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Information technology promotes the development of agriculture in China: the mechanism, bottleneck problems and solutions

R Feng[1]

E-commerce Department, Guangdong University of Foreign Studies, Guangzhou, China

E-mail: fengran@oamail.gdufs.edu.cn

Abstract: With the purpose of maximizing productive efficiency by means of leveraging information technology in agriculture, this study creates agriculture information system which constitutes factors from supply-side based on the theories of economics. Then, Gray Correlation Analysis has been used to analyze agro- industrialization. The wide application of the Internet and financial support in agriculture exert significant positive effect on the development of agriculture. At the same time, less agriculture weather stations, developing agriculture futures have no obviously positive effect on it. Low level education of the rural labour has the negative effect on it. Therefore, suggestions like increasing the investment on rural education, giving more support on land conservation, integrating the data from different relevant fields to develop agriculture futures, developing meteorological monitoring technology are given based on the experience of developed countries.

1. Introduction

Traditional agriculture in China is mainly promoted through increasing productive factors. Specifically speaking, the factors are: high investment in agriculture resources, high emission of pollutants, relatively high yield of agriculture products, and low usage of energy. Such “extensive” business model cannot keep a long-term and sustainable growth since solid agriculture resources in China are in short. And the model does not match the thought that China’s economic transformation should be high-level, clustering, informatized, green and low-carbon. Therefore, it is urgent for China’s agriculture development to shift from being “extensive” to “intensive”.

Among all the driving factors of “intensive” agriculture, information technology is a key one that cannot be neglected. It is not only the main tool to realize agriculture modernization, but also a significant way to stimulate national GDP (Gross Domestic Product, GDP). According to survey data, the GDP of developed countries has increased by 5%-9% because of information technology, and the figure is as high as 15%-25% in developing countries [1]. Therefore, to enhance the application efficiency of information technology and agriculture informatization is of great significance for facilitating agriculture modernization [2]. However, nowadays, China is suffering from many adverse factors of agriculture informatization, for example, the education in rural areas is "of low quality" and the agriculture information seems to be "isolated", etc [3]. How to solve these problems become the key for developing agriculture and rural new kinetic energy. Therefore, in this study, the current condition and existed problems will be combed through and analyzed. Also, on the basis that information technology and agriculture modernization mechanism has been well illustrated, quantitative analysis will be performed to locate adverse factors on agriculture informatization. Then, the experience in agriculture of developed countries will be referred to before coming up with corresponding measures for improvement to accelerate the process of agriculture modernization.

2. Current status and problems of agriculture informatization in China

In the area of agriculture production, there is a relatively large gap between the Internet of Things in China and that in the United States. However, since 2010, when the National Development and Reform Commission launched the industrial plan of the Internet of Things covering fine husbandry, until 2015, when the Ministry of agriculture promoted 116 items of the Internet of Things model to save water, fertilizer and labor, which can "save costs and improve performance". Within a short period of over ten years, during the research and development stage of the technology of Internet of Things, China has completed the task of 3S (Include Remote sensing, Geography information systems and Global positioning systems) integrated technology and application software and developed in the direction of manufacturing production equipment and agriculture machines or tools with intelligent control on a large scale. As for the implementation, in the past, the information was collected manually and the mechanical operation was regular, but now it is semi-automated, and will be fully-automated. During the promotion stage, it has been shifting from large-scale farms and high-tech agriculture pilot zone which are less affected by natural conditions and of high-level industrialization degree to capable rural and farming households [4]. However, when the technology of Internet of Things is developing fast, the agriculture yield capacity becomes relatively low. According to UN's Food and agriculture Organization (FAO), the amount of fertilizer use and average crops (grain) production index in 43 countries show that the fertilizer amount in China is 364.4 (ton/1000 hectares). It is far more than the figure of Australia, 50.9, and that of the United States, 131.9. China's figure also surpasses the average use amount of major countries, which is 284.96 tons. On contrast, the per capita yield of crops (grain) in China is only 948.51 (kilo/hectare) in 2016. It is only about 1/15 of that of Australia, 13925.05, and about ¼ of the average level at 3765.88. Therefore, from the perspective of yield, information technology hasn't effectively stimulated agriculture production efficiency.

