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An Empirical Analysis of the Impact of farmland Scale on Agricultural productivity in China--Based on 2002-2016 panel data

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***Abstract*—The modern agricultural production system plays a vital role in agricultural production efficiency. Based on the country's vigorous promotion of large-scale operation of rural land moderately, this paper has discovered that there exists an inverted U-type relationship between farmland scale management and agricultural productivity through the panel data from 2002-2016 in 31differernt regions in China, the current optimal farmland operation scale is 3.94hm2. Furthermore, we compare the agricultural productivity among three regions that divided by the Geography, and get the conclusion that agricultural development has regional heterogeneity. At present, farmland management scale is far less than the optimal one, therefore, it is important to keep on improving farmland scale management. Simultaneously, the government needs to arrange agricultural production according to local conditions, and ultimately to realize the diversified development of agriculture.**

Keywords—Scale management, Agricultural productivity, Optimal farmland operation scale, Fixed effect model, regional difference

I. INTRODUCTION

Chinese agriculture has achieved remarkable achievements since the reform and opening up in 1978. However, with the development of dual economic structures in China, the internal motivation and stamina of Chinese sustainable agricultural development are still lacking in the long run. The existing voices for the reform of “Household Contract Responsibility System” (HCRS) are becoming higher and higher, so this paper will analyze a new land scale management model based on the framework of HCRS.

The relationship between farmland management scale and agricultural productivity has been concerned by many scholars. The predecessors have done a lot of research, some had the position that small-scale agricultural production could improve agricultural productivity in developing countries, e.g. Chayanov & Sen(1962), Carter(1984), Heltberg(1998), Gucheng Li (2004),Qing Xu(2011).Some scholars had opposite opinion that small-scale operation had its limitation on agricultural production, e.g. Shoufu Yao(2012),Weibo Liu, Aimin Zhen(2017), Xunbo Cheng(2011), Qingen Gai(2017).What’s more, Other scholars thought that the relationship between farmland management and agricultural productivity was not simply Linear, it could be inverted U or inverted L shape in the chart. e.g. Chuzhi Hu(2007), Yahui Wang(2016).

Previous research lacks regional differences. So in this paper, we will take agricultural labor productivity as the standard for measuring agricultural productivity, and makes the following assumptions: 1) the degree of scale and labor productivity have inverted u-shaped curve relationship; 2) regional land endowment for agricultural productivity has a significant impact. This paper will use the agricultural panel data from 2002 to 2016 to quantitatively analyze productivity and farmland management scale in order to obtain the best farmland management scale and give the government some suggestions.

II. DATA

In 2002, China promulgated “the Land Contracting Law”, which meant that China had begun to encourage agricultural intensive production officially. Therefore, this paper selects 2002-2016 as the observation interval and uses statistics from 31 provinces, autonomous regions and municipalities. For the classification criteria of the eastern, central and western regions of China, referring to the existing literature[①]. The data mainly comes from China Rural Statistical Yearbook, China Statistical Yearbook and China Population and Employment Statistics Yearbook.

This paper selects the primary industry per capita output value (AP) as the explanatory variable in the model. The output value of the primary industry reflects the total amount of money produced by agricultural production in the same year, based on the number of employees in the primary industry. The ratio of the two can reflect the per capita agricultural output value, and can measure the labor productivity of agriculture to a certain extent.

The farmland management scale (Area) is used as an explanatory variable in the equation. This paper selects the ratio of the area planted with crops to the number of employed people in the primary industry to measure the scale of farmland

[①] The eastern region includes 10 provinces and cities including Beijing, Tianjin, Hebei, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, and Hainan; the central region includes Shanxi, Anhui, Jiangxi, Henan, Hubei, and Hunan; and the western region includes Chongqing and Sichuan. , Guizhou, Yunnan, Xizang, Shanxi, Gansu, Qinghai, Ningxia, Xinjiang, Inner Mongolia, Guangxi, 12 provinces and municipalities; Northeast China includes Liaoning, Jilin, Heilongjiang provinces, in the actual calculation, the Northeast region is merged into the eastern region

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management. The main reasons are as follows: First, the planting area of crops can better reflect the actual utilization and operation of land relative to the area of cultivated land and exclude the possibility of idle land; the second is that the number of employed people in the primary industry is more accurate than the number of households in the rural areas, which reflects the actual effective labor force in the rural areas; and the third is existence of the lack of data on the cultivated land area in each province over the years.

