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Influencing factors of the high-quality economic development in China based on LASSO model

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Abstract

This paper constructs an index system for high-quality economic development in China from four dimensions: economic system, social system, environment system, and power system. The LASSO method was presented as screen indicators, then we use the panel fixed effect model to investigate the specific impact of key factors on high-quality economic development. The results indicate that: (1) Innovation-driven, infrastructure construction, green technology development, power supply, and efficient utilization of electrical equipment are the most important influencing factors to promote high-quality economic development. (2) Increasing financial expenditures for pollution prevention and control and strengthening the application of green technology will help to adjust the economic structure. (3) Building a complete green energy system will be an essential part of high-quality economic development. On this basis, heterogeneity analysis is carried out according to regional economic differences and power supply and demand positioning. These findings have great significance in high-quality economic development of China.

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Keywords: High-quality economic development; Index system; LASSO model; Regional difference

1. Introduction

High-quality economic development is an issue that many economies need to study. As one of the fastest-growing economies in the world, China's current economic development has shifted from rapid growth in volume to structural adjustment [1]. In this regard, the Chinese government clearly stated in the "14th Five-Year Plan" that "Economic development should focus on high-quality development, deepen the supply-side structural reform as the mainline, take reform and innovation as the fundamental driving force". The high-quality development of economy

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will be a long-term dynamic process. Therefore, what factors have a significant impact on high-quality economic development, whether there are differences between different regions, and how to improve high-quality economic development through effective ways are important issues to be solved.

Many studies have discussed the influencing factors for the high-quality economic development. As economic play key role in the high-quality economic development, many scholars focus on economic factors. Hong et al. [2] find technological innovation, institutional reform, transformation, and upgrading have significant effects on development effectiveness. Yang et al. [3] discuss fintech development interacts with green finance to affect economic development. Environmental factors is the common explanation. Gan et al. [4] analysis the inhibitory effect on economic development. Zhang et al. [5] find environmental quality in promoting economic development exist. Lin and Zhu [6] verify the Clean Air Action has enhanced the green development of Chinese cities. In addition, there are some studies from the perspective of social system, such as transport [7], technology innovation [8] and corporate social responsibility [9]. More scholars realize that the influence factors of the high-quality economic development is a unified body that involves coordinated and orderly development in many aspects. Lin and Zhou [10] establish an evaluation index system derived from the four development concepts of economic development, social progress, ecological civilization, Innovation-driven. Li [11] builds a three-layer index system considering the aspects of economic growth structure and economic efficiency, ecological environment, and social coordination. Yang et al. (2021) evaluate high-quality economic development from economic structure, economic efficiency, ecological environment.

Although the existing literature has done some work on the influence factors of the high-quality economic development, these indicators often leave out the important influence of electricity system. As a “barometer” of the operation of the national economy, researchers revealed that there had been a relatively stable relationship between economic growth and electricity utilization [12–14]. In China, under the development concept of a green and low-carbon economy, energy system would transfer towards a clean and low-carbon “modern energy system” [15]. The most important is that build a power system dominated by renewable energy [16]. We conclude the power industry development is an essential factor affecting the changes in economic development. Also, applying power data to judge economic development is the mainstream direction of economic research at the macro level [11,17]. Hence, starting from the power industry, we can identify the characteristics of high-quality economic development.

A summary of the method for establishing the indicators of the economic development evaluation system, First, the literature analysis method uses the high-frequency indicators of the achievements of authoritative institutions, local governments, and academia to form the initial set of the evaluation index system [18,19]. Second, theoretical analysis, according to the connotation of high-quality economic development, uses economic theory to identify the impact of indicators and finally form an indicator system [9,20]. It can be found that the index system of most studies is comprehensive, but there is some problem. On the one hand, indicators are only determined through research experience without quantitative analysis; On the other hand, since too many indicators are considered, there may be severe multicollinearity between indicators.

