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How Can Agriculture Achieve High-quality Development in China?
——A Multisectoral Model Perspective

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ABSTRACT
This paper aims to analyze main factors affecting China's agricultural development and try to put forwards practical measures to help it achieve high-quality development. The authors construct a multi-sector model that includes agricultural production, R&D and intermediate product departments, and then use empirical method of simultaneous equations to analyze factors affecting China's agricultural development in recent years. Empirical results show that the input of intermediate products (such as fertilizers, pesticides and agricultural machinery), agricultural financial support and development of agricultural technology are important driving forces for agricultural development at this stage. In the context of high-quality agricultural development, the era of dependence on labor input and blind expansion of land has passed. The cross-sectoral transfer of agricultural labor and idleness of land have also brought new opportunities and challenges to the development of China's agriculture.

Keywords: *High-quality development, Multi-sector model, Simultaneous Equations Model, Motivation factor.*

1. INTRODUCTION

Agriculture problem is one of the difficult issues challenging high-quality development of Chinese economy. The No. 1 Central Document (the first policy statement released by Chinese central authorities each year) in 2020 clearly pointed that government will continue to focus on stabilizing agricultural production and increasing farmers' income to promote high-quality agricultural development. However, the number of labors, as a traditional agricultural input factor, has dropped significantly in recent years. According to data released by the National Bureau of Statistics, the number of employees in China's primary industry dropped from 360.43 million in 2000 to 194.45 million in 2019. The labor force has gradually shifted from agricultural sector with low production efficiency to non-agricultural sector with high production efficiency, which has brought huge challenges to traditional agricultural production. Therefore, new production power is needed for high-quality development of agriculture.

2. LITERATURE REVIEW

According to theory of endogenous economic growth, the driving force of economic growth comes from technological progress and capital accumulation [1]. Profit stimulates technological progress, and technological progress increases the marginal productivity of capital and labor, and further promotes economic growth. It can be considered that high productivity and its production possibility boundary caused by technological progress are one of the decisive factors for the limit of economic growth rate. Therefore, it is inevitable to discuss the impact of agricultural technology input. At this level, Aghion-Howitt's R&D model reveals that on the path of balanced growth, economic growth comes from technological innovation [2]. And similar to traditional endogenous growth model, the A-H model also assumes that the growth of technology has a scale effect (the increase in the number of R&D personnel results in continuous technological progress). However, Jones denied this conclusion through data verification, and proposed a multi-sector semi-endogenous growth model based on traditional endogenous growth model, which solved the existing scale effect problem [3]. In recent years, continuous growth of China's agricultural economy is due to continuous deepening of labor division in agricultural sector. For example, Gao Fan believes that main driving force of China's agricultural development should come from the promotion with five evolution factors including material capital circulation, human capital circulation, professional organization promotion, internal structural adjustment and external labor transfer, verified by empirical analysis [4]. Therefore, a multi-sectoral semi-endogenous growth model may be able to provide a good explanation for China's agricultural economic growth.

Different from traditional factor input, another important source stimulating economic growth is fiscal input. Firstly, fiscal input would form public capital that is different from private investment to promote economic growth directly [5]. Secondly, fiscal input could improve the average level of social welfare to stimulate consumer demand and to drive economic growth [6]. Thirdly, fiscal input helps the flow of public capital into production units, which promotes the innovation of enterprise productivity and indirectly stimulated economic growth. Recently, the relationship between fiscal input and agricultural development has also been favored by many scholars. Wang Yinmei and Liu Dandan believe that China's construction of modern agriculture requires strong support from government finances, but it is found that the scale and efficiency of China's fiscal agriculture are not ideal through evaluation of the efficiency of fiscal agriculture, and the efficiency of fiscal expenditures needs to improve [7]. Yu Yang and Wu Mingran studied dynamic relationship between agricultural fiscal input and agricultural economic growth, and found that fiscal input has a negative impact on agricultural economic growth in a short term, but it has a positive effect in the long run [8]. Of course, the research on the role of fiscal input is not all overwhelmingly supportive. Scholars such as Peng Keqiang pointed out that although fiscal support for agriculture can promote long-term agricultural production, the lack of growth of agricultural funds due to financial investment has hindered further development of agriculture to some extent [9]. In short, when studying the input and output of agricultural sector and the growth momentum of agricultural economy, fiscal expenditure should be included in analysis system besides traditional input factors. However, the way that fiscal expenditure affects agricultural economy still needs further research.

