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Study on the effect of minimum purchase price policy on China's wheat production

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최저수매가격정책이 중국 밀 생산에 미치는 영향에 관한 연구

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Abstract Wheat is one of the three main grain crops in China and its production plays an important role in industrial development and the daily lives of the Chinese people. In China, wheat production accounts for about 22% of total grain production, and thus, greatly contributes to Chinese food security. The implementation of the minimum purchase price policy for wheat was designed to increase wheat production. According to statistics, after the implementation of this policy, wheat production increased from 108.466 million tons in 2006 to 133.596 million tons in 2019, but it is not known to what extent this policy contributed to wheat production. Using the panel data of 15 major wheat-producing provinces in China from 1998 to 2019, we used propensity score matching and difference-in-differences methods (PSM-DID) to conduct robustness and empirical tests on the impact of the Chinese minimum purchase price policy on wheat production. After controlling for other factors that affect wheat production, our results showed that implementation of the policy significantly increased wheat production by 76.89%.

요 약 밀은 중국의 3대 주요 식량 작물 중 하나로, 밀 생산은 사람들의 삶과 산업 발전에 중요한 역할을 했다. 또한, 중국은 세계 최대 밀 소비국가이다. 중국의 밀 생산량은 전체 곡물의 약 22%를 차지하는데, 이는 중국 식량 안보에 매우 중요한 의미를 지닌다. 밀의 최저수매가격정책을 실시하는 목적은 밀 생산의 증가를 촉진하기 위한 것이다. 통계에 따르면 밀 생산량은 최저수매가격정책 시행 후 2006년 1억 846만 6,000톤에서 2019년 1억 3359만 6,000톤으로 증가했다. 따라서, 최저수매가격정책의 시행은 밀 생산의 증가에 어느 정도 기여한 것인지 살펴볼 필요가 있다. 본 연구는 1998년부터 2019년까지 중국 15개 주요 밀 생산성 패널 자료를 바탕으로 성향점수매칭(PSM)과 이중차분법(DID)을 채택하였으며, 중국의 최저 수매가격정책이 밀 생산에 미치는 영향에 대한 로버스트 테스트(robustness test)와 임피리컬 테스트 (empirical test)을 실시하였다. 분석결과 밀의 최저수매가격정책 시행은 밀 생산에 큰 영향을 미치고, 밀 생산에 영향을 미치는 다른 요인이 바뀌지 않는다면 밀의 최저수매가격정책 시행은 밀 생산을 76.89% 늘릴 수 있는 것으로 나타났다.

Keywords : China's Wheat, Wheat Production, Minimum Purchase Price Policy, Propensity Score Matching, Difference-in-Differences Model

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1. Introduction

As a kind of agricultural product with inelastic demand and supply, the imbalance of supply and demand often leads to the violent fluctuation of the violent fluctuation of the market price, which is detrimental to the interests of food producers and the stability of food production [1]. Since 2004, a minimum purchase price policy has been implemented for the most important grain varieties and varieties in major producing areas. The grain minimum purchase price policy is a grain price regulation policy to protect the interests of farmers and ensure the supply of grain market. According to the history of grain fluctuation development in China, continuous harvest is inevitably followed by continuous production reduction. The reason is that in addition to a number of uncontrollable factors, the most important lies in the occurrence of "grain prices hurt farmers". continuous led to the relative surplus of the grain harvest has sold grain difficult phenomenon recurring,Greatly inhibits the enthusiasm of farmers to grow grain, thus leading to the orderly cycle of good years and bad years. The decision of the state to implement the minimum purchase price policy preplan is an important measure to prevent the recurrence of history. At the same time, with the acceleration of China's industrialization process, "agriculture, rural areas and farmers" has become more and more limited to the main factors of China's economic development, and the increase of grain production and farmers' income is a key link of "agriculture, rural areas and farmers".