The main contribution of this paper is shown in the following aspects. First, the evaluation of high-quality economic development needs to rely on an objective and complete multi-dimensional index system. Hence, incorporating the power system into the evaluation system is conducive to improving the accuracy of high-quality economic development. Second, the necessary quantitative screening of indicators can effectively minimize the influence of subjectivity. The LASSO method is suitable for processing high-dimensional data. By adding penalty items, unimportant variables can be eliminated. Third, this paper comprehensively considers the regional differences of high-quality economic development and discusses the influencing factors of it. Based on this, this paper will construct an indicator system for high-quality economic development at the inter-provincial level and use the LASSO method to analyze the dilution and optimization of indicators. Finally, we examine the specific impact of the selected indicators on economic development and verify heterogeneity analysis to provide helpful support for the efficient evaluation of high-quality economic development in China.

The rest of this paper is arranged as follows: Section 2 is the research methods and data. Section 3 introduces the empirical test results and discussion. Section 4 includes the conclusion and policy implications.

2. Models and data

2.1. Model construction

(1) Panel data regression via LASSO method

We construct a panel regression model with individual fixed effects using GDP as the dependent variable. The expressions for the panel data regressions are shown below:

$$y_{it} = \beta_0 + \sum_{n=1}^{q} \beta_n x_{int} + \alpha_i + \varepsilon_{it} \quad \text{where} \quad i = 1, 2, \ldots, n \quad \text{and} \quad t = 1, 2, \ldots, T \tag{1}$$

The above expression y_{it} represents the GDP of the ith province at the t year. x_{int} represents the nth indicator of the ith province at the t year. α_i is the individual fixed effects for the ith province and ε_{it} is the error term. β_0 and β_n are the panel data regression coefficients, q is the number of variables. $n = 30$ is the number of the provinces. $T = 12$ is the number of years.

Considering the high-dimensional influence of the data and the possible multicollinearity problem, we use the LASSO method to estimate. The LASSO method can be applied to regression models for cross-sectional data but cannot be applied to panel regression. We extend the LASSO method to panel regression. In Eq. (1), taking an average over time, we have

$$\overline{y}_i = \beta_0 + \sum_{n=1}^{q} \beta_n \overline{x}_{in} + \alpha_i + \overline{\varepsilon}_i \tag{2}$$

Where $\overline{y}_i = \sum_{t=1}^{T} y_{it}/T$, $\overline{x}_{in} = \sum_{t=1}^{T} x_{nit}/T$, and $\overline{\varepsilon}_i = \sum_{t=1}^{T} \varepsilon_{it}/T$. By (1) minus (2), we have

$$y_{it} - \bar{y}_i = \sum_{n=1}^{q} \beta_n (x_{int} - \bar{x}_{in}) + \varepsilon_{it} - \bar{\varepsilon}_i \tag{3}$$

Denote $\tilde{Y} = [y_{11}^* - \bar{y}_1^*, \ldots, y_{nT}^* - \bar{y}_n]^T$ and $\tilde{x}_{int} = x_{int} - \bar{x}_{in}$. Let design matrix $\tilde{X} = \begin{pmatrix} \tilde{x}_{1,1,1} & \cdots & \tilde{x}_{1,p,1} \\ \vdots & \vdots & \vdots \\ \tilde{x}_{n,1,T} & \cdots & \tilde{x}_{n,p,T} \end{pmatrix}$

The expression for the panel regression via LASSO method is shown below:

$$\min_{\beta} \frac{1}{2} (Y - \tilde{\mathbf{X}}\boldsymbol{\beta})^T (Y - \tilde{\mathbf{X}}\boldsymbol{\beta}) + \lambda \sum_{n=1}^{p} |\beta_n| \tag{4}$$

Where λ is the hyperparameter, the larger λ, the fewer variables are filtered into the model. In this paper, we use the generalized cross-validation method with minimum mean square error to select the hyperparameter. After solving the model, the variables corresponding to zero estimated parameters can be directly excluded from the composition of the indicator pool in the final index.

