

Influence of Soil Testing and Formula Fertilization Project on Agricultural Development and Urbanization Process

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Abstract. In order to study the impact and role of the implementation of soil testing and formula fertilization project on China's agricultural development and urbanization, this paper selects the panel data of 31 provinces in China from 2000 to 2018 based on the perspective of agricultural development and urbanization, and uses the difference-in-differences method (DID) analysis based on double fixed effects to test the impact of soil testing and formula fertilization project on the total sown area of crops and the level of urbanization. The main conclusions are as follows: First, soil testing and formula fertilization project have a positive and significant impact on increasing the total sown area of crops in various provinces, but there is a one-year lag period; Second, the level of urbanization is also significantly positively affected by soil testing and formula fertilization project, but there is also a two-year lag period.

Keywords: Soil Testing and Formula Fertilization Project; Difference-In-Differences Method; Agricultural Development; Urbanization Process.

1. Introduction

As a world-famous agricultural country, farming culture has been spread in China for a long time. As an indispensable agricultural production factor since modern times, the use of chemical fertilizers has greatly promoted China's grain production. However, the excessive use of chemical fertilizers has also caused many problems such as grain production decline, soil erosion, and ecological environment damage. At present, excessive fertilization and inefficient fertilization are still the main problems in the use of chemical fertilizers in China [1]. In order to solve this problem, in 2005, the central government issued the No. 1 document to carry out soil testing and formula fertilization project across the country to promote the introduction of technology into households, and to promote the appropriate and scientific use of chemical fertilizers [2]. The soil testing formula is to sample the soil in the land before sowing to check the content of nutrients such as trace elements. The "suit the remedy for the case" approach was used for the land to formulate formula fertilizer rich in its missing or insufficient nutrients and use it scientifically. After the implementation of the project, China's social, economic and agricultural benefits have been greatly improved. But what impact will the implementation of this project have on agriculture and cities? Is the impact significant? This paper will focus on its impact on China's agricultural development and urbanization process.

Since the implementation of the soil testing and formula fertilization project, more and more researches have been done on it, but there are very few targeted researches from the two aspects of agricultural development and urbanization process. Up to now, the research focus of scholars on soil testing and formula fertilization project is mostly on the implementation of this project on the nutrient content in soil[3~7], grain yield[8~11], fertilizer utilization rate[12~14], and the impact of pollutant emissions [15~16]. There are few comprehensive studies on its environment and economic benefits [17], and there are almost zero articles on the role and impact of soil testing and formula fertilization project from the urbanization process and rural development. In addition, most of the research objects are concentrated in local areas, and there are few comprehensive researches nationwide; and the data used are relatively old and cannot more accurately reflect the impact and role of the policy at this stage. Therefore, this study is of great significance to accurately reflect the role and impact of soil testing and formula fertilization project on agricultural and social benefits nationwide in recent years.

2. Theoretical Analysis and Research Hypotheses

The implementation of the soil testing and formula fertilization project is implemented to solve the problem of excessive and inefficient fertilization in China's rural areas, and has great guiding significance for rational and efficient fertilization in China's agriculture. According to the existing research, it is easy to see that the implementation of this policy does have a significant positive impact on China's agricultural conditions, including soil quality and the content and proportion of nutrient elements contained in it. The improvement of these agricultural conditions will theoretically promote the expansion of the available sown area in China's rural areas. Therefore, this paper proposes Hypothesis 1.

Hypothesis 1: After the implementation of the soil testing and formula fertilization project, the total sown area of crops in China will be significantly and positively affected.

Since the implementation of the soil testing and formula fertilization project in 2005, the rational use of chemical fertilizers in China has significantly improved the soil quality used in agriculture, and the improvement of soil quality will definitely reduce a lot of unnecessary labor. Those redundant laborers will flock to cities and towns in order to obtain higher economic benefits. After the material level and living conditions of cities and towns are improved, they may directly settle in cities and towns, which will inevitably increase the proportion of urbanized population in China. Accordingly, this paper proposes Hypothesis 2.

