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Analysis of Influencing Factors of Change of Manufacturing Energy Intensity in China Based on WSR System Methodology and VAR Model

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ABSTRACT

Since China's reform and opening up, although energy intensity of manufacturing industry has showed a trend of decline overly, compared with developed countries, it remains high. The research object of this paper is energy intensity of manufacturing industry, based on Wuli–Shili-Renli system methodology, it builds factors system of energy intensity of manufacturing industry. Based on time series data from 1980 to 2014, it uses VAR model to explore influence law of various factors on manufacturing energy intensity. Impulse response analysis shows that in the short term, the whole society fixed asset investment structure, technological progress, economic development level and structure of property rights have a great influence on energy intensity. With the increase of technological progress rate, per capita GDP, proportion of state-owned enterprises, manufacturing energy intensity starts to reduce; with the increase of proportion of investment in fixed asset of energy intensive industries, manufacturing energy intensity starts to rise. In the long term, energy price, energy consumption structure, FDI and industry structure have a great influence on manufacturing energy intensity. With the increase of proportions of coal consumption and heavy industry, manufacturing energy intensity starts to rise; with the increase of energy price, manufacturing energy intensity starts to reduce. Variance decomposition shows that energy consumption structure, energy price and technological progress have a greater contribution to manufacturing energy intensity, optimizing energy consumption structure, controlling energy price and promoting technological progress are important approaches to reducing manufacturing energy intensity.

Keywords: manufacturing industry, energy intensity, VAR model, Wuli–Shili-Renli, technological progress

INTRODUCTION

Since China's reform and opening-up, with China's tremendous economic growth, energy demand is growing rapidly. Rapid growth of energy consumption has led to increased pressure in energy supply and energy security situation is increasingly grim. For example, China's crude oil dependence has reached 65% in 2016.At the same time, large-scale development and utilization of fossil fuels have increased environmental pressure. Environmental problems accumulated by extensive economic development mode have occurred in China. Contradiction between environment and supply and demand of energy shows that restriction of energy on economic growth is gradually exacerbated (Kai & Haokai, 2016). In the future, domestic and foreign scholars will focus on the common concern that whether China could get higher economic growth under less energy consumption and achieve coordinated and sustainable development among energy, economy and ecology or not. Therefore, social development requirement of "energy saving" was first put forward in 2006 in China. Manufacturing industry is the main body

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Contribution of this paper to the literature

- A scientific and comprehensive influencing factor system of manufacturing energy intensity is constructed based on the Wuli–Shili-Renli system methodology.
- Through the VAR model, the dynamic response of manufacturing energy intensity towards the impulse of each influencing factor is analyzed based on manufacturing-related data from 1980 to 2014.
- The contribution rate of every factor to the decline of manufacturing energy intensity is explored in order to put forward scientific and reasonable policy suggestions.

of national economy and consumes more energy and produces more environmental pollution (Tu, Tu, & Jhangr, 2016). It has been a key area of energy conservation. To effectively achieve proposed energy-saving emission reduction targets, it is the key way to promote energy-saving of various sectors of manufacturing industry. It is generally believed that improving energy efficiency is the main way to reduce energy consumption. Energy efficiency can be reflected by indicator of energy intensity. Energy intensity is energy consumption per unit of industrial added value. If energy intensity is greater, energy efficiency is lower. Based on constant price in 1980, energy intensity of China's manufacturing industry decreased from 20.13 tons of standard coal/ten thousand yuan in 1980 to 3.72 tons of standard coal/ten thousand yuan in 2014.However,a rising trend of manufacturing energy intensity appeared in 2001-2005, 2008 and 2013.Under context of energy saving and emission reduction, energy intensity of manufacturing industry rebounded in the continuous decline, reflecting the vulnerability of current energy-saving mechanism. It can be seen that theoretical and practical significance is great to explore reasons for manufacturing energy intensity change in China.

In recent years, a lot of research on China's energy intensity appeared at home and abroad. Methods used can be divided into two categories: one is the factorization method, the other is the measurement method. C. B. Ma and D. I. Stern (2008) found that technological change was the main contributor to the decline of energy intensity through LMDI decomposition based on energy data from 1980 to 2003. M. J. Herrerias, A. Cuadros and V. Orts (2013) found non-state investment played a leading role in regional energy intensity decline and there was no evidence that state-owned investment played an active role in energy intensity decline under panel correction standard error modeling based on 1985-2008 data. S. H. Cai et al. (2012) analyzed influencing factors of energy efficiency change through dynamic and static panel data model based on provincial panel data. X. G. Zhao and P. K. Liu (2014) empirically analyzed relationship between economic growth and energy intensity under panel smoothing transition regression (PSTR) model and improved algorithm based on panel data from 1960 to 2009. J. R. Tang and L. C. Jia (2015) analyzed the coupling relationship among energy consumption structure, industry structure, technological progress and energy intensity through energy price regulation effect model. Q. J. Chen, H. X. Yang and Y. Jiao (2016) explored impact of information fusion and industrialization on regional energy intensity based on panel data of 30 provinces and regions in China from 2000 to 2012. It can be seen that influencing factors of energy intensity have been systematically analyzed by domestic and foreign scholars and these achievements are the important foundation for the research of this paper.

