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Analysis on the change of total factor productivity of wheat in China and its influencing factors

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중국 밀의 총요소 생산성 측정 및 영향요인분석

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Abstract As one of the three major food crops in China, wheat production plays a vital role in people's lives and industrial development. This study used a DEA-Malmquist model to calculate and analyze the wheat total factor productivity (TFP) of 12 major wheat-producing provinces from 2005 to 2019. The data necessary for this calculation were obtained from the "National Farm Product Cost-benefit Survey". Further to this calculation, an LSDVC model was used to explore the factors influencing the TFP. For this, the data were obtained from the "China Statistical Yearbook", "Rural Statistical Yearbook of China", and "Transport Yearbook". The results showed that from 2005 to 2019, China's wheat total factor productivity showed a decline and increased at an average annual rate of -1.5%. As far as the factors influencing the wheat production efficiency are concerned, the total mechanical power has a significant positive impact on the TFP of wheat. In contrast, government expenditures for agriculture, forestry and water resources, and industrialization have significantly adverse effects on the wheat TFP. Moreover , the rural road density and urbanization showed no significant impact on the TFP of wheat. Therefore, to promote the sustainable improvement of wheat productivity, the future development of the wheat industry should focus on the transformation of the agricultural development mode, human resources investment, and encourage the industry sector to nurture agriculture.

요 약 밀은 중국의 3대 식량작물의 하나로서 생산량은 사회생활과 산업발전에 중요한 역할을 한다. 본 연구에서 중국 12개 밀 주요 생산지역을 대상으로 중국의 농산물 비용 및 수익의 데이터를 통하여 2005년부터 2019년까지 DEA-Malmquist 모델을 이용하여 밀의 총요소 생산성을 측정하였으며, 또한 중국 통계연감, 교통 연감, 중국 농촌 통계 연감의 데이터를 기반으로 LSDVC 모형을 이용하여 효율성은 영향요인을 측정하였다. 분석결과, 2005년부터 2019년까지 중국 19년간 밀의 총요소 생산성은 내림세를 보였고 연평균 증가율은 -1.5%였다. 밀의 생산 효율성 영향요인을 보면, 농업의 기계화동력은 밀의 총요소생산성에 뚜렷한 긍정적(+)인 영향을 주지만 정부의 농업 공공지출, 산업화는 밀의 총요소생산성에 뚜렷한 부정적(-)인 영향을 준다. 또한 농촌의 도로밀도와 평균 기온과 도시화는 밀의 생산성 요소의 영향이 뚜렷하지 않다. 밀 생산력의 지속적인 향상을 위해 앞으로 밀 산업의 발전은 농업 발전방식을 중점적으로 전환하고 인력 투입을 확대하며 공업 부문의 농업 육성을 장려해야 한다.

Keywords : Wheat, Total Factor Productivity, Productivity Growth, DEA-Malmquist Model, LSDVC

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1. Introduction

Grain cereals such as maize, wheat, and rice are the three major food in the world. Thus, these crop plants are the first guarantee for the survival of humans and animals and are essential in terms of global food security. Among them, wheat, as the second most important food crop is a staple source of nutrients for around 40% of the world's population [1]. In 2019, 765.77 million metric tons of wheat were produced globally on 215.90 million hectares of farmland [2].

As one of the three major food crops, wheat output plays an important role in people's life and industrial development in China. It has been cultivated for at least 4000 years but took until 1914 in Nanjing before crossbreeding programs commenced [3]. The main wheat production areas in China are divided into the middle and lower reaches of the Yangtze River, the northwest wheat region, the southwest wheat region, and the Huang-Huai-Hai wheat region [4]. According to the seasons, wheat is divided into the winter wheat region in the south, the spring wheat region, and the winter wheat region in the north [4-7]. In 1999, China began to implement import quota management on wheat, and in 2002, a zero-tariff rate policy was implemented on wheat, which improved the enthusiasm of wheat planting and increased wheat output and export. China's grain had continued to increase, but grain prices had been declining. For preventing cheap crops hurt the farmers, protecting farmers' interests, and motivate farmers to grow grain, the government began to implement the policy of wheat's minimum purchase price in some regions of major wheat-producing regions in 2006. From the year of 2006 to 2019, China's wheat output grew at an average annual rate of 8.9%, basically guaranteeing China's food security [8].