China implemented a minimum purchase price policy for wheat which is one of China's three major grains, since 2006. According to the policy, the National Development and Reform Commission, with the approval of the State Council, made public the minimum purchase price of the wheat before planting. During the autumn harvest period, if the market price of wheat is lower than the published price of the policy, the policy implementation province will start the minimum purchase price of wheat policy plan. The state entrusts wheat enterprises that meet certain qualifications to purchase wheat from farmers at the lowest purchase prices fixed by the state. If the market price of the wheat is higher than the published price of the policy, the minimum purchase price of wheat policy plan will not be activated, and wheat circulation will be carried out according to the market price. The minimum purchase price for wheat is announced before planting. Farmers will plant wheat based on the published minimum purchase price and the expected cost. Farmers plant more wheat if the minimum purchase price is higher than expected costs. If the minimum purchase price is lower than the expected cost, you may plant less wheat or manage the wheat more carefully to make more profit. Wheat minimum purchase price policy affects wheat production by influencing sown area and production per unit area.

With the continuous implementation of the wheat minimum purchase price policy, China has abundant literature on the grain minimum purchase price policy research. Zhu et al. (2016) through the ARCH effect of different grain price fluctuation rates, found that the lowest price purchase policy has the greatest influence on the stability of wheat price and ensures the income of wheat farmers [2]. Wang et al. (2012) used the difference-in-differences model and panel data of 7 provinces to study the 7 years weekly price data of wheat and found that the minimum purchase price policy can improve the price of wheat [3]. Zhang (2013) took wheat as an example, making dynamic and static comparisons of the total production, structure, and efficiency of the wheat production of the executing provinces and non-executing provinces before and after the implementation of the minimum purchase price policy, and found that concentration of wheat production, sown area, production per unit area, sales price and return to scale advantages of the wheat executing provinces and non-executing provinces increased steadily [4]. Ru et al. (2016) used gray model and neural network to analyze and evaluate the effects of grain minimum purchase policy from four aspects: planting area, main grain output, grain price volatility, and farmers' income, and clarified the important role of the minimum purchase price in stabilizing grain price in China [5]. Liu et al. (2020) based on the interest demands of the government, farmers, grain enterprises, and consumers, constructed a policy satisfaction evaluation model based on the Analytic Hierarchy Process and Fuzzy Comprehensive Evaluation. The research shows that the implementation effect of this policy has promoted the sustainable development of China's grain in four aspects: improving farmers' enthusiasm for planting, optimizing the structure of supply and demand, reducing the adverse impact of disasters, and ensuring the steady increase of output [6].

The research related to wheat minimum purchase price policy mainly evaluates the policy effect through producer and consumer welfare, yield, planting area, price mechanism, production efficiency, and other aspects. Although some pieces of literature use the difference-in-differences model to analyze the minimum purchase price policy, there are many data bias and confounding variables due to various reasons in the observation and research. In this study, the propensity score matching method was adopted to reduce the influence of these bias and confounding variables before using the difference-in-differences model, and a more reasonable comparison was made between the experimental group and the control group.

The DID model is a common method to evaluate the policy effect. Wang et al. (2019) explored China "most stringent command-and-control" directive's effects on the public's risk perceptions of haze in the country, the analysis showed that the directive significantly reduced the public's perceptions of risk, even when we controlled for factors related to knowledge, attitudes, health conditions, and expectations from government governance of air pollution [7]. Zhou et al. (2019) conducted an empirical analysis, using decomposition and DID approach to study how does emission trading reduces China's carbon intensity, founded that China's emission trading pilots have driven a significant decline in the carbon intensity [8]. Zhu et al. (2020) based on the multistage difference-in-differences model study that opening a high-speed railway can positively influence urban land expansion, as evidenced by the 9.5% increase in the urban land expansion index after such opening [9]. Wang et al. (2019) used the panel data from 2000 to 2016 of 30 provincial-level administrative regions in China and adopted the PSM-DID method to test the impact of China's carbon trading pilot system on the transformation of a low-carbon economy. The empirical results show that under the constraints of the established resources and environment, there is a positive relationship to some extent between China's carbon trading system and low-carbon economic transformation [10].

The objective of the implementation of the minimum purchase price policy for wheat is to promote an increase in wheat production. According to statistics, wheat production increased from 108.466 million tons in 2006 to 133.596 million tons in 2019 after the implementation of the minimum purchase price policy. However, how much did the implementation of the minimum purchase price policy contribute to wheat production increase? Based on the panel data of 15 major wheat-producing provinces in China from 1998 to 2019, this study adopted the propensity score matching and difference-in-differences methods

(PSM-DID) to conduct a robustness test and empirical test on the impact of China's minimum purchase price policy on wheat production.

