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Basic Farmland Construction in China: A cost-effective investment for agricultural productivity and disaster resistance

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Abstract

Starting in 2006, China launched a project to carry out Basic Farmland Construction in 116 representative counties. The objective of this project was to enhance agricultural productivity. China invested 30 billion yuan in this project from 2006 to 2013. Using a difference-in-differences approach, this study estimates that Basic Farmland Construction increased per capita agricultural output by 6.3%, crop sown area by 5%, and agricultural mechanization by 7.3%. The total benefits of the project far exceeded the total investments. By incorporating with rainfall shocks, this study finds that the project could mitigate most of the damage from droughts and floods.

KEYWORDS

agricultural productivity, disaster resistance, public agricultural investment

JEL CLASSIFICATION

O13, Q18, H42

Food security has always been a major concern in China. The Chinese civilization has been accompanied by food shortages for thousands of years, and social unrest caused by nationwide famines has been the main reason for historical regime changes (Chu & Lee, 1994; Mallory, 1926). In the first few decades since the 1950s, explosive population growth raised global concerns about food security in China (Anderson & Strutt, 2014; Oberschall, 1996). Given China's large population and food consumption, ensuring food security in China primarily depends on domestic production rather than food imports (J. Huang et al., 2004; J. Huang & Yang, 2017).[1]

The relative scarcity of arable land is considered the greatest potential threat to food security in China (J. Huang & Yang, 2017; Xu et al., 2006). China uses 9% of the world's arable land to support nearly 20% of the world's population. The rapid economic development of the past few decades has led to an increasing demand for nonagricultural land and a continuous reduction of already insufficient agricultural land. Protecting agricultural land has therefore become an important aspect of ensuring food security in China. To this end, China has gradually developed a basic farmland protection system in the past few decades and has made policy-oriented investments to ensure the production capacity of basic farmland.

In 2006, China designated 116 counties as national Basic Farmland Construction demonstration areas and invested in Basic Farmland Construction through national finance. These counties were selected based on their ability to represent different regions' planting structures and geographical features. The focus of Basic Farmland Construction in these counties was to level fields, improve soil quality, construct irrigation and drainage facilities, enhance inter-field roads, and improve ecological environment preservation systems. According to data released by the Ministry of Land and Resources in 2013, these counties had established a total of 2769 land improvement projects, covering a construction area of 219,474 hectares, with an investment amounting to 30.41 billion yuan.

The main objective of this study is to evaluate the impact of China's Basic Farmland Construction Policy. Specifically, this study aims to address the following questions: (1) What is the effect of Basic Farmland Construction on agricultural output? (2) Does government investment in Basic Farmland Construction yield a higher return than the cost? (3) Does Basic Farmland Construction hinder the growth of the nonagricultural sector? While it is evident that Basic Farmland Construction can enhance agricultural productivity, the extent of its impact and cost–benefit outcome are crucial. Government-led Basic Farmland Construction initiatives may be inefficient and yield a low investment return rate (Beekman et al., 2014). Furthermore, basic farmland protection could reduce the availability of nonagricultural land and labor, potentially impeding the growth of the nonagricultural sector (Gollin, 2010; Matsuyama, 1992). The answers to the above questions are crucial for ensuring food security and promoting economic development in China. Additionally, since food security is a widespread challenge faced by many developing countries (Falcon & Naylor, 2005; Rosegrant et al., 2013), the experience of Basic Farmland Construction in China can provide valuable insight for other developing countries.

Using data from 110 Basic Farmland Construction counties and 110 comparison counties from 2000 to 2019, we employ a difference-in-differences (DID) approach to estimate the causal impact of the Basic Farmland Construction policy. We find that prior to the implementation of the policy, there were no significant differences in agricultural growth between the Basic Farmland Construction and comparison counties. However, after the implementation of the policy, the growth of agriculture in Basic Farmland Construction counties surpassed that of comparison counties by a significant margin. The DID estimates suggest that the policy led to a 6.3% increase in per capita agricultural GDP, a 4.0% increase in total food output, a 5.0% increase in total food crop sown area, and a 7.3% increase in total agricultural machinery power. The robustness tests demonstrate that these results are not sensitive to factors such as the level of economic development, sample years, comparison county selection methods, and other important contemporary shocks. Based on these estimates, we calculate that the overall benefits of the policy far outweigh its total investment.

We also correlate the Basic Farmland Construction county with household-level data obtained from the National Fixed Point Survey (NFP), which is a panel survey collected by the Research Center of Rural Economy (RCRE) of the Chinese Ministry of Agriculture. We find that 28 Basic Farmland Construction counties were also part of the NFP sample counties. By selecting control households from non-Basic Farmland Construction counties, we construct a sample of nearly 4000 households from 2000 to 2015 (with a total number of observations of 35,402). The DID estimates based on the household-level data confirm the results estimated using the county-level data.

We analyzed whether Basic Farmland Construction hindered the development of the non-agricultural sector. Both macro- and microlevel estimates reveal that Basic Farmland Construction significantly reduced nonagricultural employment among rural laborers. However, we also find that Basic Farmland Construction did not diminish per capita nonagricultural output. This could be due to the fact that large-scale agricultural investment increased the demand for non-agricultural products, thus offsetting the negative impact of Basic Farmland Construction on the nonagricultural sector. It is important for policymakers to take note of the increase in agricultural labor caused by Basic Farmland Construction. The growth of nonagricultural employment is a vital indicator of rural economic transformation (Herrendorf et al., 2014) and a key driving force of economic development in developing countries (Duarte & Restuccia, 2010). Basic farmland policies may restrain China's long-term economic growth by reducing non-agricultural employment (Au & Henderson, 2006).

We combine the DID model with rainfall shocks to estimate the extent to which Basic Farmland Construction reduced the damage of droughts and floods on agriculture. One of Basic Farmland Construction's primary objectives is to reduce the impact of meteorological disasters on food security by investing in irrigation, drainage facilities, and other infrastructure. To evaluate this impact, we create drought and flood indicators using county-level rainfall data. By estimating the coefficients of the interaction terms between these indicators and the DID indicator, we are able to identify how much Basic Farmland Construction can reduce losses from drought and flood shocks. Both county-level and household-level estimates demonstrate that Basic Farmland Construction can effectively mitigate the negative impacts of droughts and floods on agriculture.

