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Research on the Effect of Technological Innovation on the Energy Consumption in Heilongjiang Province

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Abstract: Since the reform and opening up, China's rapid industrial development has always been an important force for supporting the continuous growth of national economic aggregate and such industrial development has contributed to the significant growth in energy consumption. Over the years, the irrational energy consumption structure, backward technology and stubbornly high energy consumption per unit of GDP in many domestic heavy industrial base provinces have result in increasingly serious environmental pollution and restricted the coordinated development of energy consumption, economic growth and environmental protection. Through the statement of the status quo of energy consumption and technological innovation in Heilongjiang, an old industrial base, and based on the result of GRA of the effect of technological innovation on energy consumption, specific recommendations for reducing the energy consumption per unit of GDP in Heilongjiang are put forward in this article.

Keywords: Technological innovation, GRA, Energy consumption

1 Introduction

Human development is bound up with human understanding and utilization of energy. It is the constant scientific and technological innovation that has allowed man to gradually know himself and constantly obtain the desired energy resources from nature, thereby promoting the rapid development of human society and economy. However, the constant expansion of economic scale and continuous improvement of people's living standards have in turn contributed to higher requirements for the quantity and quality of energy.

With the continuous rapid growth of China's economy, the contradiction between energy production and consumption has become increasingly prominent and insufficient energy reserves have become a major bottleneck restricting China's sustainable economic development. An important way to solve the dilemma is to advance technological innovation[1]. From an overall perspective, although technological innovation has resulted in various problems, the solution to energy-related problems must rely on it. On the one hand, it can enhance energy use efficiency, and on the other hand, it can develop new energy resources and renewable energy resources to maintain energy sustainability.

Since the reform and opening up, as a national heavy industrial base city, the background of sustained economic growth of Heilongjiang is stubborn high total energy consumption and energy consumption quality remaining low. In spite of Heilongjiang's constant adjustment of three-industry structure and vigorous development of the tertiary industry since the “12th Five-Year” Plan, the actual situation dominated by industry hasn't gone through substantive changes. Therefore, coupled with the “Green” development concept proposed based on the national “13th Five-Year” Plan, Heilongjiang's advancement of energy consumption structure and quality optimization must gradually achieve the goal of the speed reduction of energy consumption per unit of GDP exceeding the growth speed of energy consumption by depending on technological innovation and process and equipment innovations to reduce energy consumption per unit of GDP. Against this background, the study on the effect of technological innovation on Heilongjiang's energy consumption can provide theoretical support for the formulation of science and technology policies and energy management policies by relevant departments of Heilongjiang Province[2-3], and provide decision-making basis for Heilongjiang's realization of the goal of continuous energy consumption reduction during the “13th Five-Year” Plan period.

2 Energy Consumption and Technological Innovation in Heilongjiang Province

2.1 Analysis of total energy consumption and structure in Heilongjiang

Heilongjiang, as a domestic typical resource-type province, has always depended on its own resource endowment advantages for regional economic development. As shown in Fig. 1, during the

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2000~2011period, Heilongjiang's total energy consumption showed an overall upward trend, but since 2012, the turning point of total energy consumption has appeared, showing a downward trend year after year. Overall, Heilongjiang's total energy consumption was still at a high level, involving an increase from 56.631 million tons of standard coal in 2000 to the maximum 100.318 million tons of standard coal in 2011 during the observation period, with average annual increase of 5.51% before 2011, showing a downward trend year after year after 2012, with total energy consumption realizing average annual decrease of 2.5%. Heilongjiang saw an energy consumption structure remaining dominated by traditional energy resources such as coal, petroleum, natural gas and electricity and a low development and utilization level of new energy resources like wind power. The total coal consumption had a great effect on the changes in the total energy consumption, which is the main cause of reduced total energy consumption in 2012, and consumption of energy resources such as petroleum, national gas, hydropower and wind power had gentle volatility during the observation period.