In terms of agriculture operation, as the increase of agriculture cooperative and large agriculture-related enterprises, information integration system has extended from pure production plan and management to various areas including supply and sales, financial management and personnel management. An integrated agriculture ERP (Enterprise Resource Planning, ERP) system covering various agriculture areas has been formed. For government organs of agriculture, agriculture information system can not only be used to collect the information about price, environment, quality control and farming. These data will be released to the public through databases like “agriculture Economic Information Calendar”, “agriculture Macro Data Enquiry”, and so on. These have also been applied to daily administrative management by all levels of agriculture departments in the form of “electronic administration”. In this way, the efficiency of the government will be enhanced. For example, in 2017, the website of the Ministry of agriculture has undertaken as many as 49 online administrative business items and the daily capacity of case handling has reached about 250 [5]. Despite of the fact that China’s e-government has already reached the above-average level [6], but there is a distinct imbalance in the management of agriculture information. Such imbalance is not only manifested geographically, but also in each part of supply chains. To be specific, the e-government level in eastern China, southern China, and northern China is relatively high, but that in the southwest and northwest is relatively low. There is an obvious disadvantage in future information management of high-end agriculture products. Currently, there are 192 categories of future trading around the globe, but in China, there is only 22 categories future trading of agriculture products.

In the area of agriculture multi-industrial fusion, in 2015, the Ministry of agriculture started the e-commerce pilot projects for agriculture products in 10 provinces and cities including Beijing, Guangdong, Hainan, and Hebei. In 2016, the cold chain network for agriculture products of the leading enterprise “Yiguo Fresh Products” has covered 27 provinces and 310 large and medium cities in China. The new industrial chain model of “the Internet+ the New Three Rural Issues” which makes the delivery of agriculture products possible within the day or order has been achieved. In 2017, the number of electronic platforms for China’s agriculture products has reached 585. The average yearly increase rate of online sales volume has reached 52.58% (during the period from 2013 to 2017) [7]. In the meantime, the leisure tourism in rural areas has seen prominent increase. Supported by the “No.1 Document” issued by the Central Government and the “Poverty-Relief Plan by Rural Tourism” issued by National Tourism Administration, there has been 2.1 billion person time of tourists visiting rural areas in 2016, with the business revenue increasing 570 billion yuan, accounting for about 14.47% of total domestic tourism income [8]. However, according to “China’s Unicorn Enterprise Development Report” released by the Ministry of Science and Technology in 2016, among 30 “Unicorn” e-commerce enterprises in China, only 2 serve for agriculture products. Another example is that in 2017, the number of model county for e-commerce entering the rural areas has reached 36, with 1946 e-commerce service stations built. However, the 800 million yuan of e-commerce volume only accounted for 0.46% [9] of the total value of agriculture output which was 175.25 billion yuan in Guangxi Province hat year. From the above analysis, despite of the fact that information technology and the Internet has been applied into agriculture production, operation and multi-industrial integration, it still shows distinct geographical imbalance. That is to say, successful cases are mostly in the southeastern and coastal areas or the key agriculture pilot industries in China; moreover, it does not show significantly positive impact on agriculture production efficiency or multi-industrial integration.

Obviously, information technology hasn’t given play for enhancing China’s agriculture production, operation and service. Then, what indeed are the problems? For agriculture operation, there are many procedures, which are independent from each other but also overlap. As a result, to locate the problems becomes difficult. But if looking at the issue from economic perspective, it can be found that information technology is affected by several factors like the current level of domestic information technology, how IT has penetrated agriculture area, the labor force, tools, subjects who carry, spread and use the information, as well as social system. Therefore, from the supply-side perspective, the factors affecting agriculture informatization will be pinpointed.

3. Mechanism of how information technology enhances agriculture modernization

Agriculture modernization mainly refers to the process of enhancing farmers' quality through modern equipment, management approaches, service system and knowledge. These are mainly manifested in the procedures of agriculture production, operation and service. In the modernization drive of agriculture, information technology plays an important role, improving the efficiency of agriculture production, operation and service and facilitating the multi-industrial structural integration of agriculture (details in Figure 1 below) [10].