The study has three main contributions. Firstly, it is the first to systematically evaluate the impact of China's Basic Farmland Construction by utilizing a causal inference method and large-sample data. Previous analyses were mostly qualitative or based on small study samples (Nickerson & Lynch, 2001; Peng et al., 2022). The study examines 110 Basic Farmland Construction counties with a total population of close to 80 million, representing China's major agricultural production areas. The finding that Basic Farmland Construction is a cost-effective investment supports its nationwide implementation and provides an important reference for other developing countries to formulate similar policies.

Secondly, the study contributes to the literature evaluating the effect of agricultural infrastructure investment on agriculture development. China's Basic Farmland Construction is essentially a government-led investment in agricultural infrastructure. Numerous studies have analyzed the effect of infrastructure construction on agriculture development (Chambers & Lopez, 1993; Ersado et al., 2004; Fan & Hazell, 2001; Haughwout, 2002; Markussen & Tarp, 2014; Rosegrant et al., 1998). However, most existing studies did not fully address endogeneity issues. Specifically, infrastructure investment could be caused by local agricultural development potential, economic development level, and other confounding factors. Therefore, the estimated effect of agricultural infrastructure investment could be driven by reverse causality and omitted variables. The Basic Farmland Construction policy, mainly funded by the central government of China and selecting policy counties based on their nationwide representativeness, provides a quasi-experiment for causal effect inferences in this study.

Finally, the study contributes to the literature on mitigating the impact of climate change through adaptive investment in agriculture. One of climate change's significant characteristics is the increased possibility of drought and flooding disasters (Trenberth, 2011). A vast number of studies have analyzed how agricultural infrastructure investment can reduce the impact of climate change on agriculture (Dwe Falco et al., 2011; K. Huang et al., 2018; K. Huang et al., 2020; Wang et al., 2010). However, previous studies generally ignored that local infrastructure investments may not be exogenous to local potential for drought and flood. For example, a region's topography and soil quality may affect both the likelihood of drought and flood and the costs of constructing agricultural infrastructure. This study addresses the endogeneity concern by utilizing the exogenous infrastructure investment from the Basic Farmland Construction policy.

POLICY BACKGROUND

China uses 9% of the world's arable land to sustain almost 20% of the world's population. The rapid economic development of the past few decades has resulted in an increasing demand for nonagricultural land, leading to a continuous reduction of already insufficient agricultural land. To ensure food security, China has enacted a series of laws and regulations to safeguard arable land. The "Land Management Law," issued in 1986, stipulates that national construction must not occupy arable land. The "Agriculture Law," promulgated in 1993, mandates that governments at the county level and above demarcate basic farmland protection zones and implement special protections for arable land in these zones. The "Regulations on the Protection of Basic Farmland," published in 1994, clarifies the concept, demarcation, supervision, penalties, and other aspects of basic farmland. Furthermore, the "Land Management Law" of 2004 requires that basic farmland accounts for over 80% of the arable land in the administrative region to protect it.

While early policies focused on protecting basic farmland, China started heavily investing in it in 2006. The Chinese Ministry of Land and Resources designated 116 county-level administrative units as national Basic Farmland Construction demonstration areas in 2006. The criteria for selecting Basic Farmland Construction counties were based on their representation of the local agricultural characteristics of different terrain and geomorphology and their significant role in grain, cotton, and oil production. These Basic Farmland Construction counties covered China's primary crop planting areas (refer to Figure 1). The goal of Basic Farmland Construction was to achieve complete infrastructure, high and stable yield, good ecology, and strong disaster resistance. Public funds were primarily invested in flattening land, improving soil quality, constructing irrigation and drainage facilities, repairing roads between fields, improving the system of agricultural protection and ecological environment maintenance, and supporting rural electrification facilities. According to the Ministry of Land and Resources, by 2013, the 112 Basic Farmland Construction counties in 30 provinces (data are not available for four Basic Farmland Construction counties in Tibet and Xinjiang) had established a total of 2769 land

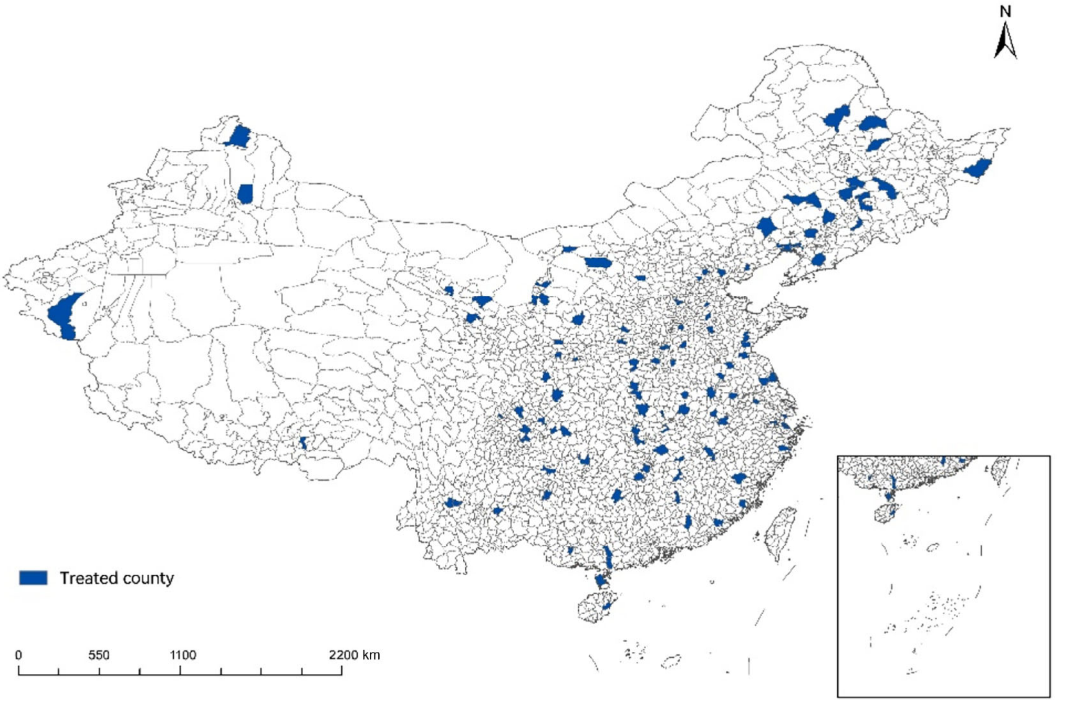

FIGURE 1 Map of the 116 Basic Farmland Construction counties.

reclamation projects, with a construction scale of 219,474 hectares and an investment of RMB 30.41 billion.