Hypothesis 2: After the implementation of the soil testing and formula fertilization project, China's urbanization process has been significantly promoted.

3. Variable Selection and Data Sources

3.1 Variable Selection

1. Explained variable

Total sown area of crops (sa): This paper selects the total sown area of crops in 31 provinces in China from 2000 to 2018 as an indicator to measure China's agricultural development.

Urbanization level (ur): This paper selects the ratio of the urban population of 31 provinces across the country from 2000 to 2018 to the total population of the province in that year as an indicator to measure China's urbanization process.

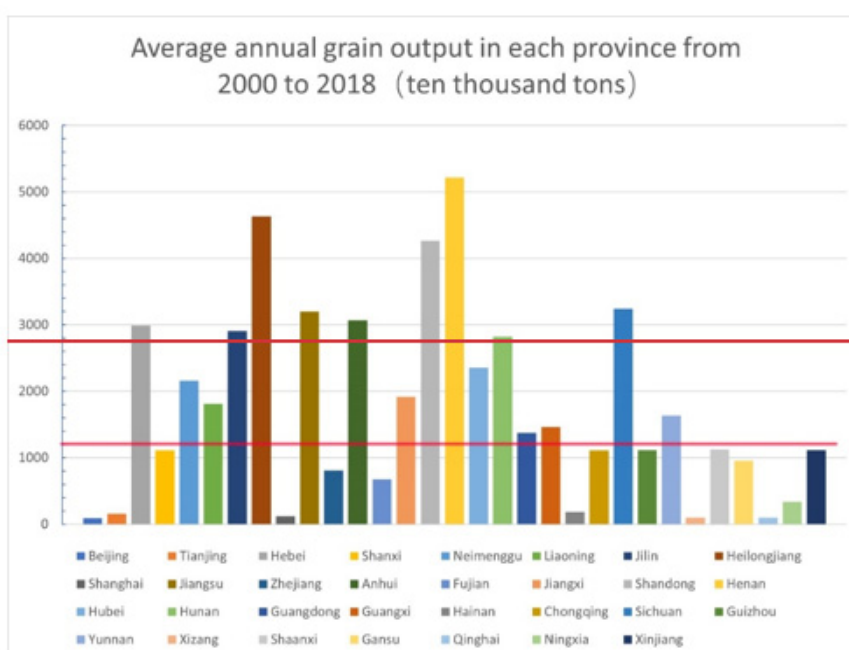


Figure 1. Average annual grain output in each province from 2000 to 2018

2. Explanatory variables

Policy implementation variable (dudt): This paper evaluates the implementation of soil testing and formula fertilization project from the perspectives of provinces and time.

du (province dummy variable): Assuming that the influence of other factors is not considered, compare the average annual grain output of each province with 12 million tons during the period from 2000 to 2020 (as shown by the red line in Figure 1). If it is smaller than 12 million tons, it is regarded as a province with small grain output, and it is recorded as 0. If it is greater than or equal to 12 million tons, it is regarded as a province with large grain output, and it is recorded as 1, as shown in the figure below.

dt (time dummy variable): Whether the province has carried out a soil testing formula subsidy project this year: if it is, it is recorded as 1; otherwise, it is recorded as 0.

3. Control Variables

In addition to the explanatory variables selected in this paper, agricultural development and urbanization will also be affected by other factors. In this paper, the amount of chemical fertilizer application, the proportion of agricultural expenditure in financial expenditure, provincial per capita GDP, effective irrigation area and soil erosion control area are selected as the control variables in this study.

The symbols and meanings of each variable are shown in Table 1.