3. METHODOLOGY

In this section, we construct a multi-sector model that includes agricultural production, intermediate product and R&D departments.

3.1. Production Department

Based on the existing research, we propose following hypotheses. The progress of agricultural technology is mainly reflected in two aspects, one is to improve the quality of agricultural production materials (that is, products used in production) and the other to improve the production technology of agricultural labor [10]. Different from traditional industrial production models, in agricultural production, intermediate products mainly include production materials such as agriculture machinery, fertilizers, seeds, etc., and the updating of these production materials will replace original ones. Therefore, the process of technological progress in agriculture is actually a process of technological innovation. And the improvement of intermediate products by technological changes is mainly reflected in quality improvement. As mentioned earlier, the scale and efficiency of government fiscal expenditures will also have an impact on agricultural production. So, we make improvements on the basis of the traditional C-D production function:

$$Y(t)=\left(Z(t)L_Y(t)\right)^{\alpha}\cdot\prod_{i=1}^{m}\left(Q_i(t)X_i(t)\right)^{\beta_i}\cdot G_Y^{\phi}(t) \quad (1)$$

where: Y – agricultural output; Z – agricultural labor technology; L_Y – labor input engaged in agriculture; X – intermediate product input; Q_i –quality of the i-th intermediate product; G_Y – fiscal input for agricultural production;$\varphi\in[0,1]$ represents the efficiency index of fiscal expenditure; α represents the output elasticity of effective labor; β_i represents the output elasticity of the i-th intermediate product, and $\alpha+\sum_{i=1}^{m}\beta_i=1$.

3.2. Intermediate Products Department

Assume that the quality of intermediate product at time t is *Q(t)*, the quality at t-1 is *Q(t-1)*, and its quality has increased by z (z > 1) times by technological improvement. The probability of successful R&D is δ, otherwise it is $1-\delta$. So the following relationship exists at time t:

$$Q(t)=(1-\delta)Q(t-1)+z\delta Q(t-1)=(1-\delta+z\delta)Q(t-1) \quad (2)$$

Assuming that the quality of intermediate product at the beginning is Q(0), the function at time t is

$$Q(t)=Q(0)\square f(\delta) \quad (3)$$

which means the quality Q of agricultural intermediate products can be expressed as a function of agricultural scientific research output. As analyzed in the first part, the increase in agricultural research output has resulted in an improvement of the quality of agricultural intermediate products. Since the quality of intermediate products could not be measured by an accurate standard, it may be replaced by the number of scientific research results.

3.3. R & D Department

Similar to other scientific research, agricultural scientific research requires support of human capital and financial capital. So does the output of agricultural scientific research. However, financial support of agricultural research and development has characteristics that are different from others. For example, investment risk and failure rate of research are both high, the return period of agricultural research is too long, and the external effects are obvious [11]. Therefore, the source of funds for agricultural research in China still mainly depends on government investment. We construct the R&D production function as follows:

$$\dot{A}(t)=\delta L_A^{\beta}(t)G_A(t)^{1-\beta}A(t)^{\theta},\quad \delta>0,\beta\geq 0 \tag{4}$$

where: $\dot{A}$– agricultural research output; L_A –number of labor force engaged in agricultural scientific research; G_A – government investment in agricultural research; $A(t)$ – existing knowledge stock; θ reflects the impact of existing knowledge stock on the success or failure of R&D. We do not limit the sign of θ, because the influence of existing knowledge on new scientific research results is uncertain. On the one hand, past achievements may provide reference for the birth of new achievements, making it easier for new scientific research results to be born, that is, $\theta>0$; but on the other hand, the easiest results have often been invented, and with the increase of scientific research results, it is often difficult to make some new discoveries, that is, $\theta<0$.

At the same time, combined with analysis of the first two departments, we assume that new technology is completely substitute for original one. And we do not consider the losses and costs in the process of technology promotion, and part of new technology is used to improve technical level of labor, and the other part is used to improve the quality of agricultural production materials (intermediate inputs). A relationship is set as follows:

$$\begin{aligned}&\dot{A}_0(t)=Z(t)\\&\dot{A}_j(t)=Q_i(t)\ ,j=i\end{aligned} \tag{5}$$