In 2013, the policy was expanded to include 500 high-standard Basic Farmland Construction counties. The goals of the high-standard Basic Farmland Construction were similar to those of the 2006 Basic Farmland Construction, but with higher requirements for protecting agricultural ecology and improving land quality. After 2013, more regions, with both national and local investment, joined in the construction of high-standard farmland in addition to the 500 counties. Existing documents only provide information on the total amount of planned and constructed high-standard farmland nationwide, but not the locations of the policy counties.[2]

DATA AND IDENTIFICATION STRATEGY

Data

This study uses data from both the county and household levels. The county-level data are used for the baseline analysis, while the household-level data are used to provide more reliable estimates and to analyze the micro mechanisms of the policy effect. Additionally, we have constructed county-level climate indicators based on gridded climate data. We combined these climate indicators with county-level and household-level data to estimate to what extent Basic Farmland Construction can improve the agricultural sector's ability to withstand climate impacts.

County-level data

In adopting a DID approach, we selected the nearest county to each Basic Farmland Construction county that was unconnected as the comparison county. This selection was based on the assumption that the nearest county would be the most comparable in terms of natural geography and economic development. We excluded the connected counties from the comparison group to mitigate concerns of spillover effects.

The data were obtained from 110 Basic Farmland Construction counties and 110 comparison counties. Originally, there were 116 Basic Farmland Construction counties, but six of them (located in Tibet and Xinjiang) had missing agricultural data. To adopt a DID approach, we selected the nearest county to each Basic Farmland Construction county that was unconnected as the comparison county. This selection was based on the assumption that the nearest county would be the most comparable in terms of natural geography and economic development. We excluded counties connected to Basic Farmland Construction counties from the comparison group to mitigate concerns of spillover effects.[3] Matching methods were not used in the main analysis due to concerns about their reliability (Caliendo & Kopeinig, 2008). In robustness tests (Table 2, Column 4), comparison counties obtained from 1:1 propensity score matching (PSM) were also used, and the estimated results were very similar. The main analysis utilized data from 2000 to 2019, resulting in a total sample size of 4400. The county-level agricultural production and socioeconomic data were obtained from the "*China County Statistical Yearbook*."

It is important to note that there was a significant change in the scope of the Basic Farmland Construction policy after 2012. While the existing 116 Basic Farmland Construction counties were maintained, the program was expanded to 500 counties for high-standard Basic Farmland Construction nationwide. However, the causal effect identification did not depend on the 500 high-standard Basic Farmland Construction counties for the following reasons: Firstly, these 500 counties included the Basic Farmland Construction counties starting from 2006, and the policy intensity was significantly increased after 2012. Secondly, these 500 Basic Farmland Construction counties were soon expanded to even more counties, but specific policy scope data is not available.[4] Thirdly, these 500 Basic Farmland Construction counties contain most of China's major grain-producing counties, making it difficult to choose comparison counties. In a robustness check, data after 2012 were removed to eliminate the interference of the policy expansion in 2012 on the comparison group (Table 2, column 3).

Household-level data

The household-level data used in this study were derived from the National Fixed Point Survey (NFP), which is a panel survey conducted by the Research Center of Rural Economy of the Chinese Ministry of Agriculture, starting from 1986. The database comprises randomly sampled rural households from over 300 villages across the country, distributed evenly among different counties. The NFP data were been widely used in previous studies (Chari et al., 2021; Kinnan et al., 2018), and its high quality has been demonstrated by Benjamin et al. (2005).

Of the Basic Farmland Construction counties, 35 were found to be included in the NFP dataset. However, after contacting the NFP villages by phone, it was found that only 28 of these counties had NFP villages that had carried out Basic Farmland Construction projects (not all villages in the Basic Farmland Construction counties have undergone Basic Farmland Construction). Consequently, the household-level analysis is based on the NFP data from these 28 Basic Farmland Construction counties and the NFP data from 28 nearest non-Basic

Farmland Construction counties. The panel survey data from 2000 to 2015 were used for the analysis.[5] After excluding missing values and households that appeared only once in the sample period, the total number of households available for analysis was 3993, with a total sample size of 35,402. Since some households left the village permanently each year and were replaced by new households, the panel data are unbalanced.

Climate data

We obtained gridded climate data with a resolution of $0.1^\circ \times 0.1^\circ$ from ERA5-Land (https://cds.climate.copernicus.eu), which is one of the most commonly used databases for global climate change research. Using ArcGIS, we constructed monthly temperature and precipitation data for sample counties from the database. Since one of the goals of the Basic Farmland Construction program is to reduce the impact of droughts and floods on agriculture, precipitation is the climate variable of interest, while temperature is used as a control variable.

We used monthly precipitation data to construct annual drought and flood indicators. Following recent literature (Ashraf & Michalopoulos, 2015; Kotz et al., 2021), drought was defined as follows: if there was at least 1 month of precipitation during the crop growth season that was lower than one standard deviation of the average precipitation for that month in the past 30 years for that county, then that year was considered to be impacted by drought, and the drought indicator took a value of 1; otherwise, it was 0. Similarly, if there was at least 1 month of precipitation during the crop growth season that was higher than one standard deviation of the average precipitation for that month in the past 30 years for that county, then that year was considered to be impacted by flood, and the flood indicator took a value of 1; otherwise, it was 0.