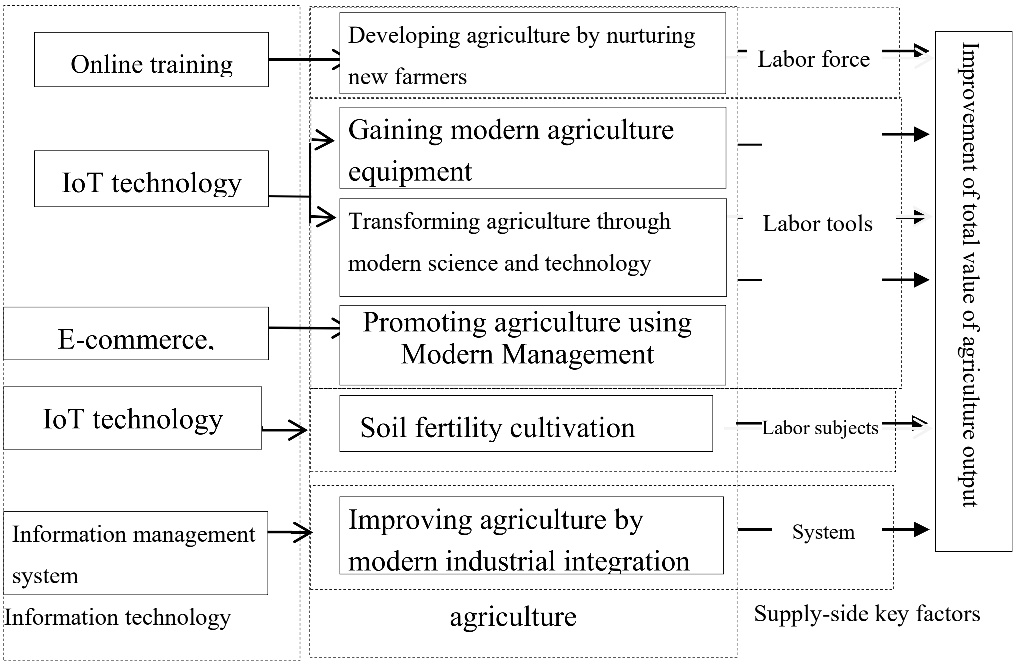

Figure 1. Relation scheme of information technology and agriculture modernization.

3.1. Function of information technology in enhancing labor force and labor subject potency

The Internet is the infrastructure carrying and spreading information and the important channel and physical basis for arranging the Internet of Things and cultivating rural new labor force. The features of the Internet make it possible for information transmission to break the limitations of time and region. Thus, Metcalfe's rule can be well functioned. The agriculture information and corresponding overflow value can show an increase of N^2 online. Therefore, as the advancement of projects of "Broadband China" and "Broadband Village Plus", 201 million users (by the end of 2017) have been involved in rural Internet, showing a penetration rate of 34.0% [11]. Particularly, the balanced development of regional Internet, i.e. 62.7% in the eastern costal area, 43.0% of central area, and 45.8% of western area, will all enhance the educational level of farmers. Then the means of labor will help improve the efficiency of labor subjects [12], and there will be overflow effect of voluntary innovation. In the meantime, the Internet of Things will be effectively leveraged to monitor the soil condition.

3.2. Function of information technology in the enhancing efficiency of labor tools

To enhance the efficiency of labor tools include the in-depth integration of first and second industry, as well as to improve the efficiency of labor tools in a limited sense and to expand the function of labor tools of broad sense through the integration of first and tertiary industry.

To enhance the efficiency of labor tools of limited sense through information technology refers to the process that advanced biological technology, information technology and industrial equipment are put into application in agriculture production to improve agriculture production efficiency and output by better farming, water conservancy, mechanization and informatization. A typical example is the technology of the Internet of Things, which centers on information technology and composed of sensors, network transmission and software analysis. It can monitor the indicators of farming and cultivation like water content [13-14], temperature [15], nutrient [16], salination degree [17], and so on in a real-time manner. It will adjust the land fertility, save much labor costs, and improve crop output. Moreover, it is demonstrated that when the application rate of the technology of the Internet of Things is 80% in the farms of Untied States, the grain production has realized an output of 7.34 tons/hectare, which is far higher than the average global level of 3.85 tons/hectare [18].

To improve the potency of labor tools of broad sense through information technology refers to the process of gaining as much as agriculture development, extending the industrial chain, and fully leveraging the features and functions of the tertiary industry. The purpose is to increase sales channels of agriculture products, improve corresponding added value, reduce agriculture production risks and stabilize price in the market [19]. For example, under the external effect of network, the marginal effect will show progressive increase, which is different from traditional economy [20]. To be specific, the larger the number of users in the network, the lower the marginal effect of each user, and the stronger the potency will be. Therefore, in the rural areas, the e-commerce platform can be used to sell agriculture products and develop tourism, as well as online trading of forward futures of agriculture products. Such high-end financial tools of agriculture industrial chain can be used to protect and guarantee the benefits of farmers.

