The Growth Path of Agricultural Labor Productivity in Major Grain Producing Areas

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Abstract The growth of agricultural labor productivity in major grain producing areas arises from the increase in production factors or improvement of efficiency, and is related to the sustainability of agricultural economic growth and national food security. We study the growth path of agricultural labor productivity in 13 major grain producing areas of China, and the analysis results show that from the relative endowments of land and labor in major grain producing areas, the growth rate of the output value per unit of labor is higher than that of the productivity per unit of land; in essence, this growth path of increasing the output value relying on increasing the production factor inputs is the reduction of labor, and the reduction of agricultural labor has a great elasticity of impact on the total value of agricultural production. In the case of stable future number of agricultural labor in China, the growth of agricultural labor productivity will be impossible to rely more on the increase in agricultural production factor inputs, and the growth path of agricultural economy still has to rely on the improvement of land productivity and take the efficiency-based path.

Key words Agricultural labor productivity, Production factors, Efficiency, Major grain producing areas

The agricultural labor productivity is an important indicator for measuring the agricultural development of one region, and its growth is ascribed to the increase in production factors or the improvement of efficiency. The major grain producing areas are the main force of China's grain supply, bearing the responsibility to ensure national food security. The growth path of agricultural labor productivity in major grain producing areas is of great importance to the domestic food production, and affects the food production stability and future development sustainability in major grain producing areas. Therefore, the study of the law and growth path of agricultural labor productivity in major grain producing areas, is of very important significance to China's agricultural modernization and food security in China.

The agricultural labor productivity has long been studied abroad, and especially Yujiro Hayami *et al.* [1] have gained significant achievements in terms of agricultural labor productivity. They use the data concerning high, middle and low-income countries during the period 1960 - 1980 for the international comparison of agricultural labor productivity, and divide the agricultural growth path in various countries into the growth path of land productivity and the growth path of labor equipment ratio.

The Chinese scholars draw inconsistent conclusions on whether the agricultural output growth in China is mainly from the increase in factor inputs or productivity improvement. Wang Xiaoping[2] draws the conclusion that the growth path of China's agricultural labor productivity over 50 years (1952 - 2003) is "increase in labor inputs-improvement of land productivity-improvement of agricultural labor productivity".

The analysis of Guo Qingwang *et al.* [3] show that the economic growth differences between the Chinese provinces were great from 1979 to 2003, and there is a tendency to gradually expand, which is mainly caused by the gradual expansion of differences in technical process rate. Luo Liangguo *et al.* [4] analyze the factors influencing the agricultural growth of China's major grain producing areas in different periods, and draw the conclusion that the adjustment and optimization of agricultural structure and the full exertion of regional advantages are the important factors for promoting the agricultural development in major grain producing areas.

Most scholars still form a relatively consistent view[5-7]. Currently, in terms of the relative amount of the Chinese agricultural production factors and agricultural labor productivity, the output mode of increasing production factor inputs to bring economic growth occupies the main position of economic growth. However, from the effects of the overall macroeconomic growth, it still ultimately depends on the improvement of agricultural labor productivity.

Starting from the question "Does the growth of agricultural labor productivity in China's major grain producing areas mainly come from the increase in factor inputs or the improvement of production efficiency?", we learn from the research methods of Yujiro Hayami *et al.* to derive the growth path of agricultural labor productivity in major grain producing areas, and put forth practical policy recommendations for the sustainable agricultural development in major grain producing areas and national food security from the labor productivity.

1 Data and model setting

We learn from the method of comparing the international agricul-

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tural productivity by Yujiro Hayami *et al.*[8], to analyze the growth path of agricultural labor productivity (Y/L) in major grain producing areas. The productivity per unit of land (Y/A) and the growing area of crops per unit of labor (A/L) represent the efficiency of agricultural output and production factor inputs, respectively. The agricultural labor productivity (Y/L) can be decomposed into the product of productivity per unit of land (Y/A) and the growing area of crops per unit of labor (A/L), as shown in formula (1).

$$\frac{Y}{L}=\frac{Y}{A}\cdot\frac{A}{L} \tag{1}$$

Take the logarithm on both sides of formula (1):

$$\log\frac{Y}{L}=\log\frac{Y}{A}+\log\frac{A}{L} \tag{2}$$

where Y is the total agricultural output value (product of the agricultural product quantity and price); L is the number of agricultural labor input (number of the labor force in the primary industry in various major producing areas); A is the growing area of crops; $\frac{Y}{L}$ is the agricultural labor productivity; $\frac{Y}{A}$ is the productivity per unit of land; $\frac{A}{L}$ is the growing area of crops per unit of labor.

