducing the energy intensity. Therefore, the regression result is expected to be negative.

⑥Traffic conditions ($vrode$). Referring to the research method of Liu Yingshi et al. (2018), the level of transportation infrastructure is measured using the per capita road area and taking logarithms. A developed transportation system can improve the operational efficiency of enterprises and effectively improve the energy consumption efficiency of regional transportation. Therefore, the per capita road area can reduce the energy consumption intensity of the region to a certain extent. Therefore, the expected regression result is significantly negative.

⑦Distorted industrial structure (DIS). Referring to the research method of Shen Xiaobo et al. (2021), the square root of the sum of the squares of the differences between employment shares and output shares in each sector is used to characterize the distortion of industrial structure. The specific calculation formula is shown in Equation (5):

$$DIS_i = \frac{L_i}{\sum_k L_k} - \frac{VA_i}{\sum_k VA_k}, DIS = \sqrt{\sum_i DIS_i^2} \tag{5}$$

In Equation (5), VA_i and L_i represent the added value and employment of sector DIS. The larger the industrial structure, the more distorted it becomes. The essence of industrial structure distortion is that the proportion of employment in a sector is far lower than the share of output in that sector, resulting in inefficient allocation of energy resources, which is inevitably detrimental to the decline in energy intensity. Therefore, the expected regression result is significantly positive.

⑧Human capital ($lneff$). Referring to the research method of Shixiang Li et al. (2020), human capital stock is used to measure. The stock of human capital is expressed by multiplying the average number of years of education by the number of workers and taking a logarithm. The number of workers is represented by the number of employees over the years. The specific calculation formula for the average number of years of education is shown in Equation (6):

$$H = \sum_{i=1}^{5} p_i h_i \tag{6}$$

In Equation (6), H is the average number of years of education; i refers to the educational level, which is divided into four levels: primary school, junior high school, high school, junior

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college, and above; p_i is the proportion of employees with education level i; h_i is the number of years of education at level i, with values of 6, 9, 12, and 16, respectively. Under certain conditions, there is a substitution effect between energy consumption and manpower. When human capital increases, enterprises will use more energy to reduce labor costs. Therefore, the increase in human capital hinders the decline in energy intensity. Therefore, the expected regression result is significantly positive.

(2) Data processing and sources

This study is based on panel data from 30 provinces, autonomous regions, and municipalities in China (excluding Hong Kong, Macao, Taiwan, and Tibet) from 2001 to 2020, and includes 600 sample units.

The data on the number of employed persons in various provinces and cities and the number of employees with different levels of education are derived from the China Labor Statistics Yearbook over the years, the per capita road area is derived from the China Urban Construction Statistics Yearbook, the per capita energy output is derived from the China Energy Statistics Yearbook, and other data are derived from the National Bureau of Statistics of the People's Republic of China and the China Statistical Yearbook over the years. Partial missing data were processed using interpolation methods.

The descriptive statistical results of the main variables are shown in Table 1

Table 1. Statistical description of main variables

variable	variable	sample size	mean value	standard deviation	minimum	maximum
energy intensity	$energy$	570	1.3516	0.7796	0.2934	4.3193
Upgrade of industrial structure	ISU	570	2.3348	0.1320	2.0695	2.8337
energy efficiency	eef	570	0.5626	0.1547	0.1570	0.8502
Energy consumption	VEC	570	0.8839	0.5353	-0.5976	2.3570
Environmental regulation	$lnpcp$	570	11.5773	1.1310	6.9141	14.1637
Economic openness	$open$	570	3.1718	3.7680	0.1278	17.3241

3.2. Model Settings

As the data used in this article is panel data, there may be significant differences between the data of various provinces and municipalities directly under the central government, so the fixed effect term representing regional heterogeneity should be included in the above Econometric Model; At the same time, the economic low-carbon development policies of local governments have been changing during the sample period, and the central government has also continuously upgraded its environmental protection and low-carbon development policies. Therefore, it is necessary to incorporate time fixed effects on the basis of the basic model.

The benchmark regression model is set as follows, and the specific formula is shown in Equation (7):

$$energy_{it} = \alpha_0 + \alpha_1 ISU_{it} + X_{it}^{'}\alpha_3 + \delta_1 u_i + \delta_2 \lambda_t + \varepsilon_{it} \tag{7}$$

In Equation (7), i represents each province and municipality, t represents the year, and the interpreted variable $energy_{it}$ is energy intensity; The main explanatory variable ISU_{it} is industrial structure upgrading; $X_{it}^{'}$ is a control variable, mainly including energy efficiency, per capita energy consumption, environmental regulations, economic openness, transportation

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conditions, industrial structure distortion, economic development level, and human capital; u_i is the individual effect of region i, and λ_t is the time effect of year t.