3.3. Function of information technology in enhancing systematic potency

Reasonable agriculture system can help to achieve large scale operation of agriculture lands. The costs before, during and after the agriculture production, trading and operation can be lowered. At present, as the proposal of the concept of "three separate rights" of lands, the issue that restricts the scale expansion of China's agriculture has been shifted from land property dispute to agriculture management. In the meantime, since agriculture operation is easily affected by market supply and demand, price fluctuation and other external factors, its management requires the collection and fast handling of various kinds of information. According to the bounded rationality theory of Herbert Simon, complicated and uncertain external environment will affect the rationality of human beings. In order to observe the matters more objectively, human will collect more information, which will increase the rational costs [21]. The new institutional economics holds the opinion that social activities will generate trading costs between enterprises and between the enterprise and government. Therefore, the Internet is not limited by time and space and can spread as fast as light. The automatic approaches of information management system can help people to collect information in a more convenient way, enhance their cognitive ability, improve the management efficiency of agriculture matters, lower the imbalance of trading information, and reduce trading costs, so that various trading risks can be avoided [22].

4. Quantitative analysis on factors affecting China's agriculture informatization drive

In this study, the agriculture informatization development index system has been established based on the agriculture modernization index system proposed by Literature Information Center of Chinese Academy of agriculture Sciences from the perspective of four key factors of supply-side in economics, i.e. labor force, labor subjects, means of labor and labor mechanism. In the meantime, quantitative analysis has been performed on the relations among these factors, with the purpose of locating adverse factors on the full functioning of information technology in the agriculture area.

4.1. Establishment of agriculture informatization development index system

Since China's agriculture informatization statistics is not complete, the factors of authority, system and collectability of the data are taken into consideration for the agriculture informatization quantitative index system designed in this study (details specified in Table 1 below). The index system includes: 1. The Internet infrastructure construction status, which reflects the development of information of technology; among which, the index of the total number of national IP4 and IP6 addresses can reflect the network construction status; 2. The Internet popularization rate, which reflects the penetration degree of IT in agriculture areas; among which, the penetration rate can be reflected by the number of national IP addresses and the population with access to the Internet; 3. The rural labor forces carrying information and imparting knowledge; among which, the number of graduates from technical training school and high school and rural labor force can reflect the information conversion capacity; 4. Labor tools of integrating and applying information technology; among which, the electricity amount in rural areas and rural mechanical total power can reflect the popularization degree of modern labor tools; the information socialization degree, agriculture product future trading volume and the number of agriculture meteorology station can reflect how modern operation can facilitate agriculture development; 5. Means of labor (land) which accept informatization; among which, the ratio of total grain output against total fertilizer amount can reflect the fundamental abilities of China's lands; 6. System and industrial structure environment which supports agriculture development; among which, the portion of agriculture costs of total fiscal costs and the portion of the first industry in total GDP can reflect how supportive the government is for the new form of agriculture development and the degree of multi-industrial integration.

Table 1. Index system to evaluate agriculture informatization.

Overall Index	Main Index		Group Index
Degree of agriculture informatization	Popularization of information technology		Number of IP address in the country
			Population with access to the Internet
	Labor force	Developing agriculture by nurturing new farmers	Number of graduates from technical training school
			Number of graduates from middles school in rural area
	Means of labor	Equip agriculture with modern materials	Used electricity of rural areas
			Total mechanical power in rural areas
		Facilitate agriculture by modern operation form	Index of information socialization
			Futures trading volume of agriculture products (bean pulp, corn)
			Number of agriculture meterology stations
	Labor subjects	Transforming agriculture through modern science and technology	Unit output of agriculture products (grain)/fertilizer amount
	System	Government supports the development of new agriculture	Proportion of agriculture costs against total fiscal costs
		agriculture enhanced by modern industrial integration	Trading volume of agriculture products*
agriculture informatization benefits		Increase of agriculture GDP	Total production value of agriculture, forestry, animal husbandry and fishery

Note: The agriculture modernization index system proposed by Literature Information Center of Chinese Academy of agriculture Sciences has been referred to; *The e-commerce trade volumes were only recorded in 2016 and 2017. Therefore, it is unable to measure the integration degree of first and tertiary industry facilitated by informatization.

4.2. Effect of analyzing informatizing factors

4.2.1. Data description. The data includes the gross value of agriculture production (the gross value of agriculture, forestry, animal husbandry and fishery production in real terms) as the explained variable, number of IP addresses, online population of rural areas, graduates from technical training school, number of secondary school graduates, electricity for rural use, total machinery power, information socialization index and agriculture product futures trading volume (bean pulp, corn) , the ratio of grain production to chemical fertilizer application, the number of national agriculture meteorological observatories and the proportion of fiscal agriculture expenditure to total fiscal expenditure as the explanatory variables. The above indicators are selected from 2005 to 2015 (see Table 2 for details), as the statistics of online population in rural areas started in 2005 and the data of 2017 China agriculture Statistical Yearbook is up to 2015.

