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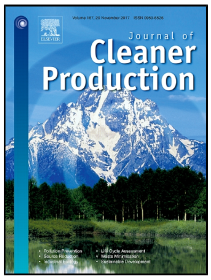

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Highlights

(1) Constructing the panel data of strategic emerging industries in China between 1997 and 2012 from the perspective of energy conservation and low carbon emission reduction.

(2) The evaluation model is developed by the stochastic frontier analysis method.

(3) An empirical analysis is made to study the driving effect of technological innovation from energy conservation and low-carbon development of strategic emerging industries.

(4) Analyzing the role and its influencing factors of technological innovation impacting energy utilization efficiency of China's strategic emerging industries.

Driving Effect of Technology Innovation on Energy Utilization Efficiency in Strategic Emerging Industries

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Abstract: Under the policy of energy saving and emission reduction, technological innovation has become the key power-driver to improve energy utilization efficiency. By using the panel data of 21 industrial segments between 2000 and 2015, this paper investigates the driving effect of technological innovation on energy-utilization efficiency in strategic emerging industries and analyzes the critical factors influencing the driving effect of technological innovation by the stochastic frontier analysis method. The empirical result shows that technological innovation between 2000 and 2015 has had a significant positive driving effect on the energy utilization efficiency of strategic emerging industries and exhibits a development trend of year-by-year steady-state growth on the whole. The greater the value of the development expenditure of new green products and the investment in environmental pollution treatment, the greater the technological efficiency; the greater the value of the transformation expenditure of energy-saving technology, the greater the technological inefficiency. Finally, the paper proposes the countermeasures and suggestions for the driving effect of technological innovation on energy utilization efficiency in strategic emerging industries. An empirical study is made to analyze the driving effect of technological innovation on energy utilization efficiency, the positive and negative factors of technological innovation are forgotten. Strategic emerging industries can select optimal innovation behavior to improve quality and efficiency of energy utilization based on the results.

Key Words: Technology innovation; Strategic emerging industries; Energy utilization efficiency; Stochastic frontier analysis

1. Introduction

Energy is indispensable for the economic development of various countries in the world. It contributes to economic development and the improvement of technical efficiency in the short run (Birgit et al., 2016). In the past, high energy consumption resulted in high investment and high pollution. The long-standing low energy-utilization efficiency and high environment pollution have had a strong impact, particularly on economic development (Sanford, 2015; Francesco et al., 2016). Strategic emerging industries are the new breakthroughs and growth poles for driving regional economic development (Dan, 2016). However, strategic emerging industries still face multiple constraints if they are expected to be the leading industries or pillar industries. The developmental trajectories of traditional industries lack the critical core technologies for industrial development (Florian, 2015). A good mastery of industrial core technologies is crucial to the development of strategic emerging industries; energy utilization efficiency must be rapidly improved by the industrial technological innovation so that the industrial growth and expansion are also rapidly promoted (Jagjit et al., 2016; Hans et al., 2016). However, the driving effect of technological innovation on energy utilization efficiency is mainly theoretical, empirical studies are still lacking. From this new perspective, the paper analyzes the influencing relationship between technological innovation and energy utilization efficiency of strategic emerging industries, gets the positive and negative influencing factors. The technological innovation model can be proposed to improve energy utilization efficiency, it is of great theoretical significance and practical value.

The extensive development mode leads to excessive consumption of energy, exhaustion of limited energy, and deterioration of the beautiful environment (Tommy et al., 2016). Thus, various countries in the world need a new growth pattern, i.e., an intensive growth pattern. In this historical reformation, various countries propose developing strategic emerging industries, accelerating industrial structure adjustments and upgrades, transforming the economic growth pattern, and leading and guiding the economic society to achieve long-term development (Li-yan Sun et al., 2017; C. Vasanthakumar et al., 2016). To achieve such a transformation, it is imperative to strengthen the technology-innovation construction of strategic emerging industries, attach importance to technological-innovation issues, and improve the labor productivity and technological innovation efficiency based on the role of technological innovation in driving the energy-utilization efficiency of strategic emerging industries (Gustav et al., 2016).

Technological innovation is one of the critical impetuses for strategic emerging industries to improve energy utilization efficiency (Ulf Andersson et al., 2016; Piret, 2015). Technology innovation not only has a strong impact on the production modes of strategic emerging industries, but also plays roles in reforming the technological paradigm and continuously developing ecological production modes and ecological technologies (Bronwyn and Christian, 2013). To create sustainable utilization of energy needs means that strategic emerging industries must raise energy-utilization efficiency by relying on technological innovation to promote the economic transition and development when achieving energy conservation and emission reduction (Kassahun and Toshio, 2017; Wolfgang et al., 2016). However, the impetuses for traditional economic and social development in the world are high energy consumption and high investment rather than the improvement of technological innovation (Masachika, 2015).