The following explains the other explanatory variables in the model. The level of rural economic development (Eco), this paper uses the per capita income of rural residents to measure the level of regional economic development. This indicator is used to examine the impact of regional economic prosperity on agricultural production efficiency and to measure the impact of agricultural infrastructure construction on agricultural productivity. Fert, Film, and Power can show the amount of capital investment and the level of scientific investment in agriculture to a certain extent, and examine the impact of current agricultural capital and technology investment on agricultural productivity development. Effective irrigation ratio (Irrigation), due to the frequent occurrence of extreme weather events in recent years, irrigation is becoming more and more important for the development of agricultural production. The effective irrigation ratio can indirectly reflect the climate of the region, the richness of water resources, and the degree of perfection of local water conservancy facilities. The disaster rate (Disaster) reflects the extent to which the area is affected by natural disasters and the extent to which disaster prevention and mitigation facilities are well-equipped. The higher the re-cultivation index, the more frequent the agricultural activities on the area of cultivated land per unit, which indirectly reveals the level of land quality and people's efforts to invest in agricultural production. All above variables measured by currency are subject to exponential deflation (based on 2002), in which the output value of the primary industry is reduced by the index of agricultural gross output value and the per capita income of rural residents is based on the index of rural resident net income. For deflator, each deflator is derived from the above-mentioned relevant statistical yearbook. The descriptive statistics of each variable are shown in Table I.

TABLE I VARIABLE SETTING AND CALCULATION METHOD

Variable classification	**Variable**	**Calculation method**	**Variable unit**
Dependent variable	AP	LN(Primary industry per capita output value)	Yuan/person
Independent variable	Area	LN(Sown area of per capita agricultural products)	hm^2/person
	$Area^2$	The square of Area	hm^2/person
Control variable	Economic	LN(Per capita income of rural residents)	Yuan/person
	Fert	LN(Fertilize usage)	Ten thousand tons
	Power	LN(Total mechanical power)	10000 kilowatts
	Film	LN(Film usage)	Ton
	Irrigation	LN(Effective irrigation area / Total sown area)	%
	MCI	LN(Total sown area of crops / cultivated area)	%
	Disaster	Crop affected area / Total sown area	%

III. MODEL CONSTRUCTION AND EMPIRICAL TEST

A. National and sub-regional model construction

In order to explore the relationship between farmland scale operation and agricultural productivity, this paper establishes the following overall measurement model:

$$AP_{it} = \beta_0 + \beta_1 Area_{it} + \beta_2 Area_{it}^2 + \theta X_{it} + \mu_{it}$$

In the overall regression model, *AP* is the explained variable, which is the average output value of the per capita primary industry, which reflects the production efficiency of agricultural labor in a region; *Area* represents farmland management scale, $Area^2$ represents the square of farmland management scale. X_{it} represents the matrix of control variables, including *Economic, Fert, Power, Film, Irrigation, MCI, Disaster*; β_0 is the intercept term, μ_{it} is the random disturbance term, θ is the regression coefficient matrix of the control variable matrix, and β_1, β_2 represent the elastic coefficient of farmland management scale and its squared term. If $\beta_1 > 0$, there is a positive correlation between farmland management scale and the productivity of agricultural labor. If $\beta_2 < 0$ simultaneously, there may be an optimal agricultural production., and *i* and *t* in the model (t = 2002, ... ,2016) indicates the *i*-th province and the *t*-th year respectively.