4. ANALYSIS OF EMPIRICAL RESULTS

4.1. Benchmark regression results

As for the selection of panel specific model form, first, test whether the model needs to include time effect. The results show that the joint statistics of dummy variables in all years are significant at the significance level of 1%, so time effect should be included in the model; Secondly, the Mixed Regression Model and the Fixed Effect Model were compared. The results showed that the individual effect existed at the significance level of 1%, so the Fixed Effect Model was selected; Thirdly, comparing the Mixed Regression Model with the random effect model, the LM Test was 12.99, and it was significant at the significance level of 1%, so the hypothesis of "no individual random effect" was rejected and the Random Effect Model was selected; Finally, comparing the Fixed Effect Model with the Random Effect Model, the Hausman test is 78.79, and it is significant at the significance level of 1%, that is, the Fixed Effect Model is selected. To sum up, this paper uses a Two-way Fixed Effect Model.

Table 2. Benchmark regression estimation results

Variable	Mixed regression	REM	FEM
ISU	-0.3278**	-0.5554***	-0.4946**
	(-2.24)	(-2.63)	(-2.11)
eef	-1.2299***	-2.1686***	-2.526***
	(-6.84)	(-10.35)	(-11.38)
VEC	1.1065***	0.7016***	0.518***
	(17.84)	(9.38)	(6.05)
$lnpcp$	-0.0589***	-0.0487***	-0.049***
	(-3.25)	(-3.41)	(-3.48)
$open$	-0.0115***	-0.0186***	-0.0134**
	(-2.73)	(-2.94)	(-2.03)
$vrode$	-0.1699***	-0.3341***	-0.3378***
	(-4.41)	(-8.48)	(-8.02)
DIS	0.292***	0.1466***	0.1488***
	(6.35)	(3.51)	(3.14)
$vGDP$	-0.9457***	-0.433***	0.0203
	(-17.17)	(-4.82)	(0.14)
$lneff$	0.8535***	0.3642***	0.3637***
	(14.14)	(4.19)	(3.49)
Constant term	2.8674***	4.8453***	1.3596
	(6.51)	(6.68)	(0.95)
R2	0.888	0.7535	0.759
Sample size	570	570	570
Individual effect	-	Yes	Yes
Year effect	-	Yes	Yes

Note: * * *, ** *, * respectively indicate that the test of statistics is significant at the level of 1%, 5% and 10%, and T statistics are in brackets.

The estimation results of the Mixed Regression Panel Model, the Random Effect Panel Model and the Two-way Fixed Effect Panel Model are shown in Table 2. The estimates of the three

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models show that there is a significant negative correlation between the industrial structure upgrading ISU and $energy$ intensity, which verifies hypothesis 1 and is consistent with the conclusions of the existing literature. The regression coefficients of eef、$lnpcp$、$open$ and $vrode$ are negative, that is, energy efficiency, environmental regulation, economic openness and traffic conditions are negatively correlated with energy intensity; The regression coefficients of VEC、DIS and $lneff$ are positive, that is, per capita energy consumption, distortion of industrial structure, human capital and energy intensity are positively correlated; It is consistent with the expected results. $RGDP$ is significantly negative in mixed regression panel model and random effect panel model, but not significant in two-way fixed effect panel model, which may be related to regional heterogeneity.

4.2. Analysis of heterogeneity in different regions

According to the classification of China's four major economic regions, the sample is divided into eastern region, central region, western region and northeast region for research (see Table 3). The coefficient of the eastern region is negative, but not significant. It may be because the industrial upgrading in the eastern region mostly shifted from agriculture to industry and services from 2000 to 2010, and the production capacity of basic industrial products such as cement, steel and chemical industry was rapidly put into production. The upgrading of industrial structure accompanied by the rapid growth of energy consumption, and more high energy consumption was put into production in some regions. Although the industrial structure was upgraded, the energy intensity also increased synchronously, This is also consistent with some early literature conclusions (Wu, 2012), and the upgrading of industrial structure has played a negative role in the decline of regional energy intensity. Therefore, taking the eastern provinces from 2011 to 2020 as the sample, the regression analysis was conducted again. The regression results showed that the industrial structure upgrading was negative at the significant level of 1%, and the industrial structure upgrading in the western and northeastern regions was significantly negative, that is, the industrial structure in the western and northeastern regions contributed positively to the decline of energy intensity, which was mainly because the economic development in the northeastern region was slower than that in the eastern region during the study period, There is no rapid expansion stage of high energy consuming industries, the proportion of secondary industries is relatively stable, the upgrading of industrial structure is relatively gentle, and the degree of distortion is not high, which has always been a positive contribution to the decline of energy intensity. The western region is similar to the eastern region. The proportion of agricultural output value and employment is relatively high. The upgrading of industrial structure is mainly based on the transfer of agriculture to service industry. The northeast and western regions have superior resource endowment and extensive economic development in the early stage. With the optimization and upgrading of industrial structure and the improvement of energy efficiency, the energy intensity will decline. During the study period, the coefficient of the central region is positive at the significance level of 1%. The upgrading of the industrial structure in the central region is mainly based on the transfer from the primary industry to the secondary industry, and the economic growth is mainly driven by energy consumption. Therefore, the upgrading of the industrial structure in the central region will lead to the increase of energy consumption intensity. $vGDP$ is significantly negative in the eastern and northeastern regions, positive in the central region at 10% significance level, and negative but not significant in the western region, which just verifies the conjecture that $vGDP$ is not significant in the whole sample.