Table 1. Symbols and meanings of variables

Variable name	Symbol	Meaning
Policy implementation (0/1)	dudt	Implementation of soil testing and formula fertilization project in different years and provinces
Total sown area of crops (mu)	sa	The total sown area of crops in each province and year
Urbanization level (no unit)	ur	The ratio of the urban population of each province in each year to the total population of the province in that year
Fertilizer application amount (tons)	cf	Total fertilizer application amount of each province by year
Proportion of agricultural expenditure to financial expenditure (no unit)	ae	Proportion of the government's agricultural expenditure in each province in each year to the total financial expenditure of the year
Provincial GDP per capita (yuan)	pgdp	GDP per capita in each province by year
Effective irrigated area (thousand hectares)	ia	The total agricultural effective irrigated area of each province by year
Soil erosion control area (hectare)	ca	The area of soil erosion control in each province by year

Note: the unit of Total sown area of crops, mu, is the Chinese version of acre, which 1 mu is equal to 666 square meters.

3.2 Data Sources

In this paper, 31 provinces and municipalities across the country from 2000 to 2018 were selected for research, and 16 major grain provinces (municipalities) that met the standards set in this paper were used as the experimental group, and the remaining 15 provinces (municipalities) were used as the control group to analyze the impact of the implementation of the soil testing and formula fertilization project on agricultural behavior. The data for this study come from the Ministry of Agriculture, State Forestry Administration, National Bureau of Statistics of China, Ministry of Water Resources, China Meteorological Administration, China Customs, National Bureau of Statistics of China, and State Administration of Grain of China.

3.3 Descriptive Statistics

Table 2 shows the descriptive statistics of each variable. It can be seen from Table 2 that the maximum value of the total sown area of crops is 15,000,000, the minimum value is 100,000, the mean value is 5,100,000, and the standard deviation is 3,700,000, indicating that the total sown area of crops in different provinces varies greatly; The maximum value of the urbanization level is 0.896, the minimum value is 0.003, the mean value is 0.483, and the standard deviation is 0.19, indicating that the urbanization level of different provinces is also quite different. In addition, the values of chemical fertilizer application amount, the ratio of agricultural expenditure to financial expenditure, provincial GDP per capita, effective irrigation area and soil erosion control area are all within a reasonable range, indicating that the samples and variables selected in this paper are reasonable.

Table 2. Statistical description of variables

Variable	Mean	Standard deviation	Min	Max	N
sa	5.100e+06	3.700e+06	100000	1.500e+07	589
ur	0.483	0.190	0.00300	0.896	589
cf	1.700e+06	1.400e+06	25000	7.200e+06	589
ae	0.0800	0.0480	0.00600	0.190	589
pgdp	24000	17000	2759	100000	589
ia	1932	1510	109.7	6120	589
ca	3.300e+06	2.800e+06	0	1.400e+07	589

4. Empirical Analysis

4.1 Model Construction

For the evaluation of policy implementation effects, the current four mainstream methods in academia are instrumental variable method, breakpoint regression, difference-in-differences method and propensity score-matching method. Since the application condition of the difference-in-differences method is that the policy is partially implemented in all the research objects or the policy is fully implemented for the research object and can be divided into two categories according to certain standards, and the difference-in-difference method can also see the near-term impact of policy implementation. Therefore, the double-difference method was used in this paper to study the impact of soil testing and formula fertilization project on China's agricultural development and urbanization. The model is built as follows:

$$Sa_{it} = \alpha_1 + \beta_1 du_{it} \times dt_{it} + \gamma_1 z_{it} + \theta_{it} \quad (1)$$

$$Ur_{it} = \alpha_2 + \beta_2 du_{it} \times dt_{it} + \gamma_2 z_{it} + \delta_{it} \quad (2)$$

Among them, *i* represents the province; *t* represents the year; *sa* represents the total sown area of crops; *ur* represents the level of urbanization; *du* represents the dummy variable of the province: according to the standard of the average annual grain yield stipulated in this study, it is recorded as 1 if it reaches the standard, otherwise Recorded as 0; *dt* represents the time dummy variable, the policy implementation year is recorded as 1, otherwise it is recorded as 0; *z* is the control variable selected in this paper: fertilizer application amount (tons), the proportion of agricultural expenditure to financial expenditure, the provincial per capita GDP, effective irrigation area and soil erosion control area.