The data in this study are from *Fifty years of New China Statistical Data Collection* (1949 – 2004), *China Agriculture Yearbook* (1979 – 2010) and the related data concerning 13 major grain producing areas (Liaoning, Jilin, Heilongjiang, Inner Mongolia, Hebei, Henan, Hubei, Hunan, Shandong, Jiangsu, Anhui, Jiangxi and Sichuan).

2 Empirical analysis of the growth path of agricultural labor productivity in major grain producing areas

Based on the study of Yujiro Hayami *et al.*[8], with the logarithm of the productivity per unit of land ($\log\frac{Y}{L}$) as the vertical axis and the logarithm of agricultural labor productivity ($\log\frac{Y}{A}$) as the horizontal axis, the path map is drawn according to the two indicators at the beginning and end of a certain period in major grain producing areas, and it can represent the growth path of regional agricultural labor productivity.

The growth path map of agricultural labor productivity in 13 major grain producing areas from 1979 to 2010 is shown in Fig. 1.

The horizontal ordinate of growth path starting point of various provinces is the logarithm of mean of three years of $\frac{Y}{L}$ (1979 – 1981); the vertical ordinate is the mean of three years of $\frac{Y}{A}$ (1979 – 1981). The horizontal ordinate in the early period is shown in formula (3), and the vertical ordinate in the early period is shown in formula (4).

The vertical ordinate of end point data of various provinces is the mean of three years of $\frac{Y}{L}$ (2008 – 2010). The horizontal ordinate is the logarithm of mean of three years of $\frac{Y}{A}$ (2008 – 2010). The horizontal ordinate in the late period is shown in formula (5), and the vertical ordinate in the late period is shown in formula (6).

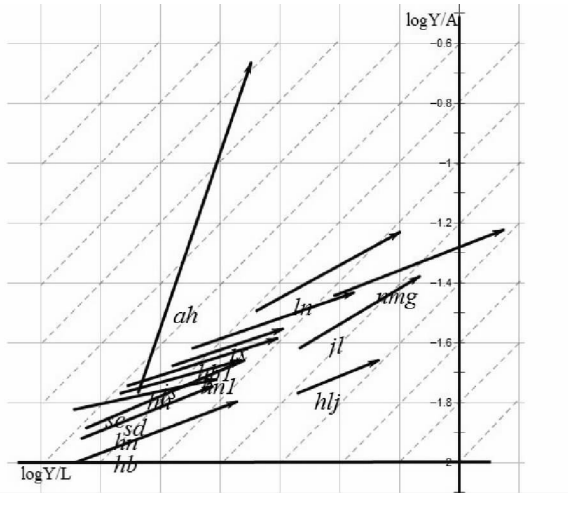
Both the starting point and end point of data take the three – year average can effectively avoid data anomalies in a given year, and taking logarithm of the independent and dependent variables can ignore the measurement unit of variables, making the results have the meaning of elasticity.

$$\log\left(\frac{Y}{L}\right)_{\text{starting point}}=\left[\log\left(\frac{Y}{L}\right)_{1979}+\log\left(\frac{Y}{L}\right)_{1980}+\log\left(\frac{Y}{L}\right)_{1981}\right]\div 3 \tag{3}$$

$$\log\left(\frac{Y}{A}\right)_{\text{starting point}}=\left[\log\left(\frac{Y}{A}\right)_{1979}+\log\left(\frac{Y}{A}\right)_{1980}+\log\left(\frac{Y}{A}\right)_{1981}\right]\div 3 \tag{4}$$

$$\log\left(\frac{Y}{L}\right)_{\text{starting point}}=\left[\log\left(\frac{Y}{L}\right)_{2008}+\log\left(\frac{Y}{L}\right)_{2009}+\log\left(\frac{Y}{L}\right)_{2010}\right]\div 3 \tag{5}$$

$$\log\left(\frac{Y}{A}\right)_{\text{starting point}}=\left[\log\left(\frac{Y}{A}\right)_{2008}+\log\left(\frac{Y}{A}\right)_{2009}+\log\left(\frac{Y}{A}\right)_{2010}\right]\div 3 \tag{6}$$