With the significant improvement of wheat production capacity in China, wheat supply has become a structural contradiction, which makes the development of wheat production face some major problems and constrains the improvement of wheat production efficiency in China. There is an oversupply of ordinary wheat in China while there is a shortage of high-quality wheat. On the one hand, China's wheat inventory continues to increase, the purchase price of wheat is constantly depressed seriously affected the enthusiasm of wheat farmers planting. From 2016 to 2020, China's wheat inventory increased year by year with a growth rate of 29.9%, significantly higher than the 16.7% growth rate of the world's total wheat inventory [10]. On the other hand, the production of high-quality special wheat is seriously inadequate and needs to be imported from abroad [9]. In addition, despite the high quality of wheat seeds, the quality of wheat varies greatly after harvest. Due to the disunity of planting technology and the lack of standardized technical means, the wheat that can be recognized by processing enterprises and meet the processing needs is still insufficient [11].

The report of the 19th China National Congress and the No. 1 Document of the Central Government in 2019 pointed out that promoting agricultural supply side reform is the main line of rural agriculture work, ensuring sustained increase of grain supply is the target, and innovating institutional reform is the approach. The No. 1 document of the Central Government in 2020 proposed that promoting grain quality projects, optimizing the distribution of planting areas, supporting the core grain production areas, and improving grain production efficiency. In this context, relevant questions are raised: What are the problems facing Wheat production in China? How does wheat production efficiency change? How to improve wheat production efficiency in main producing areas?

Data Envelopment Analysis (DEA) is widely used in productivity research of the agricultural sector. As for the measurement of the influence on wheat production efficiency, scholars explored the wheat production efficiency from the Angle of different regions in different periods. Miao (2014) used the DEA analysis method to analyze the production efficiency of wheat per unit area in the main wheat-producing areas in China and found that the average technical efficiency of wheat per unit area was 0.87 in the main wheat-producing areas from 2000 to 2014, with an average annual increase rate of 1.9%, which showed rapid growth, but there were great differences among different regions [12]. Masuda (2016) measured the eco-efficiency of wheat production in Japan at a regional scale using a combined methodology of life cycle assessment and DEA [13]. Hassan (2020) incorporated undesirable outputs in the operational assessments through the integration of Life Cycle Assessment (LCA) and DEA to test the efficiency assessment of the winter wheat cropping system [14]. There are also many studies on the measurement of agricultural dynamic efficiency, usually using the Malmquist index method to measure total factor productivity change. Bhushan (2005) applied the DEA approach to estimate the Malmquist productivity index for the wheat-producing states in India during the period 1981-82 to 1999-2000 [15]. Bidadadi (2015) investigated the three Northern provinces and compared them to country mean from 2000 through 2010 in Iran [16]. Elasraag (2017) used the Global Malmquist TFP index as a non-parametric approach to measure the total factor productivity of the main governorates of wheat production in Egypt during the period 1990-2012 and decompose it into technical change, efficiency change, and scale change [17]. Yan (2019) used the DEA-Malmquist model to calculate and analyze the total factor productivity of wheat in 15 major wheat-producing provinces in China from 2001 to 2016. The results showed that the national total factor productivity of wheat increased by 2.8% annually, the northeast region had the fastest growth rate, the growth rate in the eastern region was slightly higher than that in the central region, while the development in the western region was slow [18].

As for the research on the factors that affect wheat production efficiency, scholars have explored from different influence angles. Dessale (2019) used the maximum likelihood parameter estimates to showed wheat output was positively and significantly influenced by the area, fertilizer, labor, and some oxen [19]. Liu (2019) found that the wheat production efficiency of farmers with a land scale economy was higher, and land fragmentation was not conducive to the improvement of wheat production efficiency [20]. Liu (2019) found that increasing the input of agricultural mechanization services can significantly promote the improvement of wheat technical efficiency and optimize the allocation of wheat production factors [21]. Luan (2019) used the stochastic frontier model to analyze the technical efficiency of wheat production in the main wheat-producing areas and found that the improvement of irrigation rate had a promoting effect on the technical efficiency of wheat production, and the effect of drought on wheat production efficiency decreased with the increase of irrigation rate [22].