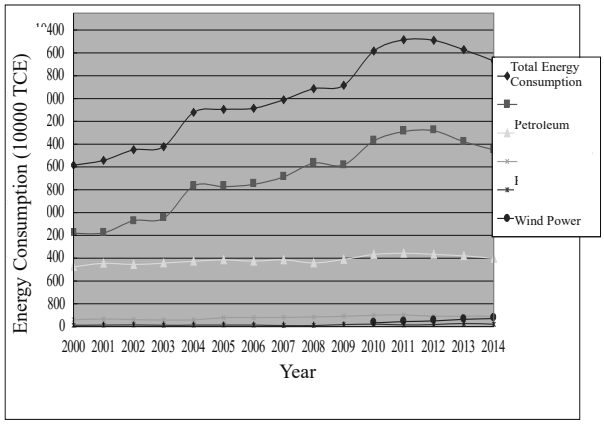

Fig.1 Heilongjiang's total energy consumption and consumption structure scatter diagram 2000~2014

Tab.1 Proportions (%) in the energy consumption constitution in Heilongjiang Province

Year	Coal	Petroleum	Natural Gas	Hydropower	Wind Power
2000	57.8	37	4.3	0.9	—
2001	56.5	38.1	4.6	0.8	—
2002	59.9	35.1	4	1	—
2003	60.2	35.3	3.7	0.8	—
2004	65.6	30.5	3.1	0.8	—
2005	64.4	30.7	4.2	0.7	—
2006	65.2	30	4.1	0.7	—
2007	66	29.4	4.1	0.5	—
2008	68.7	26.8	4	0.5	—
2009	67	27.9	4.3	0.8	—
2010	67.4	26.2	4.1	0.9	1.4
2011	68	25.6	4.1	0.6	1.7
2012	68.4	25.2	3.6	0.7	2
2013	66.8	25.6	3.8	1.2	2.6
2014	66.5	25.7	3.9	0.9	3

Source of Data: Heilongjiang Statistical Yearbook 2000~2015

It can be clearly seen in Tab.1 that coal occupied a proportion of over 56.5% in the energy consumption from 2000 to 2014, reaching the highest proportion 68.7% in 2008, the proportions of such non-solid energy as petroleum and natural gas fluctuated between 28%~43% and the proportions of such renewable energy as wind power and hydropower were significantly low in the energy consumption structure, with the proportion of hydrogen maintaining around 1%, and the wind power involved in formal consumption since 2010 occupying a proportion of not more than 3%, which shows that Heilongjiang's hasn't changed the situation in which its energy consumption structure remains dominated by coal, and energy consumption structural adjustment is the focus of the current energy management work.

2.2 Analysis of energy consumption per unit of GDP in Heilongjiang

According to the requirements in the national overall energy-saving and emission-reduction planning target, Heilongjiang has realized gradual reduction of energy consumption per unit of GDP year after year (as shown in Fig. 2) by adopting various effective measures. In the observation period, the average annual decrease was 1.35%, and from 2003 to 2004, Heilongjiang's energy consumption per unit showed slight increase because technological innovation lagged behind the large-scale energy consumption demand due to heavy industrialization development, after which Heilongjiang saw significant downward trend of energy consumption per unit of GDP, which shows that during the period from 2004 to 2014, Heilongjiang's energy consumption efficiency gradually increased year after year and important influencing factors relating to it, i.e. energy consumption structure optimization and technological innovation level, steadily improved.

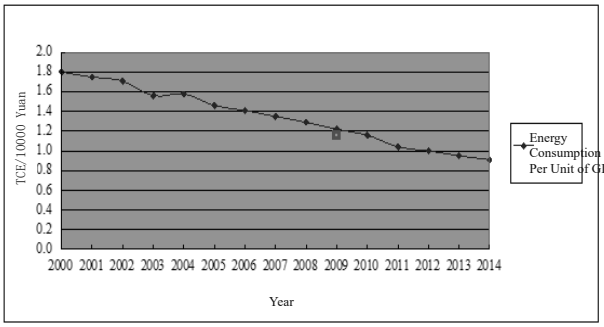

Fig. 2 Heilongjiang's Energy Consumption per Unit of GDP 2000~2014

2.3 Situation of technological innovation in Heilongjiang

During the “10th Five-Year” Plan and the “11th Five-Year” Plan period, Heilongjiang saw increasing spending on research and experimental development year after year, and the R&D expenses increased from 1.36 billion Yuan in 2000 to 10.79 billion Yuan in 2010 during