Variable definition and summary statistics

Table 1 presents the definitions and summary statistics for the key variables of this study. Panel A of the table lists nine county-level variables: agricultural GDP per capita, total sown area, total grain output, rural per capita net income, rural total population, total agricultural machinery power, nonagricultural GDP per capita, drought indicator, and flood indicator. The first seven variables are derived from the China County Statistical Yearbook, while the last two variables are obtained from ERA5-Land. Panel B lists six household-level variables: grain output, grain sown area, irrigation expenses, expenses on agricultural machinery, off-farm labor income, and total income. These variables are derived from the NFP. All monetary values have been adjusted to constant 2012 yuan using the consumer price index.

Identification strategy

DID model

We estimate the impact of Basic Farmland Construction based on the following DID model:

$$Y_{it} = \alpha + \beta_1 Treat_i \times Post_t + X_{it}\beta_2 + \tau_i + \mu_t + \varepsilon_{it}, \tag{1}$$

where Y_{it} is the outcome variable of interest in county i and year t, including all county-level agricultural production measures listed in Table 1. $Treat_i$ is the treatment indicator that takes the value of 1 when county i is a Basic Farmland Construction county and 0 otherwise. $Post_t$ is the policy time indicator that takes the value of 1 when $t \geq 2007$ and 0 otherwise.[6] X_{it} is a vector of six control variables: the county's total population and its square, the mean temperature of the county and its square, and the total rainfall of the county and its square. These control variables are likely exogenous and may significantly affect agricultural output. τ_i is the county-fixed effect that controls for time-invariant factors within the same county. μ_t is the year-fixed effect that controls for the same fluctuations among counties in the same year. α, β_1, and β_2 are the coefficients to be estimated, and ε_{it} is the error term. The coefficient of interest is β_1, which captures the causal impact of Basic Farmland Construction.

TABLE 1 Definition and summary statistics of key variables.

Variable	Definition	Sample[a]	Mean	SD
County-level variable				
Agricultural GDP per capita (yuan)	Agricultural output per rural population	4020	3822	3135
Total sown area of crops (ha)	Total sown area of crops	4020	95,026	115,572
Total grain output (ton)	Total food grain output	4280	383,189	384,671
Rural per capita net income (yuan)	Rural net income per capita	3880	7260	5088
Rural population (thousand)	Rural resident population	3960	49	31
Agricultural machinery power (10,000 kW)	Total agricultural machinery power	4011	46	39
Nonagriculture output per capita (yuan)	The sum of the GDP of the secondary and tertiary industries/total population	4020	22,650	32,118
Drought (0–1)	See definition from the main text	4400	0.4	0.5
Flood (0–1)	See definition from the main text	4400	0.3	0.4
Household-level variable				
Grain output (kg)	Family total yield of food crops	51,413	3083	2896
Grain sown area (mu)	Family total area planted with food crops	51,413	10	14
Irrigation expenses (yuan)	Total irrigation expenditure	51,413	79	729
Agricultural machinery expenses (yuan)	Total expenditure on agricultural machinery	51,413	7	440
Off-farm wage income[b] (yuan)	Family total off-farm wage income	63,298	1816	6280
Total income (yuan)	Family total income	63,298	22,379	36,651

[a]The expected sample size for this study is 4400 (220 counties from 2000 to 2019); however, the actual sample size varies across variables due to missing values.
[b]Wage income is only one part of farmers' off-farm income, with self-employed businesses being another major income source. However, self-employed business income cannot be accurately measured and is therefore excluded from the analysis. All monetary values have been adjusted to constant 2012 yuan using the consumer price index.

The identification assumption of Model (1) is that, without the policy, Basic Farmland Construction counties should follow the same trends as non-Basic Farmland Construction counties. Recall that the selection of Basic Farmland Construction counties was based mainly on their representation of the local agricultural characteristics of different terrain and geomorphology and their significant role in grain, cotton, and oil production. This selection rule reduces concerns that Basic Farmland Construction counties could have different growth trends than non-Basic Farmland Construction counties. To further ensure parallel trends, we choose the county closest to each Basic Farmland Construction county as the comparison county. In a robustness check, we also use propensity score matching to select comparison counties.

When using household-level data, the DID model is expressed as follows:

$$Y_{ijt} = \alpha + \beta_1 Treat_i \times Post_t + X_{it}\beta_2 + \tau_j + \mu_t + \varepsilon_{ijt}. \tag{2}$$

The only different from Model (1) is that the variables are defined at the household level. Specifically, Y_{ijt} represents the dependent variable for household j in county i and year t, including all household-level agricultural production measures listed in Table 1, and τ_j represents the household-fixed effects.

Parallel trend

To support the parallel trend assumption when using county-level data, we estimated the following flexible model:

$$Y_{it} = \alpha + \sum_{\gamma=2001}^{2019} \beta_{1\gamma} Treat_i \times D(t=\gamma) + X_{it}\beta_2 + \tau_i + \mu_t + \varepsilon_{it}. \tag{3}$$

The only difference from Model (1) is that Model (3) estimates the effect of Basic Farmland Construction in each year before and after the policy by $\sum_{\gamma=2001}^{2019} \beta_{1\gamma} Treat_i \times D(t=\gamma)$ (2000 is the base year). Here, D is a dummy variable that takes a value of 1 when $t=\gamma$, and 0 otherwise. If the parallel trend assumption is met, the coefficient $\beta_{1\gamma}$ should not be significantly different from zero when $\gamma < 2007$. We also expect to see that when $\gamma > 2007$, the coefficient $\beta_{1\gamma}$ should increase and eventually be significantly larger than zero.

Figure 2 shows the estimates of Model (3) that uses county-level log per capita agricultural GDP as the independent variable. We have also tried other county-level independent variables listed in Table 1 and found similar results (see Appendix Figures A1–A5). The results show that before the Basic Farmland Construction policy, all estimated coefficients were close to zero and statistically insignificant.[7] As expected, after the implementation of the policy, the per capita agricultural GDP of the Basic Farmland Construction counties significantly increased compared with that of the comparison counties and has been significantly higher than zero since 2009.