Most of the studies on wheat technical efficiency and its influencing factors are analyzed from the static point of view. In this paper, dynamic DEA and dynamic panel data are used to analyze it. The objective of this study is to examine the efficiency change of the wheat industry from the year 2005 to 2019 and the determinants of efficiency change of the wheat industry of China. The empirical aspect of this paper consists of two stages. First, we applied the DEA-Malmquist to estimate the efficiency change of wheat in China from the year 2005 to 2019. Secondly, we examine the determinants of the efficiency of the wheat industry using the biased corrected least squares dummy variable (LSDVC).

2. Materials and Methods

2.1 Malmquist TFP index

The commonly used production efficiency measurement methods include stochastic frontier analysis (SFA) and data envelopment analysis (DEA). The feature of the SFA model is that it uses a certain production function and panel data for an accurate solution, however, the main defect of the SFA model is that the form deviation is easier to occur when the production function is setting, and the production measure fails. The advantage of the DEA model is that it does not need to know the specific production function in advance, which can avoid the measurement failure caused by human factors. On the base of it, the DEA model was adopted in this study to measure wheat total factor productivity. The specific formula is as follows:

$$\begin{cases} \min(\theta,\lambda)\theta \\ s.t.\sum_{j=1}^{n}\lambda_j y_j + s^- = \theta x_0 \\ \sum_{j=1}^{n}\lambda_j y_j - s^+ = y_0 \\ \lambda_j \geq 0; j=1,2,\ldots,n \\ \sum_{j=1}^{n}\lambda_j = 1 \\ s^+ \geq 0; s^- \leq 0 \end{cases} \tag{1}$$

Where, x_0, y_0 represent input vector and output vector of each DMU, λ represents the constant ratio, θ represents the efficiency value of the DMU, s^+ represents the output relaxation variable, and s^- represents the input relaxation variable.

When the data of evaluated DMUs is the panel data containing more than one observed value of time points, the changes in productivity and respective roles of technical efficiency and technical progress on the productivity changes can be analyzed, which is the commonly used Malmquist TFP index analysis.

DEA method is a non-parametric method, which cannot calculate TFP, but it can calculate TFP index. Assume that the input x of a DMU in the period t and t-1 which remains constant, and its output is respectively y_t and y_{t-1}, then,

$$y_{t-1} = TFP_{t-1} \times f(x) \tag{2}$$

$$y_t = TFP_t \times f(x) \tag{3}$$

Since the production function f(x) is unknown, TFP of the two periods cannot be calculated, but its TFP index can be calculated, which is the basic idea of DEA method to calculate the TFP index.

$$MI(t-1,t) = \frac{TFP_t}{TFP_{t-1}} = \frac{y_t}{y_{t-1}} \tag{4}$$

As for the index selection of input-output, the output variable was the average wheat yield per hectare in 12 major wheat-producing provinces from 2005 to 2019. Labor input, land input, machinery cost, pesticide input, fertilizer conversion amount, and seed amount were selected as input factors of wheat total factor production efficiency. Labor input could be able to effectively reflect the actual input of agricultural labor in a certain period. In this study, the average labor price per hectare was used to represent the labor input of wheat. The cost per hectare of land symbolizes the land input, including the cost of transfer rent and self-owned lease. The index of pesticide input was the average price of pesticide used per hectare. The average mechanical cost per hectare of wheat stood for machinery cost. The average price per hectare represented pesticide input. Fertilizer input refers to the amount of nitrogen fertilizer, phosphorus fertilizer, potassium fertilizer, and compound fertilizer for wheat use per hectare, which is represented by converting into the purification of chemical fertilizer application in this study. Seed input using the average amount of seed per hectare as an indicator.