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Table 3. Estimation results of the impact of regional industrial structure upgrading on energy intensity

Variable	Eastern Region	Eastern Region ($year > 2010$)	Western Region	Central region	north-eastern region
ISU	-0.0095	-0.6949***	-1.4985***	2.92***	-0.8959**
	(-0.05)	(-3.96)	(-3.4)	(6.46)	(-2.73)
eef	-0.1492	-0.6986***	-3.4518***	0.1064	-2.4098***
	(-0.82)	(-4.43)	(-8.47)	(0.29)	(-5.99)
VEC	0.5227***	0.5547***	0.5566***	1.3117***	0.4938
	(11.06)	(8.67)	(3.06)	(8.11)	(1.68)
$lnpcp$	-0.0152**	0.0027	-0.0171	-0.0748***	-0.0372*
	(-2.14)	(0.69)	(-0.56)	(-3.89)	(-1.76)
$open$	-0.0156***	-0.0116***	0.2332***	0.0996**	-0.001
	(-5.33)	(-3.74)	(6.95)	(2.47)	(-0.03)
$vrode$	-0.1249***	-0.0559*	-0.3713***	0.365***	-0.2193
	(-6.97)	(-1.89)	(-3.58)	(3.71)	(-1.28)
DIS	0.2496*	0.0466	0.2509***	-0.5774***	0.018
	(1.69)	(0.33)	(3.04)	(-3.36)	(0.15)
$vGDP$	-0.1964**	-0.2414	-0.1894	0.4419*	-2.2661***
	(-2.22)	(-1.38)	(-0.76)	(1.71)	(-3.89)
$lneff$	0.0315	0.0131	0.6237***	0.675***	0.6313
	(0.48)	(0.24)	(3.18)	(3.72)	(1.69)
Constant term	2.7085***	4.6957**	2.9676	-14.8557***	17.4631***
	(3.1)	(2.55)	(1.06)	(-6.47)	(3.95)
R2	0.9343	0.9609	0.8396	0.9739	0.9833
Sample size	190	90	209	114	57
Individual effect	Yes	Yes	Yes	Yes	Yes
Year effect	Yes	Yes	Yes	Yes	Yes

Note: * * *, ** *, * respectively mean significant at the significant level of 1%, 5% and 10%, and T statistics in brackets.

4.3. Utility analysis

(1) Mesomeric effect test

In order to verify the driving mechanism that the upgrading of industrial structure will reduce energy intensity through the energy consumption structure, the energy consumption structure is selected as the mesomeric variable of the impact of industrial structure upgrading on energy intensity, and the mesomeric effect test method of Feng Han and Ligao Yang (2020) is used for reference to test the transmission mechanism of the impact of industrial structure upgrading on energy intensity by constructing the mesomeric effect. The mesomeric effect model can be expressed as equations (8) to (10):

$$\text{energy}_{it} = \alpha_0 + \alpha_1 \text{ISU}_{it} + X_{it}^{'}\alpha_2 + \delta_1 u_i + \delta_2 \lambda_t + \varepsilon_{it} \tag{8}$$

$$\text{M}_{it} = \alpha_{01} + \alpha_{11} \text{ISU}_{it} + X_{it}^{'}\alpha_{21} + \delta_{11} u_i + \delta_{21} \lambda_t + \varepsilon_{it} \tag{9}$$

$$\text{energy}_{it} = \alpha_0^{'} + \alpha_1^{'} \text{ISU}_{it} + X_{it}^{'}\alpha_2^{'} + \alpha_3 \text{M}_{it} + \delta_1^{'} u_i + \delta_2^{'} \lambda_t + \varepsilon_{it} \tag{10}$$

