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Comparative Research on Sino – US Agricultural Innovation Model in Science and Technology

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Abstract This research was conducted to provide a comparative analysis of China's and US's agricultural innovation in science and technology and offer some guidance on the construction of agricultural innovation system in science and technology in China. The countermeasures are proposed with a hope to shorten China's and US's gap of agricultural innovation in science and technology by analyzing agricultural innovation model features in science and technology of the United States. The advantages of United States model of agricultural innovation in science and technology include sound legal framework safeguard, complete scientific and technological innovation system, high quality and talented personnel, sufficient technical development and extension funding, and extensive applications of modern agricultural high-tech. There is a gap in agricultural innovation between China and the United States. Agriculture innovation in science and technology in China should improve in several aspects such as agricultural legislation, construction of sound agricultural innovation system in science and technology, building first-class agricultural innovation and extension teams, establishing diversified channels for investment, and improving the applications of high technology in agriculture.

Key words Sino – US comparison, Agricultural science and technology, Innovation mode, Countermeasures

1 Introduction

As an economic power nation in the world today, the US's agricultural economy is taking the lead. The fast economic development in the US mainly benefits from its technical innovation. Agricultural statistics (2010) in the US showed that the total national income was about $ 12.2 trillion, and farm income was about $ 343.2 billion. There were about 2.2 million farms, and only 762 000 hired farm workers. The agricultural exports from the U. S exceeded $943.8 billon, and funding for agricultural science and technology research and experimental development (R&D) was about $ 11 billion in 2009. However, China Statistical Yearbook (2010) showed that China's national income was about 34.3 trillion Yuan, agricultural gross income was 3.06 trillion Yuan, rural population reached 712.88 million people. There were only 1818 farms, agricultural exports was about $ 60.7 billion, and funding for agricultural science and technology research and experimental development (R&D) was about 13.8 billion Yuan in 2009. The above data indicate that the United States has certain advantages in term of inputs and outputs in science and technology in agriculture in areas. Therefore, it is of great significance to conduct comparative research on the model of agricultural innovation in science and technology between China and USA. The research may help China enhance its agriculture innovation in science and technology. LIU Guang-qiang and WANG Hai (2003) developed China agricultural law system by learning from foreign experience. PENG Yu-wen and WU Lin-hai (2007) analyzed the deficiency of agricultural investment in science and technology in China, and proposed the countermeasures of raising investment intensity and efficiency of agricultural science and technology in China based on analysis and comparison of agricultural science and technology investment between China and USA. WANG Xue-jun (2010) analyzed agricultural development models in science and technology between China and USA by contrasting macro-objectives, public welfare goal, and marketing objectives. HUANG Guo-qing, SONG Xin-guo and QIU Bo (2011) promoted agriculture extension works in science and technology in China from the perspective of agricultural extension in science and technology by learning from extension experiences in USA. The previous studies have investigated the development of agriculture innovation system in science and technology in China from different perspective of legal system, investment in science and technology, market mechanism, technology extension in scientific and technological innovation. These developments have had positive impacts on the promotion of agricultural innovation in science and technology in China, but only few studies have been conducted on the comprehensive analysis of the advantages of agricultural technology innovation in USA. This research provides a comprehensive comparison of agricultural innovation models in science and technology between China and US by using an in-depth analysis from the aspects of law, innovation systems, human resources, funding and high-tech. This research analyzes the causes of the differences of agricultural innovation in science and technology between China and US, and proposes the corresponding countermeasures of agriculture innovation in science and technology in China. The conclusions drawn will be of guiding significance in the development of the construction of agricultural innovation system in science and technology in China, and play a

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positive role in improving the ability of agricultural innovation in science and technology, enhancement of agricultural economic development in China, and building the modern agriculture development with Chinese characteristics.