Under the policy of energy saving and emission reduction, energy is an important material basis, but the energy utilization level is lower, the utilization mode is extensive, and utilization technology is outdated(D.Q. Zhou et al., 2017). Stochastic frontier analysis (SFA) is an estimation method of technology efficiency(Koki Oikawa, 2016). It assumes that production frontier of each production unit is random, the error term of production function is divided into the random errors and technology invalid error which is used to estimate technology efficiency (Mike G. Tsionas, 2017). The related frontier production function is estimated by the econometric method, and then the parameters frontier analysis method can calculate technological efficiency and productivity through setting the specific form of the production function and assuming the random interference distribution. Thus, the paper analyzes the role and its influencing factors of technological innovation in driving energy utilization efficiency of strategic emerging industries based on the stochastic frontier analysis method (SFA). Based on the panel data of 21 industrial segments between 2000 and 2015, the paper analyzes the driving role of technological innovation in energy utilization efficiency of strategic emerging industries and the major factors influencing the driving effect by the parametric stochastic frontier analysis method. Finally, the paper proposes the appropriate development countermeasures, suggestions, and provides theoretical references for achieving sustainable development, low-carbon development, cyclic development and green development of strategic emerging industries.

2. Literature review

Scientific and technological innovation as a strategic basis leads the green development and solves the economic low-carbon development and environmental protection dilemma. Energy utilization efficiency is improved through technological innovation to achieve energy-saving and emission reduction. So energy and technological innovation have become a hot topic for many scholars. The way, policy and path of improving energy utilization efficiency have become an important research topic for many scholars. Giacomo et al. (2013) provide environmental policies to improve energy-utilization efficiency and reduce CO_2 emissions for a variety of industries, especially the most energy-intensive industries, and made an empirical analysis of the iron and steel industries to simulate the energy consumption and greenhouse gases emissions in different conditions; Ellison and Glaeser (2010) pointed out that all countries should develop a series of fiscal, financial, and other supporting policies and technological innovation mechanisms to guarantee and promote the sustainable development of emerging industries; Lovdal and Neumann (2011) found that government support and technological innovation are the main factors restricting the rapid development of the emerging marine industry.

Technological innovation has become the key driving force to improve energy utilization efficiency. Kexin Be etal. (2016)proposed an analytic framework for the low-carbon technological innovation process under the global value chain and analyzed the low-carbon technological innovation performance and its influencing factors in China's manufacturing industry by using the factor analysis and DEA-Tobit two-stage approach. Maria etal. (2014) studied the main driving forces of the ecological innovation of small and medium-sized enterprises through a case study, analyzed the factors that affect the efficiency of green technological innovation and non-green technological innovation, and the difference between the influence of each factor. S. Sinan et al. (2013) identified the key influencing factors of technological innovation efficiency, and further analyzed the interrelationships among these factors. Gemaet al. (2016) pointed out that technological innovation efficiency can help to achieve greater corporate performance, and establish and strengthen the core competitiveness of enterprises. An empirical analysis was made to show that the dynamic ability and static ability of enterprises have a positive and significant direct impact on technological innovation efficiency. Nevenkaet al. (2016) analyzed that the factors affecting technological innovation efficiency are similar but not the same, pointed out that energy cost share, market share, and export orientation have a significant impact.

The influence factors of energy utilization efficiency are multifaceted and comprehensive (Lingling Li et al., 2017), we should not only analyze the methods and policies improving energy utilization efficiency but also analyze the multi-dimensional factors such as technologies, systems, values and so on related to energy consumption and carbon emissions(Wenlong Wang et al., 2015). Some literature on energy utilization are mainly around the interaction between energy and environment, economy, less literature considers technological innovation(Vincenzo Bianco et al., 2017; Hana Moon et al., 2017). Especially, it is relatively lacking that the research on the relationship between technological innovation and energy utilization efficiency and industry low-carbon development (KaziSohag et al., 2015). For example, there should be an in-depth study on various measures and strategies (Abbas Mardani et al., 2017), as well as the coordination mechanism of existence differences and policy of technological innovation driving effect on energy utilization efficiency. In addition, most literature on technological innovation are from the perspective of labor, human capital, and capital stock, and ignore the impact of energy consumption, carbon emissions, scientific research input, technology management and other factors, especially the impact of these factors on the driving effect of technological innovation on energy utilization efficiency.