In order to explore the regional heterogeneity of farmland management scale, based on the overall regression model, the following sub-regional regression models were established:

$$AP_{itn} = \beta_0 + \beta_1 Area_{itn} + \beta X_{itn} + \mu_{itn}$$

Based on the overall regression model, the sub-regional regression model removes the square of the scale of farmland management. Only the extent of the impact of farmland scale on agricultural production efficiency in different regions is explored. According to the eastern, central, and western regions, 31 provinces, municipalities, and autonomous regions in China are divided into three parts. Among them, n (n = 1, 2, 3) in the model variables represent the east, middle, and west. Descriptive statistics for each variable are shown in Table II below before the measurement regression:

TABLE II STATISTICAL DESCRIPTIONS OF THE VARIABLES

Variable	Sample	Average	Min	Max	Sd
AP	465	9.6709	8.0144	10.9518	0.5858
Area	465	-0.6308	0.2550	1.5762	0.2637
$Area^2$	465	0.5499	0.00003	1.8665	0.4374
Economic	465	8.5879	7.2877	10.1472	0.6298
Fert	465	4.6605	1.0986	6.5738	1.1999
Power	465	7.4378	4.5570	9.4995	1.0870
Film	465	10.6292	6.0890	12.7470	1.2298
Irrigation	465	-0.7896	-1.9716	0.0423	0.4587
MCI	465	0.1726	-0.5755	0.8093	0.3068
Disaster	465	0.2243	0.0000	0.9356	0.1535

B. Empirical test result analysis

Before the empirical analysis of the model that uses the above method, the preliminary measurement test is carried out on the model. According to the characteristics of the short panel data, the following test steps are adopted. First, the Wald test is used to investigate whether there is heteroscedasticity. Second, we use Wooldridge test for the presence of sequence correlations in the model. Third, we use the Pesaran test to explore cross-sectional correlation problems in the model.

After three tests, it is found that the model data quality is good, and three problems above do not appear in this model. In addition, for the endogenous problems that may occur, the missing variable errors will be considered, but the intra-group fitting is excellent due to the model results. The average degree is above 90%. It is reasonable to believe that the explanatory variables already contain most of the factors that are explained, and the possibility of missing variables is small.

TABLE III EMPIRICAL RESULTS OF ALL SAMPLES IN THE COUNTRY

Variable	Fixed effect		Random effect	
	Estimation coefficient	T-value	Estimation coefficient	z-value
Area	0.6192***	6.22	0.5080***	5.53
$Area^2$	-0.2259***	-3.52	-0.2072***	-3.15
Eco	0.3306***	17.14	0.3994***	22.45
fert	0.0933*	1.66	-0.0231	-0.5
power	0.0821**	2.19	0.0192	0.53
film	0.0613***	2.81	0.0475**	2.13
Irrigation	0.1703***	3.17	0.2080***	4.10
MCI	-0.1945**	-2.57	-0.1206*	-1.96
Disaster	-0.0953**	-2.34	0.0927**	-2.12
R^2	0.9089		0.9033	
F-value	471.25		3713.96	
Optimal land management scale	$3.94hm^2$		$3.4hm^2$	

Note: 1) *, **, *** represent the significance level of 10%, 5%, 1%, respectively; 2) the calculation of the optimal land management scale, the actual form of the equation is $Y = \alpha X^2 + \beta X + \gamma$, therefore, by determining the sign positive and negative of the coefficient α and the coefficient β in the econometric model and the magnitude of the significance level, the optimal land management scale can be obtained. Since the agricultural labor productivity and the land management scale are both natural logarithm, the optimal land The calculation formula of the operating scale is $e^{\frac{-\beta}{2\alpha}}$ (e is the natural base); the processing of the model data uses stata14.1.

The empirical results of the two models are shown in Table III. After calculation, the statistic of the Hausmann test is 0.000, and the null hypothesis of random effect is rejected. Therefore, the fixed effect model is selected as the basis of the national total sample. The advantage of the fixed-effects model is that it can eliminate many uncontrollable factors, such as the degree of land fertility in different regions, other factors that are unobservable between regions, and can alleviate the regression bias problem caused by multicollinearity and autocorrelation in the general model.

This paper focuses on the impact of farmland management scale on agricultural production efficiency and whether there is an optimal agricultural land management scale. As shown in Table III, the coefficient of agricultural land management (Area) is 0.6912, and its squared term ($Area^2$) is -0.2259, both of which are significant at the 1% significance level, and the squared term is negative, indicating that there is an inverted u-type relationship between the scale of land management and agricultural labor productivity indeed in the current agriculture. It can be seen from the model that under the same conditions, the agricultural production efficiency will increase by 0.6% for each 1% increase in agricultural production scale. The expansion of the scale within a certain range will significantly improve the efficiency of agricultural production, but when its scale exceeds a certain limit, its increase will not continue to improve production efficiency, and even counter-productive. The overall optimal per capita farmland management scale is $3.94hm^2$. That is to say, after the current farmland management scale exceeds $3.94hm^2$, the further expansion of farmland management scale will have a negative impact on agricultural production efficiency.