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In equations (8) to (10), M_{it} It is the mesomeric variable, expressed by the energy consumption structure. First, the parameters of equation (8) are estimated to test whether the impact of industrial structure upgrading on energy intensity is significant; Secondly, the regression of equation (9) is carried out to test whether the impact of industrial structure upgrading on mesomeric variables is significant; Finally, the econometric test of equation (10) shows that if the $\alpha_1^{'}$ and α_3 are significant and the coefficient $|\alpha_1'|$ is less than $|\alpha_1|$, it indicates that the mesomeric variable has partial mesomeric effect in the impact of industrial structure upgrading on energy intensity. If the parameter $\alpha_1^{'}$ is not significant, but α_3 is significant, it means that the mesomeric variable has a complete mesomeric effect in the impact of industrial structure upgrading on energy intensity.

Referring to the practice of Chaoyang Luo and XueSong Li (2019), the energy consumption structure is expressed by the ratio of coal consumption to total energy consumption (ESC), and the data is from the *China Energy Statistical Yearbook* over the years.

The estimated results are shown in Table 4. There are partial mesomeric effect in the energy consumption structure. In equation (8), the impact of industrial structure upgrading on energy intensity is significantly negative, and the coefficient is -0.4946; In equation (9), the coefficient of industrial structure upgrading on energy consumption structure is negative at the significance level of 1%, which is -21.8253; In equation (10), after adding the energy consumption structure to the basic model, the energy consumption structure is positive at the significance level of 5%, and the industrial structure upgrading is significantly negative, and the coefficient is -0.4163, and the absolute value of the coefficient 0.4163 is less than the absolute value of the coefficient 0.4946 of the industrial structure upgrading of the basic model. Therefore, the energy consumption structure has some mesomeric effects. The source power of industrial structure upgrading comes from technology upgrading. Technology upgrading leads to income differences between departments, which leads to the flow of employees and the change of output share between departments. Industrial structure upgrading promotes the optimization of energy structure. The optimization of energy structure is mainly to reduce the use of high emission fossil energy, especially coal, and increase the use of relatively clean natural gas and absolutely clean non fossil energy. As the conversion efficiency of natural gas and electricity to heat and power is higher than that of coal, the optimization of energy structure will significantly reduce the energy consumption per unit output, so the optimization of energy structure will also play a certain role in promoting the decline of regional energy intensity. According to the above analysis, it is also confirmed that the upgrading of industrial structure can indirectly promote the decline of regional energy intensity through the optimization of energy structure.

(2) Regulatory effect test

At present, some literatures on energy intensity are from the perspective of energy efficiency, scientific and technological level and urbanization rate. Will these factors play a role in the impact of industrial structure upgrading on energy intensity? This part mainly studies the interaction between industrial structure upgrading and these factors.

According to the practice of Feng Han and Ligao Yang (2020), a Two-way Fixed Effect Regression Model including the interaction of regulatory variables is constructed, as shown in equation (11):

$$energy_{it} = \alpha_0 + \alpha_1 ISU_{it} + X_{it}^{'}\alpha_2 + \alpha_3 T_{it} + \alpha_4 (ISU_{it} \times T_{it}) + \delta_1 u_i + \delta_2 \lambda_t + \varepsilon_{it} \tag{11}$$

Table 4. The mediating effect of industrial structure upgrading on energy intensity

Interpreted variable name	$energy$	ESC	$energy$
ISU	-0.4946**	-21.8253***	-0.4163*
	(-2.11)	(-3.36)	(-1.76)
eef	-2.526***	-0.3769	-2.5247***
	(-11.38)	(-0.06)	(-11.42)
VEC	0.518***	9.8204***	0.4827***
	(6.05)	(4.14)	(5.56)
$lnpcp$	-0.049***	0.1195	-0.0494***
	(-3.48)	(0.31)	(-3.52)
$open$	-0.0134**	0.0573	-0.0136**
	(-2.03)	(0.31)	(-2.07)
vrode	-0.3378***	5.4301***	-0.3573***
	(-8.02)	(4.65)	(-8.34)
DIS	0.1488***	2.1478	0.1411***
	(3.14)	(1.64)	(2.98)
$vGDP$	0.0203	-23.3652***	0.1041
	(0.14)	(-5.94)	(0.71)
lneff	0.3637***	3.5743	0.3509***
	(3.49)	(1.24)	(3.38)
Constant term	1.3596	258.7389***	0.4317
	(0.95)	(6.5)	(0.29)
ESC	-	-	0.0036**
			(2.26)
R2	0.759	0.2515	0.7614
Sample size	570	570	570
Individual effect	Yes	Yes	Yes
Year effect	Yes	Yes	Yes

Note: * * *, ** *, * respectively mean significant at the significant level of 1%, 5% and 10%, and T statistics in brackets.