the period 2000～2010 (as shown in Fig. 3) , showing average annual increase of 23.4%, with the proportion of R&D in GDP rising from 0.4% in 2000 to 1.05% in 2010, indicating Heilongjiang Provincial Government's attention to technological innovation input. However, during the "12th Five-Year" Plan period, Heilongjiang's R&D expenses dropped to 11.16 billion Yuan in 2014 after reaching the peak value 12.96 billion Yuan in 2012 in the observation period, showing that due to the effect of economic development's entry into the new normal, Heilongjiang's units involved in technical R&D activities was greatly affected by external environmental conditions in terms of R&D input. Besides, Heilongjiang's technological innovation input intensity was shown by the technical introduction expense and absorption & digestion expense indicators involved in the science and technology activities of large and medium-sized industrial enterprises in Heilongjiang.

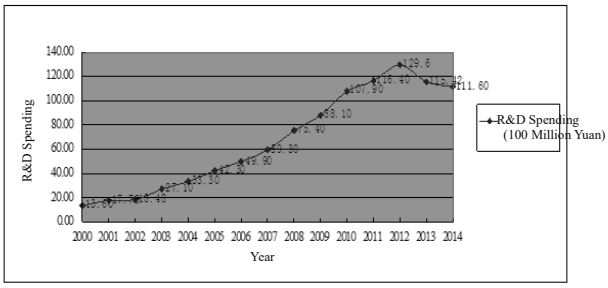

Fig.3 Heilongjiang's R&D Spending

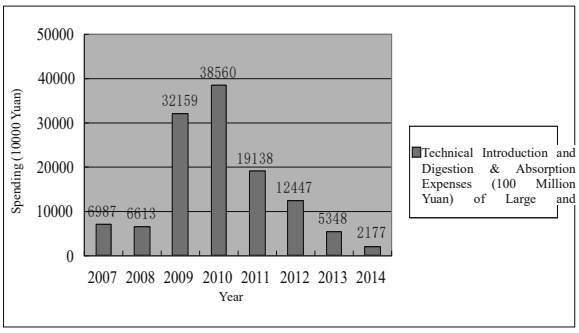

Fig. 4 Technical Introduction and Digestion & Absorption Expenses in the Science and Technology Activities of Large and Medium-sized Enterprises in Heilongjiang Province

As shown in Fig.4, Heilongjiang saw an upward trend of technical introduction expenses and absorption & digestion expenses in the science and technology activities of large and medium-sized industrial enterprises in the "11th Five-Year" Plan period, with the expenses even reaching up to 385.6 million Yuan in 2010, followed by a downward trend year after year after 2011, with the expenses dropping to 21.77 million Yuan in 2014, merely 5.6% of the expenses in 2010. However, under the guidance of China's policies for advancing the transformation and upgrade of northern old industrial base cities, Heilongjiang Provincial Government has always provided various kinds of support for advancing technological innovation and constantly elevated the technological innovation level while shifting the local economic development mode.