Fewer domestic and foreign scholars studied China's manufacturing energy intensity. R. T. Sun, L. Y. Sun and Z. He (2008) analyzed the influencing factors of manufacturing energy intensity by regression method and tested the regulation of energy price towards energy intensity. L. Li and F. Wang (2008) studied manufacturing energy intensity in China from 1995 to 2006 through five common factorization methods and pointed out manufacturing energy intensity in China remained generally declining. T. Kong, N. Y. Sun and Z. He (2008) studied relationship between energy price and energy intensity from 1995 to 2005 in 24 major manufacturing industries through hierarchical regression method. T. W. Fen, N. Y. Sun and Z. He (2009) studied impact path of manufacturing service industry towards manufacturing energy intensity through time series data from 1994 to 2006. At the same time, they studied adjustment effect of regulation variable of technical level and energy price towards manufacturing structure and energy intensity. Y. F. Wang (2011) found that institutional factor, energy consumption structure, enterprise scale and other factors had significant influence on energy consumption of manufacturing industry based on data of 28 manufacturing sectors from 2003 to 2007. High energy-consuming industries should focus on improving degree of economic openness, reducing proportion of coal consumption and improving geographical concentration; low energy-consuming industries should strive to reduce proportion of nationalization and improve scale of enterprises. R. J. Zhen, and B. B. Wang (2011) studied variability of energy intensity through LMDI decomposition. They found that technical effect was the dominant factor in manufacturing energy intensity change and contribution rate was over 80%. L. Q. Zhou and R. D. Ye (2013) empirically analyzed influencing factors and change trend of manufacturing energy intensity based on panel data of 27 manufacturing sectors from 2003 to 2011. Y. Wang and L. C. Zhang (2015) analyzed correlation among manufacturing output, energy consumption and CO_2 emissions from 1995 to 2012.W.Q. Zhou (2016) measured total factor productivity growth of 36 industrial sectors through global DEA model and total factor productivity was decomposed into technological progress, pure technology efficiency and scale efficiency change effect. The effects of efficiency improvement, technical progress and relative energy price towards industrial energy intensity were tested from the perspective of industrial heterogeneity. The research results above are theoretical basis for construction of influencing factors of manufacturing energy intensity.

From above literatures, domestic and foreign scholars focus on energy intensity of macro level and pay little attention to energy intensity of medium-micro level. Some scholars apply decomposition analysis method to explore the key factors of manufacturing energy intensity. However, main factors that industrial structure and departmental energy efficiency are included in this method, which cannot systematically explore deep reasons for manufacturing energy intensity change. Other scholars apply regression analysis to explore reasons of manufacturing energy intensity change based on a small number of factors. This method is static and non-systematic. It is difficult to systematically consider the impact of various factors on energy intensity because most scholars select few influencing factors of energy intensity only according to characteristics of their own research. Therefore, the systematical reasons of manufacturing energy intensity change are studied in this paper. A scientific and comprehensive influencing factors system is constructed based on the Wuli–Shili-Renli system methodology. Through the VAR model, dynamic response of manufacturing energy intensity towards impulse of each influencing factor is analyzed based on manufacturing-related data from 1980 to 2014. What is more, the contribution rate of every factor to decline of manufacturing energy intensity is explored in order to put forward scientific and reasonable policy suggestions.

RESEARCH METHODS AND VARIABLE SELECTION

Research Method

VAR model

When describing relationship among economic variables and dealing with economic variables with dynamic characteristics, traditional structured model usually requires a complex economic theoretical basis, but for some economic theory or complex system, a structured model is difficult to describe dynamic relationship among variables (Wu et al., 2011). Endogenous variables tend to appear at the left or right ends of structural model equations and parameter estimation is very complex. In order to solve the above problem, in early 1980s, Sims proposed the vector auto-regressive model that applies unstructured method to analyze relationship among variables. Based on statistical properties of data, VAR model constructs the model that makes every endogenous variable as function of lag value of all the endogenous variables in the system, so that the univariate autoregressive model is extended to "vector" auto-regressive model composed of multiple time series variables. This paper tries to explore influencing factors system and its law on manufacturing energy intensity, which is much more systematic and complex (Zhang and Ge, 2002). Therefore, the VAR model is suitable for this paper.

Formula (1) is mathematical expression of the VAR (p) model.

$$y_t = \Phi_1 y_{t-1} + \cdots + \Phi_p y_{t-p} + H_1 x_t + \cdots + H_r x_{t-r} + \varepsilon_t;\ t = 1,2,\cdots,T \tag{1}$$

In formula (1), y_t is column vector of k-dimensional endogenous variable, x_t is column vector of d-dimensional exogenous variable, P is the lag order, T is the number of samples. Here $k \times k$ dimensional matrix Φ and $k \times d$ dimensional matrix H are coefficient matrices to be estimated. ε_t is column vector of k-dimensional perturbation, $E(\varepsilon_t) = 0$, and $E(\varepsilon_t y_{t-p}) = 0$. They can be related to each other, but they are not related to their own lag values and variables on the right side of the equation. In economic analysis, y_t can be an original economic variable sequence or a differential sequence.