(2) The refitted panel regression model

The parameter estimates obtained by the LASSO method are biased, so the coefficients cannot be correctly analyzed for the economic impact factors. For the robustness of the model, we do another panel regression with the variables screened by the LASSO method. We select d indicators by LASSO method and do the panel regression.

$$y_{it} = \beta_0 + \sum_{n=1}^{d} \beta_n x_{int} + \alpha_i + \varepsilon_{it}$$

2.2. Index system for the high-quality economic development

We establish an evaluation system with four dimensions: economic, social, environment, and power system, including 40 indicators. This paper takes 30 provinces in China as research samples (the data of Hong Kong, Macau, Taiwan, Tibet are seriously missing, so they are excluded). The data comes from the Wind, CEIC, EPS, and DRCNET database. For some missing values in the original data, the linear interpolation method is used to fill in the processing. We also perform logarithmic processing on 18 variables with large absolute values like labor input. The statistics for the indicators are shown in Table 1.

Table 1. Index system of high-quality economic development level and descriptive Statistics for Variables.

First level	Second level	Third level	Variable	Sd.	Mean	Min	Max
Economic system	Industry structure	Share of secondary industry	X_1	8.72	44.82	16.2	61.50
		Share of tertiary industry	X_2	9.79	45.01	28.6	83.50
		Number of industrial enterprise units above the scale (take the log)	X_3	1.21	8.85	5.8	11.09
	Level of trade	Degree of external openness (take the log)	X_4	1.71	12.67	6.1	16.54
		Export dependence	X_5	22.64	17.49	0.7	129.7
		Import dependence	X_6	21.05	14.75	0.5	126.0
	Elemental inputs	Labor input (take the log)	X_7	0.92	6.35	4.0	8.53
		Resource input	X_8	86.62	142.50	11.4	413.9
		Human capital input	X_9	13.11	33.12	9.1	80.50
	Innovation-driven	R&D input (take the log)	X_{10}	1.37	14.49	10.4	17.25
		Invention patent output rate	X_{11}	15.88	30.26	5.2	67.77
Social system	Urban and rural development	Urbanization rate	X_{12}	13.20	56.38	29.1	89.60
		Urban-rural consumption ratio	X_{13}	0.47	2.41	1.6	3.86
	Inclusive equity	Medical resources	X_{14}	1.21	4.74	2.3	8.07
		communication facilities (take the log)	X_{15}	0.78	8.00	5.5	9.73
		Household refuse (take the log)	X_{16}	0.75	6.17	4.2	8.12
		Urban road area per capita	X_{17}	4.65	14.78	4.0	26.20
		The proportion of railroad and waterway freight	X_{18}	13.30	22.86	2.1	63.31
Environment system	Technology development	Number of green invention patent applications (take the log)	X_{19}	1.55	7.03	2.6	10.38
		Environmental pollution control investment (take the log)	X_{20}	0.90	9.74	6.9	11.86
		Wastewater treatment capacity	X_{21}	4.31	5.02	0.2	24.53
	Low carbon living	Forest coverage rate	X_{22}	17.78	32.07	2.9	66.80
		Urban green space area (take the log)	X_{23}	0.86	10.97	8.1	13.13
		Public transportation	X_{24}	3.24	12.24	6.8	26.55
Electricity system	Electricity supply and demand	Per capita electricity consumption (take the log)	X_{25}	0.51	8.27	7.1	9.62
		Electricity consumption (take the log)	X_{26}	0.71	7.24	4.8	8.81
		Electricity supply (take the log)	X_{27}	0.71	7.02	4.6	8.68
		The total energy available for consumption: Electricity	X_{28}	628.6	432.1	−1026	3262
		Electricity end consumption (take the log)	X_{29}	0.72	7.20	4.7	8.83
		The proportion of household electricity terminal consumption	X_{30}	5.31	13.78	2.2	29.41
		The proportion of industrial electricity terminal consumption	X_{31}	13.00	68.49	21.1	93.01

(*continued on next page*)

3. Results and analysis

3.1. Full sample analysis

To investigate the impact of each indicator on high-quality economic development, this section uses the indicators screened by LASSO to construct a panel double fixed-effect model for regression. In the full sample regression, we select 34 crucial variables from 40 candidates, as shown in Table 2.