2 Analysis of agricultural innovation in science and technology model in the USA

Innovation in science and technology provides power of agricultural modernization in USA. Under legal protection in agriculture, integration of production, education, and research improves agricultural innovation system, promotes sound development of agricultural innovation in science and technology, optimizes the agricultural innovation resources, and improves the efficiency of agricultural innovation in science and technology. The model of agricultural innovation in science and technology in USA has several characteristics such as a complete legal framework, productive innovation system in science and technology, education and training of qualified personnel, appropriate and timely technical developments and funding for extension, and widely used modern agricultural high-techs.

2.1 Complete legal framework of agricultural innovation in science and technology The legislation of agricultural innovation in science and technology in USA may be traced back to the Morrill Act of 1862 and the Hatch Act 1877. The establishment of colleges of agriculture through the land-grant funding, agricultural experiment stations through the funding from the federal government, and the agricultural extension system by a way of legislation significantly improved agriculture in USA (YU Xue-jun, 2012). The first Agricultural Adjustment Act was enacted in 1933. Since then, the United States has formed a good and workable agricultural law system based on agricultural law, and more than 100 important laws supporting agriculture (XU Shi-ping, 2005). In 2007, farm bill proposed, that in the next 10 years, US would increase direct subsidies by $ 5.5 billion in commodity plan, ecology protection, trade, nutrition plan, credit, rural development, agricultural research and extension, forest, the energy, and family farm bankruptcy protection. According to agricultural product exportation analysis of Ministry of Commerce of People's Republic of China in 2009, agriculture domestic support and subsidy amounts were very high in United States. At the beginning of 2008, US Congress had passed 2007 – 2012 "New Agricultural Bill". As a result of this agricultural subsidies would reach up to $ 290 billion, with more attention paid to the interests of new entrants of new and small farms (GU He-jun, 2008). This is bound to strengthen the ability of farmers, especially small farms to withstand market risks, and increase the interests of farmers and small farmers in agricultural production. Based on the agricultural law, the government price support and subsidies promote farmers to enhance competitiveness in the free markets in USA (WANG Ruo-xi, 2009), avoid agriculture crisis due to surplus of agricultural products, and protect agricultural development (WENG Ming *et al.*, 2007). This has positive effects on the establishment of market mechanisms for agricultural products, and protection of U. S. agriculture. (CAO Pei-zhong *et al.*, 2004).

2.2 Perfecting "trinity" in agricultural innovation system in science and technology Agriculture in USA has a well developed scientific research structure and strong scientific research capability. It is not only one of the most productive nations in the world, but also is the biggest exporter of agricultural products (BAI Zhen-zhong, 2009). "Trinity" of production, education, and research is the highlight of agricultural innovation in science and technology in the United States. Firstly, US has the a well developed and comprehensive agricultural innovative research organization in science and technology at the national level; Secondly, market-oriented needs of agricultural education, research and extension agencies are mainly based on colleges of agriculture of each state's land-grant universities; Thirdly, extension and application of agricultural innovation in science and technology are mainly based on the needs and demand of agricultural enterprises and farmers.

2.2.1 National agricultural innovation research institutes in science and technology. According to the organizational charts of Agricultural Research Service (ARS) of United States Department of Agriculture (USDA), national agricultural innovation research institutes in science and technology are its components. The ARS is to develop new knowledge and technology needed to solve agricultural problems of broad scope and high national priority in order to ensure adequate production of high-quality food and agricultural products to meet the nutritional needs of the American consumer, to sustain a viable food and agricultural economy, and to maintain a quality environment and natural resource base. The ARS administers Office of National Programs, Administrative and Financial Management, Office of International Research Programs, Office of Chief Information Officer, Legislative Affairs Office, Office of technology Transfer, Budget and Program Management Staff, and Office of Scientific Quality Review. The ARS supervises research institutions at different locations including Beltsville Area, Mid South Area, Midwest Area, North Atlantic Area, Northern Plans Area Pacific West Area, South Atlantic Area, Southern Plains Area, and National Agricultural Library. They mainly focus on scientific and technological research on nutrition, food safety and quality, animal production and protection, natural resources and sustainable agricultural systems, and crop production and protection.