Although Heilongjiang failed to continue the trend of significantly increasingly high scientific and technological innovation level year after year (2000 to 2010) during the "12th Five-Year" Plan period, it can be seen from the downward trend of energy consumption per unit of GDP during the period 2000~2014 in Heilongjiang that technological innovation has significant negative effect on energy consumption. However, due to the differences in development environment involving economic foundation, technical development level and degree of opening to the outside world in different areas, the effect of technological innovation on energy consumption shows the characteristics of hierarchy. In the eastern area of China, favorable conditions like solid economic foundation, high technical level, advanced management means and strong innovative ability have contributed to the comparative advantages in terms of improving energy utilization efficiency and strengthening the role of technological innovation in conservation involved in energy consumption in the eastern area of China. However, compared with the eastern area, the northeastern area where Heilongjiang Province lies is backward in terms of economic foundation, technical development level and degree of opening to the outside world. Besides, Heilongjiang, as a major resource and energy production province, is still in the dilemma "the more abundant resources an area in China has, the lower energy efficiency the area has"[4]. These restrictive factors have contributed to the weak role of technological innovation in energy consumption reduction in Heilongjiang Province. In addition, the features of a typical old industrial base province have caused Heilongjiang to continue undertaking many manufacturing projects characterized by high energy consumption, low technical level and serious environmental pollution, which has weaken the role of technological innovation in conservation involved in energy consumption in Heilongjiang. However, seen from another angle, the presence of this phenomenon has caused Heilongjiang to propose a planning scheme for shifting the economic development mode and vigorously developing the tertiary industry and cyclic economy, giving full play to the role of technological innovation in improving energy consumption efficiency.

3 Gray relational analysis of effect of technological innovation in energy consumption in Heilongjiang

3.1 Model and method

Relational degree refers to the correlation degree between two things and it quantitatively describes the relative changes between elements. GRA analysis is quantitative comparative analysis of system situation. Its

essence is to compare the degree of closeness between the curve composed of several sequences and the curve geometry composed of ideal sequences, the closer the geometry degree, the greater its relational degree. Therefore, GRP can be used to analyze and compare evaluation object's advantages and disadvantages, with specific steps as follows [5]:

Denote one sequence for eliminating dimensions as $\{\hat{X}^{(0)}(t)\}$ and the other sequence as $\{X^{(0)}(t)\}$ and if the values of the two sequences at the same moment k are denoted by $\{\hat{X}^{(0)}(k)\}$ and $\{X^{(0)}(k)\}$, i.e $\hat{X}^{(0)}(k)=\{\hat{X}^{(0)}(1),\hat{X}^{(0)}(2),...,\hat{X}^{(0)}(n)\}$, $X^{(0)}(k)=\{X^{(0)}(1),X^{(0)}(2),...,X^{(0)}(n)\}$, the relational coefficient is

$$\eta(k)=\frac{\min\min\left|\hat{X}^{(0)}(k)-X^{(0)}(k)\right|+\rho\max\max\left|\hat{X}^{(0)}(k)-X^{(0)}(k)\right|}{\left|\hat{X}^{(0)}(k)-X^{(0)}(k)\right|+\rho\max\max\left|\hat{X}^{(0)}(k)-X^{(0)}(k)\right|}$$

Where:

① $\left|\hat{X}^{(0)}(k)-X^{(0)}(k)\right|$ is the absolute error of the k^{th} point $X^{(0)}$ and $\hat{X}^{(0)}$

② $\min\ \min\ \left|\hat{X}^{(0)}(k)-X^{(0)}(k)\right|$ is two level smallest difference

③ $\max\ \max\ \left|\hat{X}^{(0)}(k)-X^{(0)}(k)\right|$ is two level maximum difference

④ ρ is referred to as resolution, 0<ρ<1, with ρ=0.5 generally taken

⑤ As for a sequence with inconsistent units and different initial values, conduct initialization first before relevant coefficient calculation, i.e. all data of this sequence divided by the first data respectively

Then the relational degree is denoted as: $r=\frac{1}{n}\sum_{k=1}^{n}\eta(k)$, where r is called the relational degree of $\hat{X}^{(0)}(k)$ and $X^{(0)}(k)$

3.2 Empirical analysis of the effect of technological innovation on energy consumption in Heilongjiang

3.2.1 Establishment of an indicator system for the effect of technological innovation on energy consumption in Heilongjiang

Based on the actual situation of the effect of technical innovation in Heilongjiang on the energy consumption in Heilongjiang, under the premise of strictly complying with the principle of completeness, the operability principle, the independence principle, the principle of systematization and the principle of comparability, based on the emphasis on indicator choice in existing research, the article plans to select indicators for evaluation of effect on energy consumption in terms of the development of regional economy, the whole province's R&D activities, the R&D activities of large and medium-sized industrial enterprises in Heilongjiang and scientific achievement application handling and technology introduction and select total energy consumption, coal and petroleum consumption and energy consumption per unit of GDP as reference variables for gray relational analysis(with specific indicators as shown in Tab.2).