2.2 Least squares dummy variable corrected (LSDVC) estimation

In this paper, a least-squares dummy variable corrected (LSDVC) technique is employed in the empirical analysis. The LSDVC was first developed by Kiviet (1995), Judson and Owen (1999), Bun and Kiviet (2003) that it is infeasible for unbalanced panels [23-25]. Bruno (2005) extended it to accommodate unbalanced panels with a strictly exogenous selection rule [26]. For ascertaining robustness, LSDVC (AH), LSDVC (AB), and LSDVC (BB) estimators - which stand for dynamic bias-corrected estimations developed by Anderson and Hsiao (1982), Arellano and Bond (1991), and Blundell and Bond (1998), respectively are applied [27-29].

In addition, compared with other dynamic estimators, the LSDVC estimator provides efficient and robust estimators: the generalized method of moments (GMM) estimator is used because this method has a higher root mean square error (RMSE) and smaller deviations. Specifically, this method performs better when the sample of cross-section units is small, and panel data are unbalanced [26]. However, our paper covers a panel comprising 12 provinces in China, and the sample is considered small. It is consistent with the empirical literature [30].

As the MI has a lower bound of zero, the logarithm of the indexes is used as the dependent variable. To reduce any possible endogeneity bias, we lagged the total factor production efficiency index as well as variables one period.

The seven explanatory variables are respectively: (1) The rural roads density (road). The density of rural road reflects the convenience of rural transportation, and the improvement of its level can often reduce the cost of agricultural production and transportation, thus increasing the exchange opportunities of agricultural products and agricultural means of production in rural towns and cities. It is calculated according to the ratio of the mileage of substandard way + tertiary highways + township road per 10,000 population in each province. (2) Government expenditures for agriculture, forestry and water resources. Higher expenditures are likely to reduce the total factor productivity of wheat. (3) Total power of agricultural machinery. The total power of agricultural machinery refers to the total power of all kinds of power machinery mainly used in agriculture, forestry, animal husbandry, and fishery. Including tillage machinery, drainage, and irrigation machinery, harvesting machinery, agricultural transport machinery, plant protection machinery, animal husbandry machinery, forestry machinery, fishery machinery, and other agricultural machinery, according to the power of the fold into tile calculation. (4) Urbanization. With the transfer of surplus rural labor to non-agricultural industries, China's urbanization rate shows a steady growth trend year by year. The process of urbanization is conducive to the increase of capital-labor ratio, the diffusion of new factors such as technology and management into agriculture, land transfer, and agricultural operation on an appropriate scale. However, due to urbanization, the rural labor force has been decreasing. (5) Industrialization. Industrialization mainly refers to the proportion of the output value of the secondary industry in the gross national product. The development of industrialization is conducive to the production and processing of agricultural products.

The model is specified as:

$$\begin{aligned}\ln MI_{it} &= a_i + \rho \ln MI_{it-1} + \beta_1 \ln road_{it} \\ &+ \beta_2 \ln fiscal_{it} + \beta_3 \ln mach \\ &+ \beta_4 \ln urban_{it} + \beta_5 \ln indus_{it} + \varepsilon_{it}\end{aligned} \quad (5)$$

i=1, 2, ⋯, 12

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t=1, 2, ⋯, 12

Where:

$\varepsilon_{it} = \eta_{it} + \nu_{it}$

lnMI denotes the logarithm of Malmquist productivity index,

lnroad denotes the logarithm of rural road density per 10,000 people,

lnfiscal denotes the logarithm of government expenditures for agriculture, forestry and water resources,

lnmach denotes the logarithm of total power of agricultural machinery,

lnurban denotes the level of urbanization,

lnindus denotes the level of industrialization, and

ε_{it} is disturbance, which consists of individual effect η_{it}, and disturbance ν_{it} assumed to be identically and independently distributed. α, ρ, and β are parameters to be estimated.

2.3 Data Sources

The study was limited to 12 provinces of main wheat production area in China – Anhui, Gansu, Hebei, Henan, Hubei, Jiangsu, Inner Mongolia, Shandong, Shanxi, Shanxi, Sichuan, Xinjiang - accounts for more than 93% of the whole country from the year of 2005 to 2019. To eliminate the impact of price factors, all indicators are calculated using the GDP deflator based on constant prices in 2006. The data of average wheat yield per hectare, labor input, land input, machinery cost, pesticide input, fertilizer conversion amount, and seed amount which is used in Malmquist model are obtained from "National Farm Product Cost-benefit Survey (2005-2019)", the data of total power of agricultural machinery are obtained from "Rural Statistical Yearbook of China (2006-2019)", the data of roads are obtained from appendix of "Sichuan Transport Yearbook" and "Chongqing Transport Yearbook (2006-2019)", and the data of government expenditures for agriculture, forestry and water resources, permanent resident population, total population, total value of secondary industry, and total value of production of each province are obtained from "China Statistical Yearbook (2006-2019)".

