Research on Macro Influencing Factors of Energy Intellectual Property in China: Analysis Based on Dynamic Panel Data Model

Lingyao Pan

Guangdong University of Finance, Guangzhou 510521, PR China

Keywords: energy intellectual property; macro influencing factors; panel co-integration; dynamic panel model

Abstract: At present, the contradiction between the supply and demand of China's energy industry is still relatively prominent. Energy intellectual property can reflect China's energy technology innovation capability. This paper constructs an econometric model to empirically analyze the macro factors that affect China's energy intellectual property. The empirical results show that there is a panel co-integration relationship between openness, barriers to industry entry, and energy technology innovation. There is no panel co-integration relationship between industrial competitiveness and energy technology innovation, but there is a co-integration relationship between the openness, barriers to industry entry, markets the degree of competition and the application of technological innovation; overall, the degree of openness to the outside world can promote the innovation and application of energy technologies in China, and the reduction of barriers to entry in the industry will play a role in energy technology innovation, but its role is greater for the application of energy technologies, the reduction in market competition does not have a significant effect on energy technology innovation, but it has a significant impact on the application of energy technology innovation.

1. Introduction

Technological innovation is the driving force for improving industrial competitiveness and achieving leap-forward development. Discussions on technological innovation have received widespread attention from scholars, especially for discussions on innovative and dynamic industries such as high-tech industries and manufacturing industries. However, due to many factors influencing energy technology innovation, technological development is more difficult and risks are higher, and analysis of energy technologies has not received enough attention. Energy resources are the foundation and guarantee of modern economic development. However, the situation facing China's energy is very serious. China's per capita energy resources are relatively low. The per capita energy of major energy resources, such as coal, is equivalent to about half of the global average. The per capita resources of oil and natural gas are no more than one-fifth of the global average. Comprehensive indicators such as energy consumption, China's energy efficiency is also much lower than in developed countries and some developing countries, energy shortages have constrained China's sustained and healthy economic development. Under the background of accelerated urbanization in China, energy demand has also continued to grow. The contradiction between insufficient energy supply and strong demand has become increasingly prominent. Both the improvement of energy efficiency and the development of new energy are inseparable from the support of technological innovation. How can we effectively improve China's energy technology innovation capability, and thus the realization of sustainable development of energy and economy, has become one of the important issues that China urgently needs to solve.

Technological innovation is the key driving force for the optimization and upgrading of the energy industry. Compared with other industries, energy technology research and development invests heavily, risks are high, and the innovation process is designed into all aspects of production. In recent years, China’s energy technology innovation has been steadily increasing, research and development of new and renewable energy technologies have accelerated, and a number of key energy science technologies and projects have reached internationally advanced levels. However,

China's energy industry still faces some outstanding problems, such as the distinctly gaps of some frontier technologies and key technologies and advanced levels, the distinctly in the level of equipment and technology in the energy industry, and long periods in the application of technology and new product development. It is necessary to accelerate the R&D and innovation of energy technologies to ease the contradictions in China's energy supply. Therefore, they are particularly important that in-depth analysis of the factors that affect energy technology innovation, targeted improvement of energy technology R&D environment and promotion of energy technology innovation are particularly important.

Domestic and foreign scholars discussed factors influencing technological innovation in terms of markets, systems, and policies. For example, Lee (2005) examined the impact of market competition on technological innovation, and pointed out that the degree of industrial concentration and technological innovation were inverted. In the “type” relationship, when the absolute value of industrial concentration is small, the increase in industrial concentration is conducive to technological innovation activities. When the industrial concentration is too large, the continued increase in industrial concentration will restrict technological innovation activities; Joseph et al. (2001) pointed out that policy support plays a significant role in promoting technological innovation, and its effect is closely related to the level of economic development and technological basis. Mallett Alexandra (2007) analyzed the application of solar energy in Mexico City and pointed out that technical cooperation can accelerate renewable energy sources. Domestic scholars' discussion on the factors affecting technological innovation focused on high-tech industries. For example, Hu Yidong (2011) conducted empirical tests on the impact of technological innovation performance on new materials, electronic information, and new energy industries in Jiangsu Province. The results showed that investment in research and development funds factors and firm size have significant impact on technological innovation; Liu Wei (2009) considered the impact of factors on technological innovation such as industry financing structure, ownership structure, firm size, and market concentration; Chen Cheng (2012) examined the impact separately of high-tech development and achievement transformation, the research found that the impact of property rights organization and enterprise scale on technology innovation activities is significant in the stage of technology development, and the enterprise scale and enterprise support have a significant impact on technological innovation activities in the stage of achievement transformation.