Impulse response function

On the basis of VAR model, the dynamic relationship among variables available can be established through impulse response function and variance decomposition analysis. Impulse response function describes impact effect of information impulse of a standard size of deviation from a random disturbance towards variable current and future value. It can vividly portray the path change of dynamic effect between variables. It can test duration and impact strength from the change of every factor towards manufacturing energy intensity. The basic thoughts of impulse response function can be analyzed through VAR (2) model of two variables.

$$\begin{cases} x_t = o_1 y_{t-1} + o_2 y_{t-2} + p_1 x_{t-1} + p_2 x_{t-2} + \varepsilon_{1t} \\ y_t = m_1 x_{t-1} + m_2 x_{t-2} + n_1 y_{t-1} + n_2 y_{t-2} + \varepsilon_{2t} \end{cases};\ t = 1,2,\cdots,T \tag{2}$$

Random perturbation term ε in formula (2) is called new innovation. If ε changes, not only current value of x will change, it will also influence variable value of x and y in the future through current value of x. Impulse response function attempts to describe the trajectory of these effects. It shows the process that how an arbitrary variable disturbance to affect all other variables through model and feedback to their own in the end.

Variance decomposition

Variance decomposition method is that fluctuations of each endogenous variable in the system are decomposed into the sum of all the random disturbance effect according to its genesis. Through size of variance contribution, it can measure the relative importance of random disturbance towards the variable. It can be formulated as formula (3).

$$y_{it} = \sum_{j=1}^{k} (\eta_{ij}^{(0)} \varepsilon_{jt} + \eta_{ij}^{(1)} \varepsilon_{jt-1} + \eta_{ij}^{(2)} \varepsilon_{jt-2} + \cdots);\ i = 1,2,\cdots,k; \quad t = 1,2,\cdots,T \tag{3}$$

In formula (3), the sum of disturbance term ε_j from the infinite past to present moment is effect of ε_j towards y_i. Assume that no serial correlation in ε_j and solve variance of ε_j, formula (4) can be obtained.

$$E[(\eta_{ij}^{(0)} \varepsilon_{jt} + \eta_{ij}^{(1)} \varepsilon_{jt-1} + \eta_{ij}^{(2)} \varepsilon_{jt-2} + \cdots)^2] = \sum_{q=0}^{\infty} (\eta_{ij}^{q})^2 \sigma_{jj};\ i,j = 1,2,\cdots,k \tag{4}$$

The sum of effect from disturbance term *j* towards variable *i* can be evaluated through variance from the infinite past to present moment. Here also assumes that covariance matrix $\sum$ of disturbance vector is a diagonal matrix, the variance of y_i is k simple sum of above variance.

Variance of $\mathbf{y}$ can be decomposed into k types of effect that are not relevant. In order to measure contribution degree of every disturbance term for the variance of *y*, the dimensions are defined as shown in formula (5).

$$RVC_{j\to i}(\infty) = \frac{\sum_{q=0}^{\infty} (\eta_{ij}^{q})^2 \sigma_{jj}}{var(y_i)} = \frac{\sum_{q=0}^{\infty} (\eta_{ij}^{q})^2 \sigma_{jj}}{\sum_{j=1}^{k} \left\{ \sum_{q=0}^{\infty} (\eta_{ij}^{q})^2 \sigma_{jj} \right\}}, \quad i,j = 1,2 \cdots, k \tag{5}$$

Fluctuations of each endogenous variable in the system can be decomposed into each associated part of innovation of every equation. In this way, the relative importance of innovation to endogenous variable in model can be understood.

Variable Selection

As influencing factors of manufacturing energy intensity change are more complex and the change is caused by dynamic interaction of a number of influencing factors. Therefore, the influencing factors of manufacturing energy intensity can be regarded as a complex factor system composed of Wuli, Shili and Renli, so as to analyze mechanism and size of influencing factors of manufacturing energy intensity comprehensively, objectively and accurately. Influencing factors system of manufacturing energy intensity is constructed by Wuli-Shili-Renli system methodology. In the process of manufacturing energy intensity change, to grasp "Wuli" that is to grasp the most basic attributes of manufacturing energy intensity. Manufacturing enterprises need to integrate a large number of advanced technologies and heighten operational efficiency in order to survive and develop in global market competition. Under normal circumstances, foreign direct investment (FDI) and enterprise scale mainly reflect the level of development of manufacturing technology. Therefore, technological progress, FDI, enterprise scale mainly represent Wuli factors. Shili means that the truth of work, it mainly answers how to do and how to arrange existing people, finance, material to raise efficiency. This paper is mainly manifested in the aspect of structure, including energy consumption structure, industry structure, structure of property rights, the whole society fixed asset investment structure. Renli is the truth of life. To deal with anything cannot be separated from people and need people to judge whether it is appropriate under the content of humanities and social science. Energy conservation awareness, energy policy, economic development level, energy saving measures, etc. mainly represent Renli factors. Energy conservation awareness and energy saving measures are not considered because it is difficult to obtain large span time series for them. In energy policy, the impact of energy price on the energy intensity is more obvious and large span time series of energy price can be obtained. Therefore energy price and economic development level are accepted to represent Renli factors finally. All the selected variables are shown in **Figure 1**.