Similarly, when using household-level data, the parallel trend assumption can be examined by estimating the following model:

$$Y_{ijt} = \alpha + \sum_{\gamma=2001}^{2019} \beta_{1\gamma} Treat_i \times D(t=\gamma) + X_{it}\beta_2 + \tau_j + \mu_t + \varepsilon_{it}. \tag{4}$$

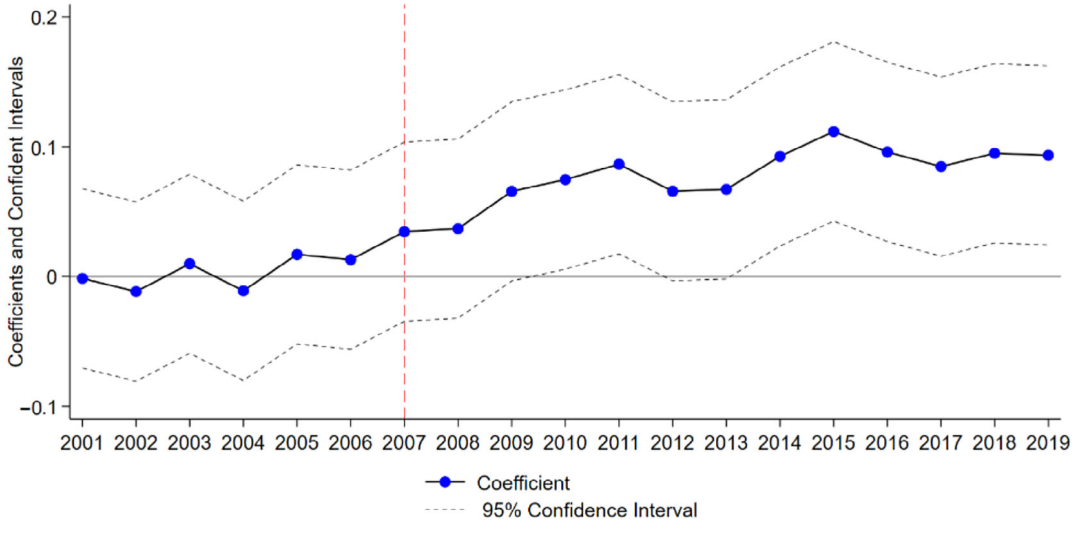

FIGURE 2 The impact of Basic Farmland Construction on log per capita agricultural GDP, county-level estimates. The figure shows the estimated value of coefficient $\beta_{1\gamma}$ when using county-level log per capita agricultural GDP as the independent variable for Model (3).

All variables are defined the same as before. Figure 3 shows the estimated results of Model (4) that uses household-level log total grain output as the independent variable. Before the Basic Farmland Construction policy, all estimated coefficients were very close to zero. Soon after the implementation of the policy, the grain output of households in the Basic Farmland Construction county significantly increased. Note that when using household-level data, the estimated percentage impact is significantly higher than when using county-level data. We will explain this later.

Drought and flood impacts

One of the main goals of the Basic Farmland Construction policy is to ensure stable agricultural production in the face of droughts and floods. We use the following model to analyze whether Basic Farmland Construction has improved the resilience of agriculture to droughts and floods:

$$Y_{it} = \alpha + \delta_1 Treat_i \times Post_t + \delta_2 Treat_i \times Post_t \times \mathrm{Shock}_{it} + \delta_3 \mathrm{Shock}_{it} + X_{it}\beta_2 + \tau_i + \mu_t + \varepsilon_{it}. \tag{5}$$

where Shock_{it} is a dummy variable indicating drought or flood (defined in the previous subsection), and other variables are the same as those in Model (1). We expect the coefficient δ_3 to be negative, indicating that drought and flood tend to harm agricultural production. If Basic Farmland Construction has reduced the damage caused by droughts and floods, then δ_2 should be significantly positive. By comparing the relative sizes of the coefficients δ_2 and δ_3, we can infer the extent to which Basic Farmland Construction can reduce the impact of drought or flood on agriculture.

Similarly, when using household-level data, the model is:

$$Y_{ijt} = \alpha + \delta_1 Treat_i \times Post_t + \delta_2 Treat_i \times Post_t \times \mathrm{Shock}_{it} + \delta_3 \mathrm{Shock}_{it} + X_{it}\beta_2 + \tau_j + \mu_t + \varepsilon_{ijt} \tag{6}$$

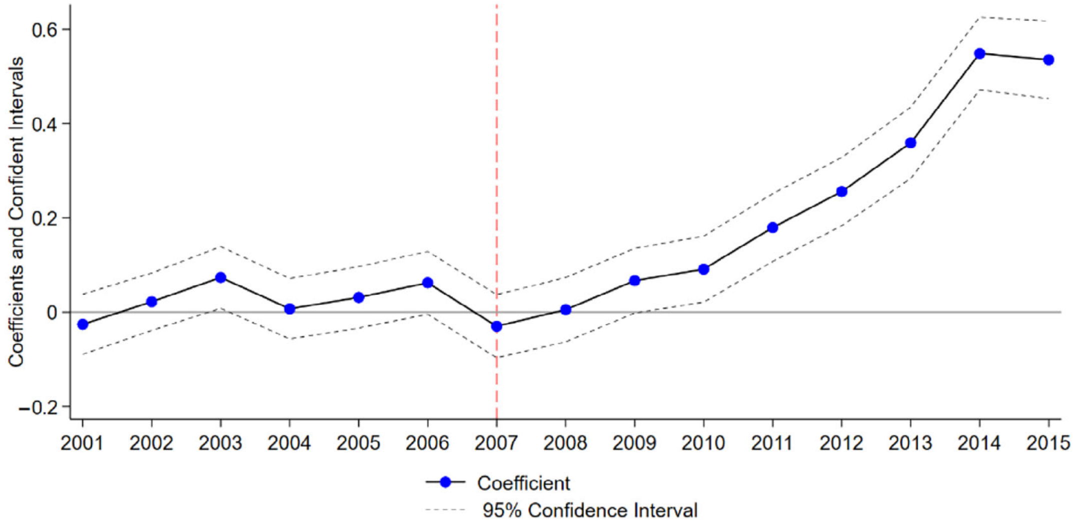

FIGURE 3 The impact of Basic Farmland Construction on log total grain output, household-level estimates. This graph shows the estimated coefficient $\beta_{1\gamma}$ from Model (4) that uses the household-level log total grain output as the independent variable. This figure ends in 2015 because the household-level data are only available up to 2015.