2. Materials and Methods

The purpose of this paper is to study the effects of minimum purchase price policy on wheat production before and after implementation. If the sample provinces are directly divided into provinces that implement the policy and provinces that do not implement, and then the traditional ordinary least square (OLS) method is used for regression analysis, sample selection bias and endogenous problems will inevitably occur. However, if only the propensity score matching method is used, it can overcome the sample selection bias, but cannot effectively remove the endogenous problems. If only the dual difference method is used, although it can solve the endogenous problem, it cannot alleviate the sample selection bias. Therefore, we used the PSM-DID method to study the differences between provinces that implemented the minimum purchase price policy and those that did not.

2.1 DID Model

DID model is mainly used to evaluate policy effects in sociology. Its principle is based on a counterfactual framework to evaluate the change of observed factor Y in the case of policy occurrence and non-occurrence. If an exogenous policy shock divides the sample into two groups - treatment group and control group - and there is no significant difference in Y between the treatment group and the control group before and after the policy shock, then we can consider the change in Y of the control group before and after the policy shock as the treatment group not affected by the policy. By comparing the change in Y of the treatment group (D1) with the change in Y of the control group (D2), we can obtain the actual effect of the policy shock (DD= D1-D2).

Specifically, the dual difference model of a single impact point is as follows:

$$Y_{it} = \alpha_0 + \alpha_1 treat_{it} \times d_{it} + \alpha_2 treat_{it} + \alpha_3 d_{it} + \beta Z_{it} + \varepsilon_{it} \quad (1)$$

Where, Y_{it} represents the dependent variable of policy effect, $treat_{it}$ is a classified dummy variable. When sample i receives a policy intervention at time t, $treat_{it}$ will be assigned a value of 1, and when sample i does not receive a policy intervention at time t, $treat_{it}$ will be assigned a value of 0. d_{it} is a time dummy variable, which is 0 before policy implementation and 1 after policy implementation. $treat_{it} \times d_{it}$ is the cross term of the above two dummy variables, Z_{it} is the the control variable selected by the study, and ε_{it} is the random interference term.

$$D_1 = E(Y \mid t=1, d=1) - E(Y \mid t=1, d=0) = (\alpha_0 + \alpha_1 + \alpha_2 + \alpha_3) - (\alpha_0 + \alpha_2) = \alpha_1 + \alpha_3 \quad (2)$$

$$D_2 = E(Y \mid t=0, d=1) - E(Y \mid t=0, d=0) = (\alpha_0 + \alpha_3) - (\alpha_0) = \alpha_3 \quad (3)$$

Actual effect of policy shork:

$$DD = D_1 - D_2 = (\alpha_1 + \alpha_3) - \alpha_3 = \alpha_1 \quad (4)$$

In particular, the obtained differential estimator is unbiased only satisfies the condition that there is no significant difference in Y between the treatment group and the control group before the policy shock (parallelism hypothesis). When the common development trend is met, as shown in Fig. 1, the net effect of the policy can be obtained by calculating the ordinate value of the policy effect, that is, the policy effect.

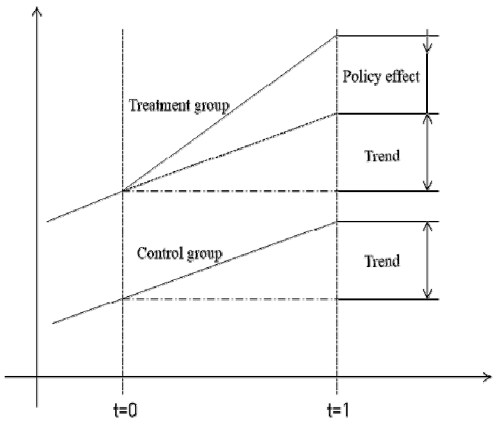

Fig. 1. Theory of DID model.

In this study, the difference-in-differences method effectively stripped the time effect of time passage or industry change on wheat production and obtained the net effect of the implementation of the minimum purchase price policy, namely the policy effect. It can be estimated by the following difference-in-differences model:

$$\begin{aligned} \ln produ_{it} &= \alpha_0 + \alpha_1 Treat_{it} \times T_{it} \\ &+ \alpha_2 Treat_{it} + \alpha_3 T_{it} \\ &+ \beta_1 \ln land_{it} + \beta_2 \ln labor_{it} \\ &+ \beta_3 \ln mach + \beta_4 \ln ferti_{it} \\ &+ \beta_5 \ln rain_{it} + \varepsilon_{it} \end{aligned} \quad (5)$$

Where,

$\ln produ_{it}$ denotes the logarithm of wheat production.