Note: The letters beneath arrow are the abbreviation of the name of provinces (hn Henan; hn1 Hunan; hb Hebei; hb1 Hubei).

Fig. 1 The agricultural growth path of 13 major grain producing areas

Each arrow in Fig. 1 represents the growth path of agricultural productivity in one major producing area, and from the gradient and length of growth path map, we can get the differences in the growth path of agricultural labor productivity between the major grain producing areas.

From the growth path of agricultural labor productivity, if the gradient is negative, it means that within a certain time, both the logarithm of land productivity ($\log\frac{Y}{A}$) and the logarithm of agricultural labor productivity ($\log\frac{Y}{L}$) decline; if the gradient is positive, it means that within a certain time, both the logarithm of

land productivity ($\log \frac{Y}{A}$) and the logarithm of agricultural labor productivity ($\log \frac{Y}{L}$) increase.

When the gradient of growth path is less than 1, namely the growth path is less than 45° dotted line, it indicates that the growth path is the growth of the production factor inputs (The growth rate of $\log \frac{Y}{A}$ is less than that of $\log \frac{Y}{L}$, indicating that the growth of Y mainly comes from the increase in the output value per unit of labor, and is the growth of factor inputs).

When the gradient of growth path is greater than 1, namely the growth path is greater than 45° dotted line, it indicates that the growth path is the growth of efficiency (The growth rate of $\log \frac{Y}{A}$ is greater than that of $\log \frac{Y}{A}$, indicating that the growth of Y mainly comes from the increase in the output value per unit of growing area, and is the growth of efficiency).

Judging from the length of the path, if the path is longer, the growth rate of land productivity $\log \frac{Y}{A}$ or agricultural labor productivity $\log \frac{Y}{L}$ will be greater; if the path is shorter, it indicates that there is little change in the agricultural productivity in a given period.

2.1 Simultaneous increase in the agricultural labor productivity and land productivity in major grain producing areas

From the direction of growth path of agricultural productivity in major grain producing areas, the gradient of growth path of agricultural productivity is positive in all major grain producing areas, indicating that over 30 years, in all major grain producing areas, both the logarithm of land productivity $\log \frac{Y}{A}$ and the logarithm of agricultural labor productivity $\log \frac{Y}{L}$ have been increasing, indicating that both the agricultural labor productivity (Y/A) and land productivity (Y/L) increase, and the agricultural economy achieves rapid development.

The growth rate of the agricultural labor productivity (Y/A) and land productivity (Y/L) in major grain producing areas over 30 years is shown in Table 1, namely the ratio of horizontal and vertical coordinates in the early period to horizontal and vertical coordinates in the late period in Fig. 1.

From the numerical value, the growth rate of Y/L is about 3, and it is the highest in Inner Mongolia (3.7), while the lowest in Heilongjiang (1.9); the growth rate of Y/A is mostly greater than 1, and it is the highest in Anhui (13). Overall, during the period 1979 – 2010, the agricultural labor productivity and land productivity were increased simultaneously in 13 major grain producing areas, making the total value of agricultural production increase significantly.

2.2 The growth of agricultural labor productivity in major grain producing areas mainly manifested as the increase in the production factor inputs per unit of labor

According to the decomposition of agricultural labor productivity in formula (2), the deeper meaning is to decompose the agricultural labor productivity into the labor efficiency improvement type and production factor increase type. Part of $\log \frac{Y}{A}$ is the output value of per unit of growing area, and the increase in it represents the increase in the output value of established production factors.

