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Analysis of Changes in Energy Consumption and Demand Trend in China's Agricultural Production

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Abstract China's energy consumption for agricultural production has relied on petroleum and coal with relatively low input from power and other types of energy for a long time. Projections indicate that as China's existing development trend leads to substantial growth of energy demand for agricultural production, such a long term irrational energy consumption pattern would unlikely be able to meet the needs of the country's developing agricultural sector. As such, it is recommended that China's agricultural sector should follow the national energy development strategy guideline by gradually increasing the use of wind power, solar energy, biomass and other new energy sources while advancing technological innovations on traditional energy sources. Meanwhile, as the consumption structure of three major energy sources (*i.e.* petroleum, coal, and power) is optimized, development and application of biomass from agriculture as raw materials for alternative energy should be enhanced. Lastly, the development and application of wind power, solar energy, and hydropower in agricultural production should be increased in areas where appropriate.

Key words Rural energy, Energy structure, Consumption elasticity, Consumption projection, China

1 Literature review

With the development of the agricultural sector, energy demand in agricultural production continues to grow. Research on energy consumption pattern in agricultural production is of great significance to the formulation of environmental friendly, resource-saving types of agriculture, and sustainable agricultural development policies. The field of agricultural production energy has been studied by many scholars at home and abroad. Back in the early 1990s, Ye Yiguang integrated three international models of modern agricultural development and analyzed the characteristics of China's modern agricultural development[1]. He then proposed that resource-saving would be the inevitable choice of China's agricultural development. As for the relations between energy, economy, and environment, scholars believe that energy issues on agricultural production usually have negative impacts on both the economic and environmental aspects, and a program was suggested to alleviate such impacts from the legal perspective[2]. On the other hand, the research of Uhlin, Hans-Erik on Swedish agricultural transformation process shows that energy consumption does not always lead to reduced efficiency of agricultural production[3]. In the meantime, some scholars focus on analyzing the relationship between energy and agricultural production; for example, Wang Lihong had conducted an empirical analysis of dependence of agricultural production on petroleum in China and concluded that there are regional and structural differences in such dependence[4]; Tang Huacang analyzed the existing problems in commodity energy input in agricultural production and explored the optimization strategies of energy inputs in agricultural production[5]. Some scholars studied the relationship between energy consumption in China's agricultural production and national income and confirmed that the short-term co-integration relationship was more apparent than the long-term co-integration relationship[6]. In addition, Guan Weihua *et al.* used model fitting to predict the coal consumption structure of China's three major industries and pointed out the changing trend of coal consumption in agricultural production[7]. In views of the development needs of agriculture in modern era, we should also conduct further analysis on energy consumption in agricultural production to better understand the current status, characteristics and demand trends of energy consumption in agricultural production in order to provide basis in developing supportive energy policies for sustainable development of China's agricultural sector.

2 Analysis of energy consumption in agricultural production

With the development of rural economy, increase of farmers' income, and support from the national policy, consumption of China's agricultural production energy has been increasing continuously. Statistical data showed that from 1985 to 2007, energy consumption of China's agricultural production increased from 30.818 1 million tons of standard coal to 60.857 3 million tons of standard coal, an increasing rate of 97%.

According to the consumption structure, sources of agricultural production energy have been primarily petroleum, coal and power for a long time. In 2007, the consumption of these three main agricultural production energy sources accounted for more than 98% of the total energy consumption, of which petroleum accounted for 51.11%, coal accounted for 27.75%, and power accounted for 19.78%.