Energy is indispensable for industry economic development, contribute to the development of the industrial economy and improve technological innovation efficiency in short-term (Junming Zhu et al., 2017), but the "three high" system thought was formed that includes high energy consumption, high investment and high pollution in the past (Tong Xu et al., 2017). The heavy waste of energy and the high degree of environmental pollution bring the serious influence, especially have also a serious negative impact on the industrial economy and technological innovation efficiency (Jian Wang et al., 2017). Thus, taking full account of the impact of energy, ecology, environment and other factors on technological innovation, this paper makes empirical analysis on the driving effect of technological innovation from energy conservation and low-carbon development of strategic emerging industries, analyzes the role and its influencing factors of technological innovation impacting energy utilization efficiency of China's strategic emerging industries. By using the panel data of 21 industrial segments between 2000 and 2015 in China, this paper analyzes the driving effect of technological innovation in strategic emerging industries on energy utilization efficiency and the major factors influencing the driving effect by using the parametric stochastic frontier analysis method. Finally, the paper proposes the appropriate development countermeasures and suggestions and provides theoretical references for achieving sustainable development, low-carbon development, cyclic development, and the green development of strategic emerging industries.

3. Model specification, sample selection, and data description

3.1 Model construction

At present, the models and methods adopted by domestic and foreign scholars include DEA method (Qunwei Wang et al., 2013), Super-SBM model (Hong Li and Jinfeng Shi, 2014), SEM model (Maryono et al., 2016), Theil index decomposition method, vector autoregressive (VAR) model (Bin Xu and Boqiang Lin, 2016), LEAP model (Nnaemeka Vincent Emodi et al., 2016), scenario analysis method (Yusuke Kishita et al., 2016) and input-output method and so on. However, the above methods can not consider the influence of the random error factors in the operation process, ignore the influence of the price and other factors, and don't describe the production process. SFA can combine the input and output indicators in the survey sample of the research object. The frontier surface obtained by constructing the stochastic frontier model is random. SFA can test the rationality of the model, and check the parameter values to be estimated. In addition, SFA can describe the production process, and then can control and measure the efficiency state of each sample, and further analyze the impact factors, especially the results obtained by SFA are closer to reality for the panel data with period span.

The sample data of this paper is the panel data of 21 industrial segments between 2000 and 2015, the difference of energy utilization efficiency in different industries and different periods will be more obvious, that is, the random error term will have a more serious impact on the efficiency measurement, SFA method is more reasonable and more suitable for the research needs of this paper. Therefore, this paper will measure the driving effect of technological innovation on energy utilization efficiency and its influencing factors by SFA method.

This paper collects and collates the panel data of strategic emerging industries in China from 2000 to 2015, and analyzes the driving effect of technological innovation in strategic emerging industries on energy utilization efficiency by using the parametric stochastic frontier analysis method and the logarithmic Cobb-Douglas production function. The model construct is as follows:

$$\ln Y_{it} = \beta_0 + \beta_1 \times \ln L_{it} + \beta_2 \times \ln K_{it} + (\nu_{it} - u_{it}) \tag{1}$$

$$TE_{it} = \exp(-u_{it}) \tag{2}$$

$$u_{it} = \beta(t) \times u_i \tag{3}$$

$$\beta(t) = \exp[-\eta(t-T)] \tag{4}$$

$$\gamma = \frac{\sigma^2}{\sigma_v^2 + \sigma_u^2} \tag{5}$$

$$m_{it} = \delta_0 + \delta_1(NPDE) + \delta_2(TTE) + \delta_3(EPCI) \tag{6}$$

In formula (1)-(6), i represents the serial numbers of 21 strategic emerging industries ($i = 1, 2, \cdots, N, N = 21$); t represents the serial numbers from 2000 to 2015 ($t = 1, 2, \cdots, T$, $T = 16$, serial number 1 corresponding to 2000, …, sixteen corresponding to 2015); in formula (1), Y_{it} represents total output value in the t th year in the i th industry; L_{it} represents the average number of scientific and technological activities in the t th year in the i th industry; K_{it} represents the capital stock in the t th year in the i th industry; β_0 represents the intercept term; β_1, β_2 respectively, represent the degree of the impact of scientific and technological activities and fixed assets; ν_{it} represents the random error, $\nu_{it} \sim iid\ N(0, \sigma_v^2)$; u_{it} represents the non-negative factors influencing the technological innovation driving inefficiency, $u_{it} \sim iid\ N^+(m_{it}, \sigma_u^2)$; ν_{it} and u_{it} are mutually independent. Formula (2) reflects the promotion states of technological innovation impacting on energy utilization efficiency in 21 industries; $TE_{it} = 1$ when $u_{it} = 0$, indicating that the promotion of energy utilization efficiency is efficient; $0 < TE_{it} < 1$ when $u_{it} > 0$, indicating that the promotion of energy utilization efficiency is inefficient; the degree of impact of time t on u_{it} is quantitatively described by formula (3) and formula (4), and η is an unknown parameter; the value of γ reflects the applicability of the stochastic frontier model established in the paper, if $\gamma = 0$, it indicates that energy utilization efficiency of strategic emerging industries are on the production frontier, and the OLS method can be used for measurement; otherwise, the SFA method will be used. Formula (6) represents the inefficiency function; $\delta_0, \delta_1, \delta_2, \delta_3$ represent four parameters to be estimated; $\delta_1, \delta_2, \delta_3$ reflect the effects of appropriation expenditure for green new-product development expenditure ($NPDE$), energy-saving technology-transformation expenditure (TTE), and environmental pollution control investment ($EPCI$) on the energy utilization efficiency in 21 industries. If $\delta_i > 0$, the greater the value of corresponding variable, the greater the technical inefficiency; otherwise, the reverse is the opposite.