Tab.2 Evaluation Indicator System for the Effect of Technological Innovation on Energy Consumption in Heilongjiang

Serial No.	Indicator Selection Direction	Selected Indicators
1	Regional economic development	X1: GDP (100 million Yuan)
2	The whole province's R&D activities	X2: Number of R&D staff (10000)
3		X3: R&D spending (100 million Yuan)
4	R&D activities of large and medium-sized industrial enterprises in Heilongjiang	X4: Number of R&D staff involved in science and technology activities of large and medium-sized industrial enterprises (10000)
5		X5: Number of science and technology activity agencies of large and medium-sized industrial enterprises (PCS)
6		X6: Number of R&D enterprises involved in science and technology activities of large and medium-sized industrial enterprises (PCS)
7		X7: R&D spending of science and technology activities of large and medium-sized industrial enterprises (100 million Yuan)
8	Scientific achievement application handling and technology introduction	X8: Number of patent applications handled (item)
9		X9: Number of granted patents (item)
10		X10: Transaction value in the technical market (100 million Yuan)
11	Target variable-energy consumption	M1: Energy consumption (10000 TCE)
12	Target variable-energy consumption structure	M2: Coal consumption (10000 TCE)
13		M3: Petroleum consumption (10000 TCE)
14	Target variable-energy consumption per unit	M4: Energy consumption per unit of GDP(10000 Yuan/TCE)

3.2.2 Analysis of effect of technological innovation on the total energy consumption in Heilongjiang

The constant elevation of the technological innovation level in one area has a significant positive external effect on the energy consumption efficiency in this area, but such positive role of promotion may shows certain posteriority in an area dominated by industry, shown by insignificant degree of relation between technological innovation-related influencing factors and reduced total energy consumption in this area. As for as Heilongjiang Province is concerned, this phenomenon is more significant.

Tab.3 Degree of Gray Relation between Energy Consumption and Each Technological Innovation Indicator in Heilongjiang

Indicator	Gray Relational Degree	Gray Relational Degree Ranking
X1: GDP	0.506	6
X2: Number of R&D staff	0.701	4
X3: R&D spending	0.501	7
X4: Number of R&D staff involved in science and technology activities of large and medium-sized industrial enterprises	0.760	2
X5: Number of science and technology activity agencies of large and medium-sized industrial enterprises	0.838	1
X6: Number of R&D enterprises involved in science and technology activities of large and medium-sized industrial enterprises	0.739	3
X7: R&D spending of science and technology activities of large and medium-sized industrial enterprises	0.555	5
X8: Number of patent applications handled	0.430	10
X9: Number of granted patents	0.435	9
X10: Transaction value in the technical market	0.464	8

It can be learned from Tab.3 the calculation result of the degree of gray relation between technological innovation and total energy consumption in Heilongjiang, the indicators with a relational degree of greater than 0.7 (Level III accuracy) are X2, X4, X5 and X6, which can be used as important indicators for the effect of technological innovation on total energy consumption and whose effects on the total energy consumption in Heilongjiang are mainly reflected in the following aspects: the increase in the number of R&D staff, the number of R&D staff involved in science and technology activities of large and medium-sized industrial enterprises, the number of science and technology activity agencies of large and medium-sized industrial enterprises and the number of R&D enterprises involved in science and technology activities of large and medium-sized industrial enterprises has promoted the scientific and technical development activities, enhanced the vigor of regional economic activities, helped expand the industrial production scale and led to the increase in the total energy consumption in Heilongjiang, at the same time, scientific and technological innovation has pulled the development of new industrial technologies in Heilongjiang, contributed to the change of the economic development mode and held back the growth rate of energy consumption to a certain degree. However, seen from the overall trend of energy consumption, these factors had greater effect on energy consumption acceleration than on energy consumption reduction before 2011, and since 2012, their influence has undergone radical changes, contributing to the decline trend of total energy consumption in Heilongjiang.