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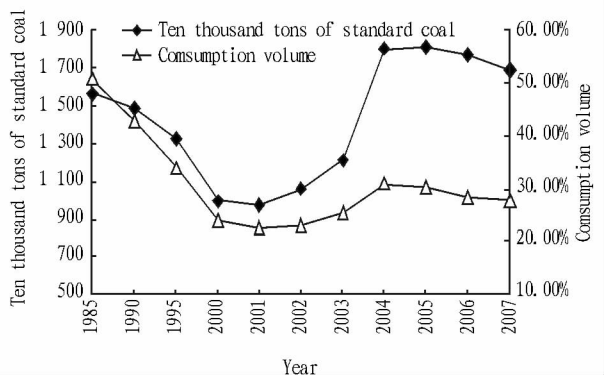
Analysis to the three major energy sources in agricultural production are done and presented as follows.

2.1 Coal consumption China has abundant coal resources. Coal has always been one of the major production energy sources in China's various industries. In agricultural production, the types of coal consumed mainly include raw coal, washing coal and coke, of which raw coal occupies a dominant position. In 2007, consumption of raw coal in agricultural production accounted for more than 90% of the total coal consumption in agricultural production.

Although there were ups and downs in coal consumption in agricultural production since 1985, coal consumption showed an upward trend in general, increasing from 15.643 3 million tons of standard coal in 1985 to 16.879 6 million tons of standard coal in 2007 with an average annual growth rate of 1.67% (Fig.1). However, coal consumption in agricultural production began to decline from 2006. According to statistical data, 17.680 4 million tons of standard coal was consumed in China's agriculture in 2006, decreasing by 2.28% compared with that of the previous year; 16.879 5 million tons of standard coal was consumed by China's agriculture in 2007, declining by 2.25% compared with that of the previous year. In terms of relative volume, the proportion of coal consumption showed a downward trend from 1985 to 2007. In 2007, the proportion of coal consumption in agricultural production accounted for 27.75% of total energy consumption in agricultural production, dropped by 23.04% compared with that of 1985 while dropped by 0.58% compared with that of the previous year.



Note: Data are from *China Energy Statistical Yearbook* from 1989 to 2008.

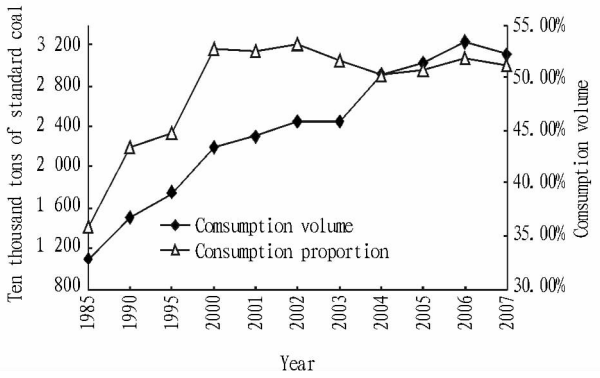
Fig.1 Coal consumption in agricultural production from 1985 – 2007

Overall speaking, total coal consumption has risen continuously since 1985 but the proportion of coal consumption to the total energy use in agriculture has declined. Particularly in the last two years, due to restructuring of the agricultural sector, improvement of agricultural technology, changes in energy price and other economic factors, coal consumption in agriculture declined.

2.2 Petroleum consumption As one of today's major energy sources domestically and internationally, petroleum also plays an important role in China's energy consumption in agricultural production, providing power for agricultural machinery and tools in the forms of diesel and gasoline.

In 2007, petroleum consumption in agricultural production totaled 31.092 3 million tons of standard coal, accounting for 51.11% of energy consumption in agriculture. Within this petroleum consumption, 27.325 6 million tons of standard coal was used for diesel oil consumption, accounting for 87.89% of the total petroleum consumption in agriculture; 3.631 8 million tons of standard coal was used for gasoline consumption, accounting for 11.68% of the total petroleum consumption in agriculture; 22.7 thousand tons of standard coal for kerosene, 114.9 thousand tons of standard coal for liquefied petroleum gas, and 9.9 thousand tons of standard coal for fuel oil, which altogether accounted for 0.4% of total petroleum consumption.