All variables are the same as those defined in Model (5), with the only difference being that the independent variable and fixed effects are at the household level.

A potential concern regarding Models (5) and (6) is that droughts or floods may not be exogenous to agricultural output. Specifically, since droughts and floods do not occur randomly across different locations, it is possible that farmers reduce agricultural production in areas with a relatively high risk of droughts. To address this concern, the regression models incorporate county-fixed effects or household-fixed effects to account for the impact of all time-invariant factors, including the long-run average likelihood of droughts and floods. Consequently, the coefficients δ_2 and δ_3 from these two models are identified based on plausibly exogenous inter-annual changes in droughts and floods, and thus should not be biased by the cross-sectional long-run disparities in droughts and floods.

RESULTS

County-level results

Tables 2 and 3 present the regression results based on Model (1) and county-level data from 220 counties from 2000 to 2019. All regressions control for county-fixed effects, year-fixed effects, and the six other control variables. Standard errors reported in brackets are clustered at the county level.

Baseline estimates

Column 1 of Table 2 presents the baseline estimates. The DID estimates suggest that, on average, the Basic Farmland Construction increased agricultural GDP per capita by 6.3%, and this

TABLE 2 The impact of Basic Farmland Construction on per capita agricultural GDP (dependent variable: Log per capita agricultural GDP).

	(1) Baseline	(2) Excluding districts	(3) Exclude years after 2012	(4) PSM comparison county	(5) Agricultural taxes abolition	(6) 2008 financial crisis
$Treat_i \times Post_t$	0.063*** (0.014)	0.079*** (0.016)	0.049*** (0.013)	0.054*** (0.017)	0.071*** (0.015)	0.063*** (0.014)
County-fixed effects	Y	Y	Y	Y	Y	Y
Year-fixed effects	Y	Y	Y	Y	Y	Y
Six control variables	Y	Y	Y	Y	Y	Y
Farmland per apita × 2004 dummy					Y	
GDP per capita × 2008 dummy						Y
N	4020	3380	2613	4020	4020	4020
R^2	0.848	0.851	0.837	0.837	0.873	0.848

Note: The estimations are based on Model (1) and county-level data for 220 counties from 2000 to 2019. All regressions control for year-fixed effects, county-fixed effects, and the six control variables. Standard errors in brackets are clustered at the county level.
***, **, and * respectively indicate significance at 1%, 5%, and 10% statistical levels.

effect is statistically significant at the 1% level. More specifically, the estimates should be interpreted as follows: relative to the average before the policy (2000–2006) and non-Basic Farmland Construction counties, the Basic Farmland Construction policy increased the average agricultural GDP per capita for Basic Farmland Construction counties by 6.3% from 2007 to 2019.

However, the average effect presented in Table 2 may not provide the most accurate measure of the impact of Basic Farmland Construction, as indicated by Figure 2, which demonstrates that the treated counties trend upward over time in comparison with the comparison counties after treatment. According to Figure 2. To demonstrate this, Appendix Table A1 replicates Table 2 by using 'treat × years since treatment' to replace the 'treat × post' setting in the baseline model. Naturally, the estimated coefficients show similar upward trends as those presented in Figure 2.

Robustness checks

Excluding district samples

Out of the 110 Basic Farmland Construction county-level units in the baseline sample, 19 of them are districts of cities. Because agriculture accounts for a small share of the production in

TABLE 3 The impact of Basic Farmland Construction on other economic outcomes.

	(1) Log total grain output	(2) Log sown area of crops	(3) Log rural income per capita	(4) Log rural population	(5) Log agricultural machinery power	(6) Log non-agriculture GDP per capita
$Treat_i \times Post_t$	0.040*** (0.017)	0.050*** (0.018)	0.045*** (0.017)	0.014** (0.007)	0.073*** (0.018)	0.022 (0.019)
County-fixed effects	Y	Y	Y	Y	Y	Y
Year-fixed effects	Y	Y	Y	Y	Y	Y
Six control variables	Y	Y	Y	Y	Y	Y
N	4280	4020	3880	3960	4011	4280
R^2	0.162	0.051	0.862	0.085	0.546	0.897

Note: All estimations are based on Model (1) and data from 220 counties between 2000 and 2019. The dependent variable for each column is shown in the column header. All regressions control for year-fixed effects, county-fixed effects, and six county-level control variables. Standard errors in brackets are clustered at the county level.
Significance levels are denoted by ***, **, and * respectively for statistical significance at the 1%, 5%, and 10% levels.

city districts in China, we expect the impact of Basic Farmland Construction on city districts to be relatively small. Column 2 of Table 2 shows the estimated results after excluding the city districts. As expected, excluding city districts increases the effect of Basic Farmland Construction to 7.9%.

Excluding samples years after 2012

After 2012, the Basic Farmland Construction policy extended from 116 counties to 500 counties and extended further soon after that (see Policy Background section for details). For this reason, column 3 excludes sample years after 2012. The resulting estimate is slightly smaller than the baseline estimate. The smaller estimated effect may reflect that the policy effect was not fully exerted before 2012, consistent with Figure 2.

Propensity score matching

As the propensity score matching method has a significant controversy in the literature (Caliendo & Kopeinig, 2008), the baseline regression adopts the nearest distance principle to select comparison counties. Column 4 presents the regression results that uses comparison counties selected through 1:1 propensity score matching. The estimated effect is slightly smaller but has no statistically significant difference from the baseline estimate.

Confounding effect of agricultural tax abolition

China abolished agricultural tax in 2004, and this may confound the Basic Farmland Construction policy starting from 2006. To exclude this confounding effect, column 5 controls for the interaction between the 2004 dummy and county-level intensity of the tax abolition (measured by per capita farmland). The resulting estimate is comparable with the baseline estimate.

Confounding effect of the 2008 global financial crisis

Similarly, in column 6 excludes the potential confounding effect of the 2008 financial crisis by controlling for the interaction between the 2008 dummy and county-level intensity of the financial crisis (measured by per capita GDP). The resulting estimate is identical to the baseline estimate.