Table 2. Agriculture Informatization.

Year	AgricultureGDP(100 million yuan)	Number of IP Address (unit: 10,000)	Online Population in Rural Areas (unit: 10,000)	Number of secondary school graduate (unit: 10,000)	Graduates from technical training school (unit: 10,000)	Electricity for Rural Use (myriawatt)	Total Machinery Power (myria watt)	NIQ	Corn futures trading volume * (unit: 100 million yuan)	Grain Yield/Fertilizer	Agriculture Meteorological Stations **	Proportion of agriculture Expenditure***
2005	23537.	7439	1931.4	75.1	4793.2	4375.7	68549.	-	-	0.0895	836	7.2
2006	24418.	9802	2284.9	79.7	4520.6	4895.8	72636	-	1.35	9.1521	839	7.9
2007	25732.	13527	2311	115.7	4670.3	5509.9	76878.	-	1.19	8.9338	808	6.8
2008	26809.	18127	7460	75.9	4358.2	5713.2	82190.	-	1.12	9.1329	720	7.2
2009	27954.	23245	10681	51.6	4130.7	6104.4	87496.	-	0.33	8.9105	721	8.7
2010	40530.	27764	12500	59.8	3813.1	6632.3	92780.	-	0.72	8.9248	721	9.0
2011	42253.	33045	13600	59.5	3794.7	7139.6	97734.	0.32	0.54	9.1054	721	9.1
2012	44174	33054	15600	56.4	3563.2	7508.5	102559	0.36	0.76	9.2372	721	9.5
2013	45923.	33033	17700	47.1	3416.0	8549.5	103906	0.39	0.27	9.3488	721	-
2014	47849.	33201	17800	56.8	3207.7	8884.4	108057	0.42	0.19	9.2964	721	-
2015	49786.	33654	19500	-	-	9026.9	111728	0.43	0.84	9.5022	723	-

Data source: “China’s agriculture Statistical Yearbook” and “China’s Information Statistical Yearbook” during the period of 2006 to 2017 [23-24]. Note: *Limited by the data, the corn futures trading volume only include the annual trading volume in Dalian Future Exchange; ** The amount of agriculture meteorological observation stations includes the number of agro-meteorological observatories plus the number of ecological and agriculture meteorological stations; ***The proportion of agriculture expenditure refers to the proportion of agriculture fiscal expenditure to total fiscal expenditure; ****Reciprocal of proportion of agriculture GDP in the total GDP.

4.2.2. Model design. To further verify changes in the relationship between agriculture informatization indicators from the quantitative perspective and avoid endogenous problems encountered in the use of multi-consumption model, this study adopts the Grey System Theory and T's Correlation Degree Analysis suitable for analyzing "small sample" data to get the correlation degree. Specifically, the relationship between gross farm production and total machinery power are exemplified to explain the solution process of T's Correlation Degree.

Set x_1 as the reference sequence that represents the agriculture GDP, x_j as the comparison sequence (j=2, 2...12) that represents the remaining eleven variables (listed in the table 2) such as the Number of IP Address, and values of the reference sequence and the comparison sequence between

$[t_1, t_n]$ are $x_1 = \{x_1(t_1), x_1(t_2), \cdots, x_1(t_n)\}$ and $x_j = \{x_j(t_1), x_j(t_2), \cdots, x_j(t_n)\}$ respectively, where the number of periods is n which is from 2005 and 2015. According to the improvement of Grey Correlation Analysis by Tang Wuxiang [25], the basic calculation steps of T's correlation degree analysis are as follows:

① Standardize to make the values of each sequence comparable:

$$D_1 = \frac{1}{n-1}\sum_{j=2}^{12}\left|x_1(t_n) - x_1(t_{n-1})\right|$$

$$D_j = \frac{1}{n-1}\sum_{j=2}^{12}\left|x_j(t_n) - x_j(t_{n-1})\right|$$

② Get the standardization sequence:

$$y_1 = \{x_1(t_n) / D_1, n = 1, 2, \cdots, 11\}$$

$$y_j = \{x_j(t_n) / D_j, n = 1, 2, \cdots, 11, j = 2, 3, \ldots, 12\}$$

③ Get the Incremental sequence:

$$\Delta y_1 = \{\Delta y_1(t_n) = y_1(t_n) - y_1(t_{n-1}), n = 1, 2, \cdots, 11\}$$

$$\Delta y_j = \{\Delta y_j(t_n) = y_j(t_n) - y_j(t_{n-1}), n = 1, 2, \cdots, 11; j = 2, 3, \ldots, 12\}$$