There are 11 indicators in the economic system, and 9 indicators in Table 1 have passed the screening. The import and export dependence representing trade levels show a significant negative impact. Energy consumption and R&D investment have a significant positive effect. Excessive dependence on foreign trade will bring risks and uncertainties to the economy, resulting in structural weaknesses in economy. Therefore, the level of trade has

Table 1 (*continued*).

First level	Second level	Third level	Variable	Sd.	Mean	Min	Max
	Electrical equipment capacity	The capacity of power generation equipment (take the log)	X_{32}	0.76	10.47	7.9	11.85
		The capacity of power generating equipment: thermal power (take the log)	X_{33}	0.84	10.01	7.6	11.58
		Power generation equipment capacity of 6000 kW and above power plants (take the log)	X_{34}	0.87	6.21	3.9	8.24
		Power grid new 220 kV and above substation equipment capacity (take the log)	X_{35}	0.76	8.17	5.6	9.55
		Length of the transmission line circuit (take the log)	X_{36}	0.73	10.65	8.8	11.69
		Transformer capacity (take the log)	X_{37}	0.80	11.76	9.1	13.43
	Electrical equipment utilization	Average utilization hours of power generation equipment (take the log)	X_{38}	0.15	8.33	7.8	8.69
		Average utilization hours of power generation equipment: thermal power (take the log)	X_{39}	0.20	8.40	7.3	8.73
		Industrial value-added electricity consumption reduction rate	X_{40}	13.18	1.27	−89.2	29.62

Table 2. Full sample results.

Dimension	Index	Result	Dimension	Index	Result	Dimension	Index	Result
Economic system	X_2	−36.09 [80.2464]	Social system	X_{12}	−108.40 [184.6391]	Electricity system	X_{25}	7562.70 [5.4e+03]
	X_3	2087.40 [1.6e+03]		X_{13}	516.50 [934.8519]		X_{26}	−6564.70 [5.6e+03]
	X_4	624.30 (404.9165]		X_{14}	1726.9** [790.9196]		X_{27}	−2133.00 [3.0e+03]
	X_5	−192.2*** [45.0056]		X_{15}	−2729.40 [3.1e+03]		X_{28}	12.56*** [1.2662]
	X_6	−73.60* [40.7244]		X_{16}	6541.6*** [1.9e+03]		X_{29}	−13913.4*** [3.5e+03]
	X_7	576.00 [1.2e+03]		X_{17}	367.9** [157.7585]		X_{30}	352.2* [207.1506]
	X_8	126.4*** [23.4875]		X_{18}	317.2*** [54.4171]		X_{31}	20.82 (136.4514]
	X_9	91.54 (69.4306]		X_{20}	1168.2** [563.2900]		X_{34}	−209.90 (283.3482]
	X_{10}	5635.0*** [1.6e+03]	Environment system	X_{21}	1296.3*** [217.3171]		X_{36}	−9958.2*** [3.4e+03]
				X_{22}	−107.50 (120.4609]		X_{37}	2176.80 [2.4e+03]
				X_{23}	2580.2** [998.4377]		X_{38}	−3136.40 [3.1e+03]
				X_{24}	−203.10 (148.0473]		X_{39}	8999.9*** [1.9e+03]
							X_{40}	13.50 [14.3418]

Notes: t-statistics in parentheses.
***p < 0.01.
**p < 0.05.
*p < 0.1.

a negative impact. As the cornerstone of economic development, the significant positive effect of energy factors indicates that China's economy is still in a period of growth and development. At the same time, increasing R&D investment can effectively improve economic development, which shows that increased R&D investment injects strong impetus into the innovation drive, thereby forming a competitive economic advantage.