Impacts on other economics outcomes

Table 3 presents the estimated impact of Basic Farmland Construction on six other county-level economic outcomes. All estimations are based on Model (1) and data from 220 counties between 2000 and 2019. All regressions control for year-fixed effects, county-fixed effects, and six county-level control variables. Due to missing values for some dependent variables, sample sizes vary across columns. We have also estimated the model using the same sample size for each column and found very similar estimates.

Columns 1–3 show that Basic Farmland Construction increased grain output by 4.0% (column 1), increased the sown area of crops by 5.0% (column 2), and increased rural per capita net income by 4.5% (column 3). Basic Farmland Construction also increased rural population by 1.4% (column 4) and total agricultural machinery power by 7.3% (column 5). All these estimates are consistent with the baseline finding that Basic Farmland Construction increased per capita agricultural GDP. Additionally, these estimates suggest that Basic Farmland Construction increased agricultural output not only by increasing the input of land and physical capital (machinery), but also by increasing the input of labor. The increase in rural per capita net income suggests that Basic Farmland Construction enhanced agricultural labor productivity. These findings are consistent with the goal of Basic Farmland Construction, which is to ensure food security by increasing farmland areas and agricultural productivity.[8]

The findings that Basic Farmland Construction increased crop sown areas (column 2) and rural labor (column 4) reinforce the concern that Basic Farmland Construction may impede the growth of nonagricultural sectors by reducing the supply of land and labor for these sectors. However, column 6 shows that Basic Farmland Construction has no negative effect on the per capita GDP of nonagricultural sectors. A potential explanation for this finding is that the large-scale agricultural investment from Basic Farmland Construction increased the demand for non-agricultural products, thus offsetting the negative impact of Basic Farmland Construction on nonagricultural sectors. Additionally, the increase in agricultural land areas does not necessarily reduce the land supply for nonagricultural sectors because the infrastructure investment from Basic Farmland Construction may make land that was previously unsuitable for agriculture production become suitable. However, it is important to note that the negative impact of Basic Farmland Construction on off-farm labor supply may have a negative long-term impact on economic development that cannot be captured in this study.

Household-level results

Table 4 presents the results estimated based on household-level data. All estimations are based on Model (2) and control for household-fixed effects, year-fixed effects, and six county-level control variables. All estimations use an unbalanced panel data set of approximately 4000 rural households between 2000 and 2015.

TABLE 4 Household-level impact of Basic Farmland Construction.

	(1) Log grain output	(2) Log grain sown area	(3) Log irrigation expenditure	(4) Log agricultural machinery expenditure	(5) Log total income	(6) Log total off-farm labor income
$Treat_i \times Post_t$	0.165*** (0.014)	0.069*** (0.012)	0.344*** (0.033)	0.092*** (0.014)	0.057*** (0.012)	−0.067*** (0.025)
Household-fixed effects	Y	Y	Y	Y	Y	Y
Year-fixed effects	Y	Y	Y	Y	Y	Y
Six control variables	Y	Y	Y	Y	Y	Y
N	45,744	45,744	45,744	45,744	45,744	45,744
R^2	0.154	0.072	0.217	0.008	0.493	0.249

Note: All estimations are based on Model (2) and data from about 4000 rural households from 2000 to 2015. All regressions control for year-fixed effects, household-fixed effects, and six county-level control variables. The dependent variable for each column is shown in the column header. Standard errors in brackets are clustered at the county level.
Significance levels are denoted by ***, **, and * respectively for statistical significance at the 1%, 5%, and 10% levels.

Column 1 of Table 4 suggests that Basic Farmland Construction increased grain output for farms in Basic Farmland Construction counties by 16.5% compared with farms in non-Basic Farmland Construction counties. This estimate is much larger than that based on county-level data, potentially because only some of the villages in the Basic Farmland Construction counties have implemented the policy, while all households in the household-level study were selected from villages that implemented the policy. Column 2 shows that Basic Farmland Construction increased the sown area of food crops by 6.9%, which is slightly larger than the county-level estimate of 5%. The much higher increase in grain output than the increase in the sown area indicates that Basic Farmland Construction significantly increased land productivity. This higher productivity is possible because Basic Farmland Construction increased irrigation expenditure by 34.4% (column 3) and agricultural machinery expenditure by 9.2% (column 4).

Column 5 of Table 4 shows that Basic Farmland Construction increased the total income of an average rural household (from both agricultural and nonagricultural work) by 5.7%. However, this effect is smaller than the effect on grain output, partly because the policy reduced off-farm income. As presented in column 6, Basic Farmland Construction reduced the off-farm wage income of an average rural household by 6.7%. This finding warrants the attention of policymakers because the increase in off-farm employment is an important form of rural economic transformation and a significant driving force for economic development in developing countries (Duarte & Restuccia, 2010; Herrendorf et al., 2014). Therefore, Basic Farmland Construction may inhibit long-term economic growth by reducing off-farm employment.

The impact of droughts and floods

This section aims to estimate the extent to which Basic Farmland Construction can reduce the damage of droughts and floods on agricultural production. We estimate the effect using Models (5) and (6) based on both county- and household-level data, respectively. The results indicate that Basic Farmland Construction can offset most of the damage of droughts and floods on grain output. We have also estimated the impact of high temperatures on grain output in the same model setting and found that Basic Farmland Construction has no effect on the impact of high temperature (omitted from reporting).

Columns 1 and 2 of Table 5 present the estimates based on county-level data. Column 1 shows that Basic Farmland Construction significantly reduced the damage of drought on agricultural output (measured by per capita agricultural GDP). Specifically, the estimated coefficient of the drought indicator suggests that drought reduces agricultural output by 3.9%. The coefficient of $Treat_i \times Post_t \times \mathrm{drought}_{it}$ suggests that when facing drought, the loss in Basic Farmland Construction counties can be reduced by 2.9%. It can be calculated that Basic Farmland Construction reduced 74% of the damage of drought (i.e., 2.9/3.9). Column 2 shows that Basic Farmland Construction can increase agricultural output by 1.1% in the event of a flood shock, but this estimate is not statistically significant at a conventional level.