4.2 Benchmark Regression Analysis

1. In order to eliminate the impact of inflation and other factors on prices, the data related to economic indicators used in this paper have been calculated as the data obtained after deflator based on the consumer price index in 2000.

2. In order to avoid the inconvenience of subsequent analysis of the results due to the inconsistency of the data units of each variable, this paper adopts logarithmic processing for all collected data in the subsequent research process.

In this study, the benchmark regression results obtained by using double fixed effects for the two variables of total crop sown area and urbanization level are shown in Table 3 and Table 4.

Column (1) in Table 3 only controls the time fixed effect and province fixed effect for the total sown area of crops and then adds dudt for regression. The regression coefficient of dudt is 0.1283, which is significant at the 5% level. Column (2) adds control variables on the basis of column (1), and the regression coefficient of dudt is 0.1147, which is significant at the 1% level. The above results show that after adding the control variable, the control variable is still significant and positive for the total sown area of crops. In addition, the control variables, the ratio of agricultural expenditure to financial expenditure, provincial GDP per capita and effective irrigation area all have a significant positive impact on the total sown area of crops, while soil erosion control area has an insignificant positive impact on it.

Table 3. Benchmark regression on Insa

	(1) Insa	(2) Insa
dudt	0.1283** (0.0584)	0.1147*** (0.0334)
lnae		0.1384** (0.0576)
lnpgdp		0.1673* (0.1073)
lnia		0.4238*** (0.1368)
lnca		0.0272 (0.0372)
dudt05	0.0442** (0.0179)	0.0095 (0.0180)
dudt06	0.0601* (0.0357)	0.0342 (0.0357)
dudt07	0.0780** (0.0354)	0.0631** (0.0313)
dudt08	0.0734* (0.0385)	0.1030*** (0.0298)
dudt09	0.0726* (0.0421)	0.0946*** (0.0347)
dudt10	0.0807 (0.0496)	0.0928** (0.0383)
dudt11	0.0987* (0.0522)	0.1090*** (0.0392)
dudt12	0.1206** (0.0594)	0.1225*** (0.0421)
dudt13	0.1466** (0.0656)	0.1511*** (0.0509)
dudt14	0.1741** (0.0771)	0.1703*** (0.0499)
dudt15	0.2018** (0.0845)	0.1863*** (0.0499)
dudt16	0.2023** (0.1012)	0.1721*** (0.0555)
dudt17	0.2207** (0.1092)	0.1886*** (0.0578)
dudt18	0.2218* (0.1173)	0.1940*** (0.0601)
_cons	12.5450*** (0.0456)	8.9168*** (1.4207)
R^2		
N	589	570

Standard errors in parentheses * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$, the same below

Using the multiplication term $dudt05-dudt18$ of the time dummy variables $dt00\sim dt18$ and the province dummy variables as the main explanatory variables, the year-by-year effect of policy implementation on the total sown area of crops can be obtained. It can be seen from the table that the positive effect of the main explanatory variable on the total sown area of crops gradually appeared and became significant year by year. Therefore, it can be shown that the implementation of the soil testing and formula fertilization project does have a significant positive impact on the total sown area of crops. The soil testing and formula fertilization project can increase the input of agricultural production factors, thereby making agriculture more efficient. At the same time, the benchmark regression results can also show that after the release of the soil testing and formula fertilization project documents, relevant government departments have made strong arrangements and implementation guidance, and farmers are also actively responding to and cooperating with the call and arrangement of the state and the government, and have achieved remarkable results. Overall, its implementation effect is consistent with Hypothesis 1 of this paper.