3.4. Empirical Model

The output of agriculture is affected by many factors. According to Equation (1), we can generally see that factors which affect agricultural output roughly include labor, production materials in production process (intermediate inputs), technical factors, etc.. It is worth noting that land, a special production factor, is not directly reflected in multi-sectoral model. The reason is as following. The finiteness of land makes it stable in agricultural production, and it can be used as a quantitative treatment when constructing a model to facilitate the analysis of the model. Moreover, the non-tradable nature of land in China sets it apart from ordinary capital inputs, so our model does not include land in the category of intermediate inputs *X*. But in this part of the empirical analysis, in order to fully reflect the driving force affecting agricultural economy as much as possible, we need to incorporate land factor into empirical model for analysis. Take the logarithm of both sides of Equation (1), and simplify to get:

$$\begin{aligned}\ln Y(t)=&\left(\alpha\ln Z(t)+\sum_{i=1}^{m}\beta_i\ln Q_i(t)\right)+\alpha\ln L_Y(t)\\&+\sum_{i=1}^{m}\beta_i\ln X_i(t)+d\ln D(t)+\phi\ln G_Y(t)\end{aligned} \tag{6}$$

where, $\alpha\ln Z(t)+\sum_{i=1}^{m}\beta_i\ln Q_i(t)$ represents the impact of agricultural research output on agricultural output, while scientific research factors are endogenous and are mainly obtained through Equation (4), that is, the output of agricultural scientific research is a function of government's investment and the number of agricultural scientific research employees, and it is also affected by existing knowledge stock. Therefore, the empirical model of agricultural scientific research output is:

$$\ln PA(t)=g\left(\ln GA(t),\ln LA(t),\ln PA(t-1)\right)+\mu_t \tag{7}$$

where: *PA* – agricultural research output; *GA* – government's financial investment in agricultural research; *LA* –number of agricultural scientific research employees; μ is the error term. In empirical model, we use the lag of agricultural scientific research output to represent existing knowledge stock and we replace $\alpha\ln Z(t)+\sum_{i=1}^{m}\beta_i\ln Q_i(t)$ with PA. Then combine Equation (6) with Equation (7) to get simultaneous equation:

$$\begin{cases}\ln Y(t)=c_1+\psi\ln PA(t)+\alpha\ln L_Y(t)+d\ln D(t)\\\qquad+\sum_{i=1}^{m}\beta_i\ln X_i(t)+\phi\ln G_Y(t)+\varepsilon_t\\\ln PA(t)=c_2+\gamma_1\ln GA(t)+\gamma_2\ln LA(t)\\\qquad+\gamma_3\ln PA(t-1)+\mu_t\end{cases} \tag{8}$$

4. DATA

Considering the availability and timeliness of data, we select panel data from 2007 to 2018 of China's 31 continent provinces. Most of the variable data comes from *China Statistical Yearbook 2019*, *China Science and Technology Statistical Yearbook 2019* and some provincial statistical yearbooks the same year. Variables and descriptions are shown in Table 1.

Two points need to be emphasized. First, the employee number in primary industry of Heilongjiang from 2011 to 2013 and Xinjiang in 2018 is not found. Therefore, when we analyze the data, we use unbalanced panel method. Second, there is no corresponding measurement of agricultural R&D personnel and financial expenditures in the statistical yearbooks of each province. However, knowledge and R&D personnel are not specifically limited to a certain department but are constantly flowing, which is knowledge sharing. Therefore, it is completely feasible for us to use the overall level of R&D personnel and government financial investment in the region instead of specific related indicators.

Table 1. The description of variables and data sources

Variable	Description	Data Sources
Y	Gross output value of agriculture	Statistical Yearbook
PA	Number of agricultural research patents	PatSnap Database
LY	Number of employees in the primary industry	Statistical Yearbook
X1	Agricultural diesel consumption	Statistical Yearbook
X2	Agricultural fertilizer consumption	Statistical Yearbook
X3	Pesticide consumption	Statistical Yearbook
D	Effective irrigation area	Statistical Yearbook
GY	Local financial expenditure on agriculture, forestry and water affairs	Statistical Yearbook
GA	Government investment in scientific research	Statistical Yearbook
LA	Full-time equivalent of R&D personnel	Statistical Yearbook

5. EMPIRICAL ANALYSIS

The estimation methods for simultaneous equations model mainly include single equation method (also called limited information estimation method) and system estimation method. Each of them has advantages and disadvantages in respective. When a single equation estimation method is used, the relationship between those equations is ignored, so it is not as efficient as the system estimation method. As a system estimation method used, if an equation is not accurately estimated, the estimation of other equation parameters in the system could be affected and then results in systemic bias. Generalized moment estimation (GMM) and two-stage least squares (2SLS) are common methods of single equation estimation, while system estimation methods mainly include three-stage least squares (3SLS) [12]. Therefore, in this article, we mainly use 2SLS and 3SLS to estimate and compare them. At the same time, in order to make the analysis more convincing, estimation results of ordinary least squares estimation (OLS) are presented together. The estimated results are shown in Table 2.