Table 1 The growth rate of the productivity per unit of land and agricultural labor productivity in major grain producing areas since the reform and opening up

	Growth rate of Y/L	Growth rate of Y/A	Gradient
Anhui	2.4	12.8	5.359
Hebei	3.5	1.6	0.46
Henan	2.8	1.5	0.54
Heilongjiang	1.9	1.3	0.685
Hubei	2.4	1.3	0.563
Hunan	2.6	1.3	0.505
Jilin	2.6	1.8	0.686
Jiangsu	3.2	1.4	0.45
Jiangxi	3.5	1.5	0.439
Liaoning	3.1	1.8	0.603
Inner Mongolia	3.7	1.7	0.446
Shandong	3.4	1.7	0.494
Sichuan	3.0	1.3	0.417

Note: The data in the table is calculated according to the data in Fig. 1.

It is an efficiency-based growth mode and the biggest factor is technological progress. Part of $\log \frac{A}{L}$ is the growing area of crops per unit of labor, namely the land equipment ratio of labor, and its increase represents the increase in the land area per unit of labor. It is a factor-based growth mode by relying on the increase of production factor inputs to promote output value.

As can be seen from Fig. 1, the growth path of agricultural labor productivity in most major grain producing areas is less than 45° dotted line, and only the growth path of Anhui Province is greater than 45° dotted line. Based on the gradient value in Table 1, the growth of agricultural labor productivity in most major grain producing areas is not mainly from $\log \frac{Y}{A}$, and over 30 years, the output value per unit of growing area in major grain producing areas has not been increased significantly, and the output efficiency of land resources has also not been improved obviously.

Then, the growth of agricultural labor productivity is from the additional $\log (\frac{A}{L})$ part of formula (2), that is, the increase in the growing area per unit of labor and the improvement of land equipment rate of labor contribute to the rapid growth of agricultural labor productivity, and such growth path is the growth path for most of major grain producing areas only except Anhui.

The above analysis shows that in terms of resources and efficiency, the growth of agricultural labor productivity in China's major grain producing areas mainly relies on the increase in the production factor inputs per unit of labor and the growth of agricultur-

al labor productivity still falls within the resource type.

This is basically consistent with the conclusion drawn by Clark[9] that when the new technology can not be effectively adopted, the gap in labor productivity does not come from technological differences, nor does it come from the differences in education or workers' physical fitness.

Major grain producing areas are rich in agricultural land resources, but in comparison with the western countries with developed agriculture or even Japan, China is not a country with abundant agricultural land resources, and the reasons for the rapid growth of agricultural labor productivity mainly relying on the increase in resource endowments need to be explored.

2.3 The reduction of agricultural labor as the main reason for the increase in the production factor inputs per unit of labor in major producing areas According to the dual economic theory of Lewis[10], the economy of developing countries consists of traditional sectors and modern sectors, and the wage gap between the traditional sectors and the modern sectors results in the labor flow. The modern sectors continuously expand, and for the traditional sectors, the labor productivity is promoted after the surplus labor is absorbed.

Based on this point, we continue to carry out in-depth analysis of the reasons for the increase in the production factors per unit of labor in major grain producing areas from the perspective of agricultural labor transfer in the traditional sectors.

Statistics show that the total sown area of crops in China showed an increasing trend from 1979 to 2010 (148.4769 million hm^2 in 1979 and 160.675 million hm^2 in 2010), and the total sown area of grain crops also rose. The reason is that the national farmland protection policies become increasingly stringent, the area of arable land for crops is reduced slowly, and with the continuous improvement of multiple cropping index, the total sown area of crops does not fall but rise.

The agricultural labor concentration index is used to analyze the changes in agricultural labor in 13 major producing areas, and the results are shown in Table 2. It can be found that since 1986, only the agricultural labor concentration index in Anhui Province has kept above 1, and the agricultural labor concentration index in other provinces has the values fluctuating below 1.

The high agricultural labor concentration index indicates that there are many agricultural labor forces in Anhui Province, and compared with the amount of labor in other industries, the agricultural labor has not been significantly reduced over 30 years.