2.2.2 College of agriculture of land-grant state universities. Colleges of agriculture of land-grant state universities are the colleges having the unique mission, which were founded by the funding through auction of land from government grant, engaging in education, research and extension of agricultural innovation in science and technology. As an important part of agricultural innovation in science and technology in USA, colleges of agriculture often integrate agricultural, human and natural sciences in education, research and extension. The main domain involves agribusiness, agricultural and extension education, animal science, plant and soil

science, food science, biochemistry, and family and consumer sciences. College of agriculture focuses on cultivation of innovative ability for graduate students. There are many scientists and researchers which allow students to participate in the innovation of agricultural science and technology research projects.

2.2.3 Extension organization of agricultural innovation achievement in science and technology. Extension system of agricultural innovation in science and technology (CHEN Ya-dan, 2005) consists of three levels: Federal Bureau of agricultural extension, state agricultural extension station, and county agricultural extension station. The mission of Federal Bureau of agricultural extension (CUI Chun-xiao *et al.*, 2012) is to implement the relevant laws and regulations of agricultural extension in science and technology, and manage them to ensure that the cooperative extension system has high quality services for the agricultural enterprises, and to coordinate agricultural extension work carried out smoothly throughout the country. State agricultural extension stations in different states are the intermediate agricultural extension institutions, and were set up at colleges of agriculture at state universities, integrating agricultural education, research and extension. Experiment Station Director holds a concurrent post as the dean of the second-level college of agriculture. Professors at the college of agriculture are responsible for the extension, demonstration and the transportation and sale work of agricultural innovation achievement in science and technology. County extension station has part of the state cooperative extension program. Its mission is to make concrete extension plan and implement extension and education policy of agricultural technology, and to provide the information consultant service to the producers and farmers.

2.3 High-quality of personnel for agricultural innovation in science and technology The main reason the United States is a world power in the military, economic and other aspects because it has a large number of highly qualified scientific and technical personnel. United States Government understands the great importance of educating and training of creative talents, develops relevant educational system, immigration policies to attract the world's best talents to the United States, and creates a good environment for them. Because agriculture is the foundation of industry, sci-tech innovative talent engaging in agricultural is relatively weak (ZHANG Jing, 2011). Therefore, the United States hires international high-tech talents to engage in agricultural innovation in science and technology. Colleges of agriculture at land-grand universities provide higher scholarships to attract overseas students to study for degree to compensate for the relative shortage of talents of agricultural innovation in science and technology every year. Due to good polices and environment, the US has highly-qualified agricultural technology innovation talent. For example, county-level agricultural extension workers are with a master degree or above, which provides powerful intelligence support for agricultural innovation achievement extension in science and technology.

2.4 Sufficient technical development and extension funding The United States agricultural technical development and extension funding comes from a wide range of investment system. On the one hand, the main funding is from fiscal budget investment of federal state, the state, and the county, in which federal state's investment approximately accounts for 30%, the state and the county authority's investment approximately accounts for 51%. On the other hand, American private enterprises invest a lot in agricultural research. Approximately 19% of the investment funding of the state agricultural experiment station comes from private enterprise grants (HUANG Jun, 2011). Funding for agricultural science and technology research and experimental development (R&D) was about $ 11 billion in 2009. Federal state funding is mainly used for Beltsville Area, Mid South Area, Midwest Area, The North Atlantic Area, Northern Plans Area, the Pacific West Area, The South Atlantic Area, Southern Plains Area, and so on. The state and the county authority' funding is mainly used for each state and county's scientific and technological innovation research and agricultural extension. The private enterprise's funding is mainly used for enterprise's product research and development.