From a historical perspective, petroleum consumption in agricultural production has shown a linear increase. Over the past 30 years, petroleum consumption in agricultural production increased from 11.071 9 million tons of standard coal in 1985 to 31.092 3 million tons of standard coal in 2007, with an increase rate of nearly three times and the average annual increase rate of 3.77%. In terms of relative volume, the proportion of petroleum consumption to energy consumption in agricultural production gradually increased, from 35.93% in 1985 to 51.11% in 2007. It is noteworthy that, the rising domestic and international petroleum price from 2002 to 2007 has little effect on petroleum consumption quantity in China's agricultural production (Fig.2).

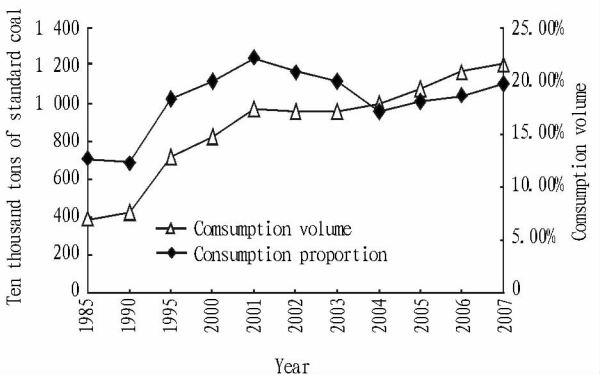


Note: Data are from *China Energy Statistical Yearbook* from 1989 to 2008.

Fig.2 National petroleum consumption in agricultural production from 1985 to 2007

Generally, due to continuous development of agricultural mechanization and modern agricultural technology, petroleum consumption in China's agriculture has kept rising since 1985; but in recent years, the growth rate of petroleum consumption in agriculture is slowing down and the petroleum consumption of 2007 decreased compared with that of 2006. The proportion of petroleum consumption in agriculture to total energy consumption in agriculture increased continuously before 2000. Besides, although the absolute volume of petroleum consumption in agriculture increased continuously, the proportion of petroleum consumption in agriculture to total energy consumption in agriculture showed a downward trend after 2000 due to rising price of finished product oil. This proportion had been maintained at around 51% from 2003 to 2007.

2.3 Power consumption In 2007, total power consumption in agricultural production was 12.031 4 million tons of standard coal, converted to 97.9 billion kWh, accounting for 19.78% of the consumption energy in agricultural production. Generally speaking, power consumption in agricultural production has shown a rising trend since 1985 with an average annual growth of 5.08%, which is significantly higher than the growth rates of petroleum, coal and total energy consumption. However, China's power consumption in agriculture began to significantly decline after 2001 compared with previous consumption rate. China's power consumption in 2002 was 9.539 9 million tons of standard coal, declined by 0.1 million tons of coal compared with that in 2001. After 2004, power consumption for agricultural increased steadily. Over the last three decades, the proportion of power consumption in agriculture has also shown an overall upward trend. The proportion of power consumption in agriculture increased from 12.66% to 19.78% from 1985 to 2007, an increase rate of 7.15% (Fig.3).



Note: Data are from *China Energy Statistical Yearbook* from 1989 to 2008.

Fig.3 National power consumption in agricultural production from 1985 to 2007

It can be seen that one of the main energy sources in rural areas is power. Despite that consumption of power is smaller compared to the other two types of energy (*i.e.* coal and petroleum), its growth rate is relatively higher with greater development potential. With the release of the new rural development initiatives and other types of preferential agricultural policies, production conditions in rural areas have been improved and income has increased. Therefore, it is believed that power consumption will play an even greater role in this regard.

3 Analysis of energy consumption elasticity in agricultural production

Energy consumption of agricultural production affects the development of China's agricultural production. In the same way, the level of agricultural production will also affect the energy consumption and consumption structure of China's agricultural production. With the increase in the total agricultural output, total energy consumption volume of agricultural production will gradually increase. However, the different energy sources do not have the same sensitivity to the growth of the total agricultural output value, which also changes the energy consumption structure of agricultural production. Changes in the relationship between total agricultural output value and consumption volume of a variety of agricultural production energy sources can be analyzed through calculating energy consumption elasticity; changes in the relationship between total agricultural output value and energy consumption structure in agricultural production can also be analyzed by calculating energy consumption proportion elasticity (Fig.3).