3.2 Sample selection and data collection

Report on Development of Strategic Emerging Industries in China 2013 released in January 2013 presents the basic situations, existing problems, and influencing factors in specific aspects of the current strategic emerging industries based on the typical cases from six provinces/cities, but it still lacks reduction and statistics of related data. Therefore, the paper is intended to approximately measure strategic emerging industries by using the data related to the indexes selected above in high technology industries. The measurement primarily conforms to the specific interpretations on strategic emerging industries in The 12th National Five-Year Plan for Strategic Emerging Industries in China and Statistical Classification Cataloger for High Technology Industries (2006). There is a close relationship between high technology industries and strategic emerging industries. Strategic emerging industries are characterized by high technology, high knowledge, low consumption, high development potential, etc. and intensively incorporate the emerging industries and emerging technologies (Dirk Czarnitzki and Susanne Thorwarth, 2012). Strategic emerging industries cover the major fields of high technology industries to some extent. High technology industries can be considered as the main component of strategic emerging industries in a sense. Therefore, 21 industrial segments are selected from high technology industries in China as samples (See Table 2 for details). The index data between 2000 and 2015 are collected from the *China Statistical Yearbook*, *China High Technology Industry Data (2000–2015)* and *China*

Statistics of Science and Technology (2000–2015).

The numerical values of various indexes can be computed as follows:

y_{it} is the total output value of each year between 2000 and 2015 in 21 strategic emerging industries (Unit: 0.1 billion yuan), and its value is converted by price deflectors taking the price in 1990 as 100.

L_{it} is the average number of scientific and technological activities between 2000 and 2015 in 21 strategic emerging industries (Unit: persons).

K_{it} is the average stock of fixed assets between 2000 and 2015 in 21 strategic emerging industries (Unit: 0.1 billion yuan) and estimated with the perpetual inventory method of Goldsmiths $K_t = I_t / P_t + (1 - \delta_t) K_{t-1}$; K_t represents the stock of fixed assets in the t th year; I_t represents the fixed assets investment in the t th year in the 21 strategic emerging industries; P_t represents the price indexes of fixed assets investment and the numerical values published in the *China Statistical Yearbook* can be used; δ_t represents the depreciation rate and the specific numerical values use 15% in Hannes and Dennis (2015) and Kidanemariam and Makoto (2015) of references; the base period fixed capital stock is computed with the method in Koki (2016) of references. After the above data is determined, the stock of fixed assets of each year (2000–2015) is sequentially calculated. The capital stock is allocated to various subdivided industries based on the ratio of the total output value of 21 industries between 2000 and 2015 to the total output value of the entire strategic emerging industries. The capital stock of 21 industries can be obtained following approximate calculation (The price of 1980 acts as the criterion).

The data from each statistical yearbook are accounted at the price in the appropriate year. The monetary forms are different. Thus, the index data related to price can be easily affected. The data will be deflated with the price of a certain year being the benchmark. The paper apportions the price indexes of fixed assets investment based on the proportion of the total output value of each specific industrial segment in the total output value of the whole strategic emerging industries, deflates the related data based on the prices indexes of fixed assets investment, and uses the data of 1990 as 100 for the conversion of index data.

The inventory data of various funds expenditure is estimated by formula (7):

$$k_t = (1-\delta)k_{t-1} + E_{t-1} \tag{7}$$

k_t and k_{t-1} respectively, represent the capital stock of 21 subdivided industries in the t th year and the t-1 th year, E_{t-1} represents various funds expenditure in the t-1 th year (the data are deflected by the fixed asset price index).

The estimation formula of base period capital stock is

$$k_0 = E_0 / (g+\delta) \tag{8}$$

g is calculated by formula (9):

$$g = \sqrt[16]{E_{16} / E_0} - 1 \tag{9}$$

The capital stocks of various funds expenditure in 2000 is estimated by formulas (8) and (9), and we can then estimate the capital stocks of funds expenditure of each subdivided industry by formula (7).

4. Empirical results and analysis

4.1 SFA parameter estimation results

By using the panel data of strategic emerging industries between 2000 and 2015 in China, this paper makes an empirical analysis of the driving effect of technological innovation on energy utilization efficiency in strategic emerging industries by using the stochastic frontier function and estimates each parameter of the SFA model by the Frontier4.1 computational software. See Table 1 for the estimated values of all parameters.