2. Research Design and Ideas

Since the output of technological innovation activities is not easy to observe directly, refer to the research of relevant scholars (Bode, 2004; Wu Yuming, 2006). This paper uses the number of patents as a proxy of patent(pa) for the measurement of technological innovations. At the same time, this paper also selected the proportion of new product sales revenue index as a percentage of product sales revenue to measure the technical innovation application status product (np), and comparative analysis of related factors affecting energy technology innovation and its application. Compared with patent indicators, new product sales revenue reflects the final result of the interaction of technological innovation input factors or related factors, reflecting the ultimate commercial value of innovation activities.

Energy technology innovation is inseparable from good macro-environmental support. Socio-economic development and market structure optimization can support, promote and promote energy technology innovation. This paper focuses on the analysis the impact of the macro factors to energy technology innovation from the perspective of openness, market competition, and entry barriers. Under the conditions of an open economy, with the increasing openness to the outside world, energy technology innovation has also been affected by the level of world development. Through product trade, domestic enterprises can understand the application of new energy technologies and stimulate energy companies to improve their technological level; through advanced equipment and the introduction of technology, it can accelerate the improvement of the level of technology research and development of domestic enterprises, increase the technology accumulation of energy companies, and through the export of products can also stimulate

enterprises to accelerate technological innovation and improve product competitiveness. Therefore, the increase in openness may have a positive impact on energy technology innovation. This paper selects the degree of participation of foreign direct investment, that is, the proportion of total industrial output value of foreign direct investment enterprises in total industrial output value to measure the degree of openness (kf).

The level of market competition is one of the main characteristics of the industry. The more companies in the industry, the more intense the competition within the industry. If the market is too competitive, it may force companies to reduce profit margins, pay more attention to short-term benefits, and ignore longer-term energy technology innovations. There are many indicators to measure the degree of market competition. Considering the availability of data, we refer to the research of relevant scholars (Xiao Hong, 2007). This article uses the growth rate of product sales revenue to reflect the market competition degree (mar) of the energy industry.

Barriers to industry entry have multiple effects on technological innovation. In industries with lower entry barriers and market competition, companies have the incentive to increase technological innovation and improve competitiveness. However, at the same time, the industry's economies of scale, product differentiation and technology complexity are often relatively low, Technological innovation can be easily imitated and stolen. The company's technological innovation activities may not receive sufficient financial returns. Certain barriers to entry can create conditions for companies to enjoy the benefits of their technological innovation and stimulate technological innovation activities. Industry barriers to entry are reflected in many aspects, among which the number of enterprises in the industry is an important aspect. This article uses the growth rate of the number of companies to reflect the industry's barriers to entry (ir). The greater the growth in the number of companies, the lower the barriers to entry in the industry.

In addition to macro factors, there are still many factors affecting energy technology innovation. When examining macro factors for energy technology innovation, this paper mainly considers the impact of R&D investment (rd) and human capital (cap). This article collects data on coal mining, oil and gas extraction, petroleum processing coking and nuclear fuel processing, power heating steam supply, and gas supply for the energy industry. The data are mainly derived from the “China Statistical Yearbook”, "China Science and Technology Statistical Yearbook" and "China Energy Statistical Yearbook" in 2000-2011

3. Data Processing and Empirical Test

In order to avoid spurious regression and other issues, the unit root test is first performed on the variables. The panel unit root test can make full use of the section information to improve the inspection efficiency. The corresponding panel unit root test method is more, and there are certain differences in the coefficients of auto regression and cross-section correlation setting. Based on different assumptions about cross-sectional correlation, these test methods can be divided into first-generation panel unit root tests with assumed cross-sectional units independent of each other, such as Breitung test, LLC test, IPS test, etc., and second-generation panel units that take into account cross-sectional correlation. Root test such as Choi test, Pesaran test, etc. Taking into account the different methods have their own advantages and disadvantages, in order to enhance the credibility of the test results, this paper selected the pesaran test, IPS test and LLC test three methods, of which the pesaran test takes into account the cross-sectional heterogeneity and cross-sectional correlation, The IPS test took into account the serial correlations that accounted for cross-section heterogeneity and distracters. LLC tests that the hypothesis sequence obeys AR (1) and that the correlation coefficients are the same, but allow individual fixed effects.

Because the traditional panel co-integration test assumes that the long-term error correction coefficient is equal to the short-term dynamic adjustment coefficient, the test result is sensitive to the parameter setting of the model, and the test efficiency is low. This paper selects the panel-based panel co-integration test proposed by West relund (2007).