2.5 Widely used modern agricultural high-techs Agriculture in the United States is highly developed , and agricultural labor productivity in US has been ranked top in the world. In 1977, the year before China's economic reform, annual output value of one agricultural labor force has reached US $ 23,800, and the production generated by one person a year can support 56 people (ZHENG Lin-zhuang, 1979). The success was mainly due to widespread application of agricultural innovation achievement in science and technology. Firstly, the mechanization, regionalization and specialized production greatly improved agriculture in USA. The degree of Agricultural mechanization on American farm is very high, and this is one of the main reasons for the high productivity per labor in USA. Also the variable and favorable climates and soils, regionalization, and specialization of production have contributed heavily; secondly, global positioning systems (GPS) are being widely used in agriculture (XIE Yi-ya, 1999). GPS installed on agricultural machinery can receive the relevant data measured when the farm machinery works. Computer software can be used to draw graphics, and analyze factors such as soil nutrients, targeted fertilization, irrigation, which can improve agricultural outputs; Thirdly, the bio – engineering technical application, especially the genetic engineering can improve varieties of crops, nutrition and the ability of crops to resist disease; Fourthly, modern information technology application is very common. By using the Internet, farmers may inquire the weather situation, the market conditions and other information to help farmer on agricultural production and decision-making.

3 Comparison of Sino – US agricultural innovation model in science and technology and countermeasures

Productivity in nearly all industries and throughout most of the world has experienced rapid growth for several decades. This is particularly true of U. S. agriculture (Yucan Liu *et al.*, 2009). Looking over agricultural science and technology innovation devel-

opment process in the United States, which is from primitive cattle farming using cattle and horses 200 years ago, to today's modern agriculture of the highest top agricultural productivity in the world, the scientific innovation has provided the power for the US agriculture modernization. Complete legal framework, productive innovation system in science and technology, qualified personnel, sufficient technical development and extension funding, as well as widely used agriculture mechanization, improved varieties, better pest control and even satellite technology (Ron Smith,2010) in agriculture make US agriculture highly developed and productive in the world. Agriculture industry superiority in USA mainly benefits from the agricultural innovation in science and technology. In light of this U. S. model, China's agriculture development could be advanced through agricultural innovation in science and technology, and create the development model of China's agricultural modernization.

3.1 Strengthening agricultural legislation in China At present development of China's agriculture still faces many challenges, mainly because China's agricultural infrastructure is weak, disaster mitigation ability is weaker, resources environment is worsening, the demand and supply of agricultural product market is not balanced, peasant household production is small, agricultural product quality also has the problem, job holders' education is low, and especially agriculture-related laws and regulations also need to be further improved. These factors have seriously restrained the process of agricultural modernization in China. Since 1933, the United States has issued more than 100 agriculture-related laws. Its basic principle is to provide legal protection to the agriculture. More than 100 agricultural relevant laws have provided legal guarantee for the development of modern agriculture from multi-perspectives, which can be used by China as references. Since the establishment of "Land reform Law" in 1950 , China has carried on the agriculture legislation in the aspects of agricultural production and management system, agricultural production, agricultural products, the rights and interests of farmers, agriculture and environmental protection (ZHANG Nai-qin, 2009). But for now, the development of China's agricultural modernization has much difficulty. Generally speaking, the legal system is imperfect. Therefore, enacting appropriate laws and regulations, strengthening the agricultural sci-tech law enforcement, and improvement agriculture relevant law from multi-perspectives are very urgent. Under the guidance of the basic principles of agricultural law in China, the related laws should be revised and enacted, including Agricultural Mechanization Promotion Act, Agricultural Technology Extension Act, Agricultural Product Quality Security Act, Water Pollution Prevention Act, Circulation Economy Promotion Act, Wild Animal Protection Act, Animal Epidemic Prevention Act, Small and Medium-sized Enterprise Promotion Act, Science and Technology Popularization Act, Prairie Act (Revision). These laws provide the powerful legal basis for the agricultural innovation and extension in science and technology. The other related legal regulations should also be enhanced, for example, Agricultural Transgenic Biological Security Management Rule, Food Security Rule, Dairy Product Quality Safety Surveillance Rule of Administration, Major Animal Epidemic Situation Emergency Rule, Plant New Variety Protection Rule, Forest Plant Disease Prevents and Controls Rule, Agricultural Chemicals Rule of Administration, Feed And Feed Additive Rule of administration, Town Land Using Tax Provisional Regulation, Returning farmland to Forest Rule, Basic Farmland Protection Rule, and Agricultural Insurance Rule. The laws and regulations of agricultural investment, agricultural subsidies, agricultural disaster risk, and agriculture-related international trade also need to be further studied and revised to provide legal guarantees for the construction of agricultural innovation in science and technology in China.