There are 7 indicators in the social system, and all have passed the screening. Medical resources, quality of life, and transportation infrastructure, which represent inclusiveness and fairness, significantly positively impact. Improving residents' living standards is an integral part of high-quality economic development. Better medical security and livable living environment can effectively increase labor productivity, then promote economic growth. As the main artery of economic development, improving the level of transportation infrastructure not only breaks the barriers to factor flow but also enhance the spillover effect of advanced technologies.

There are 6 indicators in the environment system, 5 indicators have passed the screening. Among them, the investment in environmental pollution control and sewage treatment capacity, which represent technological development, and the area of urban green space representing low-carbon life, have a significant positive impact on economic development. Increased green investment and improved pollution control technologies can improve the environment and reduce carbon emissions, thereby promoting the development of a green and intensive economy. Enhancing a green ecological and livable environment is an essential carrier of high-quality economic development.

There are 16 indicators in the power system, and 13 indicators in Table 1 passed the screening. Among them, energy available for consumption, the proportion of household electricity, and the utilization hours of thermal power equipment have a positive impact. In contrast, the terminal electricity consumption and the length of transmission lines have a negative effect. Regarding electricity supply and demand, the positive impact of residential electricity and the proportion of industrial electricity consumption is not significant, indicating that residential consumption has injected new impetus into high-quality economic growth, suggesting that "de-industrialization" has become inevitable choice. In addition, the terminal consumption due to the high proportion of thermal power, which is contrary to the current concept of green development and has an inhibitory effect on economic. Regarding the capacity and utilization rate of power equipment, a stable thermal power supply is beneficial to the current economic development. Besides, the length of the transmission line loop may reduce the marginal benefit because the existing grid in China is mature. Meanwhile, the rise of renewable energy has increased the development of distributed generation. The proportion of thermal power has been reduced, thus weakening the role of transmission lines.

3.2. Subsample analysis

In high-quality economic development, there are apparent differences in the economic level between provinces. We divide the sample into three major economic zones of "east, central and west". At the same time, considering different responsibilities in the power supply and demand, the sample is divided into three subsamples of "power output, power input and power balance". This section uses the indicators screened by LASSO to construct a panel double fixed-effect model for regression. The results show in Tables 3 to 6.

Regarding industrial structure, developing the tertiary industry in the west and increasing the development scale of industrial enterprises will help the economic development. In contrast, the power input region should promote the coordinated development of the secondary industry and the tertiary sector. Electricity balance areas should improve industrialization. Regarding trade level, the eastern region, the power output region, and the power input region should moderately reduce the dependence on exports. Considering factor input, the eastern region and the power input region should increase energy supply, and the west should not only increase energy supply but also introduce related policies to attract more talents. The power output region has left the low-level stage of labor-intensive production. Concerning innovation drive, the central and power exporting regions need to increase R&D investment to guarantee the development of competitive economic advantages. The output of invention patents in the eastern, central, and power input regions consumes many R&D funds have not yet been converted into production technology and applied, which in turn hinder economic growth.

Concerning urban–rural development, the advancement of urbanization in the east and power output regions will help improve local economic development. In contrast, the central should focus on reducing the gap between local urban and rural areas and promote integrated urban–rural development. Concerning inclusive equity and fairness, the higher the livability of residents in the east and the power exporting region, the more conducive to economic development. Speeding up the Construction of communication infrastructure in power input areas and power balance

Table 3. Subsample regression: Economic system.