In equation (11), T_{it} is a regulatory variable, which can represent energy efficiency, urbanization rate or scientific and technological level. If both α_1 and α_4 are significant and have the same sign, the adjustment variable enhances the impact of industrial structure upgrading on energy intensity; If the sign is opposite, the adjustment variable weakens the impact of industrial structure upgrading on energy intensity.
See Table 5 for the estimated results.

① The moderating effect of energy efficiency (eef). The energy consumption structure mentioned above is the mesomeric effect of industrial structure upgrading on energy intensity. Although energy efficiency, urbanization rate and scientific and technological level are not mesomeric effects, energy efficiency, urbanization rate and scientific and technological level may play a regulatory role. The estimated results in column 2 of Table 5 show that the regression result of the interaction between industrial structure upgrading and energy efficiency is significantly positive. In other words, energy efficiency will weaken the impact of industrial structure upgrading on energy intensity. The improvement of energy efficiency can effectively reduce the energy consumption per unit output. When the energy consumption per unit output of each department is reduced and close to the lowest energy consumption in the industry, the energy consumption structure effect of industrial structure upgrading will be reduced due to the reduction of energy consumption differences between departments.

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Similarly, the reduction of energy efficiency will increase the energy consumption per unit output among departments, When the share of sector output changes, the change range of regional comprehensive energy consumption will also increase. To sum up, the improvement of energy efficiency will weaken the contribution of industrial structure upgrading to the decline of regional energy intensity.

② Urbanization rate (VU). The data of urbanization rate comes from *China Statistical Yearbook* over the years. The estimated results in column 3 of Table 5 show that the regression result of the interaction term between industrial structure upgrading and urbanization rate is significantly positive, that is, the urbanization rate will weaken the impact of industrial structure upgrading on energy intensity. The process of urbanization rate rising is also the process of agricultural population flowing to industry, construction and service industries. Regions with high urbanization rate will also provide human resources guarantee for the upgrading of industrial structure, which is more conducive to the upgrading of industrial structure. Therefore, the urbanization rate weakens the contribution of industrial structure upgrading to the decline of energy intensity.

③ Scientific and technological level (STL). Referring to the practice of Xianglan Huang et al. (2018), the investment intensity of technology level research and experimental development funds is used to measure the level of science and technology. The *China Science and Technology Statistical Yearbook* in 2006 and later directly provides the data of the investment intensity of technology level research and experimental development, but the previous data is missing. Therefore, this paper uses the calculation formula of the investment intensity of technology level research and experimental development, that is, the investment intensity of technology level research and experimental development=the ratio of the investment intensity of technology level research and experimental development to GDP. The data comes from the *Statistical Bulletin of National Science and Technology Investment* over the years. The estimation results in column 4 of Table 5 show that the regression result of the interaction term between industrial structure upgrading and scientific and technological level is significantly positive, indicating that scientific and technological level will weaken the impact of industrial structure upgrading on energy intensity. The improvement of scientific and technological level can improve the production efficiency of relevant departments. The improvement of production efficiency will increase the relative income of relevant departments, which will lead to the flow of employees between departments. That is, the improvement of scientific and technological level can promote the upgrading of industrial structure, and the improvement of scientific and technological level can also improve the energy use efficiency and save energy consumption, that is, the improvement of scientific and technological level can reduce the energy consumption intensity of various departments. Therefore, the improvement of scientific and technological level will weaken the impact of industrial structure upgrading on energy intensity.

4.4. Robust Test

This part will test the robustness of the benchmark regression conclusion from the methods of changing explanatory variables, removing municipalities directly under the central government and endogenous treatment.

(1) Transform and add explanatory variables

First, transform and upgrade the industrial structure. Industrial structure upgrading refers to the experience and practice of Jun Dai and Yanming Fu (2020), and adopts the ratio of the total added value of the tertiary industry and the added value of the secondary industry to GDP to replace the original industrial structure upgrading index. The second column of Table 6 shows the estimation results, showing that the coefficient of the new proxy index for industrial structure upgrading is significantly negative at the significance level of 5%, which is consistent

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with the significance and positive and negative signs of the industrial structure upgrading coefficient in the benchmark regression, that is, the conclusion has passed the robustness test.