3.2.3 Analysis of effect of technological innovation on the energy consumption structure in Heilongjiang

Generally speaking, in the energy consumption structure, coal and petroleum consumptions are representative, so the analysis of the Heilongjiang's energy consumption structure can be based on the calculation result of the degree of gray relation between coal and petroleum consumption and technological innovation-related influencing factors.

It can seen in Tab.4 that the indicators with a relational degree of greater than 0.7 (Level III accuracy) are merely X4, X5 and X6, and it can be seen based on the contents of the selected indicators that the number of R&D staff involved in science and technology activities of large and medium-sized industrial enterprises, the number of enterprises and scientific research institutions engaged in research and experimental development have a large degree of relation with the coal consumption in Heilongjiang. It can be learned based on the energy consumption situation in Fig.1 that the upward trend of coal consumption in Heilongjiang is bound up with the development mode of the old industrial base, and the role of all factors involved in the science and technology activities of large and medium-sized industrial enterprises in reducing coal consumption failed to change the upward trend of the total energy consumption during the period 2000~2011, but since 2012, such role has become noticeable.

Tab.4 Degree of Gray Relation between Coal Consumption and Technological Innovation-related Influencing Factors in Heilongjiang

Indicator	Gray Relational Degree	Gray Relational Degree Ranking
X1: GDP	0.513	6
X2: Number of R&D staff	0.656	4
X3: R&D spending	0.506	7
X4: Number of R&D staff involved in science and technology activities of large and medium-sized industrial enterprises	0.764	2
X5: Number of science and technology activity agencies	0.801	1

of large and medium-sized industrial enterprises		
X6: Number of R&D enterprises involved in science and technology activities of large and medium-sized industrial enterprises	0.704	3
X7: R&D spending of science and technology activities of large and medium-sized industrial enterprises	0.556	5
X8: Number of patent applications handled	0.450	9
X9: Number of granted patents	0.443	10
X10: Transaction value in the technical market	0.482	8

It can seen in Tab.5 that the technological innovation-related influencing factors with a degree of gray relation with total petroleum consumption being greater than 0.7 are merely X2, X5 and X6, and it can be found based on the change trend of consumption of various kinds of energy sources in Heilongjiang in Fig. 1 that petroleum consumption steadily increases with the growth of GDP, showing positive correlation with science and technology activities of large and medium-sized industrial enterprises. In order to protect the development environment, the government's R&D investment will focus on the development of clean energy like natural as to gradually change the low-efficiency energy consumption structure in which traditional energy consumption occupies a too large proportion.

Tab.5 Degree of Gray Relation between Petroleum Consumption and Technological Innovation-related Influencing Factors in Heilongjiang

Indicator	Gray Relational Degree	Gray Relational Degree Ranking
X1: GDP	0.552	4
X2: Number of R&D staff	0.830	1
X3: R&D spending	0.568	6
X4:Number of R&D staff involved in science and technology activities of large and medium-sized industrial enterprises	0.656	5
X5:Number of science and technology activity agencies of large and medium-sized industrial enterprises	0.790	2
X6:Number of R&D enterprises involved in science and technology activities of large and medium-sized industrial enterprises	0.740	3
X7: R&D spending of science and technology activities of large and medium-sized industrial enterprises	0.565	7
X8:Number of patent applications handled	0.415	9
X9: Number of granted patents	0.382	10
X10: Transaction value in the technical market	0.473	8

