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Energy Efficiency Estimation Based on Bayesian Method and Industrial Economic Transition: Taking Shandong as an Example

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Abstract

This paper studied the total factor energy efficiency of industrial sector's in Shandong. First, theoretical models of stochastic frontier approach on energy efficiency were structured, and then the referred parameters were estimated by using panel data of thirty-seven industries in Shandong from 2006 to 2013 and Bayesian estimation method. Finally Tobit model was applied to empirically study the influencing factors on energy efficiency of industrial sector's. The study indicates that: (1) The input of capital and energy is notably positively correlative to output, while the input of labor quantity is negatively correlative to output. This means labor redundancy exist in industrial sectors. (2) Chemical industry, machinery industry, equipment manufacturing industry and food processing industry which have high energy efficiency should be further developed, especially marine chemical industry and marine biological medicine should be focused on to realize traditional industry upgrading. (3) Enterprise scale, international trade, the level of foreign investment and technology progress are notably positively relative to energy efficiency, while the proportion of state-owned economy have negative impact on energy efficiency. Therefore, it is necessary for further improvement in industrial energy efficiency in Shandong to decrease the proportion of stated-owned, encourage private capital entrance, extend opening up, and speed up the technical innovation.

Keywords: resource economics, total factor energy efficiency, stochastic frontier model, influencing factor

1. Introduction

At present, the contradiction among energy, economics and environment is increasingly serious in China. Chinese government had declared saving target of a 40-45 percent reduction in co_2 emission unit of GDP by the end of 2020 than 2005. Improving energy efficiency and realizing saving target has become the important question for all regions, among which Shandong has faced huge pressure. Economic growth of Shandong excessively depended on industry sectors, especially heavy industry with the features of high energy consumption and high CO_2 emission, which don't contribute to realize saving target. The paper studies the influencing factors on energy efficiency on the base of measuring the energy efficiency of all industries in Shandong, and combining with the strategy of blue economic zone and yellow river delta proposes some suggestions about industry structure adjustment to transform traditional manufacturing industry to modern manufacturing industry.

Energy efficiency can be divided into economic efficiency and technical efficiency. The paper takes economic efficiency as subject. The studies about energy efficiency focus on energy efficiency condition of some region, difference of energy efficiency, influencing factors of energy efficiency, etc. Among these studies, the definition of energy efficiency is changed from single factor energy efficiency (SFEE) to total factor energy efficiency (TFEE), and the main research methods include factor decomposition method (FDM), data envelopment analysis (DEA) and stochastic frontier approach (SFA), etc.

FDM is the main research method in earlier studies on single factor energy efficiency, which is defined as energy consumption per unite of output, and that is energy intensity. Many researchers decomposed change of single factor energy efficiency based on complete decomposition raised by sun (1998). The calculation of SFEE is easy, while it ignores that energy is only one kind among many input factors, which must combine with other production factors such as capital and labor to bring output (Boyd & Pang, 2000). Therefore, more and more studies focus on energy efficiency considering other factors of labor and capital, which is called TFEE. In this field, there are two methods of parametric and non-parametric analysis. Parametric analysis include Stochastic Frontier and Deterministic Frontier analysis, and the former is more common. DEA is the main representative of Non-parametric analysis (Yang, 2009). The value of energy efficiency calculated by DEA is positive which measures actual output/maximum output under the same input or minimum input/actual input under the same output.

DEA doesn't define the specific form of production function in advance, while parametric analysis represented by SFA need estimate the production frontier by econometric regression method considering the influence of random factors. This method was presented by Meeusen and Broeck in 1977, and perfected by Jondrow in 1982. Compared with DEA, the research used SFA in energy efficiency is lack. Shidan (2008) measured the energy efficiency difference among Chinese provinces adopting SFA in 2008, which expands the traditional research idea of relying on index decomposition method in energy efficiency studies.