Table 5. Test results of the regulatory effect of industrial structure upgrading on energy intensity

interaction term Explained Variable	$ISU \times eef$ $energy$	$ISU \times VU$ $energy$	$ISU \times STL$ $energy$
ISU	-3.9739*** (-3.44)	-1.844*** (-4.48)	-0.9753*** (-3.95)
eef	-17.5517*** (-3.6)	-2.4328*** (-11.06)	-2.3535*** (-10.94)
VEC	0.7096*** (4.45)	0.6666*** (7.23)	0.7662*** (8.39)
$lnpcp$	-0.042** (-2.21)	-0.048*** (-3.46)	-0.0424*** (-3.13)
$open$	0.0015 (0.15)	-0.0072 (-1.08)	0.0026 (0.38)
$vrode$	-0.1683* (-1.93)	-0.2919*** (-6.78)	-0.2945*** (-7.02)
DIS	0.1306 (1.4)	0.096** (1.98)	0.0973** (2.06)
$RGDP$	-0.2984 (-0.96)	-0.1045 (-0.71)	-0.297** (-2.07)
$lneff$	0.3125 (1.32)	0.226** (2.08)	0.2266** (2.17)
interaction term	6.5072*** (3.32)	0.031*** (4.02)	0.2922*** (2.86)
Adjusting variable	-	-0.0699*** (-4.07)	-0.5336** (-2.14)
Constant term	11.9234*** (3.14)	6.4955*** (3.33)	5.8085*** (3.73)
R2	0.8101	0.7666	0.7798
Sample size	570	573	574
Individual effect	Yes	Yes	Yes
Year effect	Yes	Yes	Yes

Note: * * *, ** *, * respectively mean significant at the significant level of 1%, 5% and 10%, and T statistics in brackets.

Second, join the energy consumption structure (ECS). The upgrading of regional industrial structure can affect the energy intensity of the region by changing the regional energy consumption structure. Therefore, the energy consumption structure is added to the model to test the robustness of the model. Referring to the practice of Guimei Zhao et al. (2020), the energy consumption structure is expressed by the ratio of coal consumption to total energy consumption. The third column of Table 6 shows the estimated results of the impact of industrial structure upgrading on energy intensity after adding the energy consumption structure. The coefficient of ECS is significantly positive at the significance level of 5%, the coefficient of industrial structure upgrading of the core explanatory variable is still significantly

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negative, and the significance and direction of the coefficients of other control variables are almost unchanged, so the conclusion is robust.

Third, change environmental regulation. At present, the index of environmental regulation is measured by logarithm in addition to the amount of investment in environmental pollution control adopted in the benchmark regression. Mengqi Gong and Haiyun Liu (2020) use the proportion of environmental pollution control cost in GDP to measure (eni). Therefore, this part uses this index for stability test, and the data is from the National Bureau of statistics of the people's Republic of China. The regression results (see column 4 of Table 6) show that although the coefficient of eni is not significant, it is negative, and the significance and direction of the coefficient of the core explanatory variable and other control variables have hardly changed, so it has passed the robustness test.

Table 6: Robustness test results of the impact of industrial structure upgrading on energy intensity

Variable	(1)	(2)	(3)	(4)
ISU	-	-0.4163*	-0.5115**	-0.4535*
		(-1.76)	(-2.15)	(-1.83)
eef	-2.3415***	-2.5247***	-2.5285***	-2.5891***
	(-10.31)	(-11.42)	(-11.25)	(-10.9)
VEC	0.5759***	0.4827***	0.4621***	0.6979***
	(6.6)	(5.56)	(5.42)	(6.85)
$lnpcp$	-0.0464***	-0.0494***	-	-0.0398**
	(-3.29)	(-3.52)		(-2.4)
$open$	-0.0126*	-0.0136**	-0.0135**	-0.018*
	(-1.9)	(-2.07)	(-2.01)	(-1.85)
$vrode$	-0.3211***	-0.3573***	-0.3393***	-0.4759***
	(-7.69)	(-8.34)	(-7.93)	(-7.46)
DIS	0.1667***	0.1411***	0.129***	0.0791
	(3.55)	(2.98)	(2.71)	(1.45)
$vGDP$	0.0323	0.1041	0.0212	-0.1744
	(0.23)	(0.71)	(0.15)	(-1.06)
$lneff$	0.4015***	0.3509***	0.3186***	0.1888
	(3.91)	(3.38)	(3.05)	(1.52)
Constant term	0.4235	0.4317	1.3325	4.7372***
	(0.33)	(0.29)	(0.92)	(2.58)
$xgdp$	-0.9623**	-	-	-
	(-2.3)			
ECS	-	0.0036**	-	-
		(2.26)		
eni	-	-	-0.0155	-
			(-0.21)	
R2	0.7594	0.7614	0.7533	0.7711
Sample size	750	750	750	494
Individual effect	Yes	Yes	Yes	Yes
Year effect	Yes	Yes	Yes	Yes

Note: * * *, ** *, * respectively mean significant at the significant level of 1%, 5% and 10%, and T statistics in brackets.