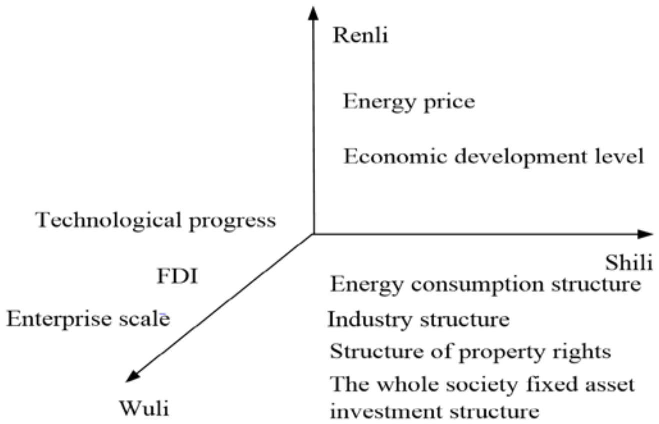

Figure 1. Influencing factors of manufacturing energy intensity based on WSR

Table 1. Technological progress rate

Y	TP	Y	TP	T	TP	Y	TP
1980	0.405	1989	0.517	1998	0.798	2007	0.788
1981	0.426	1990	0.52	1999	0.825	2008	0.835
1982	0.438	1991	0.533	2000	0.849	2009	0.865
1983	0.45	1992	0.572	2001	0.863	2010	0.886
1984	0.477	1993	0.606	2002	0.858	2011	0.898
1985	0.493	1994	0.641	2003	0.807	2012	0.926
1986	0.502	1995	0.658	2004	0.756	2013	0.957
1987	0.514	1996	0.695	2005	0.737	2014	1
1988	0.525	1997	0.748	2006	0.754		

Technological progress

To improve energy efficiency, technological progress has a stable and sustained impact and it is an important way to reduce China's manufacturing energy intensity. Production technology and management technology are the important manufacturing technology. Updating the machinery and equipment, enhancing the level of management information can improve factor productivity, thus a long-term mechanism of energy conservation is formed. Generally large and medium-sized manufacturing enterprises have a higher level of technology, which is conducive to improving the overall energy efficiency. At present, China is in the late of development of industrialization, manufacturing industry is the core of national economy. Try to speed up the pace of technological progress will effectively reduce manufacturing energy intensity. However, with rebound effect of energy efficiency, the role of technological progress in reducing energy intensity is weakened. Manufacturing technology can be measured by input-output efficiency. In this paper, energy consumption, China's labor force, fixed asset investment are input variables and the actual GDP is output variable. It applies data envelopment analysis (DEA) to calculate China's technological progress rate from 1980 to 2014.The fixed asset investment is converted into the constant price of 1980 through fixed asset investment price index. GDP is converted into the constant price of 1980 through Gross Domestic Product (GDP) index. The specific results are shown in **Table 1**.

From **Table 1**, technological progress rate is on the rise overall except for decline in some year. For example, technological progress rate is on the decline from 2003 to 2005 mainly due to relatively overheated investment. Investment growth rate is significantly greater than economic growth rate and the quality of economic growth is declining.

FDI

With the deepening of China's opening up, the continued inflow of FDI has an important impact on China's manufacturing energy intensity. According to the "China Statistical Yearbook 2016", statistical data shows that by the end of 2015 registered ratio of foreign direct investment in China's manufacturing industry investment is 43.85%.It means that FDI inflow is concentrated in manufacturing sector, which can accelerate domestic industrial development and promote the change of industrial structure, and ultimately promote the change of manufacturing energy intensity. The positive effect of FDI is that it accelerates the speed of technology diffusion and spill. Advanced production technology and management experience have been introduced by foreign-invested enterprises and some energy-saving and environmental protection technology are adopted by manufacturing sector. In addition, the inflow of foreign capital improves the level of economies of scale in manufacturing sector to a certain extent and heightens output efficiency of energy factor in micro-field. This paper examines the effect of foreign direct investment rather than contractual use of foreign capital on manufacturing energy intensity. Foreign direct investment is converted to the constant price of 1980 by fixed investment price index.

Enterprise scale

With the scale expanding, enterprises will have strong strength to use large and efficient special equipment to improve the economy and then promote energy efficiency through economies of scale. J. Shao et al. (2009) found that the expansion of average enterprise scale has a positive impact in improving the energy efficiency. In this paper, the ratio of gross value of industrial output to the number of industrial enterprises and production units is used to calculate average scale of industrial enterprises as an influencing factor to examine the enterprise scale on impact of manufacturing energy intensity. Gross value of industrial output is converted to the constant price of 1980 by industrial producer price index.

Energy consumption structure

There are large differences in efficiency between different energy varieties. Energy efficiency of the combination is directly affected by different energy consumption structures, which affect ultimate manufacturing energy intensity. Among primary energy varieties, the utilization efficiency of coal, crude oil, natural gas and electricity is approximately 27%, 50%, 57% and 85% respectively (Hu, 2010; Ju, 2009). Coal is not only lower in utilization efficiency, but also a non-clean energy. Compared to coal, natural gas, electricity and other traditional energy are much cleaner and more efficient. Therefore, to reduce the proportion of coal consumption, increase the proportion of electricity, oil, natural gas, and actively develop solar energy, wind energy, nuclear energy and other new energy, not only can effectively optimize energy consumption structure, improve energy efficiency, but also effectively reduce emissions of pollutant and pressure of environment. In this paper, the proportion of coal consumption to total energy consumption represents energy consumption structure.