Elasticity of energy consumption in agricultural production can be calculated in accordance with equation (1):

$$\delta_i = \frac{\dot{C}_{Ei}}{\dot{P}_A} = \frac{\Delta C_{Ei}/C_{Ei}}{\Delta P_A/P_A} \quad (1)$$

where δ_i is the consumption elasticity of the ith kind of agricultural production energy, $\dot{C}_{Ei}$ is the consumption growth rate of the ith kind of energy, $\dot{P}_A$ is the gross agricultural output growth rate, C_{Ei} and P_A is the consumption and total agricultural output value of the ith kind of energy, respectively, and ΔC_{Ei} and ΔP_A is the consumption variation quantity and total agricultural output variation quantity of the ith kind of energy, respectively. Table 1 reports the consumption elasticity of agricultural production energy at each period calculated by using the data in 1985–2007.

Table 1 Major energy consumption elasticity in China's agricultural production from 1986–2007

Year	Coal	Petroleum	Power	Total
1986	0.62	1.08	−2.42	0.52
1990	−0.46	0.44	0.46	0.06
1995	−0.19	0.51	0.50	0.26
2000	−53.93	4.08	8.88	−0.84
2001	−1.14	3.75	11.65	3.75
2002	11.73	8.84	−1.49	7.73
2003	1.84	1.26	−0.05	0.44
2004	3.92	1.53	0.37	1.79
2005	0.05	0.79	1.84	0.59
2006	1.24	−3.69	−4.37	−2.44
2007	−0.30	−0.25	0.22	−0.17

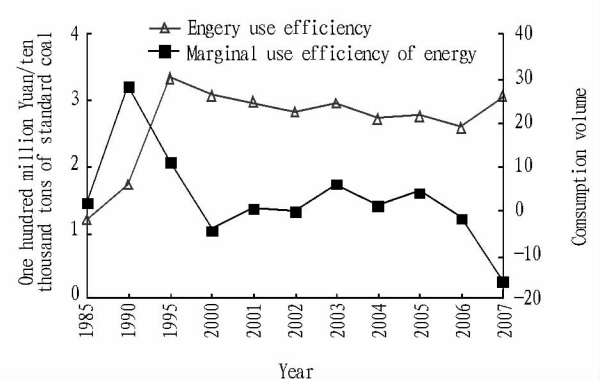
Note: The above data are calculated in accordance with relevant data of *China's Agricultural Statistical Yearbook* and *China Energy Statistical Yearbook*, of which the total agricultural output value is calculated based on the unchanged price in 1985.

Table 1 shows the elasticity changes of agricultural output value affected by consumption of China's major energy sources in agricultural production since 1986. From Table 1, it is apparent that changes in coal consumption elasticity are the most intense, but the changes began to slow down since 2003 with average elasticity of 1.35. In other words, in recent years, increase in coal consumption was faster than that in total agricultural output value with the use efficiency of coal showing a downward trend.

Changes in consumption elasticity of agricultural production for petroleum had always been relatively stable and the average from 1986 to 2007 was 1.66; power consumption elasticity showed a certain degree of volatility, and the average from 1986 to 2007 was 1.42. In other words, the use efficiency of petroleum and power also showed a downward trend.

From the overall change process of China's agricultural en-

ergy use from 1980s to the end of the 20th century, use efficiency of agricultural production energy increased with the continuous advancement of agricultural production technology. However, as we approached the 21st century, average total consumption elasticity of the agricultural production energy is 1.67, that is, energy consumption grows faster than the total agricultural output, and the use efficiency of agricultural energy showed an overall downward trend (Fig.4).