$Treat_{it}$ is a dummy variable. $treat_{it} = 1$ if the province implements the wheat's minimum purchase price policy, otherwise, $treat_{it} = 0$.

T_{it} is a dummy variable. $d_{it} = 1$ if that were the years after the wheat policy was implemented, otherwise, $d_{it} = 0$.

$\ln land_{it}$ denotes the logarithm of land cost for wheat cultivation.

$\ln labor_{it}$ denotes the logarithm of the number of manual days used for wheat cultivation.

$\ln mach_{it}$ denotes the logarithm of machinery cost for wheat cultivation.

$\ln ferti_{it}$ denotes the logarithm of fertilizer cost for wheat cultivation.

$\ln rain_{it}$ denotes the logarithm of rainfall in major provinces of wheat producing.

ε_{it} is disturbance , α, and β are parameters to be estimated.

The meanings of parameters in the above model are shown in Table 1. For provinces that implement the minimum purchase price policy for wheat ($Treat_{it}$=1), the wheat production before and after the implementation of the minimum purchase price policy are $\alpha_0 + \alpha_2$ and $\alpha_0 + \alpha_1 + \alpha_2 + \alpha_3$ respectively. so the difference of wheat production before and after the policy intervention is $\alpha_1 + \alpha_3$ which include the role of implementing a minimum wheat purchase policy and other influencing factors that vary over time. At the same time, for the provinces that does not implement the minimum purchase price policy for wheat ($Treat_{it} = 0$), the wheat production before and after the wheat's minimum purchase price policy are α_0 and $\alpha_0 + \alpha_3$ respectively, and their difference value is α_3, but the difference value does not include the influence of the wheat's minimum purchase price policy on wheat production. Therefore, the wheat production difference of the treatment group before and after the implementation of the wheat's minimum purchase price policy ($\alpha_1 + \alpha_3$), was subtracted from the relative wheat production difference of the control group before and after the implementation of the wheat minimum purchase price policy (α_3), and result α_1 is the net effect of the wheat minimum purchase price policy on wheat production. When α_3 is significantly positive, it indicates that wheat minimum purchase price policy promotes wheat production.

Table 1. The meaning of parameters in the DID model.

	Before policy implementation ($T_{it}=0$)	After policy implementation ($T_{it}=1$)	Difference
Policy implemented province (Treatment group, $Treat_{it}=1$)	$\alpha_0+\alpha_2$	$\alpha_0+\alpha_1+\alpha_2+\alpha_3$	$\alpha_1+\alpha_3$
Policy unimplemented province (Control group, $Treat_{it}=0$)	α_0	$\alpha_0+\alpha_3$	α_3
DID			α_1

2.2 Propensity score matching

Propensity Score Matching (PSM) is a statistical method used to deal with data from an observational study. In observational studies, there are many data biases and confounding variables for various reasons, and the PSM method is designed to reduce the influence of these biases and confounding variables so as to make a more reasonable comparison between the treatment group and the control group. The most important premise for the use of the DID model is that the treatment group and the control group must have the same development trend before the implementation of the policy, and the PSM method can construct "counterfactual" inference to match as many control groups as possible for the treatment group.

PSM method was first proposed by Rosenbaum and Rubin in 1983 and is commonly used in medicine, public health economics, and other fields [11]. Assume that there are N individuals, each individual in intervention $i\,(i=1,2,\ldots,N)$ will have two potential results ($Y_i(0)$, $Y_i(1)$), corresponding to the potential outcomes in the untreated state and the potential outcomes in the treated state. So the effect of treatment on an individual is marked as the difference between the potential outcome of the treatment and the potential outcome of non-treatment, namely:

$$\delta_i = Y_i(1) - Y_0(1) \tag{6}$$

Let $D_i=1$ represents accepted treatment, $D_i=0$ represents non treatment, and Y_i represents the outcome variable tested. Then the counterfactual framework can be expressed as the following equation:

$$Y_i = Y_i(D_i) = \begin{cases} Y_i(0), \text{if } D_i = 0 \\ Y_i(1), \text{if } D_i = 1 \end{cases} \tag{7}$$

namely,

$$Y_i = (1-D_i)\,Y_i(0) + D_i\,Y_i(1) \tag{8}$$

This equation shows that which of the two outcomes will be observed in reality depends on the state of the treatment, the state of D.