Compared with this two methods, DEA regards the deviation of decision unit from production frontier as its own technical efficiency results, while SFA decomposes the deviate into technical efficiency and random disturbance. Therefore, when the change of energy efficiency includes the random disturbance that DEA doesn't reflect, especially when the production frontier unit is affected strongly by random factors, the error of TFEE measured by DEA is very big. Based on the above, the study adopts SFA determining production frontier. In the existing referred research, major of SFA takes MLE or OLS method to estimate parameters. This paper takes Bayesian estimation method to estimate all parameters in frontier production function, then calculates the value of TFEE which is an innovation of this paper.

At present, there is lack of studies on energy efficiency of industrial sector's of Shandong. This paper makes a contribution to this field. Firstly, theoretical models of SFA on energy efficiency are structured, and then the referred parameters are estimated by using panel data of thirty-seven industries in Shandong from 2006 to 2013 and Bayesian estimation method. Finally Tobit model is applied to empirically study the influencing factors on energy efficiency of industrial sector's.

This study proceeds as follows. Section 2 explains the methodology. Section 3 describes the corresponding data. Section 4 presents the empirical results and policy implications. Section 5 concludes.

2. Methodology

2.1 SFA Model

Cobb-Douglas and translog functions are usually used in SFA, and the former is easier and convenient to be estimated and decomposed. This paper adopts Cobb-Douglas function to establish theoretical models as follows:

$$\ln y_{it} = \beta_0 + \sum_i \beta_i \ln x_{it} + v_{it} - u_{it} \tag{1}$$

$$TE_{it} = y_{it} / \exp[\beta_0 + \sum_i \beta_i \ln x_{it} + v_{it}] = \exp(-u_{it}) \tag{2}$$

Here y_{it} is output, x_{it} is input. v_{it} is random disturbance, and v_{it}~N $(0, \sigma^2)$. The variable of u_{it} is production inefficiency item, representing production efficiency or management efficiency, and it is usually assumed as exponential random variable or half normal random variable following independent and same distribution. U_{it} is independent of v_{it}. TE_{it} is TFEE this paper studies.

Compared with Cobb-Douglas function, the form of translog function is more flexible which can be regarded similarly as any production function. This paper will calculate respectively the efficiency value under this two forms, and choose that with high DIC value.

2.2 Bayesian Estimation Method

This paper takes Bayesian estimation method presented by Van Den Broeck (1994), Koop, Steel, and Osievalski (1995) (VKSO) to estimate Eq. (1). According to VKSO, some assumption needs be set as following: y_{it}~iidN $(\alpha+\beta x_{it}'-u_{it},\sigma^2)$, α~iidN $(0,\sigma_\alpha^2)$, β~iidN $(0,\sigma_\beta^2)$. Based on the past literature, $\sigma_\alpha^2 = \sigma_\beta^2 = 1.0E-6$.

Further, the study assumes u_{it} following exponential distribution with parameter of θ. According to the former research, the factors influencing energy efficiency include the degree of competition, technology progress and institutional reform. This paper chooses those indexes as following: industry scale (comp), the percentage of gross output value of state-owned in total gross industrial output value(state), the percentage of gross output value of foreign-funded enterprises in total gross industrial output value (priva), the percentage of export delivery value in total gross industrial output (expt), the percentage of expenditure on R&D in industrial added value (rd). Thus, we get Eq. (3).

$$\theta = exp\left(r_0 + r_1 comp + r_2 state + r_3 priva + r_4 expt + r_5 rd\right) \quad (3)$$

Further the paper assumes θ following exponential distribution with parameter of -log(r*), and r* is prior median of technological efficiency. This paper gets r* = 0.875 by taking the traditional SFA method and the sfpanel command in stata. Finally, the paper assumes σ^{-2}~iidG (α_0,α_1), and we can get $\alpha_0=\alpha_1=1.0E-3$ according to the conclusion of Griffn and Steel (2007).

2.3 Tobit Model

$$eff_{i,t} = \beta_0 + \beta_1 lncomp_{i,t} + \beta_2 lnstate_{i,t} + \beta_3 lnpriva_{i,t} + \beta_4 lnexpt_{i,t} + \beta_5 lnrd_{i,t} \quad (4)$$

Based on the value of energy efficiency calculated above, Tobit model is structured to analyze influencing factors impacted on energy efficiency.