Based on the basically stable agricultural labor and total sown area, the logarithm of sown area of crops per unit of labor $\log \frac{A}{L}$ remains stable, and the growth of agricultural labor productivity mainly depends on the increase in the logarithm of output value per unit of land area $\log \frac{Y}{A}$. This conclusion also further verifies the occurrence of abnormal values of growth rate of Anhui Province $\frac{Y}{A}$ in Table 1. The dramatic decline in the agricultural labor in other major grain producing areas increases the logarithm of sown area of crops per unit of labor $\log \frac{A}{L}$, and increases the logarithm of agricultural labor productivity $\log \frac{Y}{L}$.

And it can be verified that the impact of changes in the number of labor in various regions on total value of agricultural production is elastic, and the impact of reduction of labor on agricultural output plays an amplifying role. In major grain producing areas except Anhui Province, under the precondition of limited potential of agricultural production factor input, the improvement of labor productivity mainly comes from the reduction of the number of agricultural labor, rather than the increase in the absolute value of production factors per unit of labor.

Since the reform and opening up, the reduction of absolute number of agricultural labor in major grain producing areas has increased the production factor input per unit of labor, and this growth pattern is clearly not the sustainable growth pattern.

Table 2 The agricultural labor concentration index in major grain producing areas

Year	Anhui	Liaoning	Inner Mongolia	Hebei	Hubei	Shandong	Jiangsu	Jiangxi
1986	1.18	0.60	0.96	1.09	1.06	1.15	1.02	1.13
1990	1.21	0.60	0.99	1.09	1.05	1.10	0.90	1.14
1991	1.16	0.57	0.97	1.01	0.99	1.10	0.85	1.07
1993	1.16	0.57	0.92	0.99	1.01	1.07	0.80	1.10
1995	1.15	0.57	0.90	1.01	1.01	1.07	0.81	1.08
1997	1.16	0.58	0.94	1.05	1.03	1.07	0.94	1.09
1999	1.10	0.57	0.94	1.04	1.02	1.09	0.91	1.01
2000	1.13	0.58	0.96	1.02	1.01	1.07	0.90	1.03
2002	1.20	0.63	1.04	0.98	1.01	1.06	0.91	0.99
2005	1.18	0.65	1.05	0.99	0.96	1.06	0.87	0.93
2007	1.15	0.66	1.03	0.98	0.96	1.05	0.83	0.92
2009	1.08	0.71	1.03	0.98	0.97	0.96	0.79	0.86
2010	1.08	0.73	1.11	0.98	1.02	0.95	0.80	0.87
平均	1.15	0.62	0.99	1.02	1.01	1.06	0.87	1.02

Note: Data are derived based on *China Agriculture Yearbook*.

2.4 The efficiency improvement as the future growth focus of agricultural labor productivity The growth of agricultural labor productivity of Anhui Province shows the path inconsistent with that of other provinces, and this efficiency-type growth path relying on the productivity per unit of land is in line with the development path of greatly enhancing the agricultural production efficiency with limited agricultural production factors.

However, after comparing the number of agricultural labor per unit area of Anhui Province and the data concerning Jiangsu Province with similar conditions for agricultural production, it is found that in 1980 and 2010, the agricultural labor input quantity per unit area in Anhui Province was 2.103 persons/hm^2 and 2.124 persons/hm^2, respectively; the agricultural labor input quantity per unit area in Jiangsu Province was 2.409 persons/hm^2 and 2.186 persons/hm^2, respectively.

We can see that the relative amount of agricultural labor in Jiangsu Province is reduced, while the amount of labor in Anhui Province is not reduced but increased. This growth path of Anhui Province shows a relatively backward stage of economic development, and its economy has not yet reached the development stage at which the agricultural labor is transferred to the secondary and tertiary industries, so that the agricultural output value per unit area is higher than the output value per unit of labor.

In order to verify this conclusion, with the data on Jiangsu Province and Anhui as samples, the actual agricultural output value as the dependent variable and time t as the independent variable, SPSS software is used to carry out time-series data regression, and the results show that the quadratic and cubic curves have good fitting effect on the two provinces, and the degree of explanation is greater than 0.9, but in terms of the coefficient index, the time coefficient of Jiangsu Province is greater than that of Anhui Province, indicating that the level of development is higher in Jiangsu Province, and in the subsequent development process, Anhui Province is bound to undergo significant reduction of agricultural labor and limited improvement of output value per unit of sown area.