Industry structure

Since 2000, China entered the period of industrialization of heavy industry. The proportion of heavy industry in the industrial sector has risen from 50.6% in 1990 to 70.2% in 2014.Rapid growth of heavy industry has led to the rapid growth of energy demand. Therefore, speeding up adjustment of internal structure of manufacturing sector and promoting optimization and upgrading of industry structure have important impact on energy conservation (Chang and Ming, 2014; Zeng et al., 2014). And actively guiding manufacturing industry to high-end, low energy consumption and light-duty direction is conducive to improving the level of manufacturing development and quality. In current background of industry overcapacity, to limit the blind expansion and duplication of high energy consumption industry, support low energy consumption, high value-added and high-tech industry, and strive to reduce the proportion of high energy-consuming industries, which are conducive to maintaining high industrial growth while reducing energy consumption in the late of industrialization in China. Due to the lack of data in some years and inconsistency of statistical caliber, it is difficult to obtain time series of output value of high energy consumption industry. This paper takes the proportion of heavy industrial output to total value of industrial output to replace the influence of manufacturing structure towards energy intensity.

Structure of property rights

For a long time, there are weak external environmental regulation, higher cost transfer ability, state-owned capital advantages, national support advantages and administrative characteristics in state-owned enterprises. Thus lower resource allocation efficiency and management efficiency are formed. In contrast, non-public enterprises such as private enterprises, foreign investment enterprises are much more efficient. Therefore, reducing the proportion of state-owned enterprises, especially high-energy-consuming industries in manufacturing sector will reduce manufacturing energy intensity. As market-oriented and ownership reform is mainly the process of cutting down proportion of state-owned economy, the rising proportion of non-state-owned economy can be seen as a decline in the proportion of state-owned economy. According to the principle of data availability, structure of property rights is represented by proportion of total asset of the state-owned or state-controlled industrial enterprises to total asset of the whole industrial enterprises (González et al., 2013). It should be noted that from 1998 statistical caliber of industrial enterprises is all state-owned and non-state-owned industrial enterprises whose annual business income are over 5 million yuan, so it is not entirely comparable with the previous year. As a result, the proportion of state-owned or state-controlled industrial enterprises increases significantly in 1998.

The whole society fixed asset investment structure

During the 12th Five-Year Plan period, the growth rates of fixed asset investment in China are 23.8%, 20.3%, 19.1%, 15.2% and 9.8% respectively and average annual growth rate is 12.5%. According to 2015 statistics bulletin of the national economy and social development, 32.7% of fixed asset investment (excluding farmers) is invested to manufacturing sector, 18.4% to infrastructure and 17.4% to real estate development in 2015. The difference of structure of investment in fixed asset can bring out different overall energy intensity. As China is still in the accelerated stage of urbanization process, most of fixed asset investment flows into infrastructure and real estate industry and brings out demand of steel, cement and other high energy-consuming products to push up overall level of energy consumption. On the contrary, investment flowing into low energy consumption, high value-added industries such as electronics, medicine, high-tech, etc. can maintain sustained economic growth while achieving aim of lowering energy consumption (Chontanawat et al., 2014). According to data availability, based on 2012 China input-output table, High energy-consuming industries are composed of ferrous metal smelting and rolling processing industry, chemical raw materials and chemical products manufacturing industry, petroleum processing, coking and nuclear fuel processing industry, non-metallic mineral products industry, non-ferrous metal smelting and rolling processing industry, chemical fiber manufacturing industry, paper product industry and rubber product industry. In this paper, the proportion of fixed asset investment of high energy consumption industry to fixed asset investment of manufacturing industry represents the whole society fixed asset investment structure.

Energy price

As energy is basic input element of enterprise, energy price directly affects production cost. When energy price rises, production cost will increase. Higher cost of energy inspires companies to raise awareness of energy saving, accelerate the elimination of backward process equipment, and reduce energy consumption by strengthening enterprise management, technological improvement and equipment upgrade. Due to the long-term passive state of energy price reform, compared with other input elements, low cost of energy leads to lower level of energy use and energy waste is serious. The leverage of energy price is conducive to improving manufacturing energy efficiency. Raw materials, fuel, power purchase price index represents energy price. Since 2011, China Statistical Yearbook has changed raw material, fuel and power purchase price index to industrial producer purchase price index.

Economic development level

Development history of developed countries shows that energy intensity will rise first and then decline. In other words, energy intensity and economic development level confirm to the “Kuznets curve”. When economic development level is low, manufacturing energy intensity increases with the improvement of economic development level. When economic development reaches a high level, manufacturing energy intensity decreases with the improvement of economic development level (Voigt et al., 2014; Li et al., 2016). According to Grossman and Krueger’s theory, economic development will affect energy intensity through three effects of scale, technology and structure. Scale effect is not conducive to energy saving, but technical and structural effects are conducive to energy saving. And technical effect is conducive for manufacturing industry to enhance energy efficiency and reduce energy consumption. Structural effect is conducive to reduction of energy consumption and growth of value-added in manufacturing industry; therefore, the improvement of economic development level is ultimately conducive to reduction of manufacturing energy intensity. In this paper, the real GDP per capita is used to measure economic development level, and GDP is flattened by the base index of 1980.

The data is derived from *China Statistical Yearbook*, *China Industrial Statistics Yearbook*, *China Energy Statistical Yearbook*, *China Price Statistical Yearbook*, *China Input-Output Table* and so on. Data accounts for a large space and it is omitted here. All the time series involved in monetary measurement are deflated by 1980 price. Based on the above analysis, energy intensity, technological progress, FDI, enterprise scale, energy consumption structure, industry structure, structure of property rights, the whole society fixed asset investment structure, energy price and economic development level of manufacturing industry are expressed as EI, JSJB, FDI, PJGM, MTZB, GZB, GYZB, GGZB, NYJG and RJGDP. Data analysis tool is EViews7.0.