Table 1 SFA parameter estimation results

Parameters to be estimated	Coefficient estimate	Standard error	Z-Value
β_0	6.0849	0.2403	25.3208*
β_K	0.4710	0.0358	13.1700**
β_L	-0.0532	0.0103	-5.1867**
δ_0	3.1250	0.2359	13.2469*
δ_1	-0.1957	0.0219	-8.9521**
δ_2	0.1307	0.0238	5.490**

δ_3	-0.0704	0.0068	-10.2986***
σ^2	0.3413	0.0285	11.9714**
γ	0.7583	0.0257	29.5094**
No． of observations			336
log likelihood function			-244.6521
LR test of the one-sided error			293.8968

Note: * represents a significant level of 10%, ** represents a significant level of 5%, *** represents a significant level of 1%; LR is the likelihood ratio test statistic.

On the basis of the estimation results of various parameters of the SFA model, this paper reaches the following conclusions: $\gamma = 0.7583$ reflects that 75.83% of the errors in the SFA model largely result from the driving inefficiency of technological innovation, and the remaining errors result from random influencing factors (James Odeck and SveinBråthen, 2012). Thus, it is proper to analyze the driving effect of technological innovation on energy utilization efficiency in strategic emerging industries. It is further considered that the driving inefficiency of technological innovation is one of the major factors influencing energy utilization efficiency in strategic emerging industries. In addition, the significance estimation result of LR demonstrates that all estimation results of various parameters of the SFA model pass the test at the given significance level. To sum up, the fitting result of the established model is ideal.

In terms of the output elasticity of the technological staff and fixed assets stock of strategic emerging industries and on the basis of the estimation results of the two parameters, $\beta_K = 0.4710$ and $\beta_L = -0.0532$, energy utilization efficiency will increase by 47.10% when the fixed assets stock of strategic emerging industries increases by 1%, whereas energy utilization efficiency will decrease by 5.32% when the number of technological staff increases by 1%. In consideration of the development demand of resource-saving and environment-friendly society, the following possible reasons can account for the above situations. The resource-saving and environment-friendly society have higher requirements for energy utilization in businesses. It also means that enterprises have to improve energy utilization efficiency and reduce carbon emissions while achieving sustainable development. Businesses need to invest more in technological innovation and should be encouraged to participate in international scientific and technological exchange and cooperation, guide foreign investment and encourage social investment, develop more advanced high and new technologies, and raise the capital utilization efficiency (Wolfgang Gerstlberger et al., 2016). It can be seen from the analysis result that the input efficiency of the fixed assets in China is significant in the context that China strengthens the support for the sustainable development of strategic emerging industries and introduces related policies and incentive measures. However, a gap still exists largely due to the negative effect of technological staff (Mei-Chih Hu et al., 2017). The sustainable development of strategic emerging industries and the improvement of energy utilization efficiency need the driving effect of technological innovation. Technology innovation needs scientific and technical personnel. Thus, it has higher requirements for scientific and technical personnel, particularly the composite talents with high skills and high levels. However, the analysis result shows that the role of scientific and technological personnel decreases. The analysis indicates that the scientific and technological personnel of strategic emerging industries in China are weak in skills, research and development capability, innovation capability, etc. It also reflects that there is a lack of scientific and technological personnel in strategic emerging industries in China. Thus, more talent needs to be cultivated and introduced. In addition, the negative effect of the scientific and technological personnel may also include more personal investment. Businesses tend to increase the number of the introduced personal for accelerating development and raising the scale efficiency.

In conclusion, for achieving the driving effect of technological innovation on energy utilization efficiency in strategic emerging industries, we not only need to increase capital investment and raise capital utilization efficiency, but also need to accelerate the cultivation and introduction of high-level scientific and technological personnel, continuously optimize and upgrade technology-innovation capability, raise the capital utilization efficiency, research and develop energy-saving technologies, and raise energy utilization efficiency to reduce the amount of discharged pollutants.

4.2 The empirical results analysis

See Table 2 for the empirical results of the driving effect of technological innovation on energy utilization efficiency.