Note: The above data are calculated in accordance with relevant data of *China's Agricultural Statistical Yearbook* and *China Energy Statistical Yearbook*, of which the total agricultural output value is calculated based on the unchanged price in 1985.

Fig.4 Use efficiency of national agricultural production energy from 1986 to 2007

Different elasticity of total agricultural output value to different energy sources leads to changes in energy consumption structure of agricultural production. However, this pace of change cannot be seen in an intuitive way from the consumption elasticity, so it is necessary to calculate the energy consumption proportion elasticity of agricultural production (the consumption structure elasticity).

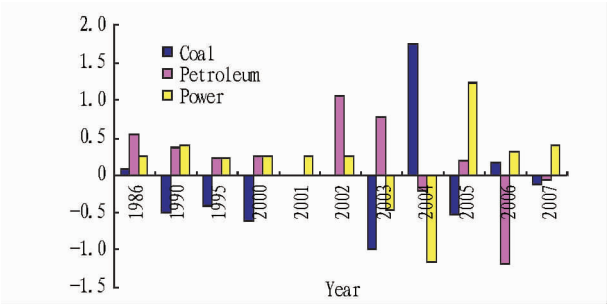
The energy consumption proportion elasticity in agricultural production can be calculated in accordance with equation (2):

$$\delta_i = \frac{\dot{C}_{pi}}{\dot{P}_A} = \frac{\Delta C_{pi}/C_{Ei}}{\Delta P_A/P_A} \quad (2)$$

where $\dot{C}_{pi}$ and $\dot{P}_A$ are the change rate of proportion of the ith kind of energy to total energy consumption volume and the change rate of total agricultural output value, respectively, C_{pi} and P_A are the proportion of the ith kind of energy to total energy consumption and total agricultural output value respectively, ΔC_{pi} and ΔP_A are the variation quantity of proportion of the ith kind of energy to total energy consumption and the variation quantity of total agricultural output value respectively.

Fig.5 illustrates the energy proportion elasticity in agricultural production at each period calculated by using the data in 1985–2007.

Fig.5 shows that with the growth of the total agricultural output value, consumption elasticity proportion of coal was negative in all the years except in 2004 (abnormal figure), 1986 (positive number), and 2006 (positive number), meaning that proportion of coal consumption in general showed a downward trend. On the contrary, although the petroleum consumption proportion elasticity has fluctuated in recent years, the average value from 1986 to 2007 was 0.18, which means that proportion of petroleum consumption was in general on the rise. At the same time, changes in power consumption proportion elasticity were relatively stable, and the average from 1986 to 2007 was also 0.18, indicating that the proportion of power consumption was on the rise in general as well.



Note: The data are converted in accordance with relevant data of *China Energy Statistical Yearbook* and *China Agriculture Statistical Yearbook*.

Fig.5 Consumption structure elasticity of national primary agricultural production energy sources from 1986 to 2007

4 Trend analysis of energy demand in agricultural production

From the above analysis of energy consumption in agricultural production (Fig.1–3), it can be seen that the changes from 2000 to 2007 basically reflected features of energy consumption in the new era. Therefore, when conducting trend analysis, it can be assumed that consumption elasticity of all the major production energy sources is maintained at the average level of 2000–2007.

According to the *National Statistical Yearbook* and based on calculation of the unchanged price in 1985, the chain base geometric average growth rate for total agricultural output value in China during the period from 2000 to 2007 is 5.08%. With 95% as the confidence interval, the confidence interval for average annual growth rate of China's agricultural output is [1.92%, 8.25%] during this period. As a result, 2%, 5% and 8% are used as low-speed, medium-speed, and high-speed growth forecast parameters for total agricultural output respectively.

In this way, by using the average consumption elasticity values of the three major production energy sources (coal 0.43, petroleum 1.05, power 0.54) from the years of 2000–2007, we can calculate the consumption level of major energy sources under different growth rates of total agricultural output in three key years of 2010, 2015, and 2020 (Table 1).