④ Calculate correlation coefficients of each period:

$$\mathrm{sgn}(\Delta y_1(t_n) \cdot \Delta y_j(t_n)) \cdot \frac{\min(|\Delta y_1(t_n)|, |\Delta y_j(t_n)|}{\max(|\Delta y_1(t_n)|, |\Delta y_j(t_n)|}$$

$$\xi(t_n) = 0 \qquad (当\Delta y_1(t_n) \cdot \Delta y_j(t_n) = 0时)$$

⑤ Calculation of correlation:

$$r(x_1, x_j) = \frac{1}{n-1}\sum_{j=2}^{12}\Delta t_n \cdot \xi(t_n)$$

Table 3. Correlation of agriculture Informatization Index.

Variables	Correlation	Variables	Correlations
GDP* & NIQ	0.71	GDP &Soybean futures trading volume	0.06
GDP & Machinery Power	0.57	GDP &Grain Yield/Fertilizer	0.04
GDP &Online Population in Rural Areas	0.38	GDP &Number of secondary school graduate	0.03
GDP &Proportion of agriculture Expenditure	0.28	GDP &agriculture Meteorological Stations	-0.01
GDP &Number of IP Address	0.19	GDP &Graduates from technical training school	-0.43
GDP &Corn futures trading volume	0.07		

Note: *GDP represents agriculture GDP.

4.2.3. Result. The degree of correlation between the explained and explanatory variables is calculated to explore the underlying reasons for restriction of the development of agriculture informatization profoundly (see Table 3). According to the final results, there is a positive correlation between the total agriculture production and the social informatization index, rural electricity consumption, total mechanical power, the number of online population, per unit output of agriculture products, the proportion of agriculture fiscal expenditure to total fiscal expenditure and the number of IP addresses. Specifically, the effects of increase of online population in rural areas on the increase of agriculture GDP are significantly higher than that of nationwide network promotion; Its relationships with the number of secondary school graduates, the number of agriculture meteorological stations, the volume of agriculture futures trading and the ratio of grain yield to the amount of chemical fertilizer utilized are not significant; and there a negative correlation between it with the number of graduates of agriculture technology training.

4.3. Conclusion and explanation

Obviously, the increased financial support in the agriculture sector of China, rural labor mechanization presented in the combination of agriculture and modern industry and the rather advanced means of labor for agriculture development resulted from the informatization and networking of key rural construction promoted the increase in the total value of agriculture production effectively. In the meanwhile, the correlation between the number of agriculture meteorological stations, the turnover of major agriculture products (corn, soybean meal) futures and the proportion of grain yield and fertilizer application and the development of agriculture is not significant, indicating that the informationized, marketized and high-tech construction of high-end sections of the agriculture industrial chain should be strengthened in combination of agriculture with means such as high-tech meteorological observation and financial futures trading to further promote the development of agriculture modernization. In addition, according to the research, the significant negative relationship between the number of graduates in secondary school and agriculture technology trainees reduced over the past ten years, especially for the agriculture technology trainees. The conclusion is in line with the idea of numerous scholars that the lower education of rural residents will hinder the deep integration of agriculture and informatization [26]. Strengthening training and delivery of agriculture technicians in rural areas should be emphasized for the promotion of agriculture modernization development.

5. Strategies for promoting the development of agriculture informatization of China

According to analysis, the effects of network popularization in rural areas on agriculture development are significantly higher than that of nationwide network popularization, so the government should continue to increase the construction of network facilities in rural areas, with the improvement of rural labor education, continuous cultivation of fundamental productivity and the application of high-end agriculture financial instruments and high-tech agriculture monitoring methods emphasized on this basis.