3. Data

This paper adopts data of thirty-seven industries in Shandong from 2006 to 2013 excluded two industries of Mining and Dressing of Other Ores and Manufacture of Automotive. To estimate TFEE, the referred data includes input and output data. Input data includes capital quantity (k), energy consumption (e), labor quantity (l). Industrial added value is applied as output variable. The above data is all converted into constant price of 2006. In Tobit model, i represents industry sector, and t represents time. $Comp_{i,t}$ is industry scale calculated by gross industrial output value/enterprise number. $State_{i,t}$ represents the percentage of gross output value of state-owned in total gross industrial output value. $Priva_{i,t}$ represents the percentage of gross output value of foreign-funded enterprises in total gross industrial output value. $Expt_{i,t}$ represents the percentage of export delivery value in total gross industrial output. $Rd_{i,t}$ represents the percentage of expenditure on R & D in industrial added value. The data in this paper are all from Shandong Statistical Yearbook (1995-2014).

4. Empirical Results

This paper uses Winbugs soft to finish Bayesian SFA estimation. The result shows that DIC of translog function is bigger than Cobb-Douglas function, therefore the later is more suitable. Fig 1 shows the convergence trajectory of parameter β_1 which proves that Markov chain monte carlo converge.

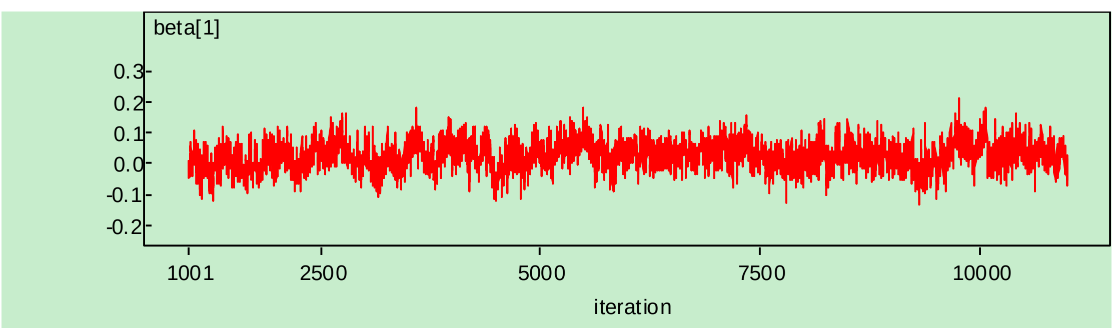

Figure 1. The convergence trajectory of parameter β_1

Table 1 shows that Bayesian estimation results of SFA. We find that input quantity of capital and energy are positive to output, while labor quantity has negative effect to output which proves that surplus labor exist in industrial sectors.

Table 1. The Bayesian estimation results of SFA

Variables	Coefficient	Mean value	Standard diviation	MC error	2.5%	97.50%
lne	β_1	0.02605	0.04392	0.002372	-0.0597	0.1104
lnl	β_2	-0.4024	0.05921	0.003207	-0.5223	-0.2874
lnk	β_3	0.7058	0.0481	0.001919	0.6099	0.7983

Table 2. TFEE and groups of thirty-seven industries of Shandong from 2006 to 2013