3. Empirical Results and Analysis

3.1 Descriptive Statistics

The Descriptive statistics of variables used in the econometric analysis are interpreted in Table 1 and Table 2, includes two stages - the inputs and output used in the DEA-Malmquist TFP index, and descriptive statistics of variables that affect MI.

The output is evaluated by yield of wheat which of the mean value is 5,521.353 kg/hm^2 and it rang from 3,299.1 kg/hm^2 to 7,624.35 kg/hm^2. The average labor used on wheat is 3,024.304 yuan/hm^2 per year which ranges from 1,134.86 to 7,521.16 yuan/hm^2. On average, the land cost used on wheat is about 1,475.577 yuan/hm^2 per year which ranges from 452.55 yuan/hm^2 to 3,164.93 yuan/hm^2. The variable on the input used among farms is found on the utilization of wheat mechanical charge is 1,146.704 yuan/hm^2 per year with the maximum and minimum approximately 132.66 yuan/hm^2 and 1,731.64 yuan/hm^2 separately. The average expenditure for pesticide is about 156.413 yuan/hm^2 per year and there was a province which spends up to 471.26 yuan/hm^2. The mean amount of fertilizer is 278.766 kg/hm^2 with a maximum of 579.3 kg/hm^2. The average amount of seeds is 311.033 kg/hm^2 per year ranged from 143.85 kg/hm^2 to 562.2 kg/hm^2 (Table 1).

Concerning the province-specific variables presented in Table 2, it is indicated that the average logarithm of growth rate is -0.025. On average, logarithm of per capita electricity consumption has mean value of 6.512 and variation of 0.829, which ranges between 5.258 and 9.014. The logarithm of rural road density per 10,000 people, government expenditures for agriculture, forestry, and water resources and total power of agricultural machinery has a mean value of 4.146, 5.672, and 8.311, respectively. The mean value of urbanization is 49.425%, which has minimum and maximum values of 31.09% and 70.61%, respectively. Industrialization has a mean of value of 48.476%, with a variability of 5.95%, and ranges between 32.83% and 61.48%.

3.2 Results analysis of wheat total factor productivity

The software of MaxDEA 8 was used to calculate the change index of TFP, PEC, SEC, PTC and STC in 12 major wheat planting provinces in China from 2005 to 2019. The geometric mean value of adjacent parameter method is used to obtain corresponding indexes in each period of the country (Table 3, Table 4).

Overall, the total factor productivity of wheat decreases by 1.5% on average from 2005 to 2019, among which, the average annual growth rate of pure efficiency is 0.5%, the average annual growth rate of scale efficiency is 0.8%, the average annual decrease rate of pure technical efficiency is 2.5%, and the average annual increase rate of scale technological change is 0.2%. During this period, the total factor productivity of wheat in China shows a downward trend, and the growth of pure efficiency, scale efficiency, and scale technology make contributions to the total factor productivity, but the growth of pure technical

Table 1. Summary Statistics of variables used in Malmquist productivity index from 2005-2019 (in 2006 price)

Indicator Type	Indicator	Unit	Num	Mean	S.D.	Min	Max
Wheat output	Yield	kg/hm^2	180	5,521.353	974.030	3,299.100	7,624.350
Wheat inputs	Labor	yuan[1]/hm^2	180	3,024.304	1,468.929	1,134.860	7,521.160
	Land	yuan/hm^2	180	1,475.577	611.839	452.550	3,164.930
	Machinery	yuan/hm^2	180	1,146.704	305.052	132.660	1,731.640
	Pesticide	yuan/hm^2	180	156.413	75.311	45.050	471.260
	Fertilizer	kg/hm^2	180	278.766	86.565	138.900	579.300
	Seed	kg/hm^2	180	311.033	101.523	143.850	562.200

[1] yuan is the unit of legal tender in the People's Republic of China.