Average Treatment Effect for the treated (ATT) is used to measure the average treatment effect of the individual in the treatment state, that is, the difference between the observation result of the individual i in the treatment state and the counterfact, which is called the standard estimator of the average treatment effect,

$$\begin{aligned} ATT &= E\{Y_i(1) - Y_i(0) \mid D=1\} \\ &= E\{Y_i(1) \mid D=1\} \\ &\quad - E\{Y_i(0) \mid D=1\} \end{aligned} \tag{9}$$

The steps of the PSM method are as follows. Firstly, matching variables are selected according to the research questions. Secondly, propensity score is calculated. Finally, matching between treatment group and control group is carried out. Caliendo et al. (2008) pointed that only when both the outcome variable and the samples are affected, the variables receiving the policy treatment will be included in the set of covariables in the PSM model [12]. Therefore, variables affecting wheat production are selected as matching variables in this chapter, including land cost, labor quantity, machinery cost, fertilizer cost, and rainfall. Due to the large number of individuals in the control group, ernel matching method is adopted for matching.

3. Data Sources

The data involved in this chapter are second hand data collected from "China Statistical Yearbook" and "National Farm Product Cost-benefit Survey" respectively. The indicators of wheat production and rainfall in this study were obtained from the "Chinese Statistical Yearbook". Data of land cost, labor days, machinery cost and fertilizer cost for wheat planting were obtained from "National Farm Product Cost-benefit Survey". Due to the availability of data, the study spanned 1998 to 2019. The period from 1998 to 2005 is the stage before the implementation of the policy, and the period from 2006 to 2019 is the stage of the implementation of the policy. There are 15 major wheat producing regions in China, including Anhui, Gansu, Hebei, Henan, Heilongjiang, Hubei, Jiangsu, Inner Mongolia autonomous Region, Ningxia Hui Autonomous Region, Shandong, Shaanxi, Shanxi, Sichuan, Xinjiang and Yunnan provinces. In 2006, the government began to implement the minimum purchase price policy for wheat in Anhui, Hebei, Henan, Hubei, Jiangsu and Shandong provinces, which are the treatment group of the study. The other major producing provinces, which have not implemented the minimum purchase price policy for wheat, are the control group of the study. All price data were caculated by GDP deflating based on 1998. In addition, before the DID model, PSM model was used to make samples as close as possible to the random experimental data through matching re-sampling, which reduces the bias of the data to a large extent. It looked for the control group that was as similar as possible to the treatment group according to the propensity score. Namely, land cost, labor days, machinery cos, fertilizer cost for wheat planting, and rainfall were analyzed by PSM method. And then the DID model was responsible for identifying the impact of wheat's minimum purchase policy impact through new control group and new treatment group which obtained from the results of PSM analysis.

4. Results and Analysis

4.1 Descriptive Statistics analysis

The descriptive statistics of variables are interpreted in Table 2. The average logarithm of wheat production is 6.058 tens of million yuan which ranges from 3.081 to 8.649 tens of million yuan. On average, the logarithm of land cost is 7.268 tens of million yuan which ranges between 5.820 and 9.337 tens of million yuan. The mean of the logarithm of labor workdays is 5.355 tens of million days with a maximum of 9.705 tens of millions of days and a minimum of 1.981 tens of million days. The average logarithm of machinery cost is 7.149 which ranges from 5.591 to 8.570 tens of million yuan. On average, the logarithm of fertilizer cost is 3.312 which ranges between 1.990 and 4.014. The mean logarithm of

Table 2. Descriptive statistics analysis.