Table 4. Benchmark regression on \lnur

	(1) \lnur	(2) \lnur
$dudt$	0.2160* (0.1259)	0.2159* (0.1124)
\lnpgdp		0.4912* (0.2686)
$\ln cf$		-0.5792*** (0.2139)
$\ln ca$		0.0792* (0.0616)
$\ln ia$		0.1639 (0.1960)
$dudt05$	0.2337* (0.1217)	0.2081* (0.1223)
$dudt06$	0.2509* (0.1303)	0.2247* (0.1273)
$dudt07$	0.2609* (0.1366)	0.2320* (0.1305)
$dudt08$	0.2672* (0.1387)	0.2516* (0.1308)
$dudt09$	0.2714* (0.1432)	0.2579** (0.1301)
$dudt10$	0.2624* (0.1451)	0.2541* (0.1316)
$dudt11$	0.2804* (0.1505)	0.2732** (0.1354)
$dudt12$	0.2845* (0.1526)	0.2682** (0.1364)
$dudt13$	0.2845* (0.1553)	0.3026** (0.1476)
$dudt14$	0.3300* (0.1923)	0.3552* (0.1920)
$dudt15$	0.3217* (0.1933)	0.3330* (0.1907)
$dudt16$	0.3149 (0.1947)	0.3334* (0.1937)
$dudt17$	0.3112 (0.1963)	0.3552* (0.2015)
$dudt18$	0.3079 (0.1974)	0.3612* (0.2035)
$_cons$	-0.5068*** (0.0919)	-0.6091 (3.0376)
R^2		
N	589	570

Similarly, column (1) in Table 4 only controls the time fixed effect and province fixed effect for the urbanization level and then adds $dudt$ for regression. The regression coefficient of $dudt$ is 0.216,

which is significant at the 10% level; column (2) is in Adding control variables on the basis of column (1), the regression coefficient of $dudt$ is 0.2159, which is significant at the 10% level. Moreover, the control variables of provincial per capita GDP and soil erosion control area have a significant positive impact on the level of urbanization, the effective irrigation area has an insignificant positive impact on it, and the fertilizer application amount has a significant negative impact on it. Using the multiplication term $dudt05\sim dt18$ of the time dummy variables and the province dummy variables $dt05\sim dt18$ as the main explanatory variables, the year-by-year effect of policy implementation on the urbanization level can be obtained. The positive effect of the year-by-year effect gradually appeared and became significant. The above results show that the implementation of soil testing and formula fertilization project does have a significant positive impact on the level of urbanization, indicating that soil testing and formula fertilization project can promote rural urbanization. At the same time, the regression results can also show that the soil testing and formula fertilization project has improved the agricultural production factors in China's rural areas and made them more efficient. Efficient agricultural production will inevitably cause excess labor to enter the cities and towns, thus promoting the process of urbanization in China. Overall, its implementation effect is consistent with Hypothesis 2 of this paper.

5. Model Test

5.1 Parallel Trend Test

Take 2004 as the base year for the obtained data to make parallel trend graphs for the two explained variables, the total sown area of crops and the level of urbanization, as shown in Figures 2 and 3 below.

It can be seen from Figure 2 that before the implementation of the soil testing and formula fertilization project, there was no significant difference in the annual total sown area of crops between the experimental group and the control group, which met a parallel trend. Although the policy effect may have a one-year lag period on the total sown area of crops due to factors such as the intensity of project implementation. However, in general, after the implementation of the policy, there was a significant difference in the total sown area of crops between the experimental group and the control group, which passed the parallel trend test and met the preconditions for the use of the difference-in-differences method.