Table 2. Summary Statistics of variables used in LSDVC estimation technique from 2006-2018 (in 2006 price).

Variables	Unit	Num	Mean	S.D.	Min	Max
Growth rate (lnMI)	/	168	-0.025	0.137	-0.498	0.404
Rural road density per 10,000 people (lnroad)	km/10000 person	168	4.146	0.547	2.795	6.609
Government expenditures for agriculture, forestry and water resources (lnfiscal)	billions yuan	168	5.672	0.665	3.838	6.735
Total power of agricultural machinery (lnmach)	kw	168	8.311	0.645	7.086	9.499
Urbanization (urban)	%	168	49.425	8.478	31.090	70.610
Industrialization (indus)	%	168	48.476	5.950	32.830	61.480

Table 3. National wheat total factor productivity index and its composition changes

Year	MI	PEC	SEC	PTC	TC
2005-2006	0.996	1.005	1.046	0.95	1
2006-2007	1.018	0.996	0.96	1.045	1.025
2007-2008	1.04	1.028	1.077	0.967	0.979
2008-2009	0.901	1.023	0.957	0.903	1.033
2009-2010	0.886	0.967	1.01	0.908	1.01
2010-2011	1.006	1.002	1.038	0.996	0.985
2011-2012	0.972	1.043	1.029	0.899	1.011
2012-2013	0.908	1.003	0.96	0.962	0.978
2013-2014	1.066	0.997	1.011	1.027	1.031
2014-2015	0.97	1.003	1.019	0.962	0.987
2015-2016	0.97	0.997	1.003	0.98	0.989
2016-2017	1.055	1.019	0.999	1.033	1.001
2017-2018	0.894	0.978	0.958	0.973	0.98
2018-2019	1.104	1.009	1.04	1.046	1.013
Mean	0.985	1.005	1.008	0.975	1.002

Table 4. Total factor productivity and composition changes of major wheat producing provinces in China

Province	MI	PEC	SEC	PTC	STC
Anhui	0.994	1.000	1.000	0.991	0.999
Gansu	0.995	1.026	1.018	0.962	1.007
Hebei	0.984	1.005	1.002	0.979	1.000
Henan	0.996	1.002	1.012	0.987	0.993
Hubei	1.016	1.000	1.021	0.985	1.006
Inner mongolia	0.961	1.032	0.994	0.957	1.014
Jiangsu	0.956	0.993	1.000	0.986	0.984
Shaanxi	0.991	1.000	1.023	0.983	0.988
Shandong	0.978	1.000	1.000	0.988	0.990
Shanxi	1.010	1.000	1.022	0.951	1.042
Sichuan	0.957	1.000	1.000	0.975	0.980
Xinjiang	0.978	1.000	1.001	0.957	1.018
Mean	0.985	1.005	1.008	0.975	1.002

efficiency in this stage are negative, which shows a downward trend for the whole wheat. From the perspective of change trend, from 2005 to 2019, the change of wheat total factor productivity in China showed phased characteristics. The growth rate is positive between the year of 2006-2007, 2007-2008, 2010-2011, 2013-2014, 2016-2017, and 2018-2019 the other years are negative. Based on the TFP index values of each province, it can be found that the index shows a huge difference: the TFP increase ranges from −4.4% to 1.6% for all provinces from 2005 to 2019. Only the TFP of Hubei and Shanxi province increase 1.6% and 1% respectively. In addition, the decline of TFP is mainly caused by the decline of PTC with an average value of 0.975.

During this period, the total factor productivity of wheat in China shows a downward trend, and the growth of pure efficiency, scale efficiency, and scale technology make contributions to the total factor productivity, but the growth of pure technical efficiency in this stage are negative, which shows a downward trend for the whole wheat. From the perspective of change trend, from 2005 to 2019, the change of wheat total factor productivity in China showed phased characteristics. The growth rate is positive between the year of 2006-2007, 2007-2008, 2010-2011, 2013-2014, 2016-2017, and 2018-2019 the other years are negative. Based on the TFP index values of each province, it can be found that the index shows a huge difference: the TFP increase ranges from −4.4% to 1.6% for all provinces from 2005 to 2019. Only the TFP of Hubei and Shanxi province increase 1.6% and 1% respectively. In addition, the decline of TFP is mainly caused by the decline of PTC with an average value of 0.975.