Variables	Unit	N	Mean	Std. Dev	Min	Max
$\ln produ_{it}$	tens of millions yuan	330	6.058	1.179	3.081	8.649
$\ln land_{it}$	tens of millions yuan	330	7.268	0.856	5.820	9.337
$\ln labor_{it}$	tens of millions days	330	5.355	1.141	1.981	9.708
$\ln mach_{it}$	tens of millions yuan	330	7.149	0.534	5.591	8.570
$\ln ferti_{it}$	tens of millions yuan	330	3.312	0.387	1.990	4.014
$\ln rain_{it}$	millimeter	330	6.345	0.590	4.316	7.510

rainfall for one year is 6.345 millimeters with a maximum of 7.510 millimeters and a minimum of 4.316 millimeters.

4.2 The DID method regression analysis

The effect of policy implementation on wheat production was analyzed by DID method with wheat production as dependent variable and time dummy variable, regional dummy variable, and interaction term as an independent variable. In order to test the robustness of the variable coefficient, the method of gradually increasing control variables was adopted in the original model. As shown in Table 3, model 1 does not add any control variables, while model 2 to Model 5 gradually increased control variables, such as land cost, labor workdays, machinery cost, fertilizer cost, rainfall. The method results show that, from model 1 to model 5, the coefficient signs of explanatory variables of interaction terms have not fundamentally changed, and among other explanatory variables, only the coefficient signs of working days have changed, and the determinant coefficient R2 of the model has also gradually increased.

Table 3. Impacts of minimum purchase price policy implementation on wheat production—the DID method.

	(1)	(2)	(3)	(4)	(5)
T_{it}	-0.0920	-0.0917	-0.2329*	-0.1075	-0.4077***
	(-0.7970)	(-0.7989)	(-1.9311)	(-0.8475)	(-3.3584)
$Treat_{it}$	1.3860***	1.4102***	1.5961***	1.4925***	1.1227***
	(9.5623)	(9.7645)	(10.4563)	(9.6208)	(7.5583)
$Treat_{it} \times T_{it}$	0.5608***	0.5411***	0.5333***	0.5607***	0.5596***
	(3.0833)	(2.9904)	(2.9933)	(3.1784)	(3.4788)
$\ln land_{it}$	0.2456***	0.3233***	0.2596***	0.2453***	0.4207***
	(4.8793)	(5.3329)	(4.1432)	(3.9477)	(6.9407)
$\ln labor_{it}$		-0.1030***	-0.0251	0.0360	0.0475
		(-2.2687)	(-0.4990)	(0.6657)	(0.9617)
$\ln mach_{it}$			-0.3694***	-0.5002***	-1.9686***
			(-3.3494)	(-4.2368)	(-9.3770)
$\ln ferti_{it}$				0.4631***	1.2542***
				(2.8911)	(7.1518)
$\ln rain_{it}$					1.3857***
					(8.1467)
_cons	3.6346***	3.6161***	6.3209***	5.4533***	3.5421***
	(9.8607)	(9.8705)	(7.1469)	(5.8981)	(4.0481)
N	330	330	330	330	330
R^2	0.5669	0.5723	0.5854	0.5946	0.6630

*p 〈 0.05, **p 〈 0.01, ***p 〈 0.001.

In model 5, at the significance level of 5%, cross-variables had a significant positive impact on wheat production, indicating that the implementation of policies promoted the increase of wheat production, in which the minimum purchase price policy increased by 55.96%. Among the control variables, the land cost had a significant positive effect on wheat production, and wheat production increased by 42.07% when land cost increased by 1%. Working days had no significant positive effect. The mechanical cost had a significant negative effect on wheat production, and wheat production decreased 196.86% when the mechanical cost increased by 1%. Fertilizer cost had a significant positive effect on wheat production, and wheat production increased 138.57% with a 1% increase in rainfall.

4.3 Analysis of PSM method

According to the implementation of the minimum purchase price policy for wheat in 2006, 15 major wheat-producing areas were divided from 2006 to 2019 into the treatment group that implements the minimum purchase price policy for wheat and the control group that does not implement the wheat's minimum purchase price policy, and propensity score matching is conducted for the two groups of data. Specifically, this study uses the kernel matching method to perform a logit model on the data to estimate propensity score matching. The matching results are shown in Table 4.

Table 4. Results of propensity score matching.