EMPIRICAL ANALYSIS

Stationary Test

At present, ADF, DF, PP are used in unit root test. ADF method is selected in this paper and test results are shown in **Table 2**. **Table 2** shows that in addition to level series of energy intensity, level series of other variables

Table 2. Series stationary test

Series	Test value	Test type	Critical value	Conclusion
EI	-2.7619	(0, 0, 0)	-2.6369**	stationary
JSJB	2.0149	(c, 0, 0)	-2.6392**	non-stationary
NJSJB	-3.2482	(0, 0, 0)	-2.9571*	stationary
FDI	-1.9066	(c, t, 0)	-4.2627**	non-stationary
NFDI	-3.6157	(c, 0, 0)	-2.9540*	stationary
PJGM	1.0243	(0, 0, 0)	-2.6347**	non-stationary
NPJGM	-5.0641	(0, 0, 0)	-2.6369**	stationary
MTZB	0.2784	(0, 0, 0)	-3.6394**	non-stationary
NMTZB	-4.7333	(c, 0, 0)	-3.6463**	stationary
GZB	-0.2172	(c, 0, 0)	-3.6394**	non-stationary
NGZB	-5.5588	(c, 0, 0)	-3.6463**	stationary
GYZB	-0.8654	(0, 0, 0)	-3.6394**	non-stationary
NGYZB	-5.0036	(0, 0, 0)	-3.6463**	stationary
GGZB	-0.8446	(0, 0, 0)	-2.6347**	non-stationary
NGGZB	-4.0688	(0, 0, 0)	-3.6463**	stationary
NYJG	-1.9232	(0, 0, 0)	-3.6394**	non-stationary
NNYJG	-2.4173	(0, 0, 0)	-1.9513*	stationary
RJGDP	3.3228	(c, 0, 0)	-2.6443**	non-stationary
NRJGDP	-5.7294	(c, t, 0)	-2.6416**	stationary

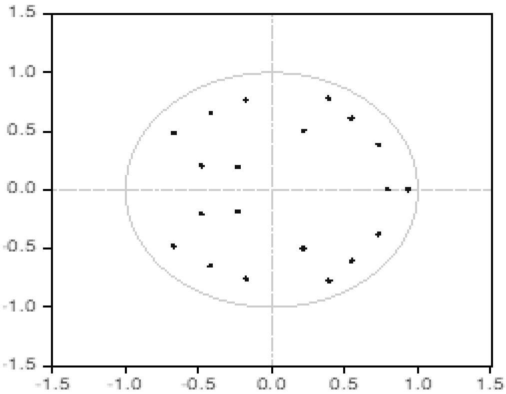

Figure 2. Model stationary test

cannot pass ADF test. Therefore, these variables need to be first-order difference. All the first-order difference series can pass ADF test under 1% or 5% significance level.

Setting and Inspection of VAR Model

According to the Schwartz Criterion and Akai Information Criterion, the lag order is chosen by minimum of Schwartz Criterion and Akai Information Criterion and the suitable model is VAR (2), whose lag order is 2. The model is estimated by least squares method. Figure 2 shows that all the characteristic roots present in the unit circle. It can be seen that the model is reliable and can be analyzed in the next step.

Impulse Response Analysis

On the basis of the VAR model, an impulse response function is established to analyze the response of manufacturing energy intensity to impulse of a unit standard deviation of influencing factors. Cholesky method is used to solve the simultaneous problem of stochastic error term of different equations. Concrete results are shown in Figure 3. In Figure 3, the horizontal axis indicates the number of tracking period, which is set to 10 years in this paper.