3.3 Unit root tests

To further verify the effectiveness of the model and avoid the phenomenon of "pseudo-regression", LLC test is selected to test the stability of panel data [31]. Table 5 shows the results of LLC test with three different cases - panel means and time trend, only panel means, and none − which are stationary.

Table 5. Unit root tests of panel data.

Variable	LLC test			
	panel means and time trend	panel means	none	Result
lnMI	-4.824***	-4.940***	-9.504***	stationary
lnroad	-8.357***	-4.541***	3.963	stationary
lnfiscal	-6.206***	-11.458***	4.399	stationary
lnmach	-2.103**	-5.686***	2.688	stationary
urban	-3.032***	-2.780***	5.634	stationary
indus	-2.060**	-3.553***	-3.610***	stationary

standard errors in brackets.
*$p<0.1$, ** $p<0.05$, ***$p<0.01$

3.4 Empirical linear regression analysis with LSDVC

The results of regression analysis which investigates the are reported determinants of efficiency change of wheat industry of China are reported in Table 3. It shows the results of LSDVC (AH), LSDVC (AB), and LSDVC (BB) estimations. We replicated 40 repetitions using a bootstrap procedure to produce the estimated standard errors. Furthermore, we interpret only LSDVC (AB) estimates to save space and other results are available upon request (Table 6).

The productivity growth rate is a cross period index. Consequently, the previous period growth rate has a direct impact on the current period growth rate, resulting in a negative intertemporal serial correlation in individuals' productivity growth indices [32]. It illustrates a high growth in the previous year leaves less potential for farms to further improve their productivity. Rural road density has no effect on TFP of wheat, the reason of it is China's rural roads are already well developed. The effect of agricultural financial support on TFP of wheat has passed the significance test of 5%, indicating that under the condition of other influencing factors unchanged, the TFP of wheat will decrease and increase by 18% when the financial support increases by 1%. That is, if the financial support increasea by 1%, the growth rate of wheat production efficiency is reduced by 18%. When the production efficiency of wheat reaches a certain level, if the production efficiency of wheat continues to be improved, more funds are needed to invest in agriculture, but the growth rate of production efficiency will become slow. The total power of agricultural machinery has a positive effect on the change rate of wheat total factor production at 1% significance level. The total power of agricultural machinery is used to reflect the degree of mechanization and its investment in agricultural production [33]. By 2018, the mechanization rate of tillage, planting, harvesting and comprehensive mechanization of wheat in China had reached 99.67%, 90.88%, 95.87% and 95.89%, respectively, which is the highest among the three major grain crops - rice, wheat, and corn [34]. The increased mechanization level will improve the technical efficiency of wheat. Industrialization has a negative effect on wheat productivity growth at the 5% significance level. Industrial development has crowded out the capital, technology, labor and other production factors needed for agricultural production. Urbanization has no effect on wheat productivity growth at the 5% significance level which is due to although the process of urbanization is also constantly encroaching on labor, capital, and land resources in the agricultural sector, resulting in a serious shortage of human resources in agriculture, but also it is conducive to the spread of advanced technologies, products and knowledge to rural areas and agricultural production, and is conducive to the formation of rural human capital, thus improving the level of agricultural production technology.