As shown in Table 2, overall, the 3SLS and2SLS are quite different, but results of 3SLS estimation and OLS estimation are relatively close, which is mainly reflected in the relationship between agricultural output value (Y) and the number of agricultural patents (PA) in agricultural output model. In 2SLS estimation, the influence of agricultural patents on agricultural output value is negative and not significant, while the influence in 3SLS estimation is significantly positive. In this regard, we use a graphical method to illustrate the relationship between the two (take the national average data as an example), as shown in Figure 1. It is easy to see that there is a positive relationship between the two. Therefore, we adopt the result of 3SLS estimation.

Regression coefficients of intermediate inputs (X) are all significantly positive. Separately, inputs of agricultural chemical fertilizers and pesticides have a significant role in promoting the growth of agricultural output value, and their output elasticities are 0.614 and 0.112 respectively, which shows that among current agricultural intermediate inputs in China, chemical fertilizers and pesticides still have a great impact on agricultural production. In a short term, agricultural production is still inseparable from the use of chemical fertilizers and pesticides. At present, China's agriculture, especially grain planting, is still dominated by extensive operations. The proliferation of this type will lead to increasing dependence on inputs such as pesticides and fertilizers. However, from a long-term perspective, the use of pesticides and fertilizers is not conducive to improving the quality of agricultural products. At the same time, we noticed that the output elasticity of agricultural diesel or agricultural machinery is very small, only 0.0420. The following two points we think could explain the result to some extent. First, China's agricultural large-scale operation is still in its infancy, and traditional farming methods based on household production still account for a large proportion. Correspondingly, the price of agricultural machinery is relatively expensive. In the case that agricultural market is not perfect and the scale of agricultural returns is limited, the use of agricultural machinery for production may not significantly increase the output value in a short term. Second, the development of agricultural machinery in China has started for only a few decades and agricultural mechanization level is still low. The coexistence of "surplus" and "shortage" of agricultural machinery made it unable to adapt well to modern agricultural production [13].

Table 2. Results of each regression method

Variable	(1) OLS		(2) TWO_SLS		(3) THREE_SLS	
	lny	lnPA	lny	lnPA	lny	lnPA
lnX_1	0.0379* (0.0214)		0.0931*** (0.0250)		0.0420* (0.0223)	
lnX_2	0.592*** (0.0311)		0.597*** (0.0329)		0.614*** (0.0291)	
lnX_3	0.0951*** (0.0170)		0.102*** (0.0180)		0.112*** (0.0160)	
lnGY	0.338*** (0.0253)		0.462*** (0.0357)		0.334*** (0.0324)	
lnLY	-0.00533 (0.0122)		0.0219 (0.0139)		-0.0139 (0.0123)	
lnD	-0.00691 (0.0299)		-0.0711** (0.0339)		-0.0516* (0.0302)	
lnPA	0.0745*** (0.0129)		-0.00801 (0.0209)		0.0466** (0.0193)	
lnLA		0.682*** (0.0676)		0.682*** (0.0676)		0.709*** (0.0642)
lnGA		0.245*** (0.0697)		0.245*** (0.0697)		0.207*** (0.0649)
lnPA(t-1)		0.245*** (0.0292)		0.245*** (0.0292)		0.269*** (0.0272)
_cons	1.490*** (0.136)	-6.105*** (0.442)	1.360*** (0.146)	-6.105*** (0.442)	1.898*** (0.129)	-6.061*** (0.433)

Note: The panel data is estimated using stata15.0, and robust standard errors are reported in parentheses. *, **, and *** represent significant at the significance levels of 10%, 5%, and 1% respectively.