Dimension	Index	East	Central	West	Electrical output	Electrical input	Electrical balance
Industry structure	X_1	455.70 [389.8376]	11.52 [98.5641]	243.80 [151.0332]	513.10 [357.2530]	431.0*** [159.4487]	396.0** [156.6911]
	X_2	−204.90 [418.9959]		387.8*** [134.2326]	291.20 [436.1136]	701.7*** [136.8771]	
	X_3	−549.70 [4.1e+03]		3643.5* [2.2e+03]	−2908.20 [3.8e+03]	1485.10 [2.4e+03]	
Level of trade	X_4	941.80 [1.3e+03]			1403.50 [1.2e+03]	90.59 [380.8911]	
	X_5	−351.9*** [88.2662]	144.60 [194.6045]	−87.28 [76.6690]	−403.2*** [87.9259]	−164.6** [82.8166]	191.10 [238.5460]
	X_6	−116.70 [71.7273]	585.6** [232.1293]	−39.46 [147.3881]	−5.60 [68.4894]	456.8*** [123.8213]	99.49 [159.3559]
Elemental inputs	X_7		−406.30 [2.5e+03]	−361.70 [1.1e+03]	−9767.9*** [3.5e+03]	460.30 [1.2e+03]	
	X_8	200.4*** [56.6112]	14.04 [66.7723]	77.52*** [23.4112]	65.19 [54.8900]	63.19** [26.4776]	63.64 [61.1162]
	X_9	226.80 [154.9677]	205.00 [125.0506]	191.4** [80.7924]			−57.47 [110.4405]
Innovation-driven	X_{10}	3180.20 [6.1e+03]	13961.0*** [3.3e+03]	2200.10 [1.3e+03]	14883.5*** [5.5e+03]	2283.90 [1.7e+03]	4987.20 [3.7e+03]
	X_{11}	−200.9*** [60.8090]		−77.51*** [21.9793]		−87.11*** [25.5153]	−12.26 [53.1101]

Notes: t-statistics in parentheses.
***p < 0.01.
**p < 0.05.
*p < 0.1.

Table 4. Subsample regression: Social system.

Dimension	Index	East	Central	West	Electrical output	Electrical input	Electrical balance
Urban and rural development	X_{12}			−13.68 [295.8672]	574.20 [412.7480]		
	X_{13}	3510.5** [1.7e+03]	−10018.9*** [2.9e+03]		4276.7** [1.7e+03]	−1428.60 [1.4e+03]	−1601.00 [4.0e+03]
Inclusive equity	X_{14}	3474.30 [2.4e+03]	487.00 [1.4e+03]	2133.1* [1.1e+03]	2208.10 [2.6e+03]	1017.20 [1.0e+03]	1646.10 [1.6e+03]
	X_{15}	−2514.40 [8.0e+03]	5365.40 [6.4e+03]	−3547.50 [3.5e+03]	3070.10 [7.1e+03]	7907.2* [4.1e+03]	17047.3** [6.8e+03]
	X_{16}	11933.8** [5.1e+03]	−2636.30 [3.9e+03]	2796.6* [1.7e+03]	9527.6* [5.0e+03]		−4400.70 [3.8e+03]
	X_{17}	590.40 [357.4381]		−62.63 [167.0541]		−77.49 [180.0793]	285.40 [286.0830]
	X_{18}		15.46 [121.5031]	253.8*** [73.3526]			

Notes: t-statistics in parentheses.
***p < 0.01.
**p < 0.05.
*p < 0.1.

Table 5. Subsample regression: Environment system.

Dimension	Index	East	Central	West	Electrical output	Electrical input	Electrical balance
Technology development	X_{19}	2970.40	−1822.80			2571.9***	−864.50
		[3.2e+03]	[1.7e+03]			[711.4982]	[2.3e+03]
	X_{20}	−821.00	2038.4**	1807.1***	−185.30	1971.3***	
		[1.2e+03]	[888.4312]	[568.4585]	[1.1e+03]	[683.9165]	
	X_{21}		1249.9***	376.2*	1110.4***		
			[426.3353]	[222.6842]	[403.7295]		
Low carbon living	X_{22}		645.1**	−59.08	244.40		
			[273.1288]	[101.5420]	[237.1058]		
	X_{23}	−850.60		1046.10		445.20	
		[2.1e+03]		[1.8e+03]		[2.1e+03]	
	X_{24}	−613.5**			−119.90	92.55	−373.60
		[276.7035]			[290.8942]	(186.7278]	[300.5357]

Notes: t-statistics in parentheses.
***p < 0.01.
**p < 0.05.
*p < 0.1.

areas will help improve economic development. What is more, the development level of the west is relatively low, and it is necessary to enhance the level of medical security, the livability of residents, and the Construction of transportation infrastructure to help local economic development.