Predicted energy consumption values of agricultural production can be calculated according to equation (3):

$$C_{i,\,t+k} = \{[1+g]^k - 1\} \times \delta_i + 1\} \times C_{i,\,t} \quad (3)$$

where C_i is the consumption in the ith kind of energy source, t is the base period, which is 2007, $t + k$ is the reporting period, δ_i is the consumption elasticity of the first ith kind of energy source, and g is the average annual growth rate of the total agricultural output (confidence interval: 95%, values: 2%, 5%, 8%).

Table 2 Forecast of energy consumption in agricultural production in key years $\times 10^4$ t standard coal

	Year	Coal	Petroleum	Power
Slow growth	2010	1 726.17	3 296.60	1 238.40
	2015	1 737.18	3 396.55	1 251.71
	2020	1 791.43	3 830.17	1 313.27
Medium growth	2010	1 751.65	3 520.33	1 268.69
	2015	1 786.15	3 791.02	1 307.49
	2020	1 997.05	5 131.03	1 523.08
Rapid growth	2010	1 781.15	3 753.48	1 301.98
	2015	1 847.93	4 223.00	1 373.35
	2020	2 329.73	6 899.59	1 839.48

As seen from Table 2, which is based on calculation with the average consumption elasticity of China's agricultural production energy during the period from 2000 – 2007, consumption level of China's main agricultural production energy sources will continue to grow during the period from 2010 to 2020. Petroleum consumption will continue to account for the largest proportion and agricultural production energy consumption will continue to have the proportion ratio of petroleum > coal > power. In addition, the gap of consumption among petroleum, coal and power will increase continuously.

By using the predicted consumption values of agricultural production energy in Table 2, it is not difficult to calculate the consumption structure of agricultural production energy at different growth rates of total agricultural output in 2010 – 2020 (Table 3).

Table 3 Forecast of energy consumption structure in agricultural production in key years %

Year		Coal	Petroleum	Power
Slow growth	2010	27.57	52.65	19.78
	2015	27.21	53.19	19.60
	2020	25.83	55.23	18.94
Medium growth	2010	26.78	53.82	19.40
	2015	25.94	55.06	18.99
	2020	23.08	59.31	17.61
Rapid growth	2010	26.05	54.90	19.04
	2015	24.82	56.73	18.45
	2020	21.05	62.33	16.62

Table 3 shows that firstly proportion of coal consumption in agricultural production energy consumption drops faster than consumption of the other two energy sources. In 2007, coal consumption accounted for 27.75%, and it is expected that coal consumption proportion will drop to 21.05% by 2020 at rapid growth, and to 25.83% at slow growth. Secondly, power consumption in agricultural production will decline. In 2007, power consumption accounted for 19.78%, and it is expected that the proportion of power consumption will be between 16.62% and 18.94% in 2020. Thirdly, proportion of petroleum consumption in agricultural production energy consumption will increase significantly; in 2007, the petroleum consumption accounted for 51.11%, and it is expected that the proportion of oil consumption will increase to between 55.23% and 62.33% in 2020.

As the above energy consumption trend predicted, China's consumption structure of agricultural production energy will be improved. Nonetheless, the outlook is not optimistic because as the proportion of power consumption declines, the absolute value of its consumption and consumption proportion are also less than those of coal up to 2020. From an ecological perspective, the negative impact of power consumption on environment and ecology is the smallest, with petroleum having relatively less negative impacts than coal. Certainly, it will be more environmentally friendly if power is not used at all. From an energy efficiency perspective, the utilization efficiency of power is higher than those of petroleum and coal, and thus at the same output conditions, consumer expenditure of power will be lower than those of petroleum and coal. In addition, energy consumption structure is also primarily based on power in developed countries, followed by petroleum, with coal consumption accounts for the smallest proportion. Such consumption structure of agricultural production energy is consistent with achieving the resource-saving and environment-friendly objectives of a developed agricultural sector. However, China's consumption structure of agricultural production energy according to the existing changing trends is petroleum-based, with power remaining at the bottom of this energy consumption structure. From that point of view, there is a gap between the existing development trend of China's consumption structure of agricultural production energy and that of the objective set forth for sustainable development in the country's agricultural sector.