Table 2 The empirical results of driving effect on energy utilization efficiency

	2000	2001	2002	2003	2004	2005	2006
Chemical manufacturers	0.7831	0.8271	0.8323	0.8139	0.8580	0.8724	0.9137
Chinese patent medicine manufacturers	0.7511	0.7828	0.7923	0.8015	0.7945	0.8099	0.8349
Biological and biochemical products manufacturers	0.6137	0.6569	0.6764	0.6857	0.7167	0.7020	0.7479
Aircraft manufacturers and repair	0.7203	0.7131	0.7316	0.7420	0.7472	0.7420	0.7870
Spacecraft manufacturers	0.5190	0.5500	0.5701	0.5720	0.5325	0.5232	0.5636
Telecommunications transmission equipment manufacturers	0.6903	0.7275	0.7533	0.7538	0.6982	0.7460	0.7366
Communications switching equipment manufacturers	0.8553	0.8411	0.8661	0.7985	0.8381	0.8600	0.8640
Communications terminal equipment manufacturers	0.7349	0.7533	0.8849	0.8858	0.7239	0.7695	0.7950
Radar and ancillary equipment manufacturers	0.5033	0.5326	0.5612	0.5843	0.6032	0.5918	0.6391
Radio and TV equipment manufacturers	0.4796	0.5586	0.5651	0.5845	0.6299	0.7251	0.7329
Electronic vacuum device manufacturers	0.7218	0.7594	0.7382	0.7424	0.7769	0.7554	0.7533
Discrete semiconductor device manufacturers	0.5939	0.6618	0.6661	0.7114	0.6530	0.6827	0.7028
Integrated circuit manufacturers	0.6268	0.7013	0.6773	0.6995	0.7329	0.7919	0.8110
Electronics components manufacturers	0.8038	0.8417	0.8405	0.8605	0.8815	0.9408	0.9789
Home audio-visual equipment manufacturers	0.9279	0.8960	0.8954	0.9319	0.9423	0.9545	0.9711
Other electronic equipment manufacturers	0.6906	0.7698	0.7367	0.7352	0.7355	0.7223	0.7634
Electronic computer manufacturers	0.8629	0.8592	0.8920	0.9422	0.9807	0.9895	0.9935
Computer peripherals manufacturers	0.8029	0.8507	0.8695	0.9042	0.9511	0.9766	0.9876
Office equipment manufacturers	0.6828	0.7224	0.7255	0.7508	0.7459	0.7944	0.8155
Medical equipment and device manufacturers	0.6554	0.6905	0.7041	0.7230	0.7156	0.7520	0.7682
Instruments manufacturing	0.7270	0.7589	0.7616	0.7773	0.8010	0.8445	0.8829
Industry average	0.7022	0.7359	0.7495	0.7619	0.7647	0.7879	0.8116

Continued table 2 The empirical results of driving effect on energy utilization efficiency

2007	2008	2009	2010	2011	2012	2013	2014	2015	annual average
0.9191	0.9453	0.9596	0.9626	0.9663	0.9776	0.9753	0.9802	0.9838	0.9107
0.8503	0.8685	0.8800	0.8882	0.9064	0.9355	0.9149	0.9251	0.9337	0.8543
0.7661	0.7965	0.8169	0.8360	0.8508	0.8767	0.8394	0.8553	0.8717	0.7693
0.7875	0.8089	0.8192	0.8330	0.8404	0.6568	0.9315	0.9104	0.9111	0.7926
0.5814	0.5923	0.6109	0.6130	0.6297	0.6495	0.7504	0.7881	0.7806	0.6141
0.7339	0.7671	0.8022	0.8317	0.8428	0.8648	0.9697	0.9778	0.9801	0.8047

0.8923	0.9229	0.9492	0.9463	0.9614	0.9773	0.9653	0.9718	0.9824	0.9058
0.8109	0.8123	0.8088	0.8185	0.8244	0.8364	0.8271	0.8325	0.8374	0.8097
0.6619	0.6609	0.6578	0.6382	0.6699	0.6919	0.7698	0.7787	0.7792	0.6452
0.7432	0.7781	0.7870	0.7905	0.8235	0.8347	0.8740	0.8794	0.8311	0.7261
0.7528	0.7601	0.7503	0.7586	0.7706	0.7804	0.7287	0.7335	0.7692	0.7532
0.7254	0.7525	0.7686	0.7729	0.7881	0.7974	0.8009	0.8185	0.8258	0.7326
0.8414	0.8598	0.8679	0.8715	0.8745	0.8995	0.9061	0.9164	0.9267	0.8128
0.9874	0.9918	0.9919	0.9880	0.9901	0.9913	0.9890	0.9902	0.9912	0.9412
0.9711	0.9739	0.9727	0.9637	0.9659	0.9770	0.9679	0.9703	0.9734	0.9534
0.8037	0.8302	0.8522	0.8689	0.8773	0.8942	0.8335	0.8589	0.8611	0.8021
0.9938	0.9951	0.9950	0.9931	0.9925	0.9935	0.9903	0.9919	0.9910	0.9660
0.9893	0.9911	0.9900	0.9859	0.9872	0.9855	0.9412	0.9551	0.9533	0.9451
0.8261	0.8317	0.8382	0.8721	0.9024	0.9117	0.8416	0.8266	0.8186	0.8066
0.7923	0.8166	0.8407	0.8484	0.8657	0.8787	0.8123	0.8441	0.9411	0.7905
0.9127	0.9389	0.9325	0.9545	0.9644	0.9762	0.9482	0.9582	0.9006	0.8775
0.8258	0.8426	0.8520	0.8588	0.8712	0.8755	0.8846	0.8935	0.8973	