Concerning technological development, increasing the proportion of investment in environmental pollution control and the level of sewage technology in the central and west will contribute to the development of the local green economy. Power output areas should focus on improving the level of local sewage technology. Electricity input regions should increase the investment in environmental pollution management and green research. Concerning low-carbon life, the rapid promotion of low-carbon transportation in the eastern region is inconsistent with the development process, resulting in the divergence of urban expansion and economic growth. In the future, attention should be paid to matching the spatial expansion of scale with the quality improvement of functions and scientifically implementing the concept of sustainable development. The central should improve the level of local carbon sinks to provide the necessary guarantee for high-quality economic development.

Regarding power supply and demand, the eastern and power output regions should increase the energy consumption and supply and the proportion of clean energy supply. On the basis of ensuring the regional energy supply, the western region and the power balance region should optimize the power supply layout and reduce power supply cost. Meanwhile, the west should focus on exploiting the household electrical appliance consumption market. Regarding power equipment capacity, the east has a higher demand for stable thermal power generation equipment. The power grid construction in the west is mature, and the addition of transmission lines can be slowed down in the short term. Due to the responsibility of power output, the power export has higher requirements on the capacity of power equipment and growth rate should be reasonably controlled. Due to the unique economic structure and stable power input in other regions, the augment of power generation equipment should be arranged in power input. According to power equipment utilization, the west can further improve the utilization rate of power generation equipment. Central and power export need to improve the utilization rate of thermal power generation equipment, which shows that power generation stability is still the key to whether clean energy can replace fossil energy.

4. Conclusions

Based on the LASSO method and panel fixed effect model, this paper builds a four-layer index system of high-quality economic development and examines the specific impact of critical factors screened from the index system. The main conclusions of this paper are as follows.

First, combined with the full sample analysis, innovation-driven infrastructure construction, green technology development, power supply, and efficient equipment utilization are essential factors that promote high-quality economic development. Excessive dependence on foreign trade and the high proportion of thermal power inhibit economic

Table 6. Subsample regression: Power system.

Dimension	Index	East	Central	West	Electrical output	Electrical input	Electrical balance
Electricity supply and demand	X_{25}			−4508.20	−1513.40		−14730.8*
				[7.5e+03]	[1.6e+04]		[7.3e+03]
	X_{26}	−10906.00	−23502.10	4081.60	810.60	1465.30	−6884.10
		[1.1e+04]	[1.6e+04]	[5.0e+03]	[2.1e+04]	[5.7e+03]	[1.5e+04]
	X_{27}		16360.20	−5022.2**	13404.70		
			[1.4e+04]	[2.0e+03]	[1.1e+04]		
	X_{28}	13.63***		8.134***	14.91***	2.53	21.54***
		[3.2094]		[1.4659]	[3.2054]	[1.8604]	[4.0197]
	X_{29}	−15596.8***	−6112.20	−2031.10	−15572.1***	−642.40	
			[1.1e+04]	[8.0e+03]		[5.6e+03]	
		[4.8e+03]			[4.3e+03]		
	X_{30}	−719.30	11.95	483.4***		199.30	138.90
		[631.8695]	[323.8904]	[179.0298]		[195.3677]	[226.0407]
Electrical equipment capacity	X_{31}						
	X_{32}				52299.9**		
					[2.2e+04]		
	X_{33}	16789.6**			21305.0***	−4931.5**	
		[6.7e+03]			[8.0e+03]	[2.0e+03]	
	X_{34}	−619.70	106.10	−85.61	−475.90	88.62	−103.90
		[760.0315]	[435.7007]	[227.2087]	[695.7364]	[264.1727]	[417.8813]
	X_{35}				−58871.9***		
					[1.9e+04]		
	X_{36}	10439.70		−5139.5*		−9239.4***	
		[8.5e+03]		[2.8e+03]			
						[3.4e+03]	
	X_{37}				14573.0***		1839.00
					[4.3e+03]		[6.7e+03]
Electrical equipment utilization	X_{38}		1993.30	7168.9**	−8552.00	4766.20	
			[5.3e+03]	[2.9e+03]	[9.4e+03]	[3.3e+03]	
	X_{39}	12557.2*		2573.00	16052.9**	2672.40	2877.10
		[7.1e+03]		[1.6e+03]	[7.1e+03]	[1.9e+03]	[4.8e+03]
	X_{40}	21.38	25.21	−5.03	52.35*	12.70	−8.15
		[32.2605]	[19.5228]	[15.5206]	[29.4540]	[17.6853]	[18.9716]