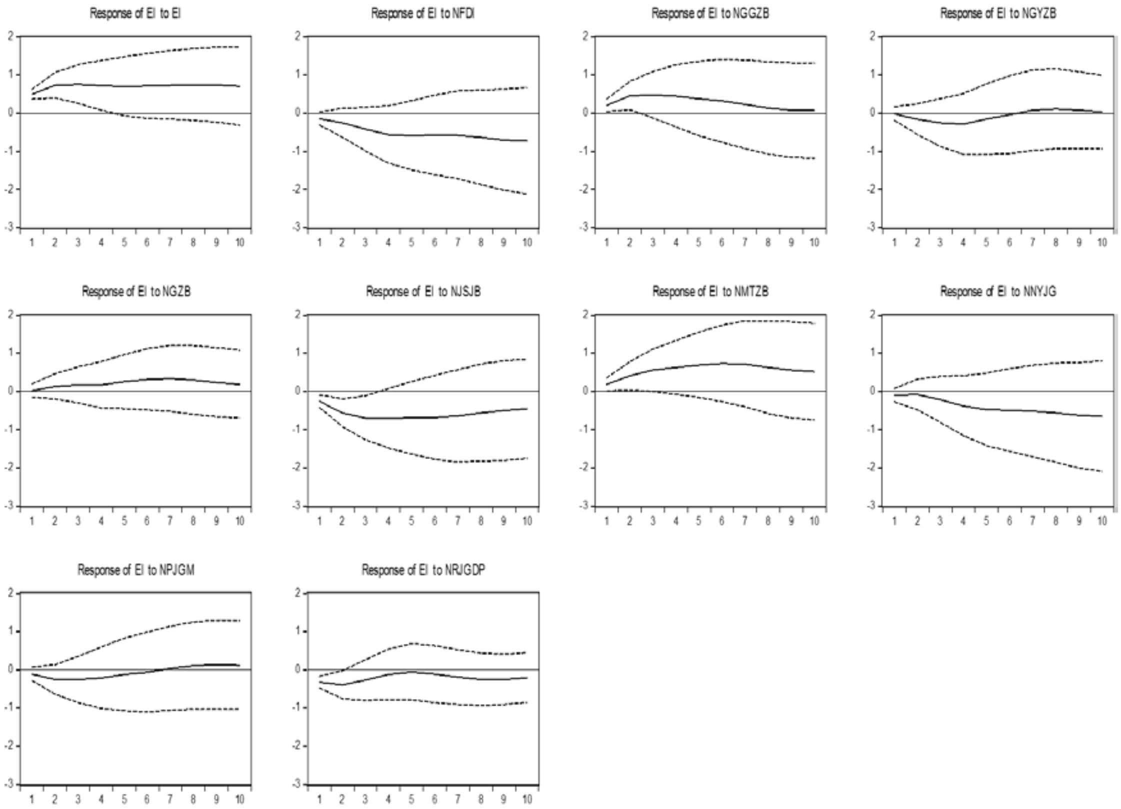

Figure 3. Impulse response result

From **Figure 3**, manufacturing energy intensity responds to the impulse of its own positively. When manufacturing energy intensity is subjected to impulse of a standard deviation innovation from its own, response of manufacturing energy intensity begins to rise from the current period, reaches the maximum positive response in the third year and maintains a positive response in the long term. When manufacturing energy intensity is subjected to impulse of a standard deviation innovation of FDI, response of manufacturing energy intensity begins to decline from the current period and reaches the maximum negative response (-0.7) in the tenth year. It means that manufacturing energy intensity always maintains a negative response status to FDI. When manufacturing energy intensity is subjected to impulse of a standard deviation innovation of the whole society fixed asset investment structure, manufacturing energy intensity begins to rise from the current period, reaches maximum positive response (0.5) in the third year and appears steady convergence state in the eighth year. When manufacturing energy intensity is subjected to impulse of a standard deviation innovation of structure of property rights, manufacturing energy intensity decreases slightly from the current period and reaches maximum negative response in the fourth year. Then it begins to rise slightly and reaches maximum positive response (0.1) in the eighth year. When manufacturing energy intensity is subjected to impulse of a standard deviation innovation of industry structure, manufacturing energy intensity increases slightly from the current period and reaches maximum positive response (0.7) in the seventh year. Then it begins to decrease slightly and finally stabilize. When manufacturing energy intensity is subjected to impulse of a standard deviation innovation of technological progress, manufacturing energy intensity begins to decline rapidly and reaches maximum negative response (-0.7) in the third year. After the third year, the degree of negative response begins to decrease and negative response is gentle and convergent in the ninth year. When manufacturing energy intensity is subjected to impulse of a standard deviation innovation of energy consumption structure, manufacturing energy intensity begins to rise from the current period and reaches maximum positive response (0.7) in the seventh year. The convergence trend of manufacturing energy intensity emerges in the ninth year. When manufacturing energy intensity is subjected to impulse of energy price, manufacturing energy intensity always maintains a negative response and the degree of negative response begins to increase from the seventh year. When manufacturing energy intensity is subjected to impulse of a standard deviation innovation of enterprise scale, manufacturing energy intensity maintains a small negative response in the first 5 years. From the sixth year, it begins to respond positively but the degree of positive response is relatively small. In the ninth year, steady convergence trend appears. When manufacturing energy intensity is subjected to impulse of a standard deviation innovation of economic development level, manufacturing energy intensity begins to decline from the current level and reaches largest negative response (0.4) in the second

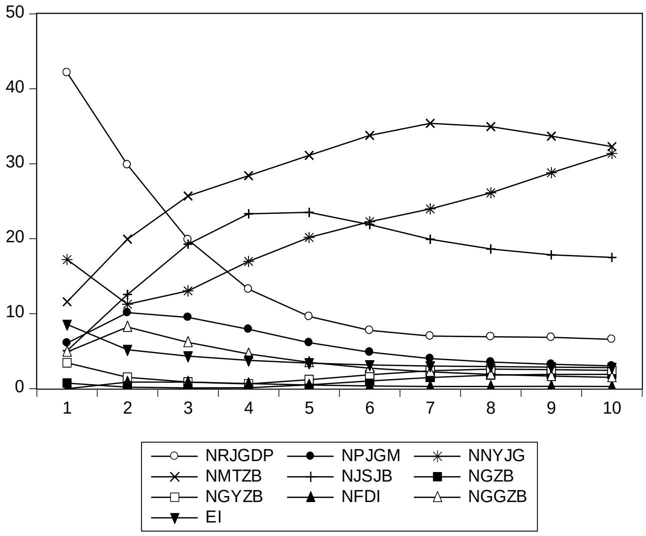

Figure 4. Variance decomposition result

year and minimum negative response in the fifth year. Then manufacturing energy intensity begins to decline and always maintains a negative response.