Table 1 Panel Unit Root Test Results

index	Pesaran test	IPS test	LLC test
pa	-1.460 [0.696]	-1.143 [0.700]	-1.421 [0.4757]
d.pa	-3.571 [0.002]	-2.372 [0.039]	-6.697 [0.0440]
np	-0.114 [0.999]	-1.431 [0.462]	-4.251 [0.0657]
d.np	-2.719 [0.076]	-2.372 [0.039]	-9.355 [0.0000]
kf	2.610 [1.000]	-1.685 [0.246]	-5.449 [0.0188]
d.kf	-3.453 [0.002]	-3.301 [0.000]	-5.971 [0.0002]
ir	-1.270 [0.8836]	-1.042 [0.9977]	-1.270 [0.8836]
d.ir	-3.578 [0.0732]	-3.578 [0.0732]	-0.65082 [0.0432]
rdr	-1.324 [0.786]	-1.405 [0.468]	-5.519 [0.0165]
d.rdr	-2.815 [0.063]	-2.703 [0.009]	-6.630 [0.0010]
mar	-1.544 [0.633]	-1.166 [0.683]	-4.038 [0.2176]
d.mar	-2.482 [0.095]	-2.963 [0.002]	-8.614 [0.0000]
cap	-1.136 [0.881]	-0.574 [0.960]	-0.078 [0.9922]
d.cap	-2.658 [0.071]	-1.809 [0.179]	-8.961 [0.0160]

The AIC criterion is used to determine the leading lag order in the test, and the co-integration relationship between energy technology innovation and major macro variables is examined. According to the cointegration test results in Table 2, it can be seen that the Gt, Pt, and Pa statistics of the technical innovation achievement index pa and the openness index kf reject the original assumption that panel cointegration does not exist at a 5% significance level. The Ga statistic also rejects the null hypothesis that there is no cointegration relationship at the 10% level; the technical innovation achievement index pa and the industrial entry barrier index ir also have similar conclusions. The Gt, Pt, and Pa statistics are all also rejects the original hypothesis at the 5% level. If the original hypothesis is rejected, the Ga statistic also rejects the original hypothesis at the 10% level, and the test statistic of the technical innovation achievement index pa and the market competition degree index mar cannot reject the null hypothesis that panel cointegration does not exist. Therefore, there is a panel co-integration relationship between the external openness, industry entry barriers, and technological innovation outcomes in the macro variables, and there is no panel co-integration relationship between the market competition degree mar and the technical innovation achievement index pa. In addition to the Ga statistic, the technical innovation application index np, the openness index kf, the industry entry barrier index ir, and the market competition index mar test statistic all significantly reject the null hypothesis that there is no cointegration relationship. Compared with the indicators of technological innovation results, the technical innovation application index is more significantly affected by the degree of market competition.

Table 2 Panel cointegration test results

variable	Gt		Ga		Pt		Pa	
	statistic	P value	statistic	P value	statistic	P value	statistic	P value
Pa and kf	-4.552	0.000	-18.290	0.080	-6.189	0.044	-16.426	0.008
Pa and ir	-6.407	0.000	-16.303	0.096	-6.471	0.032	-16.749	0.002
Pa and mar	-0.365	1.000	-2.935	0.961	2.005	1.000	4.106	1.000
np and kf	-5.663	0.000	-9.379	0.801	-8.133	0.000	-15.115	0.009
np and ir	-3.761	0.000	-16.170	0.106	-13.420	0.000	-19.649	0.000
np and mar	-3.619	0.000	-18.017	0.091	-14.777	0.000	-17.407	0.000

There are many internal and external factors affecting energy technology innovation. Based on the analysis above, this paper further builds a panel data model to examine the role of macro factors. This article has introduced the lagged terms of technological innovation indicators as proxy variables that may miss variables, and finally built the following dynamic panel model:

$$pa_i = \beta_0 + \beta_1 p_{i-1} + \beta_2 k_i + \beta_3 ir_i + \beta_4 m_i + \beta_5 r_i + \beta_5 da_i + \alpha_i + u_i$$

$$np_i = \beta_0 + \beta_1 np_{i-1} + \beta_2 k_i + \beta_3 ir_i + \beta_4 m_i + \beta_5 r_i + \beta_5 da_i + \alpha_i + u_i$$

The indicators are all logarithmic, α_i indicates the industry differences, u_{it} indicates the random error terms.

Since the lagged terms of the interpreted variables are included, the intra-group estimation of the dynamic panel data model is also inconsistent. This paper uses the differential GMM and the system GMM to estimate the model.