(2) Robustness test for removing municipalities directly under the central government

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In this part, some samples are removed for robustness test. Since the economic characteristics of municipalities directly under the central government are different from those of ordinary provinces, four municipalities directly under the central government are removed for robustness test. The estimation results are shown in column 5 of Table 6. The coefficient direction and significance of explanatory variables and control variables have little change, so the conclusion is robust.

(3) Further treatment of endogenous problems

Generally, there is an endogenous problem of reverse causality between explanatory variables and explained variables, that is, the upgrading of industrial structure will not only affect energy intensity, but also affect the upgrading of industrial structure. Although the Two-way Fixed Effect Model controls the unobservable fixed effect, it does not consider the endogenous problem caused by the cyclic causality between the two. In order to avoid the interference of this problem on the empirical results, this part uses the explanatory variable time lag and dynamic panel model to test the robustness of the impact of industrial structure upgrading on energy intensity.

First, the time lag of the core explanatory variable and the control variable is used to test the robustness. See column 2 of Table 7 for the test results of the time lag of industrial structure upgrading and control variables. The significance of industrial structure upgrading and control variables are consistent with the benchmark regression, that is, there is a significant negative correlation between industrial structure upgrading and energy intensity.

Secondly, Dynamic Panel Model robustness test. Set the regression model as shown in equation (12):

$$energy_{it} = \alpha_0 + energy_{i,t-1} + \alpha_1 ISU_{it} + X_{it}^{'}\alpha_3 + \delta_1 u_i + \delta_2 \lambda_t + \varepsilon_{it} \tag{12}$$

In equation (12), $energy_{i,t-1}$ means that the energy intensity lags behind by one period. Since the sample data in this chapter conform to the structural characteristics of "large N and small T", the Bidirectional Fixed Effect Model and the two-step system generalized moment method are used for estimation.

The regression results are shown in columns 3 and 4 of Table 7. The coefficient of industrial structure upgrading is significantly negative in both models, and the first-order lag term of energy intensity is significantly positive at the significance level of 1%. At the same time, the test of the generalized moment of the two-step system shows that the setting of the model is reasonable. Therefore, the results of empirical analysis are robust.

To sum up, using the explanatory variable time lag and Dynamic Panel Model, the symbol and significance of industrial structure upgrading are basically consistent with the benchmark regression results. In the control variables, except for the significance of individual variables, the overall conclusion is also consistent with the benchmark regression results. Therefore, there is no endogenous problem, and the estimation conclusion of the impact of industrial structure upgrading on energy is robust.

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Table 7. Endogenous test results of the impact of industrial structure upgrading on energy intensity

Variable	(1)	(2)	(3)
ISU	-0.7846***	-0.2777**	-3.5872*
	(-3.07)	(-2.07)	(-1.99)
eef	-2.264***	-0.6716***	0.7686
	(-9.33)	(-4.84)	(0.51)
VEC	0.3103***	0.2356***	0.6275
	(3.25)	(4.75)	(1.38)
$lnpcp$	-0.0325**	-0.0181**	0.0294
	(-2.1)	(-2.24)	(0.82)
$open$	-0.0078	-0.0023	-0.0418**
	(-1.09)	(-0.61)	(-2.14)
$vrode$	-0.2613***	-0.1144***	-0.4855**
	(-5.83)	(-4.58)	(-2.57)
DIS	0.1856***	0.0701***	-0.5007
	(3.55)	(2.59)	(-1.17)
$vGDP$	0.027	-0.0798	0.6953
	(0.17)	(-0.98)	(1.33)
$lneff$	0.4497***	0.1372**	-0.8943
	(3.85)	(2.3)	(-1.2)
Constant term	0.6577	1.0207	11.7148*
	(0.42)	(1.25)	(1.79)
$L.energy$	-	0.7236***	0.8536***
		(32.66)	(5.77)
R2	0.7105	0.9218	-
sample size	540	570	570
individual effect	Yes	Yes	Yes
Year effect	Yes	Yes	Yes
Hansen test	-	-	1
AR(1)	-	-	0.001
AR(2)	-	-	0.125

Note: ① * * *, **, * respectively represent the significance levels of 1%, 5% and 10%, and the t-statistics are in brackets; ② The original assumptions of AR (1) and AR (2) are that there is no first-order and second-order sequence correlation for the residual term after difference, respectively. ② this paper relaxes the assumption that the disturbance term is independent distribution, uses Hansen test, and the test statistics in the table report the corresponding p value.