Treatment assignment	Countries	Num
Treated	Anhui, Hebei, Henan, Hubei, Jiangsu, Shandong	130
Untreated	Gansu, Heilongjiang, Inner Mongolia autonomous Region, Ningxia Hui Autonomous Region, Shaanxi, Shanxi, Sichuan, Xinjiang and Yunnan provinces	52

In the method of propensity score matching, it is necessary to test the reliability of matching results to ensure that there is no significant difference between the treatment group and the control group after matching, so as to meet the assumption of a common trend. According to the study of Paul and Donald (1983), after matching, the difference between the treatment group and the control group was significantly reduced. The main statement is that the absolute value of the deviation is less than 20, and t-test is not significant. Table 5 shows the test results that the absolute values of the matched deviation values are all less than 20, and there is no significant difference in t-statistics at the 5% confidence interval. It indicates that there is no significant difference between the paired treatment group and the control group, avoiding sample selection bias.

Table 5. Results of propensity score matching balance test.

	Unmatched	Mean			%reduct	t-test	
Variable	Matched	Treated	Control	%bias	bias	t	p>t
$\ln land_{it}$	U	7.2704	7.2661	0.5		0.04	0.964
	M	7.2677	7.128	15.9	-3143.8	1.51	0.131
$\ln labor_{it}$	U	5.4246	5.308	10.8		0.91	0.364
	M	5.4196	5.5828	-15.2	-40	-1.86	0.064
$\ln mach_{it}$	U	7.4577	6.9439	110.2		9.69	0.000
	M	7.4461	7.4735	-5.9	94.7	-0.53	0.599
$\ln ferti_{it}$	U	3.5013	3.1854	92.6		7.91	0.000
	M	3.4937	3.4818	3.5	96.3	0.34	0.734
$\ln rain_{it}$	U	6.7233	6.0933	128.9		11.13	0.000
	M	6.7182	6.7786	-12.4	90.4	-1.43	0.155

4.4 Analysis of PSM-DID estimation

The method of PSM-DID was used for estimation. The estimated results are shown in Table 6. Model (1) is the PSM-DID result without covariables addition and robustness. Model (2) is the PSM-DID result without covariables addition but with robustness. Model (3) is the PSM-DID result with covariables addition but without robustness. Model (4) is the PSM-DID result with covariables addition and robustness. In models 1 to 4, interaction terms all exceeded the significance level of 5%. The coefficients were all positive, indicating that the implementation of the minimum purchase price policy promoted the increase of wheat production, which verified the robustness of the model. In model (4), the value of PSM-DID before and after the implementation of the policy is 0.7689, indicating that after the implementation of the policy, the production of the main wheat-producing areas with the policy implemented is significantly higher than that of the main wheat-producing areas without the policy implemented.

Table 6. The PSM-DID estimation.

	(1)	(2)	(3)	(4)
T_{it}	-0.0260 (-0.2192)	-0.0260 (-0.2269)	-0.2502 (-1.5778)	-0.3035* (-1.7581)
$Treat_{it}$	1.4312 (9.5657)	1.4312*** (10.4379)	1.8744*** (10.9097)	1.8744*** (14.7015)
$Treat_{it} \times T_{it}$	0.4914*** (2.6198)	0.4914*** (2.7657)	0.7155*** (3.3724)	0.7689*** (3.4919)
_cons	5.3769*** (56.8216)	5.3769*** (68.7077)	4.9337*** (37.9873)	4.9337*** (84.4451)
Control	No	No	Yes	Yes
Robust	No	Yes	No	Yes
N	330	330	175	161
R^2	0.5366	0.5366	0.7594	0.7765

$^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.

4.5 Further robustness test

According to the preliminary results, the pilot provinces of wheat minimum purchase price policy promoted wheat production after the implementation of the policy. Are the control variables that have a significant impact on the explained variables unable to play their original role due to exogenous factors, thus weakening the effect of policy implementation? Taking the above control variables as dependent variables, DID method was used to analyze the influence of policy mechanisms on these control variables. The results are shown in Table 7. The results show that at the significance level of 5%, the cross-term variable has a significant negative impact on the number of working days and the cost of fertilizer, indicating that the policy mechanism reduces the number of working days and the cost of fertilizer to some extent.

Table 7. Impacts of policy mechanisms on control variables.