3.2.4 Analysis of effect of technological innovation on the energy consumption per unit of GDP in Heilongjiang

The quality of science and technology activities represent a country's scientific and technological innovation level and the quality level of science and technology activities has effect relationships of various degrees with the factors involved in every aspect of regional R&D activities. It can seen in Tab. 6 that the indicators with a degree of gray relation between technological innovation-related influencing factors and the energy consumption per unit of GDP in Heilongjiang being greater than 0.7 are merely X6 and X8, but two indictors that have a great effect on the quality of science and technology activities, i.e. patent applications handled and transaction value in the technical market, have a low degree of relation with the energy consumption per unit of GDP in Heilongjiang. As the backbone of scientific and technological innovation in Heilongjiang, all indictors for the science and technology activities of large and medium-sized industrial enterprises, except for the number of R&D enterprises, have a similarly low degree of relation with energy consumption reduction per unit of GDP. However, seen from the actual situation of Heilongjiang as an old industrial base and resource-type province, most energy sources are consumed by large and medium-sized industrial enterprises, the R&D activity quality of which has a direct effect on the overall improvement of Heilongjiang's energy utilization rate. Large and medium sized enterprises are also a focus group in the new energy development & utilization and energy-conservation & emission-reduction work.

Tab.6 Degree of Gray Relation between Energy Consumption per Unit of GDP and Technological Innovation-related Influencing Factors in Heilongjiang

Indicator	Gray Relational Degree	Gray Relational Degree Ranking

X1: GDP	0.667	6
X2: Number of R&D staff	0.692	4
X3: R&D spending	0.657	7
X4: Number of R&D staff involved in science and technology activities of large and medium-sized industrial enterprises	0.575	8
X5: Number of science and technology activity agencies of large and medium-sized industrial enterprises	0.679	5
X6: Number of R&D enterprises involved in science and technology activities of large and medium-sized industrial enterprises	0.779	1
X7: R&D spending of science and technology activities of large and medium-sized industrial enterprises	0.694	3
X8: Number of patent applications handled	0.750	2
X9: Number of granted patents	0.450	10
X10: Transaction value in the technical market	0.529	9

4 Conclusions and Recommendations

It can be seen through the above analysis of the effect of technological innovation on energy consumption in Heilongjiang that Heilongjiang has achieved preliminary results in terms of energy consumption quality improvement and benefits. In the situation of sustained growth of GDP, the total energy consumption has declined year after year since 2012, when it reached the peak value, and the consumption of main energy coal has gone through synchronous changes while the consumption of new energy sources has been on the steady increase. However, seen from the result of analysis of gray relation between each technological innovation-related indicator and energy consumption, the degree of relation between Heilongjiang's work performance in terms scientific research fund input, patent grant, technical transformation, etc. and the substantial increase in energy consumption benefit and efficiency is not obvious, with no full play given to the role in promoting the reduced energy consumption per unit of GDP. The scientific and technological innovation of large and medium-sized industrial enterprises, as a representative group of energy consumption, still has a positive effect on energy consumption efficiency that hasn't exceeded the growth rate of their energy demands. Therefore, during the “13th Five-Year” Plan period, under the guidance of the national “Green” and “Innovative” development concept, Heilongjiang can realize the continuous steady growth of economic aggregate, reduced energy consumption per unit of GDP and gradual quality level elevation in the following aspects:

(1) To give full play to the linkage role of energy-saving policies and fiscal subsidies and improve energy use efficiency. Heilongjiang should bring in mandatory resource-saving technical policies, perfect the energy-saving targets evaluation system, advance the development process of circular economy in many fields[6], make full use of such means as energy price regulation and control, tax deduction and exemption and policy-type subsidies to cause large and medium-sized industrial enterprises to increase R&D input and exert the overflow effect of technical innovations, especially the synchronous promotion role of energy-saving and fiscal and taxation policy support, guide enterprises to attach great importance to the development and utilization of energy-saving technology to constantly improve energy use efficiency and realize the benign interaction between economic growth acceleration and maximum energy consumption reduction.