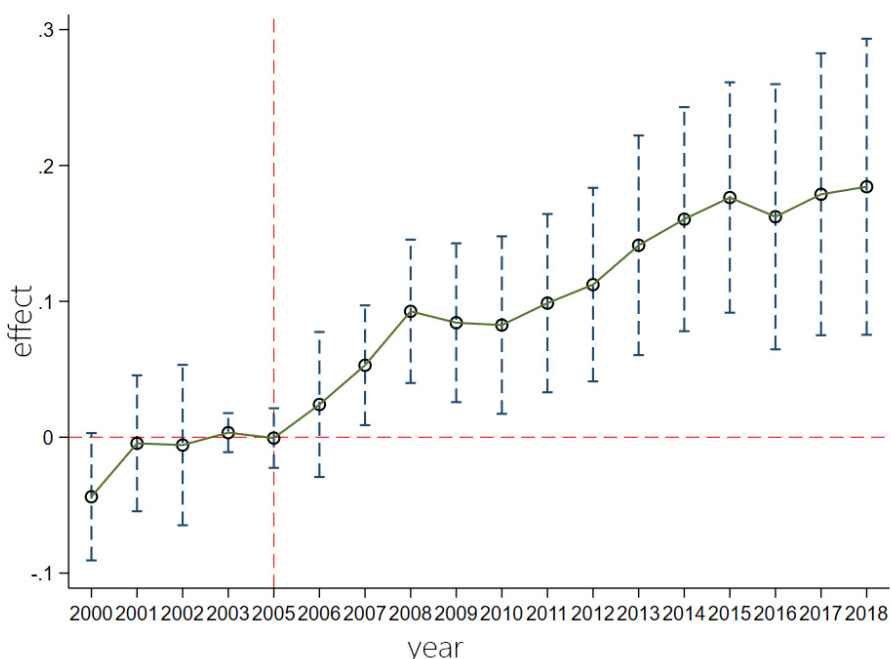


Figure 2. Parallel trend graph of Insa

It can be seen from Figure 3 that before the implementation of the soil testing and formula fertilization project, there was no significant difference in the annual urbanization level between the experimental group and the control group, which met a parallel trend. After the implementation of the soil testing and formula fertilization project, there may be a two-year lag period between the policy effect and the urbanization level due to factors such as project implementation intensity. However, in general, after the implementation of the policy, the urbanization level of the experimental group and the control group also showed significant differences, which passed the parallel trend test and met the preconditions for the use of the double-difference method.

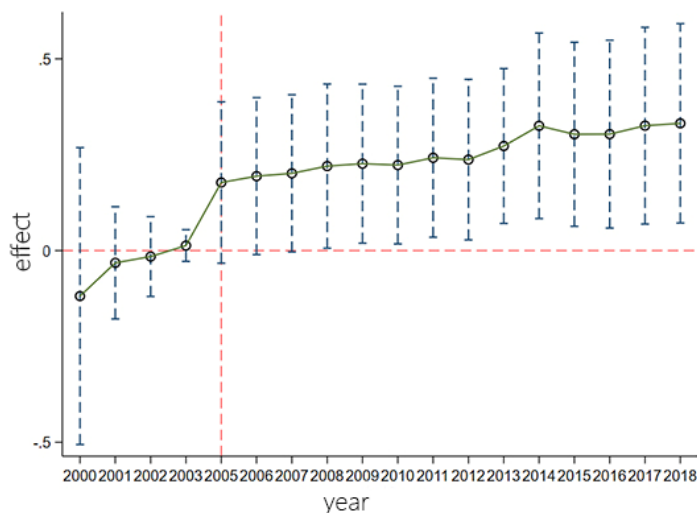


Figure 3. Parallel trend graph of lnur

5.2 Robustness Test

Placebo test: This article refers to the methods of Ferrara et al [18] and Li et al [19], randomly sampling 1000 times in all samples to perform regression consistent with the benchmark regression, and can be obtained as shown in Figures 2 and 3 in the following figures. The kernel density distribution map of the two explained variables, the total sown area of crops and the level of urbanization. In Figures 2 and 3, most of the t-values estimated by sampling are within 2, and the p-value is above 0.1, which shows that the soil testing and formula fertilization project are not significant in this 1000 sampling. Therefore, it is verified that the conclusions of this paper can be tested by placebo, thereby verifying that the conclusions of this paper are robust.