	$\ln land_{it}$	$\ln labor_{it}$	$\ln mach_{it}$	$\ln ferti_{it}$	$\ln rain_{it}$
T_{it}	0.1236	0.5067^{***}	-0.3450^{***}	-0.2788^{***}	-0.0268
	(1.6292)	(3.1670)	(-4.9922)	(-4.9366)	(-0.4174)
$Treat_{it}$	0.3623	0.5655^{*}	0.2818	0.2150^{***}	0.0416
	(0.4957)	(1.6648)	(1.1870)	(3.8429)	(0.1470)
$Treat_{it} \times$	-0.1316	-0.6850^{***}	-0.0832	-0.1411^{**}	0.0324
	(-1.4570)	(-3.5947)	(-1.0111)	(-2.0967)	(0.4244)
_cons	6.9111^{***}	4.9653^{***}	7.4431^{***}	3.5502^{***}	6.6749^{***}
	(11.5793)	(17.8497)	(38.3590)	(76.7010)	(28.8633)
N	182	182	182	182	182
R^2	0.0183	0.0553	0.1950	0.4403	0.0016

$^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.

5. Conclusion

In this study, the effects of minimum purchase price policy on wheat production were analyzed, and the characteristics of wheat production changes in the areas with and without minimum purchase price policy were summarized. Based on the data of 15 major wheat-producing provinces from 1998 to 2019, the PSM-DID model was used to empirically analyze the impact of wheat minimum purchase price policy on wheat production. The results show that the implementation of wheat's minimum purchase price policy can significantly affect wheat production, and the implementation of wheat minimum purchase price policy can increase wheat production by 76.89% when other factors affecting wheat production remain unchanged.

The minimum purchase price policy is also a policy to benefit farmers in order to prevent "low grain price hurts farmers" and protect farmers' enthusiasm for planting wheat. The minimum purchase price level is usually determined by taking into account factors such as grain production costs, market supply and demand, domestic and international market prices, and industrial development, so as to ensure that farmers do not lose money when growing wheat and stabilize their confidence. Under normal circumstances, grain purchase prices are affected by market supply and demand. When the market price of wheat in major producing areas is lower than the minimum purchase price, market purchase will be initiated to protect the interests of wheat farmers.

Since the minimum purchase price policy of wheat, wheat output has increased steadily. Wheat stocks remained high and absolute wheat security was achieved. However, because of China's wheat price formation mechanism is not perfect, the minimum purchase price becomes the highest price. As a result, policy-based acquisition gradually occupies a dominant position and squeezes the adjustment space of the market. Moreover, the minimum purchase policy focuses on production rather than quality, which makes farmers have weak quality awareness and market awareness. Farmers are keen to grow high-production wheat, leaving fewer high-quality wheat sources on the market. In addition, with the rising cost of planting, the minimum purchase price policy has an impact on the promotion of farmers' income. If China government wants to further raise the minimum purchase price, China will face the international grain price ceiling, WTO yellow box rules, and a series of factors. Then the goal of protecting farmers' income is also becoming harder to achieve.

The minimum purchase price policy is still an important system to protect farmers' income and ensure stable and increased grain production in China under the complicated situation of grain market at home and abroad.

On this basis, the government should constantly improve the minimum purchase price policy. At First, the minimum purchase price of wheat should be kept stable or gradually lowered. We will gradually adjust the minimum purchase price to a reasonable level by classifying different types of products and implementing them step by step. The formulation of the minimum purchase price level should not only keep the bottom line of grain safety, but also give full play to the role of market mechanism and stimulate market vitality. Further more, the government should guide farmers to adjust their planting structure so that the area of high-quality wheat is gradually expanded and the quality is improved, and the transformation of China's wheat production to a greener and more sustainable direction should be accelerated. Farmers plant wheat products of high quality and price according to market demand and increase income benefit through planting high quality wheat. In the end, the government should explore the pilot program of wheat crop full cost insurance and income insurance, and give full play to the important role of agricultural insurance in protecting farmers' interests.

Second hand data from the government were used in this study. It is very convenient and economical but also has great limitations, mainly manifested as poor correlation, poor timeliness and poor accuracy of data. In addition, this study only studies the effect of minimum purchase price policy on wheat production, but ignores the effect of minimum purchase price policy on farmers' income. In future study, the possible impact of the change of minimum purchase price on wheat production, consumption and trade in China will be quantitatively evaluated. Then the influence of the change of wheat minimum purchase price on farmers' income in main producing areas will be further analyzed by using the survey data of fixed observation points in rural China.

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