(2) To construct a more rational and effective R&D investment and distribution mechanism and improve the use efficiency of science and technology funds. The government can establish special energy conservation funds based on its own financial situation and promote the socialized operation of the special energy conservation funds with practically effective fiscal and taxation policies, absorb a large quantity of social investment to make up for the inadequate energy conservation fund input [7]. At the same time, the government should actively bring in a market competition system for R&D fund distribution, adopt an appropriate promotion mechanism based on different R&D types and effectively combine government-led basic R&D input and enterprise-led application technology R&D input depending on policy support to improve the use efficiency of R&D funds.

(3) To improve the quality of science and technology activities of large and medium-sized industrial enterprises. Heilongjiang should promote the constant upgrade of the industrial structure on the basis of strengthening the technical input of large and medium-sized industrial enterprises and optimizing the industrial structure, advance the development of high-tech industries featuring low energy consumption and high value added in an all-round way, accelerate product structure upgrade by depending on technical innovations, effectively control the energy efficiency level of new production capacity, realize reduce energy consumption per unit of GDP in the production process and inspire the human capital investment of R&D

personnel in large and medium-sized enterprises by improving the rate of human capital return of enterprise personnel directly involved in technical R&D to realize the sustainable improvement of science and technology activity quality of large and medium-sized enterprises.

(4) To adopt effective measures to promote the transformation and absorption of scientific and technological results. Currently, Heilongjiang has a relatively low production technology marketization level and is weak in the transformation of existing technical achievements, which has greatly restricted the role of technological innovations in energy conservation. Therefore, Heilongjiang should accelerate the development process of the technical property right trading market, construct a relatively complete service platform, accelerate the efficiency of transformation from technical achievements to practical productive force and give full play to the positive reinforcement role of technological innovation in the energy use efficiency in Heilongjiang.

(5) To further optimize the energy consumption structure and increase the consumption scale and coverage of clean energy sources. Facing the current continued sluggishness of coal and petroleum prices, increasingly serious environmental pollution problems and severe situation in which resource-type provinces urgently need transformation and upgrading, the demand for exploitation and utilization of new energy sources has increased dramatically. The local governments in Heilongjiang Province need to elevate the new energy conversion and utilization level by depending on scientific and technological innovation and national fiscal support policies for the transformation and upgrade of old industrial base cities, develop technologies for clean use of traditional energy sources and increase efforts to popularize oil-gas hybrid vehicles and lithium battery-powered cars in the market to realize the further optimization of the energy consumption structure in the “13th Five-Year” Plan period.

References

[1]Teng Yuhua. Technological Progress and Regional Energy Demand-Empirical Analysis Based on Inter-provincial Data [J]. Journal of Xinjiang Finance &Economics Institute, 2010 (4)（in Chinese）

[2]Liu Yuenyen, Liu Fenchao. Technological Progress-based China's Energy Consumption Rebound Effect - Empirical Testing Based on the Use of Inter-provincial Panel Data [J].Resources Science, 2008 (9)（in Chinese）

[3]Hao Hai, Gu Peiliang, Yin Chun-hua. Interaction between Technological Progress and Energy Consumption [J]. Journal of Southeast University (Philosophy and Social Science Edition), 2002 (10) （in Chinese）

[4]Shi Dan. Analysis of Regional Difference in Energy Efficiency and Energy-saving Potential in China [J].China Industrial Economy, 2006(10)（in Chinese）

[5]Du Dong. Modern Comprehensive Evaluation Methods and Case Selection [M]. Beijing: Tsinghua University Press,2005: 111-115（in Chinese）

[6] Feng Zhijun. Circular Economy Lies in Practice - Circular Economy Summit Forum of China [M]. Beijing: People's Publishing House, 2006（in Chinese）

[7] Du Yilong, Zhang Dan. Cause of Difficulty in Reducing Energy Consumption Per Unit of GDP and Analysis of Countermeasures [J]. Journal of Xi'an University of Arts & Science(Natural Science Edition) , 2007(5) （in Chinese）