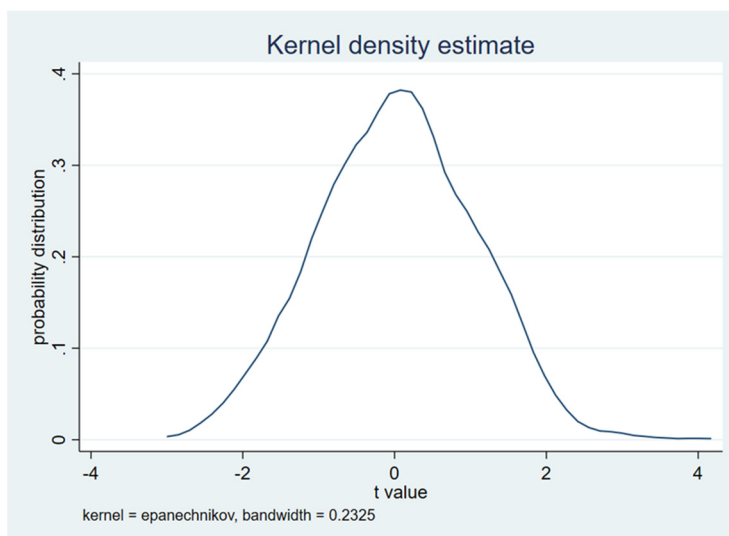


Figure 4. Kernel density plot of explained variable lnasa

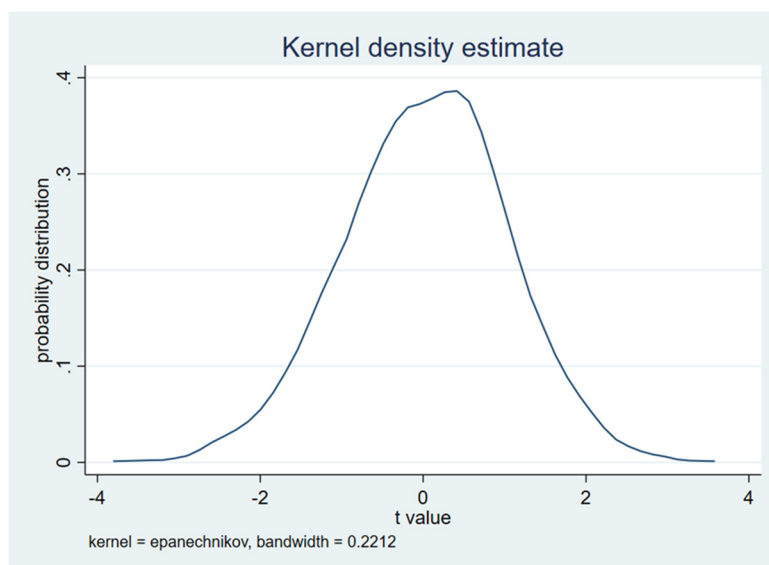


Figure 5. Kernel density plot of explained variable lnur

Winsorize test: Tables 5 and 6 were obtained by (1,99) tail-shrinking of all variable values. From the regression coefficient obtained from the test in Table 5, it can be seen that the effect of dudt on the total sown area of crops is still significant, which is consistent with the benchmark regression results. Therefore, conclusion 1 of this paper can pass the Winsorize test.

Table 5. Winsorize test on ln_{sa}

	(1) ln _{sa}	(2) ln _{sa}
dudt	0.1098*** (0.0320)	
ln _{ae}	0.1562*** (0.0474)	0.1451*** (0.0507)
ln _{pgdp}	0.1237 (0.0899)	0.1454 (0.0984)
ln _{ia}	0.3179*** (0.0750)	0.3315*** (0.0893)
ln _{ca}	0.0069 (0.0409)	-0.0044 (0.0418)
_cons	12.2503*** (0.9971)	12.0784*** (1.1085)
R^2	0.4207	0.3601
N	570	570

From the regression coefficients obtained from the test in Table 6, it can be seen that the effect of dudt on the level of urbanization is still significant, which is consistent with the benchmark regression results. Therefore, conclusion 2 of this paper can also pass the Winsorize test.