Table 6. Results from Productivity Growth Model with LSDVC estimator technique

	LSDVC		
	AH	AB	BB
	(1)	(2)	(3)
$\ln MI_{it-1}$	-0.467***	-0.486***	-0.484***
	[0.057]	[0.056]	[0.056]
$\ln road_{it}$	0.029	0.028	0.028
	[0.042]	[0.039]	[0.041]
$\ln fiscal_{it}$	-0.171**	-0.174**	-0.176***
	[0.075]	[0.070]	[0.073]
$\ln mach_{it}$	-0.198**	-0.200***	-204***
	[0.083]	[0.076]	[0.079]
$urban_{it}$	0.007	0.007	0.008
	[0.008]	[0.007]	[0.007]
$indus_{it}$	-0.008**	-0.008**	-0.008**
	[0.004]	[0.003]	[0.003]

Standard errors in brackets.
* p<0.1, ** p<0.05, *** p<0.01

4. Conclusion

In this study, the panel data of 12 provinces from 2005 to 2019 in China's main wheat producing areas were used as the research object. Based on the DEA-Malmquist model, the change of wheat total factor productivity (TFP) and its decomposition values from 2005 to 2019 in major wheat producing provinces were calculated. Then, the LSDVC model was used to analyze the effects of different influencing factors on wheat production efficiency. Finally, conclusions are drawn, and policy suggestions are put forward.

From the perspective of time trend, the decomposition of total factor productivity of wheat in our country's volatility is mainly influenced by PTC , illustrates the major wheat producing areas in China pure technical efficiency is slightly lower in wheat is the main reason for decline in total factor productivity, the government should improve from the pure technical efficiency into consideration, in order to improve the total factor productivity of wheat in China and increase China's wheat sustainable production capacity.

From the provincial perspective, except Hubei and Shanxi, the TFP of all provinces are less than 1, indicating that most of TFP are at a declining level. Since 2006, China has implemented a minimum price policy for wheat in the five provinces of Hebei, Jiangsu, Anhui, Shandong, and Henan. The farmer subsidy in the implementation area of wheat minimum purchase price is higher, the profit of planting grain is high, the farmer's enthusiasm is high, and the input and output of wheat will be increased. However, due to the sufficient inventory of policy-related wheat in China, due to the high base price of sales, the transaction continues to be depressed and the liquidity is poor, leading to the high inventory. From 2014, the minimum purchase price of wheat had reduced which means that the cost of arriving at the plant of policy-related wheat will be lower than the general wheat market price. For the non-enforcement areas with the minimum purchase price, the farmers' subsidies are not high, and it is difficult for these areas to grow wheat on a large scale due to geographical and climatic constraints, leading to the low wheat total factor productivity in these areas.

From the influence factors of wheat production efficiency, total mechanical power has a significant positive impact on the total factor productivity of wheat, while government expenditures for agriculture, forestry and water resources, and industrialization have significant negative effects on wheat total factor production efficiency. However, the rural road density, average temperature, and urbanization have no significant effect on the total factor production efficiency of wheat.

To promote the sustainable improvement of wheat productivity, the future development of wheat industry should focus on the transformation of agricultural development mode, human resources investment, and industrialization should feed back to agriculture. With the improvement of yield per unit area, the range of increase is getting smaller and smaller, and the difficulty of improvement is getting bigger and bigger, and the problems of poor quality stability are becoming more and more prominent. The government should increase investment in wheat and wheat innovation industry, constantly improve the innovation level of wheat seed industry, enhance the original innovation ability, speed up the cultivation and promotion of a batch of breakthrough wheat new varieties, and further consolidate the foundation of food security. The mechanized wheat harvest rate in China has repeatedly reached new highs, and the development mode has changed from high-speed development to high-quality development. The future development direction is intelligent harvesting machinery with high efficiency, low impurity rate and low breakage rate. In addition, drying equipment development is slow, restricted wheat quality improvement. In recent years, China's mechanized drying level grows slowly. Regionally, the demand for drying machinery and equipment in rice-wheat rotation area remains strong, while the application degree of drying in Huanghuai Hai-mai-jade rotation area is still low. On the whole, China's wheat mechanized drying and other post-processing links are still weak links, need to be further improved. When implementing the agricultural policy oriented by improving the quality and efficiency, we should focus on reducing the cost, reducing consumption, and improving the quality and efficiency, solve the contradiction of the supply side of current agricultural production, and enhance the competitiveness of China's agricultural products in the international market and the sustainable grain production capacity. With the development of urbanization, the rural labor force population is gradually decreasing. The government should vigorously strengthen the cultivation of agricultural talents, play a guiding role in cultivating a new type of professional farmers, and encourage college students and other high-level talents to invest in agricultural production.

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