Notes: t-statistics in parentheses.

***p < 0.01.

**p < 0.05.

*p < 0.1.

development. Second, in the east, urbanization and power supply are factors driving economic development. Over-reliance on foreign trade, low innovation output rate, and unmatched infrastructure construction hinder high-quality economic development. The central relies on foreign trade, innovation-driven, green technology applications but is limited by the imbalance of urban and rural development. The west relies on a complete industrial system, human resource investment, infrastructure construction, green technology application, power supply, but is limited by the lack of innovation power. Third, in the power output area, innovation input, the whole electrical power system are essential driving forces for development, and excessive trade dependence plays a restraining role. The power input area depends on the enhancement of the secondary and tertiary industries, the invention and application of green technology, the Construction of communication infrastructure but is limited by the optimization of power equipment and the R&D output rate. In power balance, industrialization, communication infrastructure, and power supply are conducive to high-quality economic development.

Based on the results of this study, we mainly summarize the following policy recommendations.

(1) Accelerate the green transformation of the economy and the application of innovation outcomes

To achieve high-quality economic development, we must vigorously promote the green transformation of industries and low-carbon development, develop emerging industries, and form a modern industrial system with

diversified development and multi-polar support. At the same time, maintain a moderate degree of dependence on foreign trade to enhance the stability of economic growth. Besides, with the continuous improvement of innovation capabilities, it is necessary to accelerate technological and institutional innovation, promote the transformation of scientific and technological achievements, cultivate new momentum for economic development. Remarkably, the western region should continue to implement the western development strategy, accelerate the upgrading of the industrial structure, develop the tertiary industry, and actively explore innovative and opening-up mechanisms.

(2) Coordinate urban and rural development and improve the livable environment for residents

We must strive to speed up the process of urban–rural integration and build an urban–rural relationship characterized by free flow of urban and rural elements, deep functional coupling, and equal rights. Particularly, the eastern region should pay attention to the adaptation of scale expansion and the quality of supporting functions while accelerating urbanization. The central should pay attention to the coordinated and integrated development between urban and rural areas and infrastructure. In addition, it is necessary to plan and create an environment with an excellent ecological environment, perfect security services, and a livable environment for residents making sure that economic development and green and livable environment are synchronized and coordinated Construction.

(3) Increase financial expenditure on pollution control and strengthen the application of green technology

It is necessary to establish and improve the system and norms of environmental protection-related financial expenditures to ensure the smooth development of pollution prevention and control. At the same time, establish and improve a long-term mechanism for pollution prevention while implementing pollution penalties, increase pollution control subsidies and support for cleaning industries and strengthen the application of green technology.

(4) Enhance energy supply and increase the proportion of clean energy

In the energy supply system, enhance the resilience of the energy supply chain, strengthen the integrated Construction of energy supply, energy operation and maintenance, and energy supervision. What is more, accelerate the construction of a clean and efficient new power system, and focus on increasing the proportion of renewable energy. Mainly, when the power output area assumes more power supply responsibilities, it is necessary to ensure the infrastructure construction of power generation equipment and transformer capacity. The power input should pay attention to the limited benefits of power infrastructure construction and make investments reasonably. The power balance areas should ensure their power supply and improve power utilization efficiency.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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