(1) Integral analysis of the driving effect

On the basis of the analysis of the last row in Table 2, technological innovation has a significant driving effect on energy utilization efficiency. It increases from the minimum value of 70.22% in 2000 to 89.73% in 2015; the annual average increase is 1.2194%. It exhibits a development trend of steady year-by-year growth. Thus, technological innovation has a positive and significant driving effect on energy utilization efficiency in strategic emerging industries (Manuchehr Irandoust, 2016). The sustainable development of strategic emerging industries requires an innovative driving force. The traditional production mode and development mode must be changed by science and technology (Sarah M. Jordaan et al., 2017). A development mode with higher energy utilization efficiency and a production mode with lower input and higher output will form based on technological innovation. China formulates the economic policies and market mechanisms for strategic emerging industries from the macroscopic and microscopic views. The sustainable development of strategic emerging industries comes from the driving effect of scientific knowledge and technological innovation. We should combine technological innovation and industrialization development, strengthen research and development of critical core green technology, further improve technological innovation and highly skilled talents, establish the support mechanism of technological innovation in strategic emerging industries, and promote commercialized and industrialized development of the achievement of technological innovation. Technology innovation has a significant driving effect on energy utilization efficiency, but the innovation output fails at the forefront of surface because there are shortcomings in green technology transformation, development technology of new green products, environmental control technology, and scientific and technological personnel.

(2) Analysis of the driving effect in the 21 industries

As seen in Table 2, in terms of the driving effect of technological innovation on energy utilization efficiency in strategic emerging industries between 2000 and 2015, computer machine manufacturers have the maximum average value of 0.9660, followed by home audio-visual equipment manufacturers, and its average value is 0.9534. The annual average values of 8 industrial segments such as computer machine manufacturers, home audio-visual equipment manufacturers, communications switching equipment manufacturers and so on exceed the total average value of 0.8197. This demonstrates that the driving effect of technological innovation on energy utilization efficiency of high-tech industries such as electronic products, medicine and digital equipment and so on has the leading position, and it also reflects that the technological innovation capabilities of these industries have achieved technology accumulation to some extent. On the contrary, spacecraft manufactures have the lowest average value of 0.6141, 0.2056 smaller than the total average value, and approximately 0.3519 smaller than the maximum value of 0.9660. The requirement for technical content in spacecraft manufacturing is higher than that in other industries. It is characterized by high-cost research and development, high-precision detection technology, and poor manufacturing performance. In addition, China lacks the critical core technology, which makes technological innovation play a less effective role in driving its energy utilization efficiency (Jorrit Gosens and Yonglong Lu, 2013).

(3) Evolution trend of driving effect

As seen in Table 2, all evolution trends of the driving effect increased between 2000 and 2015. However, individual industries fluctuated in the overall increasing trend, such as spacecraft manufacturers, communications terminal equipment manufacturers,computer peripherals manufacturers and medical equipment and device manufacturers. In particular, the industry of communication terminal equipment manufacturing fluctuated frequently and substantially. Radio and television equipment manufacturing had the highest annual average growth rate of 4.320%, followed by Radar and ancillary equipment manufacturers whose annual average growth rate was 3.4199%, which indicates that technological innovation plays a good role in driving their energy-utilization efficiency. The industry of home audio-visual equipment manufacturers had the lowest growth rate of 0.3686%. Although the industry of home audio-visual equipment manufacturers has achieved related technology development, there is a big gap between its level of technological innovation and the advanced level of the world. In particular, China's critical core technology lags behind the world's advanced level. The poor innovation capability of scientific and technological talents limits the sustainable development of the industry and the improvement of the level of technological innovation.

4.3 Analysis of influential factors of the driving effect on energy utilization efficiency

(1) The impact analysis of green new product development expenditure

$\delta_1 = -0.1957$ in Table 2 indicates that the greater the value of the development expenditure of new green products, the greater the technological efficiency, that is, the development expenditure of new green products plays a significantly positive role on the driving effect of technological efficiency. Technological innovation will increase the energy utilization efficiency of strategic emerging industries by 0.1957% when the development expenditure of new green products increases by 1%. Development of new green products is the focus of the research and development of strategic emerging industries and one of the strategic cores of improving their energy-utilization efficiency. Technological innovation is a major driving force for the development of new products, which are created by developing new technologies, improving existing technologies, or introducing new technologies. The development of new green products in strategic emerging industries plays a positive role in this paper, but the value is found to be a slightlylarge (0.1957%). This also reflects that some achievements have been made in the development technologies of new green products, but the efficiency is still low (Himanshu Gupta and Mukesh Kumar Barua, 2016).