Industry sector	TFEE	Standard deviation	Grouped according to TFEE	Grouped according to industrial added value
Manufacture of Raw Chemical Materials and Chemical Products	0.975	0.005	I	I
Processing of Farm and Sideline Food	0.969	0.010	I	II
Textile Industry	0.967	0.010	I	II
Smelting and Pressing of Ferrous Metals	0.961	0.009	I	II
Manufacture of Special Purpose Machinery	0.958	0.017	I	II
Mining and Washing of Coal	0.951	0.011	I	III
Production and Supply of Electric Power and Heating Power	0.946	0.022	I	III
Smelting and Pressing of Nonferrous Metals	0.945	0.018	I	II
Manufacture of Electrical Machinery & Equipment	0.944	0.013	I	II
Manufacture of Computer, Communications and	0.937	0.014	I	II
Manufacture of General Purpose Machinery	0.930	0.005	I	III
Manufacture of Metal Products	0.928	0.010	I	III
Manufacture of Railroad,Marine,Aerospace and Other Transportation Equipment	0.927	0.043	I	II
Papermaking and Paper Products	0.925	0.021	I	III
Petroleum Refining, Coking and Nuclear Fuel Processing	0.921	0.007	I	III
Manufacture of Textile Wearing Apparel and Finery	0.921	0.015	I	III
Extraction of Petroleum and Natural Gas	0.914	0.046	I	III
Manufacture of Rubber and Plastic	0.912	0.004	I	III
Manufacture of Food	0.911	0.023	I	III
Nonmetal Mineral Products	0.910	0.022	I	III
Manufacture of Medicines	0.906	0.012	I	III
Timber Processing, Bamboo, Cane, Palm Fiber & Straw Products	0.877	0.017	II	III
Manufacture of Wine, Drinks and Refined Tea	0.865	0.024	II	III
Manufacture of Leather, Fur, Feather & Its Products and Footwear	0.858	0.027	II	III
Manufacture of Culture, Education,Arts and crafts,Sport and Entertainment Goods	0.837	0.022	III	III
Other Manufacture	0.829	0.085	III	III
Manufacture of Furniture	0.818	0.020	III	III
Mining and Dressing of Nonmetal Ores	0.808	0.033	III	III
Mining and Dressing of Nonferrous Metals Ores	0.804	0.024	III	III
Printing, Reproduction of Recording Media	0.790	0.017	III	III
Mining and Dressing of Ferrous Metal Ores	0.789	0.017	III	III
Manufacture of Measuring Instrument	0.780	0.029	III	III
Production and Supply of Tap Water	0.777	0.034	IV	III
Manufacture of Chemical Fibers	0.753	0.049	IV	III
Production and Supply of Gas	0.746	0.028	IV	III
Tobacco Products	0.730	0.036	IV	III
Comprehensive Utilization of Waste Repair Industry	0.668	0.055	IV	III

According to the results in Table 2, some suggestion are given: Firstly, for those main industries such as Manufacture of Raw Chemical Materials, Manufacture of Electrical Machinery & Equipment, Manufacture of Food, marine industry should be focused on developing rapidly marine chemical materials, manufacture of marine machinery, manufacture of marine food. Combining with the strategy of blue economic zone, marine industry clusters should establish to upgrade traditional industries. Secondly, based on yellow river delta strategy, Manufacture of Computer and Communications, biological engineering, new materials and other high-tech industries should be fostered to form scale effect. Thirdly, for regions in Lunan, food processing industry should be regarded as emphases, take high-end products as goal to develop the deep processing of peanut and soybean oil, vegetables, fruit, animal husbandry, etc.

Table 3. Tobit model estimation result of the influencing factors of energy efficiency of industries in Shandong and Robust test

Variables	Model I	Model II	Model III
$lncomp_{i,t}$	0.019^{***}	0.038^{***}	0.032^{***}
	(0.005)	(0.006)	(0.006)
$lnstate_{i,t}$	-0.011^{***}	-0.001^{*}	-0.008^{*}
	(0.003)	(0.003)	(0.004)
$lnexpt_{i,t}$		0.011^{***}	0.008^{***}
		(0.002)	(0.002)
$lnpriva_{i,t}$		0.003^{*}	0.005^{*}
		(0.004)	(0.004)
$lnrd_{i,t}$			0.011^{***}
			(0.003)
cons	0.669^{***}	0.557^{***}	0.652^{***}
	(0.058)	(0.063)	(0.067)
/sigma	0.077	0.067	0.066
	(0.003)	(0.003)	(0.003)
Log likelihood values	320.682	331.804	336.546

Note. *, **, *** represent significance above 10%, 5%, 1%, respectively.

Empirical results of Tobit model in Table 3 shows that enterprise scale, international trade, the level of foreign investment and technology progress are notably positively relative to energy efficiency, while the proportion of state-owned economy have negative impact on energy efficiency. Therefore, it is necessary for further improvement in industrial energy efficiency in Shandong to decrease the proportion of stated-owned, encourage private capital entrance, extend opening up, and speed up the technical innovation.

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