First, we need to use the first-order difference to eliminate the individual effect in the model.

$$\Delta pa_i = \beta_0 + \beta_1 \Delta p_{i-1} + \beta_2 \Delta k_i + \beta_3 \Delta ir_i + \beta_4 \Delta m_i + \beta_5 \Delta r_i + \beta_5 \Delta da_i + \Delta u_i$$

$$\Delta np_i = \beta_0 + \beta_1 \Delta np_{i-1} + \beta_2 \Delta k_i + \beta_3 \Delta ir_i + \beta_4 \Delta m_i + \beta_5 \Delta r_i + \beta_5 \Delta da_i + \Delta u_i$$

Secondly, according to the differential GMM, all possible lags of selection of pa_{it}, np_{it} are used as instrumental variables of endogenous variables $\Delta pa_{it-1}, \Delta np_{it-1}$; due to the possible problems of differential GMM, for example, too many instrument variables may also have weak instrumental variables and the explanatory power of instrument variables may be very Lower and so on, we also use the system GMM proposed by Arellano and Bover (1995) et al. to estimate the model and improve the estimation efficiency of the model by combining the horizontal GMM which take $\Delta pa_{it-1}, \Delta np_{it-1}$ as the tool variables of riginal equations pa_{it-1}, np_{it-1} and the differential GMM.

The estimated results of the model are shown in Table 3, the coefficient of the model combined with the significant wald test statistic is significant at the 1% level. The null hypothesis that the explanatory variable coefficient is zero is rejected. Sargan test results also indicate that the instrumental variable is valid. The AR (2) test cannot reject the null hypothesis that there is no second-order autocorrelation in the residual after difference, so the model setting is reasonable. It can be seen that the coefficient of the lagging term is very significant in the equations of technological innovation (pa) and technological innovation (np), indicating that the innovative application and research foundation of energy technology is closely related. In addition to macro environmental impacts, there are many factors affecting energy technology innovation, the role of

China's energy industry's own research and development capabilities cannot be ignored. In the equation of technological innovation (pa), the effect of the degree of external openness (kf) is significant at the level of 10% significance. At present, the level of China's energy technology innovation is still relatively backward, and the degree of openness to the outside world is conducive to improvement. The improvement of the degree of external openness will be contribute to catch up with the China's energy technology; the role of industry barriers to entry (ir) is also relatively significant, but the effect is relatively small, and the reduction of barriers to entry can promote the innovation of energy technologies; the role of market competition (mar) is not significant. With the increase of market competition, companies may pay more attention to the development of short-term projects and neglect the energy technology innovation with long development cycle. In the application of technological innovation (np) equations, the impact on the degree of external openness (kf) is not significant. It may be because the proportion of foreign investment products in China's energy industry is currently very small, which has little effect on the promotion of innovative products; barriers to industry entry The role of (ir) is quite significant. It is clear that the reduction of barriers to entry can attract more enterprises to enter the energy industry and accelerate the promotion of new products; the degree of market competition (mar) has a greater impact on the application of technological innovation results, and the degree of market competition increases can promote enterprises to improve the technical content of enterprise products and enhance product competitiveness.

Table 3 Estimated results of the dynamic panel model

explained variable	explaining v ariable	difference GMM		System GMM	
		first step	Second step	first step	Second step
pa	pa(-1)	.5117173	.2612709	.4774419	.3043813
		0.000	0.011	0.000	0.003
	kf	.7802128	1.598733	9.072842	5.780427
		0.043	0.083	0.043	0.094
	ir	.3346981	.1567837	.1522595	.1444413
		0.120	0.000	0.091	0.034
	mar	39.26872	-37.25595	54.57811	-16.46233
		0.346	0.375	0.498	0.793
	rdr	12.77429	6.95558	3.132871	2.59871
		0.670	0.253	0.974	0.653
	cap	-.0014473	-.0005782	-.0009948	-.0014281
		0.282	0.332	0.524	0.214
	c	24.25901	13.77141	45.68324	1.992031
		0.595	0.522	0.620	0.979
np	np(-1)	0.4414559	.6268381	.632016	.753062
		0.000	0.000	0.000	0.000
	kf	0.0350297	.0283347	.0516085	.0186845
		0.589	0.607	0.654	0.535
	ir	.0006715	.0005025	.0014625	.0005039
		0.021	0.037	0.074	0.051
	mar	.3306236	.3717341	.2299292	.2552515
		0.074	0.079	0.104	0.062
	rd	.3556304	.6283106	.7978631	.5553616
		0.036	0.087	0.139	0.020
	cap	.0000357	.0000331	.0000164	.000156
		0.000	0.007	0.119	0.028
	c	-.3799668	-.6513451	-.4402672	-.2803285
		0.698	0.213	0.321	0.361