3.2 Development and implementation of agricultural innovation system in science and technology The USA has a productive agricultural innovation system in science and technology, and the innovation highlights model of agricultural innovation in science and technology based on "trinity" of production, education, and research. This system mainly integrates agricultural innovative research education, extension together in science and technology, optimizes the agricultural innovation resources in science and technology, and provides better development in agricultural innovation in science and technology.

At present, China's research institutions of agricultural innovation system in science and technology are composed of agricultural research institutions under the Ministry of Agriculture, agricultural college, provincial and municipal academy of agricultural sciences under the Ministry of Agriculture. This system has vertical leadership function. Administrative province in parallel with the Ministry of Agriculture has agricultural management functions, and governs the Department of Agriculture and provincial and municipal Academy of Agricultural Sciences. Among them, provincial and municipal Academies of Agricultural Sciences have dual-level leading bodies, namely, research department under Ministry of Agriculture, and provincial and municipality level administrative department. This will create a system with multiple leaderships, unproductive, with low innovation efficiency. Therefore, agricultural policy-making functions of the Ministry of Agriculture should be strengthened, relationships with provincial and municipal administrative functions should be coordinated, the decision-making power in agricultural research and innovation of provincial and municipal administrative functions should be weakened, and the division and collaboration mechanism should be formed.

Agricultural university and agricultural academy are public institutions in China. They also do not run fully in accordance with the market, the ability to withstand the market risk is poor, and responsibility of agricultural technology extension is not strong. Therefore China should learn technical innovation experience from agriculture universities in USA. The responsibility of agricultural university in agricultural innovation and extension in science and technology should make clear to university professors. Use of incentive award mechanisms makes professor and researcher

fully engage in agricultural innovation and extension in science and technology. The special policy guidance in evaluation and promotion, honor, and reward should be carried on. The professor who has made special contribution to agricultural innovation and extension in science and technology should gain tenured professorship similar to those in United States. Those countermeasures create a good environment for innovation and extension in science and technology, play a role in experts' intelligence and ability, and form the integration of "production, education and research" agricultural innovation system in science and technology.

3.3 Building first-class personnel of agricultural innovation and extension in science and technology Development of agricultural modernization in China still has many difficulties to overcome. Currently, trained personnel are the main bottleneck of agriculture innovation and extension in China. China has more than 50 million illiterate people in rural areas, and the majority of rural population does not have college or even high school education. American farmers generally received formal education, and many of them have university degrees, and some have master or doctor degrees. Farmers with a high school education are also specially trained in agricultural through vocational education. They not only understand the field cultivation techniques, are skillful in operating various machinery, but also are familiar with the agricultural products market, and management (ZHAO Xing-quan, 2001). By comparing with USA, the gap of agriculture innovation in science and technology in China is wide. Therefore, China must try to catch up and build talent teams of agriculture innovation and extension in science and technology urgently. This is the most important work in agriculture in China. China should increase the investment in the construction of talent teams. As with other industries like aviation, the policy should encourage and attract domestic and foreign outstanding talents to join in agriculture innovation and extension in science and technology. In particular, country should implement special policies to attract forward-looking leading talents from overseas. At present, country should make policy to invite or recruit Chinese-american scientists at colleges of agriculture at land-grand universities; On the other hand, China should fully stimulate the enthusiasm of agricultural innovation and extension in science and technology of the domestic agricultural experts and scholars at agricultural universities. There is need to improve the quality of agricultural scientific and technical personnel, and to strengthen the basic cultural education for the majority of farmers. These are parts of an overall effort to improve the agricultural innovation in China. National policy is required to support agricultural innovation in science and technology vigorously.