From the regression analysis of other control variables, we can find that the rural economic development level (Eco) is positive at the level of 1%, once the rural income is increased by 10%, and the agricultural labor productivity will increase by 3.3%, which indicates improvement of farmers' living conditions will promote productivity; capital and technology investment represented by fert, film, and mechanical power, all of which are at 10%. Or higher the level of significance is positive, the elastic coefficients are 0.0933, 0.0613, 0.0821, which play a positive role in agricultural production, indicating that the current improvement of agricultural production efficiency is increasingly dependent on the structure of technology and capital on the structure of agricultural production factors and replacing the labor force; the effective irrigation ratio (Irrigation) reflects the water richness of a region, agricultural production is inseparable from water sources, the model shows that for every 10% increase, agricultural labor productivity will increase by 1.7%, one with water Labor productivity in agricultural areas with resource endowment advantages will be higher; re-cultivation index (MCI) is not significant in the model, it may be due to the increase in the cost of agricultural production and the attraction of urban non-agricultural employment to migrant workers, which has led to the decline of the re-cultivation index in most areas. The most typical phenomenon is the double-season rice turning into single-season rice; The degree of disaster damage in a region is significantly negative, indicating that natural disasters can lead to reduced agricultural production and reduced productivity.

TABLE IV EMPIRICAL REGRESSION RESULTS OF REGIONAL SAMPLES

Region	**East**		**Middle**		**West**	
Variable	coefficient	T-value	coefficient	T-value	coefficient	T-value
Area	0.9781***	12.77	0.4853*	1.89	0.6386***	4.75
Eco	0.2851***	14.27	0.2548***	2.99	0.5604***	8.86
fert	-0.0493	-0.67	0.3578	1.12	-0.0645	-0.66
power	0.1720***	2.96	0.1194*	1.77	-0.1926**	-2.04
film	0.0965***	2.77	0.2235	1.19	-0.0010	-0.29
Irrigation	0.2779***	4.39	0.5072*	2.33	0.1016	0.95
MCI	-0.6382***	-6.88	-0.2217	-0.54	0.2894**	1.99
Disaster	-0.0369	-0.77	-0.0901	-0.93	-0.1747**	-2.30

Note: *, **, *** represent the significance level of 10%, 5%, 1% respectively.

The empirical test results of the sub-regional model are shown in Table IV. It can be seen from the Table IV that the scale of land management in the eastern, middle and western regions of China is significantly positive for agricultural production efficiency, and there are differences between different regions. The coefficient of the east region is the highest, indicating that for every 10% increase in the scale of land management, the local agricultural labor productivity will increase by 9.78%, followed by 6.386% in the west region and 4.853% in the middle region. There are two possible explanations for this result. First, the eastern part of China is located in an open area of the plain. The land is scattered for terrain reasons, which creates favorable conditions for mechanized operation and reduced manpower. Second, the central region is relatively scattered and the terrain is blocked due to its location in hills and mountains. It is difficult to intervene in the traditional agricultural production process in modern large-scale production technology. Agricultural production still requires a large amount of labor, so labor productivity is the lowest, while the western region has introduced many capital technologies due to the recent western development strategy. Embarking on a technology-oriented agricultural production mode under harsh conditions, The requirements for labor quality relatively high while need small quantity, so its labor productivity is in the middle of the former two.

In addition, the difference in the scale of agricultural land management in the three major regions is not only the natural factors, but also the regional economic development. Further investigation found that the rural economic level in the central and eastern regions of China has basically the same impact on labor productivity, and for every 1% increase in the local economic development in the western region, the agricultural production efficiency will increase by 0.56%, almost twice the former two. Due to the relatively backward economic development and low level of labor productivity in the western region, with the local government's investment in agriculture, the strengthening of rural infrastructure construction, and the recent local development of tourism agriculture and other special projects, it can make its labor production efficiency rapidly increased in the initial stage of agricultural capital accumulation, and increased farmers' income. Therefore, Western regional economic development has a greater impact on agricultural productivity than the middle and eastern region. The results of considering the three regional heterogeneities show that there is a significant difference in the impact of land endowment and regional economy on labor productivity. This conclusion is a good verification of Hypothesis 2.