In summary, the impact of FDI towards manufacturing energy intensity is significant in the medium and long term. When FDI rises, manufacturing energy intensity decreases. In the short or medium term, the proportion of fixed asset investment in high energy consumption industry is higher, manufacturing energy intensity is higher. Positive correlation in the long term is likely to be little due to increased efficiency and quality of social investment. In the short term, the higher the proportion of state-owned enterprises, the lower manufacturing energy intensity is. It maybe state-owned enterprises are more likely to realize economies of scale and energy saving than private enterprises because of state-owned enterprises' advantages of capital and so on. In the long term, a positive correlation maintains between them because state-owned enterprises' efficiency is relatively low in the long term. In the short and long term, the proportion of heavy industry has a negative effect on reduction of manufacturing energy intensity and the long-term effect is more obvious. Technological progress maintains a positive effect on reduction of manufacturing energy intensity in the short and long term and short-term effect is more obvious. This may be related with energy rebound effect. Proportion of coal consumption plays a negative effect on reduction of manufacturing energy intensity in the short and long term and long-term effect is more obvious. In response term, when energy price rises, manufacturing energy intensity decreases and long-term effect is more obvious. Average enterprise scale expands and manufacturing energy intensity decreases in the short term and increases in the long term. This may be the appropriate enterprise scale is helpful to improve efficiency. If the enterprise scale is too large, energy consumption will increase because of monopoly and other new issues. Per capita GDP has a positive effect on manufacturing energy intensity in the short and long term and short-term effect is more obvious.

Variance Decomposition Analysis

Variance decomposition is to analyze contribution of structural impulse on endogenous variables. Variance analysis starts from variance of observed variables and studies which control variable that has a significant effect on the observed variables. Concrete results are shown in **Figure 4**.

According to **Figure 4**, from large to small order by average effect, the influencing factors of manufacturing energy intensity are: NMTZB ＞ NNYJG ＞ NJSJB ＞ NRJGDP ＞ NPJGM ＞ EI ＞ NGGZB ＞ NGYZB ＞ NGZB ＞ NFDI. In the long term, contribution rates of influencing factors to manufacturing energy intensity are: NMTZB (about 32.3%), NNYJG (about 31.76%), NJSJB (about 17.54%), NRJGDP (about 6.58%), NPJGM (3.03%), EI (about 2.84%), NGYZB (about 2.47%), NGZB (about 1.94%), NGGZB (about 1.56%), NFDI (about 0.34%). It can be seen that energy consumption structure, energy price and technological progress contribute greatly to decline of manufacturing energy intensity. It is necessary to intensify energy saving potential of other influencing factors.

CONCLUSION

Based on the Wuli-Shili-Renli system methodology and VAR model, this paper constructs the influencing factors system of manufacturing energy intensity and explores influence law of various factors on manufacturing energy intensity through time series analysis from 1980 to 2014.Impulse response analysis shows that the whole society fixed asset investment structure, technological progress, economic development level, structure of property rights have greater impact on manufacturing energy intensity in the short term. To improve technological progress rate, per capita GDP and proportion of state-owned enterprises will reduce manufacturing energy intensity. When proportion of fixed asset investment in high energy consumption industry increases, manufacturing energy intensity will increase. In the long term, energy price, energy consumption structure, FDI and industry structure have greater impact on manufacturing energy intensity. As proportions of heavy industry and coal consumption increase, the manufacturing energy intensity increases. When energy price rises, manufacturing energy intensity will decrease. Variance decomposition shows that energy consumption structure, energy price, technological progress make larger contribution to reduction of manufacturing energy intensity.

In view of above analysis results, this paper puts forward following countermeasures and suggestions. (1) Improving ratio of high efficiency energy of electricity, oil, natural gas and so on; vigorously developing renewable energy and clean energy; promoting wind power and solar power and realizing industrialization by scale. (2) Promoting reform of energy price. On the one hand, government should minimize scope and extent that government directly intervenes in the price. On the other hand, government should improve regulatory price system towards monopoly link and encourage new competitors to enter the market by opening of market access. (3) Speeding up technological progress. Enterprises should introduce foreign advanced technology and equipment, increase intensity of independent innovation, and gradually establish technology innovation system through combination of Industry-University-Research. (4) Maintaining steady economic growth. In order to achieve steady economic growth in the middle of industrialization, government should promote continued growth of manufacturing added value. In addition, government should improve energy policy and refine manufacturing energy saving indicators so as to reduce manufacturing energy consumption while increasing output. (5) Expanding enterprise scale. In order to achieve scale of economics, government should work out development plan of manufacturing enterprises, improve market access standards and exit mechanism of high energy consuming enterprises, make a rigorous evaluation of existing high energy consuming enterprises and promote mergers and reorganization in manufacturing enterprises. (6) Achieving diversification of corporate property rights structure. Government should continue to promote reform of state-owned enterprises, vigorously develop private enterprises, foreign investment and Hong Kong, Macao and Taiwan investment enterprises to further reduce proportion of high energy-consuming, state-owned and state-owned holding enterprises. Government should persist in openness to guide and encourage foreign direct investment. (7) Promoting optimization and upgrading of industry structure. Government should vigorously develop high-tech industries, reduce proportion of high energy-consuming enterprises, and limit blind expansion of high energy-consuming industries. At the same time, governmental investment should become the leader in guiding, encouraging and promoting more private capital to flow into high-tech industries. (8) Utilizing taxation lever reasonably. To a certain degree, appropriately increasing the tax rate of coal resource will speed up energy substitution and reduce the waste of resources. In addition, in order to mobilize enthusiasm of enterprises, government can make use of price subsidies for enterprises that purchase energy-saving equipment and permit enterprises to accelerate depreciation in accounting transactions.

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