5 Conclusions and recommendations

From the above analysis we can see that the next decade will be the period when there is substantial growth of energy demand in China's agricultural production. However, according to the existing development trends, consumption of the three primary energy sources still shows an irrational pattern in a long time and consequently, the needs of a developed agriculture sector cannot be met.

The national energy development strategy states that all industries should gradually increase the use of wind power, solar energy, biomass and other new energy sources, while making advances in technological innovations on traditional energy sources. Therefore, as optimizing the proportion of consumption of the three major energy sources, we should also take advantage of the role of agriculture in production of biomass raw materials to increase the proportion of biomass energy resources in agricultural production. Meanwhile, in areas where conditions permit, development and application of wind power, solar energy, and hydropower should be enhanced in agricultural production. In addition, while the proportion of coal and petroleum consumption in agricultural production will remain large in the coming period of time, we should also focus on making technological innovations of these traditional energy sources, such as clean and efficient use of coal and development of new fuels.

As the agricultural sector in China develops, agricultural production energy, as an integral part of China's whole energy system, is increasing its impact on the country's energy supply and demand. For this reason, awareness of structural optimization of energy consumption in agricultural production must be

(To page 10)

mental level of agricultural modernization goes behind their regional economy. It can be seen that the level of agricultural modernization is inharmonious with the regional economic development.

Table 5 The harmony between agricultural modernization and regional economic development

Bad rank	Area	The number of areas
≤ -5	Xinjiang, Fujian, Hunan, Jiangxi, Hubei, Anhui, Hunan, Yunnan, Gansu	9
(-5,5)	Zhejiang, Shandong, Jiangsu, Guangdong, Hebei, Liaoning, Henan, Ningxia, Sichuan, Guangxi, Guizhou, Tibet	13
≥ 5	Shanghai, Tianjin, Jilin, Beijing, Heilongjiang, Inner Mongolia, Chongqing, Shaanxi, Shanxi	9

3 Conclusions

On the basis of factor analysis, the developmental level of agricultural modernization in each area is ranked and compared with the overall regional economic power. The results show that in China, the developmental level of agricultural modernization is inharmonious with the overall development of regional economy. The inharmonious relations are reflected on two aspects. The first one is the imbalance of the developmental level of agricultural modernization among various regions; the second one is the imbalance between the progress of agricultural modernization in the areas and regional economic power. Deepening the imbalance and inharmony of the developmental level of agricultural modernization; adopting effective measures to transfer the backward situation of agricultural modernization; pushing forward and realizing the harmonious development of agricultural modernization and regional economic development are not only conducive to the further prosperity of rural economy, but also of great significance in strengthening overall regional economic power and facilitating the national economic growth.

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increased, and the regional governments should integrate such optimization strategies into their economic and social development planning, as well as the new rural development initiatives. They should also coordinate urban and rural energy development to ensure the development of agricultural production energy is aligned with that of the national economy. Agricultural production energy should also be developed under the guidance of the country's overall energy development strategy in order to formulate locally adapted strategic objectives, principles, and supply and demand structure suitable for that region.

In the future, agricultural production energy should comply with the principle of "working out measures to suit local conditions, diversified development and combination of input-based external commodity energy and development of rural internal renewable energy". We should better coordinate urban and rural energy development systems, optimize energy structure, continuously improve the proportion of power in energy consumption in agricultural production, make use of local resources, and accelerate development and utilization of rural renewable energy to build the agricultural production energy system that is in line with the diversification and sustainability objectives for the rural regions.

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