IV. CONCLUSIONS AND POLICY RECOMMENDATIONS

A. Conclusion

From the perspective of the impact of agricultural land management scale on agricultural production efficiency, this paper uses the panel data of 31 provinces, autonomous regions and municipalities directly under the central government from 2002 to 2016 for regression analysis, and obtains the optimal agricultural land production and management scale in China at present, and the analyzed differences in agricultural production efficiency between the three different regions of East, Middle and West , the following conclusions were obtained:

First of all, the empirical results confirm that there is indeed an inverted u-curve relationship between the scale of agricultural land management and agricultural labor productivity in China. The optimal agricultural land management scale estimated by the national sample is $3.94hm^2$, but currently the scale of operation of each province has not reached the optimal production scale, which indicates that the breadth and depth of the current intensive management of rural land in China has not yet reached the expected level, and it still has a large space for improvement. In addition, the rural local economic prosperity, the level of agricultural science and technology and the improvement of mechanization level can all increase labor productivity. The continuous investment of funds and technology is still an important channel to improve the efficiency of agricultural production in China; superior geographical location and water-rich areas have superior labor production conditions, which help to increase agricultural productivity, while in areas that are often affected by natural disasters, the input factors of production are not well transformed into the final Agricultural output value. Finally, the development of agriculture should be adapted to local conditions. The different production factors and production conditions in the three regions of China's eastern, middle and western regions have different characteristics for the agricultural productivity. The government cannot implement a unified agricultural development model in the country and promote agriculture. In the process of large-scale operation, it is necessary to combine local characteristics and develop characteristic agricultural industries according to different factor endowments and economic status of the region.

B. Recommendation

In order to continue to improve the productivity of Chinese agriculture and promote the scale, modernization and industrialization of agriculture, this paper will propose policy recommendations from the following aspects:

First, in order to improve the efficiency of agricultural production, we must continue to promote the intensive management of rural land. The scale operation of farmland is an important magic weapon to realize the industrialization of agricultural modernization in China. In order to improve the efficiency of agricultural production and bring the level of labor production of farmers to a higher level, the government and relevant agricultural management departments should fully consider the actual situation of Chinese agricultural production and management. On this basis, we will continue to liberalize the restrictions on rural land transfer, clarify the beneficial subjects and legal responsibilities of agricultural land transfer, further opening up the market and policies to encourage the transfer of rural land management rights, so that the market can better intervene in the trading process of agricultural land circulation, which will reduce transaction costs, promote the prosperity of the rural land transaction market, and encourage agricultural land to flow to farming experts, family farms, agricultural professional cooperatives and agricultural industrialization leading enterprises.

Second, give full play to the role of agricultural science and technology in agricultural production and management. Promote the investment in agricultural science and technology research and development, promote accurate and efficient fertilization, and develop ecologically sustainable agricultural production models. Promote agricultural mechanized production, reduce the use of agricultural labor, and increase popular science education and professional training for farmers so that they can skillfully manipulate agricultural production equipment. In view of the emerging Internet e-commerce and artificial intelligence in recent years, it can be flexibly introduced into the agricultural production and operation and sales process, and the modernization of agriculture can effectively improve the efficiency of agricultural production. The ultimate goal is to realize agricultural modernization.

Third, we need to continue to use the driving effect of the city to promote rural development. In order to improve the labor productivity of farmers, the government should seize the favorable opportunity of economic transformation, industrialization and urbanization to accelerate the adoption of feasible measures to narrow the urban-rural gap, achieve urban and rural development, support the transformation and upgrading of township enterprises, and encourage and help through policies. provide more employment opportunities for non-agricultural workers, and smoothly realize the transfer of rural surplus labor. In this process, we must pay attention to improving the labor skills of farmers, and the government can purchase skills training services for farmers free of charge, and enhance the employment competitiveness of non-agricultural workers.

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