Therefore, under the precondition of stable number of the Chinese agricultural labor in the future, the growth of agricultural labor productivity is impossible to depend on the increase in the production factor input, and the improvement of productivity per unit of production factor is still the path of future development.

3 Conclusions

This study avoids the complicated empirical models and a lot of tedious mathematical analyses. Using the simple and convenient method of empirical analysis, we carry out a progressive analysis of the growth of agricultural labor productivity in China's major grain producing areas, and it is found that since the reform and opening up, from the relative endowments of land and labor in China's major grain producing areas, the growth rate of the productivity per unit of land (Y/A) is higher than that of the output value per unit of labor (Y/L).

In essence, this growth path of increasing the output value relying on increasing the production factor inputs is the reduction of labor, and the reduction of agricultural labor has a great elasticity of impact on the total value of agricultural production.

The transfer of agricultural labor to non-agricultural industries is the inevitable trend of historical development experience. In the course of non-agricultural transformation of labor in various developing countries, the agricultural labor productivity may be substantially increased, but this method of depending on the quantity of resources occupied to increase productivity is after all not the road of sustainable development.

In the context of completion of non-agricultural transfer of labor in China's major grain producing areas and stable number of agricultural labor, the growth of agricultural labor productivity in major grain producing areas still needs to rely on the improvement of efficiency, emphasize the research, development, promotion and application of agricultural science and technology to promote the productivity per unit of land, which is a sustainable growth path for the improvement of agricultural labor productivity.

Meanwhile, the food industry should undergo the industrial structure adjustment and follow the international trend. Vigorously developing agricultural science and technology to promote agricultural modernization is a good way to promote the agricultural labor productivity in China's major grain producing areas.

4 Discussions

As for the study of agricultural labor productivity, the predecessors have used different methods to explain from different angles. Jiang Naihua[11] links the agricultural labor productivity with the changes in the income of rural households, and believes that the decline in agricultural productivity is the direct cause of the decline in agricultural production operating income.

Xin Xiangfei *et al.*[12], Bai Xuejie *et al.*[13] also believe that the gap in China's agricultural labor productivity level leads to the expansion of regional disparities. Through the analysis of the regional difference in factor endowments and agricultural labor productivity, Xin Xiangfei *et al.*[14], Jiang Jiyu *et al.*[15] draw the conclusion that the difference in factor endowments is still an important factor affecting the agricultural labor productivity of different regions of China, and the difference in factor endowments contributes to the difference in the agricultural labor productivity between eastern and western areas, which is similar to the conclusions in this paper.

Wang Xiaoping *et al.* use regression analysis to explore the stages and characteristics of the Chinese agricultural labor productivity growth in the period 1952 – 2003, and reveals that the path of improving the Chinese agricultural labor productivity is the path of increasing labor input to promote land productivity and enhance agricultural labor productivity, which is consistent with the research ideas and conclusions in this paper.

Guo Qingwang[3] and Li Jingwen[16] estimate the total factor productivity and its contribution to economic growth in China from

1979 to 2004, and draw the conclusion that the growth rate of China's total factor productivity is low and the increase in factor inputs can not be ignored, which is exactly the same as our conclusion that at present, China's economic growth will still depend on the growth of factor inputs, but it is also necessary to pay attention to the role of factor productivity improvement in enhancing the long-term sustainable economic growth of China.

It can be found that the same view held by us and scholars is that currently, in terms of the relative amount of the Chinese agricultural resource endowments and production factor efficiency, the output mode of resource endowments bringing economic growth occupies a major position, but from the effects of overall macroeconomic growth, it will ultimately depend on the improvement of production factor efficiency.

Our study avoids the complicated empirical models and a lot of tedious mathematical analyses. Using the simple and convenient method of empirical analysis, we carry out a progressive analysis of the growth of agricultural labor productivity in China's major grain producing areas, and draw the conclusions highly consistent with previous conclusions.

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