5.1. Enhancing the quality of rural agriculture labors significantly

The improvement of peasant education will be restricted by the scarcity of educational resources, thereby affecting their acceptation and application of information technology, as well as the creation of spontaneous innovation environment [27]. For example, according to the survey conducted by China Internet Information Center, among the reasons leading to the low network penetration in rural areas, in addition to the population of too young or old age, the proportion of not being computer and network literate is up to 60.0%, that of lacking Internet devices such as computer is only 9.4%. At present, the level of rural labor education in China is lower with small proportion of education resource input in rural areas. According to the data of *2016 Educational Statistics Yearbook of China*, the number of graduates in secondary school and agriculture technology trainees has been falling from year to year at an average rate of 15.30% and 5.28% respectively. The falling range is far more than the average natural decline of rural population, which is 0.31% [28]. In the meanwhile, although China's share of education expenditure in GDP of 4.26% in 2015 exceeded the target of 4% set up in the National Medium- and Long-Term Education Reform and Development Plan (2010-2020) formulated in 2010, it is still lower than the world average of 4.67%, especially agriculture developed countries such as 6.0% of Israel, 5.6% of the United States and 5.1% of Germany. As the total national education expenditure is lower than the global average, the education resources utilized by junior high school of rural compulsory education are only half of that of city, and the education resources utilized by senior high school of rural non-compulsory education are less than one tenth of city [29].

In order to improve the spillover effect of information technology and solve the contradiction between the demand for agriculture informatization talents and the lack of rural education, the Chinese government should increase the financial investment in education, increase the quality of agriculture labor force in multiple channels and approaches and enhance the soft power and hard power of "labor" in the supply side to achieve zooming of the efficiency of all agriculture factors. Specifically, all-free vocational training of agriculture of Britain, Germany and Sweden, delivery of agriculture talents in the form of pedagogical education of France and all-round talent training for agriculture production, development, maintenance, sales and tourism of the United States worth learning from; at the moment, the Chinese government, in the context of land "separation of the three powers" reform, can loosen the admittance criterion for agriculture business entities, grant corporate entities with land management qualification and deliver highly-educated employees to rural areas for agriculture production through enterprises to improve agriculture production efficiency.

5.2. Adjusting the input structure of maintenance fund, increase cultivation of fundamental productivity of arable land

The increase in crop yields in China is largely dependent on the input of large amounts of fertilizer. According to the agriculture data in Table 1, the ratio of cereal production to fertilizer use between 2005 and 2015 continued to be about 9, indicating that grain yields not only increased with fertilizer application, but remained essentially the same weight. Since the productivity of arable land consists of fundamental productivity and fertilizing amount, soil with high fundamental productivity has higher potential for high yield, and soil with low fundamental productivity can only achieve high yield at higher fertilization level [24,30]. As the increase of grain production is almost proportional to the increase in fertilizer input in a linear regression manner in China, it is obvious that the increase of China's grain production is mainly resulted from the use of fertilizer, rather than the improvement of fundamental productivity of arable land.

China can start from strengthening the cultivation of fundamental productivity of land to achieve a good combination of land and information technology and increase the output of crops. By far, agriculture developed countries have invested a large amount of funds to protect the agriculture ecological environment. Taking the United States for instance, it spends a lot of money each year to encourage farmers to maintain their land. For example, according to the 2014-2018 agriculture budget published in the 2014 Farm Bill, USA will invest $28.165 billion in land conservation, accounting for 5.8% of total agriculture expenditure. As China has established the awareness of protecting the ecological environment, according to the data of 2016 China agriculture Statistical Yearbook, 2.005 billion yuan was invested in agriculture resources and ecological protection, accounting for 6.69% [31] of the total investment in agriculture construction of 29.974 billion yuan in 2015. The proportion is basically the same with the financial investment in agro-ecological protection of USA. However, 2 billion yuan of the 2.005 billion yuan of resource protection funds was used for returning grazing land to grassland, and 5 million yuan was used to manage the prominent environmental problems, with the funds used for pasture and arable land conservation accounting for 0.06% and 0.00009% of the gross value of livestock and agriculture production that year respectively, indicating that the proportion of funds invested in ecological protection is not proper. In addition, the funds for agriculture science and technology innovation capacity in 2015 were 470 million yuan, accounting for only 1.57% of the investment in agriculture construction. Although it is close to 2% of USA's R&D in total agriculture expenditure, due to the completely different agriculture modernization progress, China, which is in the early stage of agriculture modernization, should continue to increase financial investment in agriculture science and technology innovation to support the development and application of information technology in land productivity improvement.