Counterfactual test: Using the counterfactual analysis method, it is assumed that each province implements the time swap of soil testing and formula fertilization project, that is, it is implemented from 2000 to 2004 and not implemented from 2005 to 2018, and replace the dudt at the actual implementation time with the multiplication term of the time dummy variables dtx00~dtx18 at the time of the assumed exchange implementation and the original provincial dummy variable and this is set as the main explanatory variable. The results of the counterfactual analysis are shown in Table 7 and Table 8.

Table 6. Winsorize test on lnur

	(1) lnur	(2) lnur
dudt	0.2159* (0.1094)	
lnpgdp	0.4356** (0.2044)	0.4686** (0.2238)
lncf	-0.5091*** (0.1817)	-0.4703** (0.1711)
lnca	0.0473 (0.0283)	0.0247 (0.0295)
lnia	0.1818 (0.1513)	0.1756 (0.1690)
_cons	-0.0474 (3.0157)	-0.5052 (3.2613)
R^2	0.6818	0.6568
N	570	570

It can be seen from Table 7 that the regression coefficients of the explanatory variables on the total sown area of crops from 2000 to 2004 all changed from positive numbers to negative numbers, which shows that the conclusion of this paper has passed the counterfactual test, and that conclusion 1 of this paper is robust.

Table 7. Counterfactual test of ln_{sa}

	(1) ln _{sa}	(2) ln _{sa}
dt0001020304	-0.1147*** (0.0325)	
lnae	0.1273** (0.0599)	0.1272** (0.0610)
lnpgdp	0.1732* (0.1017)	0.1747* (0.1023)
lnia	0.4510*** (0.1448)	0.4494*** (0.1464)
lnca	-0.0013 (0.0400)	-0.0010 (0.0405)
dtx00		-0.1468*** (0.0389)
dtx01		-0.1070*** (0.0375)
dtx02		-0.1088*** (0.0374)
dtx03		-0.1045*** (0.0375)
dtx04		-0.1067*** (0.0332)
_cons	10.9319*** (1.5779)	10.9424*** (1.5875)
R^2	0.4559	0.4573
N	570	570

It can be seen from Table 8 that the regression coefficients of the explanatory variables to the urbanization level from 2005 to 2018 also changed from positive numbers to negative numbers, which shows that the conclusion of this paper has passed the counterfactual test, and that conclusion 2 of this paper is also robust.

Table 8. Counterfactual test of lnur

	(1) lnur	(2) lnur
dt0001020304	-0.2811* (0.1402)	
lnpgdp	0.4925* (0.2654)	0.4974* (0.2728)
lncf	-0.5664*** (0.1976)	-0.5661*** (0.1990)
lnca	0.0524 (0.0388)	0.0534 (0.0400)
lnia	0.1811 (0.1778)	0.1754 (0.1808)
dtx00		-0.3674 (0.2552)
dtx01		-0.2810* (0.1466)
dtx02		-0.2653* (0.1313)
dtx03		-0.2403* (0.1180)
dtx04		-0.2523** (0.1181)
_cons	0.2076 (3.0952)	0.2323 (3.1013)
R^2	0.5874	0.5885
N	570	570

6. Conclusion

In order to prove whether the implementation of the soil testing and formula fertilization project has a promotion effect on China's agricultural and social benefits and whether the promotion effect is significant or not, this research first makes a hypothesis through theoretical analysis: the implementation of the project will affect a measure of China's agricultural development. An indicator - the total sown area of crops and one of the indicators to measure the progress of urbanization - the level of urbanization has a significant driving effect. Then, through the research and analysis of the data from 2000 to 2018, this paper can draw this conclusion: the soil testing and formula fertilization project implemented in 2005 can indeed promote China's agricultural development and promote China's urbanization process, and contribute a lot to the greater agricultural and social benefits of China. The conclusion has passed the parallel trend test, robustness test, winsorize test and counterfactual test. However, there are still many problems such as insufficient publicity and promotion, insufficient popularization, and insufficient understanding of farmers in the current implementation of this policy. How to deal with these problems so that the soil testing and formula fertilization project can be better promoted in China is the focus of future experts and scholars who need further research.

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