4. The Main Research Conclusions and Discussions

According to the above empirical analysis, it can be seen that macroeconomic factors such as the degree of openness to the outside world, industry barriers to entry, and market competition have an impact on the innovation and application of China's energy technology, but the role of relevant macro factors still exists difference in technological innovation and application. Generally speaking, the degree of openness to the outside world can promote the innovation and application of energy technologies in China. The reduction of barriers to entry in the industry has a certain effect on energy technology innovation, while it has a greater role in the application of energy technologies, and the reduction in market competition for energy technology innovation. The effect is not significant, but the impact on the application of energy technology innovation is obvious.

The R&D cycle of energy technology innovation is long and the risk is high. Under the background of low energy technology level in China, the improvement of opening degree to the outside world can help China's energy technology catch up. Under the guidance of the development direction of foreign energy technologies, China’s energy industry can use foreign direct investment to reduce the research and development risk of energy technologies through technological imitation and learning; through cooperation and competition with foreign companies, it can improve the technological innovation capabilities of energy companies and Technological innovation management capabilities; The use of technology spillovers from foreign direct investment can rapidly upgrade China's energy technology innovation level. At present, the barriers to entry in the energy industry in China are still very high. The main industries are basically in the state of monopoly competition and oligopoly. Properly reducing the barriers to entry in the energy industry can stimulate enterprises to increase technological innovation and new product development and promote energy technology progress and its application. The degree of market competition can affect the market behavior of enterprises. Overall, the current level of competition in China's energy market is not high. Under the background of tight energy supply, the increase in market competition will stimulate enterprises to expand their production scale, and to technological innovation. The impact of the market is relatively small, so the role of market competition in the application of technological innovation is more obvious.

Acknowledgements

This research is supported by the Science and technology project of Guangdong Province (No. 2014B080807035, No. 2014B030303005, No. 2015B080807015, No. 2017B030301010).

References

[1] Lee, C. Y A new perspective on industry R&D and market structure[J]. The journal of industrial economics, 2005(11):101-122.

[2] Mallett Alexandra. Social acceptance of renewable energy innovations: The role of technology cooperation in urban Mexico [J]. Energy Policy, 2007,35(5):2790-2798.

[3] B ode E. The spatial pattern of localized R&D spillovers: an empirical investigation for Germany [J]. Journal of Economic Geography, 2004(4)：43~64.

[4] Joseph Z. Shyu,Yi-Chia Chiu,Chao-Chen You. A cross-national comparative analysis of innovation policy in the integrated circuit industry[J]. Technology in Sciety, 2001(23): P227-240.

[5] Hu Yidong, Zhong Weijun. Empirical research on the influencing factors of high-tech companies' technological innovation performance [J]. China Science and Technology Forum, 2011, (4): 80-85.

[6] Liu Wei. Study on the Industry Differences of the Factors Affecting China's Technological Innovation: Taking the High-tech Industry as an Example[J]. Journal of Xinjiang University of Finance and Economics, 2009, (4):21-28.

[7] Chen Cheng, Liu Hedong. Research on the Measurement and Influencing Factors of China's High-tech Industry Innovation Performance: A Two-stage Analysis Based on Innovation Chain Perspective [J]. Science and Technology Progress and Policy, 2012, 29(1):133-137.

[8] Jia Wenting, Wu Zhong. Research on the Dynamic Factors of Renewable Energy Technology Innovation Based on SD Model[J]. Journal of Information, 2012, 31(2): 32-36,18.

[9] Tao Ye, Su Shiwei, Qi Zhongying et al. R&D storage analysis of China's energy technology[J]. China Soft Science, 2007, (6):156-160.

10] Bode E. The spatial pattern of localized R&D spillovers: an empirical investing for Germany [J]. Journal of Economic Geography, 2004 (4): 43~64.

[11] Wu Yuming. Research on the application of spatial econometric model in provincial R&D and innovation[J]. Journal of Quantitative Ecy, 2006(5):74-85.

[12] Nyblom, Jukka and Andrew Harvey. Tests of common stochastic trends[J]. Econometric Theory, 2000, 16:176-199.

[13] Westerlund, J. Testing for error correction in panel data[J]. Oxford Bulletin of Economics and Statistics, 2007,69: 709–748.