5.3. Making up the weakness in informatization of high-end sections of agriculture

Agriculture commodity futures trading is one of the important symbols of modernization and marketization of agriculture development. Since agriculture is vulnerable to natural disasters and market price fluctuations, hedging in the futures market is rather useful for developed countries to transfer planting risks, guarantee farmers' income and stabilize farming. Among the numerous agriculture developed countries, USA has an over 80% proportion of farmers who hedges with futures. In addition to the rich variety of futures and active trading, USA has established an improved legal system with laws [32] such as the Futures Management Law, Speculation Restricting Act and Commodity Futures Modernisation Act. In particular, the US Department of agriculture has provided farmers and agriculture operators with comprehensive data support for getting involved in futures trading by supplying detailed information such as the total yield, acre yield, market price, market sales, warehouse inventory and demands of USA and other countries via technical means such as satellite high-angle shot and picture analysis, with the stability of US agriculture and the enthusiasm of farmers promoted effectively.

The agriculture futures trading history of China is short and the information of auxiliary transactions is incomplete at present. China only established the first agriculture futures exchange in 1993 and the government proposed the "insurance + futures" policy pilot in the No.1 Central Document in 2016, resulting to problems such as insufficient financial support in the agriculture futures market, high premium amount paid by farmers; only 22 agriculture commodity futures, few variety of active trading and small market scale; short supply of rural financial services and limited risk management awareness of farmers, etc., farms haven't fully utilized futures to stabilize the forward price of agriculture products.

China should pay much attention to the informatization construction needs of agriculture financial derivatives to make up the weakness in informatization of high-end sections of agriculture. Firstly, China shall encourage farmers to get access to the relevant information of agriculture commodity futures, guide farmers to get involved in the agriculture futures market in the form of rural cooperatives, make agriculture marketed and form the price formation mechanism for agriculture; secondly, China shall set up a modern information disclosure system for agriculture products, deepen the organic connection between the spot market and the futures market of agriculture products and provide information-based channels for predicting the price of agriculture products. It will establish unified and authoritative information dissemination channels and platforms to the greatest extent to integrate and analyze cross-border agriculture-related data of authorities such as meteorological departments, agriculture departments, environmental protection departments, industrial and commercial departments and foreign trade departments and information such as increase and decrease of planting area and changes in climatic conditions. Moreover, the system will provide channels for agribusiness and large farms to acquire real-time data and reference trend analysis reports via the Internet and database, so that reasonable agriculture product prices and production expectations can form. Thirdly, China shall improve the legal system of agriculture futures trading, guarantee the authority of agriculture products futures trading commitments and arouse the enthusiasm of farmers and agriculture commodity operators to participate in futures trading.

5.4. Strengthening supply of high-tech agriculture supervision information

The level of informatization and automation of agro-ecological climate monitoring plays a key role in all aspects of agriculture development. Prior to agriculture production, agro-meteorological information can help farmers to identify the best planting time; during agriculture production, real-time information on agro-meteorology can ensure that agriculture products meet expected standards and avoid losses resulted from climate. For example, since rain is unfavorable for cherries at maturity, orchards in USA will prepare the drone in time after getting informed of rainstorm and lift it off when the rain starts to accelerate the evaporation of water on surface of cherries with the falling airflow generated by the wing during the flight, so as to avoid cherry rot caused by excessive watering[33]. After agriculture production, the timely supply of eco-information can help farmers to get informed of the fundamental productivity of arable land and identify the cycle of agriculture recuperation. For example, with methods for measuring the bearing capacity and the natural force of land such as economic model [34], trend analysis [35-36] abandoned, Geography Information System (GIS), which was originally used for urban construction planning [37], is applied to agriculture in the United States. In other words, data of various types monitored by the remote sensor is input to decision equations with different weights with results displayed by graphical techniques, achieving measurement, monitoring and prediction of land pollution, fundamental productivity improvement, forests and biodiversity [38-39], so as to assist agriculture production and income increasing by virtue of monitoring and improving land fundamental productivity.

China should pay much attention to the positive effects of supplying high-tech agriculture monitoring information on the development of agriculture informatization. Firstly, since meteorological observatory is the basis for timely mastering the agro-meteorological situation, integrated weather monitoring station should be increased in key agriculture production areas such as the northwest and northeast to change the imbalance of meteorological information supply between the East and the West. Secondly, agro-meteorological observation projects and means should be appropriately added, for example, to observe weather changes in combination of meteorological stations, satellites, radars and meteorological balloons; multiple items such as climate, ice and snow, hydrology, earth surface, paleoclimate, remote sensing and solar activity can be included in observation to guarantee all aspects of agriculture production; thirdly, active promotion of disastrous meteorological information should be enhanced to minimize the damage caused by catastrophic natural disasters to agriculture; finally, knowledge of meteorological science should be promoted via multiple channels, so that farmers can be aware of the importance of disaster prevention and mitigation.

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