5. CONCLUSION

Based on the panel data of 30 provinces and cities in China from 2000 to 2020, this paper uses the panel fixed two-way effect model to empirically test the driving factors, driving mechanism, mesomeric effect and regulatory effect that promote the decline of energy intensity. The specific research conclusions are as follows:

(1) There is a negative correlation between industrial structure upgrading and energy intensity. The upgrading of industrial structure contributes positively to the decline of energy intensity, that is, the upgrading of industrial structure promotes the decline of regional energy

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intensity. The upgrading of industrial structure can effectively promote the decline of regional energy intensity. Judging from the degree of distortion of the current industrial structure, the path of upgrading the industrial structure is still the flow of employees from the primary and secondary industries to the tertiary industry, which will further promote the expansion of the output share of the tertiary industry and the contraction of the output share of the primary and secondary industries. To sum up, the upgrading and change of industrial structure will still make a positive contribution to the decline of regional energy intensity in the future.

(2) The coefficient of the impact of industrial structure upgrading on energy intensity in the eastern region is negative, but not significant. The main reason is that the rise of the industrial upgrading index in the eastern region from 2000 to 2010 is caused by the rapid expansion of the industrial share of the secondary industry, which is consistent with the rapid expansion of China's basic industrial product production capacity during the "Tenth Five-Year Plan" and "Eleventh Five-Year Plan".

The regression results of the eastern provinces from 2011 to 2020 show that the coefficient of industrial structure upgrading is negative at the significance level of 1%, which is mainly due to the fact that China has gradually attached importance to high-quality economic development during the “12th Five-Year Plan” period. The transformation of high-quality economic development was first implemented in the economically developed eastern regions, which has limited the development of high energy consuming industries and accelerated the elimination of backward production capacity, we will encourage the expansion of high-tech industries and service industries, and upgrade the industrial structure to a higher quality. Therefore, after the 12th Five-Year Plan, the industrial upgrading in the eastern region has played a significant role in promoting the decline of energy consumption intensity. The contribution of industrial structure upgrading in the western region and the northeast region to the decline of energy intensity is positive. During the study period, the share of secondary industry output in these two regions is relatively stable, the industrial structure upgrading is relatively gentle, and the degree of distortion is not high, so the industrial structure upgrading is a positive contribution to the decline of energy intensity. The economic development level of the central region lags behind that of the eastern region, and the output share of the service industry is relatively low. The industrial structure upgrading index mainly reflects the output share of the secondary industry. Therefore, the industrial upgrading in the central region has a negative effect on the decline of energy intensity during the study period.

(3) The energy consumption structure has a partial mesomeric effect on the decline of regional energy intensity promoted by the upgrading of industrial structure. The upgrading of industrial structure is the result of the flow of employees within departments and the transfer of output share between departments. Changes in sector share will also lead to changes in energy consumption structure. The change of energy consumption structure is mainly to reduce the use of high emission fossil energy (especially coal), increase the use of relatively clean natural gas and absolutely clean non fossil energy. Since the conversion efficiency of natural gas and electricity to heat and power is higher than that of coal, the change of energy structure will be more conducive to the reduction of energy consumption per unit output, so the change of energy structure will play a certain role in promoting the decline of regional energy intensity. Therefore, the upgrading of industrial structure can reduce regional energy intensity by promoting the optimization of energy structure.

(4) Energy technical efficiency, urbanization rate and technological level will weaken the impact of industrial structure upgrading on energy intensity. The improvement of energy efficiency can effectively reduce the energy consumption per unit output. When the share of sector output changes, the change range of regional comprehensive energy consumption will also decrease. The process of urbanization rate rising is also the process of agricultural

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population flowing to industry, construction industry and service industry. Regions with high urbanization rate can provide more skilled workers, and rich skilled employees can effectively improve the output efficiency of various industries, reduce the energy consumption per unit output, and narrow the energy consumption gap between various industries. The improvement of scientific and technological level can also reduce the contribution of industrial structure upgrading to the reduction of energy intensity by improving energy efficiency, saving energy consumption, reducing the energy intensity of each department and reducing the difference of energy intensity among departments. Therefore, provinces with low energy technical efficiency, low urbanization rate and low scientific and technological level need to pay more attention to industrial structure adjustment when formulating energy intensity control policies, which will have a more obvious driving effect on the decline of energy intensity.

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