3.4 Establishing diversified investment channels in agricultural innovation in science and technology The agricultural science and technology funding in the United States comes from government fiscal budget, enterprise investment, and private sector grants. China should learn from this kind of investment system. Because agriculture is the national foundation industry, also is the weak industry, national government should be the main investment body in agricultural innovation and extension in science and technology. Especially national government should invest in the basic scientific research which has no gains in short-terms to protect the modern development of agricultural industry fundamentally. In 2009, there were 894 national key leading enterprises in agricultural industrialization which formed the main body of agricultural production and business activities. Their sales income amounted to 143 million Yuan, and profit amounts to 58.36 billion Yuan. There is great potential for enterprise innovation investment in science and technology. But national finance should also support agricultural industrialization through technological transformation of enterprises. But in view of serious shortage of funds for extension of agricultural innovation achievement in science and technology, the government should set up special funding for extension of agricultural innovation achievement in science and technology. Country must make the related agricultural extension protection policy to reduce the investment risk. Preferential policies to attract foreign investment, and private capital should be carried on to create multi-channel financing and reward those who invest.

3.5 Improving the level of application of high technology in agriculture At present, the United States has the advantage of the modernization of agriculture, and agricultural labor productivity is ranked high in the world. Technological advances have contributed to impressive yield gains and have greatly improved US agriculture(G. F. Sassenrath *et al.*, 2008). At present, China's agricultural high-tech application still has not been as extensive as the United States. Development of modern agriculture in China also needs to do the following: Firstly, it should promote the agricultural mechanization and specialization. This has certain difficulty now due to the lack of development in rural China. China is a country with the largest agriculture population in the world. According to the 2010 China Statistical Yearbook, rural population amounted to 712.88 million persons in 2009. The cultivated land amounted to121.72 million hectares, but the average per capita holdings are small. In 1978, China's decentralization of rural policy of household responsibility makes it possible the use of right of land to peasants, which is not conducive to large areas of agricultural mechanization of harvesting, and specialized production. In 2009, agricultural machinery total power is only 875 million KW. The vast rural has not realized agricultural mechanization and specialization. Therefore, intensive rural land transformation should be undertaken, agricultural cooperation organization should be founded, and agricultural mechanization and specialization should be realized in large-scale, intensive way. Secondly, the agricultural information system be developed and promoted. Currently GPS and Internet technology is widely used in agriculture in the United States, but in China, it is still only available at early stages. As the construction of China's Beidou satellite navigation systems, the efforts of development of agricultural information should be expedited. Modern agricultural information system should be established which integrates weather forecast, analysis of agricultural production data, agriculture message communications serv-

ices and agricultural decision-making system together. Thirdly, the application of bio-technology, genetic engineering, cultivation of new varieties, disease prevention and control, agricultural product safety, and environmental protection be applied and researched. The wide applications of innovation achievements in science and technology will promote the rapid development of modern agriculture in China.

4 Conclusions

The United States agriculture has been modernized, and innovation in science and technology provides power of agricultural modernization. Integration of production, education, research of agricultural innovation system is fundamental of agricultural modernization in the United States. China should learn from the aspects of complete legal framework safeguard, perfecting innovation system, high-quality talent team building, the model of financing of technical development and extension, and wide applications of new and modern agriculture technology in the USA. There is still a wide gap in agricultural innovation in science and technology between China and the US. Legal protection systems need to be modified, and the enforcement of the law needs to be strengthened. Innovation system in science and technology still can not be fully adapted to the needs of the market mechanism. Training and recruitment of qualified personnel in agricultural innovation and extension in science and technology is an urgent need. The funding of agricultural innovation and extension in science and technology also must be diversified. The applications of science and technology must be increased in aspects of genetic engineering, cultivation of new varieties, disease prevention and control, agricultural product safety, and environmental protection. Information system, mechanization, specialization, intensification and formalization should be realized in China's agriculture. Under the protection of laws and regulations in agricultural innovation in science and technology, China should optimize agriculture innovation resources in science and technology, raise agriculture labor productivity, improve international competitiveness of agricultural products, promote China's agricultural economic development to achieve national food security, and create a sustainable development road of agricultural modernization.

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