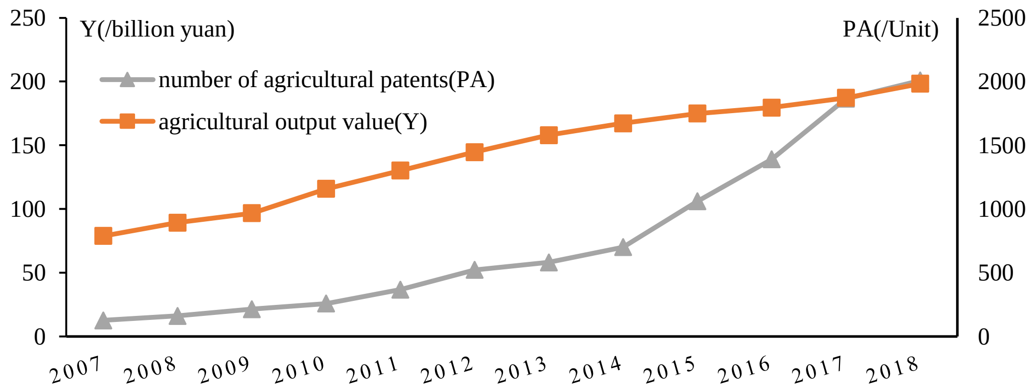

Figure 1 The relationship between agricultural research and agricultural output value

Local fiscal expenditure on agriculture, forestry and water (GY) is significantly positive and its output elasticity is 0.334. It shows that fiscal investment has an obvious impact on agricultural economic growth, and it has a strong pulling effect. In other words, it is the main part of agricultural economic growth structure. At present, it has become a consensus to treat agriculture and rural areas as a priority issue of fiscal expenditure and to increase public finances to tilt toward the national development planning for agriculture, rural areas and farmers. In the long run, fiscal expenditure would have a more significant leading role in the development of agricultural economy.The output elasticity of labor in primary industry (LY) is -0.0139 and it is not significant. As a traditional production factor, labor input has always been the focus of agricultural production. However, with emphasis on high-quality economic development, the goal of rapid agricultural economic growth using "human sea tactics" is no longer realistic. The difference in marginal returns between agricultural sector and non-agricultural sector will inevitably lead to cross-sectoral mobility of labor, leading to loss of labor in agricultural sector. However, this phenomenon is an opportunity for the improvement of China's agricultural economy. For these idea of "rural vitalization " and "high-quality agricultural development", we must use the market to regulate rational allocation of agricultural production factors and focus on efficiency of agricultural labor rather than quantity, so as to further promote the scale farming, urbanization and industrialization.

We need to combine agricultural research output models to explore the impact of agricultural patents (PA) on agricultural production. In terms of specific values, its output elasticity of agricultural patents is 0.0466, which is relatively small. We think it is mainly due to the low conversion rate of agricultural patents. In other words, patents developed did not turn into productivity. In agricultural research model, the output elasticity of the number of agricultural patents lagging one period to number of patents in current period is 0.269, which is significantly positive. Combining the analysis of θ in Equation (5), in this article, θ is greater than 0, which means that current knowledge stock will provide reference for the birth of new results, making new scientific research results easier to produce. Further, the in-depth development of agricultural scientific research requires joint support of scientific researchers and scientific research funds. In regression results shown in Table 2, output elasticities of the two are 0.709 and 0.207 respectively, and both are extremely significant, which shows that it is necessary to increase the training of scientific research talents and fiscal support for scientific research to promote agricultural scientific research output.

6. CONCLUSIONS

This paper reveals driving factors of agricultural economic growth by constructing a theoretical model. The empirical analysis used Simultaneous Equations modeling. And the empirical findings show that intermediate inputs (such as pesticides, fertilizers and agricultural machinery) are all significantly positive. Inputs of agricultural chemical fertilizers and pesticides have a significant role in promoting the growth of agricultural output value, while the output elasticity of agricultural machinery is very small. Moreover, the influence of traditional production factors (land, labor) on agricultural production is gradually weakening with the inter-departmental movement of labor. These are both opportunities and challenges for China's agricultural development. In addition, the role of agricultural financial support is second only to fertilizer input. But it is clear that agricultural finance has a broader space for development and has longer-term development goals. Intensified and large-scale farming by land transfer project still require strong government financial support. Government finance will be an important part of achieving high-quality agricultural development.

Based on the empirical results of this paper, China's current agricultural R&D is still in an immature and imperfect stage, but the model of technology-driven agricultural growth has been reflected in recent years. The increase of scientific research human capital and government financial support is especially important to promote agricultural scientific research output. As mentioned above, the influence of traditional production factors is weakening, and agricultural development from quantitative change to qualitative change will inevitably generate demand for new production factors. Agricultural research is a perfect way to provide this factor of production.

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