(2) The impact analysis of energy-saving technology transformation expenditure

$\delta_2 = 0.1307$ in Table 2 indicates that the greater the value of the transformation expenditure of energy-saving technology, the greater the technological inefficiency, that is, the transformation expenditure of energy-saving technology plays a significantly negative role on the driving effect of technological efficiency, which will decrease the energy utilization efficiency of strategic emerging industries by 0.1307% when the transformation expenditure of energy-saving technology increases by 1%. In recent years, the transformation of energy-saving technology has become particularly important as China faces such issues as energy-supply shortage, low energy utilization efficiency, increasingly serious environmental pollution, and increasingly slow (even declined) economic benefits and social benefits (Wenxi Wang et al., 2017). It is imperative that China strengthens the transformation of energy-saving technology, optimizes energy structure, achieves energy conservation and emission reduction, and improves energy utilization efficiency by relying on technological innovation. $\delta_2 = 0.1307$ indicates that the transformation of energy-saving technology plays a negative role, but the negative effect is as big as 0.1307%. The transformation of energy-saving technology in strategic emerging industries has attained increasingly significant results under the support of national policies, but it still needs to be further improved.

(3) The impact analysis of environmental pollution control investment

$\delta_3 = -0.0704$ in Table 2 indicates that the greater the value of the investment of environmental pollution control, the greater the technological efficiency, that is, the investment of environmental pollution control plays a significantly positive role on the driving effect of technological efficiency, which will increase energy utilization efficiency of strategic emerging industries by 0.0704% when the investment of environmental-pollution control increases by 1%. In the context of “harmonious development of human being and the nature,” “green Earth, beautiful China, ecological civilization, low-carbon economy” proposed by China and other countries, strategic emerging industries should not only focus on technological innovation but should also develop more advanced energy-saving high and new technology, improve energy-utilization efficiency, decrease pollutant discharge, establish the idea of “low-carbon environmental protection," and strengthen environmental-pollution control (Kyungpyo Lee and Sungjoo Lee, 2013; Alessandro Marra et al., 2017). On the basis of the estimated value $\delta_3 = -0.0704$ of index parameter, environmental pollution control plays a minor role. On the one hand, it reflects that the investment of environmental pollution control is insufficient and the control technology needs to be improved; on the other hand, it also reflects that there is a gap between the level of technological innovation and the demand for energy utilization.

5. Conclusions

Under the policy of energy saving and emission reduction, it is very urgent and important for strategic emerging industries to improve energy utilization efficiency by technological innovation, but there is a main theoretical effecting relationship of technological innovation on energy utilization efficiency. Therefore, with reference to the existing domestic and foreign research results, taking full account of the impact of carbon emissions, scientific research input, technology management output and other factors on technological innovation, the paper makes an empirical analysis on driving effect of technological innovation on energy utilization efficiency by constructing the panel data of the 21 industries between 2000 and 2015 and the stochastic frontier analysis method, and analyzes the critical influencing factors. The main conclusions of the empirical analysis are as follows: (1) $\gamma = 0.7583$ indicates that inefficiency of driving effect of technological innovation is one of the major factors that influence the energy utilization efficiency of strategic emerging industries. (2) The driving effect on energy utilization efficiency is higher and increases year by year. (3) Based on the analysis of the driving effect in specific industries, the driving effect on computer machine manufacturers is the biggest and spacecraft manufacture is the smallest. (4) The driving effect on energy utilization efficiency between 2000 and 2015 exhibits an increasing trend, but individual industries fluctuate during the increasing trend.

Based on the research conclusion, we should optimize energy efficiency by technological innovation. The sustainable development of strategic emerging industries can be conducted with limited energy, maximize energy potential based on scientific and technological development. Secondly,strategic emerging industries have no symbiotic correlation with other technology symbiotic units such as colleges and universities and scientific research institutions during research and development of the critical core green technology. In addition, technology innovation of strategic emerging industries still lags behind and there is a lack of connection with the advanced technology symbiotic units in foreign developed countries. Thus, strategic emerging industries should establish an innovative mechanism of close connection and sincere cooperation between domestic and foreign technological symbiotic units. Thirdly, strategic emerging industries should integrate the policies of domestic and foreign technology symbiotic units, and establish the dynamic mechanism of green technological innovation to meet the demand of energy saving and emission reduction. Fourthly, the key for improving energy utilization efficiency is a breakthrough of the core technology. Thus, it is imperative to further improve the investment mechanism of technology innovation and ensure the smooth link between science and technology and capital. Finally, based on different evolution situations of technology paradigms, strategic emerging industries should adopt various technology innovation management modes rather than only one mode and constantly update modes.

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