Columns 3 and 4 present the estimates based on household-level data. The results indicate that both drought (column 3) and flood (column 4) can significantly reduce household-level grain output, but Basic Farmland Construction is able to offset these impacts. Specifically, the estimated coefficient of the drought indicator suggests that drought reduces grain output by 6.3%. The coefficient of $Treat_i \times Post_t \times \mathrm{drought}_{it}$ suggests that when facing drought, the output in Basic Farmland Construction counties will be 6.8% higher. Therefore, Basic Farmland

TABLE 5 Basic Farmland Construction reduced the damage of droughts and floods on agriculture.

	County-level log per capita agricultural GDP		Household-level log grain output	
	(1)	(2)	(3)	(4)
$Treat_i \times Post_t$	0.052*** (0.015)	0.062*** (0.014)	0.129*** (0.016)	0.132*** (0.014)
Drought indicator	−0.039*** (0.009)		−0.063*** (0.008)	
Flood indicator		0.001 (0.009)		−0.037*** (0.009)
$Treat_i \times Post_t \times \mathrm{drought}_{it}$	0.029** (0.015)		0.068*** (0.015)	
$Treat_i \times Post_t \times \mathrm{flood}_{it}$		0.011 (0.017)		0.119*** (0.016)
County-fixed effects	Y	Y		
Household-fixed effects			Y	Y
Year-fixed effects	Y	Y	Y	Y
Six control variables	Y	Y	Y	Y
N	4020	4020	35,402	35,402
R^2	0.856	0.855	0.156	0.156

Note: Columns (1) and (2) are based on Model (5) and data from 220 counties from 2000 to 2019, while columns (3) and (4) are based on Model (6) and data from 3993 households from 2000 to 2015. The dependent variable for each column is shown in the column header. Standard errors in brackets are clustered at the county level.
Significance levels are denoted by ***, **, and * respectively for statistical significance at the 1%, 5%, and 10% levels.

Construction is able to offset all of the damage from droughts. Similarly, the estimated coefficient of the flood indicator suggests that floods reduce grain output by 3.7%. The coefficient of $Treat_i \times Post_t \times \text{flood}_{it}$ suggests that when facing a flood, the output in Basic Farmland Construction counties will be 11.9% higher. It is worth noting that farms in Basic Farmland Construction counties actually benefit from floods (0.119–0.037 = 8.2%). One possible explanation for this result is that heavy rainfall also means more available irrigation water, and Basic Farmland Construction has improved the ability of agriculture to utilize rainfall.

Cost–benefit analysis

We conduct a cost–benefit analysis of Basic Farmland Construction based on county-level estimates.[9] The total agricultural GDP in the 110 Basic Farmland Construction counties in 2005 was 182.6 billion yuan. Combining this with the estimate that Basic Farmland Construction increased agricultural GDP by 6.3%, we calculate that the annual gains from Basic Farmland Construction were 11.5 billion yuan. Therefore, the cumulative benefit over only 3 years would exceed the total fiscal costs, which were 30.04 billion yuan.

Formally, we assume that the infrastructure built by Basic Farmland Construction could be used for N years, and the annual discount rate is r. Then, the return on Basic Farmland Construction investment can be calculated using the following formula:

$$R = \frac{\sum_{i=1}^{N} \frac{a_i}{(1+r)^{i-1}} - Y}{Y} \times 100$$

where a_i is the annual gains (11.5 billion yuan), and Y is the total investment (30.04 billion yuan). If the infrastructure can be used for 20 years, and the discount rate is 5%, then the return is as high as 400%. It should be noted that as the treated counties continue to trend upward over time relative to the comparison counties after treatment (as shown in Figure 2 and Table A1), the estimated benefits of Basic Farmland Construction based on the "long-run" estimate, such as the effect at the end year of the sample, would be even greater. However, the true return could also be smaller because the calculation did not take into account the aging of the facilities, maintenance costs, and induced investment from farmers. Nevertheless, the large returns calculated above still suggest that the total gains from Basic Farmland Construction most likely exceeded the total investments.

CONCLUDING REMARKS

Food security has long been one of the most pressing concerns for China and many other developing countries. Given the widespread existence of externalities in agricultural infrastructure, public investment in agricultural infrastructure is often considered a crucial way to increase grain productivity and ensure food security. However, existing studies have not been able to determine to what extent public investment in agricultural infrastructure can increase agricultural productivity, mainly because public investment is likely endogenous. Moreover, public investment may be inefficient, with the costs of investment exceeding the benefits. Additionally, excessive public investment in the agricultural sector may reduce off-farm employment and harm a country's long-term economic growth.

Based on data from China's nationwide Basic Farmland Construction project started in 2006, this paper is able to identify the causal effect of agricultural infrastructure investment on agricultural productivity. We find that the central government-led Basic Farmland Construction significantly improves agricultural GDP and other agricultural production indicators. The gains from Basic Farmland Construction far outweigh the investment, alleviating concerns about the inefficiency of government-led agricultural investment. Interestingly, we find that Basic Farmland Construction can eliminate most of the agricultural production losses caused by droughts and floods. We verify these results with large-sample household data.

However, it should be noted that the conclusions of this study are based on short-term data and cannot yet evaluate the long-term impact of Basic Farmland Construction. Specifically, although we do not find that Basic Farmland Construction significantly reduced the growth of nonagricultural sectors based on our data, we find that Basic Farmland Construction significantly reduced off-farm employment among rural laborers. Since the growth of off-farm employment is an important form of rural economic transformation and the main driving force of economic growth in developing countries, Basic Farmland Construction may inhibit economic growth in the long term by reducing off-farm employment.

We conclude this study by emphasizing the need for caution when applying the findings to the entire country. Increased agricultural productivity only results in higher income at the household level and higher GDP at the county or national levels if farmers can find buyers who are willing to purchase their produce at a reasonable price. However, it is possible that an increase in agricultural production may lead to a decrease in the equilibrium market price. Taking into account the elasticity of output market demand, this price reduction could potentially offset any measured benefits in terms of increased income or GDP. Therefore, future studies implementing general equilibrium methods to consider the impact of Basic Farmland Construction on market prices could provide valuable insights.

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ENDNOTES

[1] According to data from the United Nations Food and Agriculture Organization (FAO), the total amount of global food trade in the 2019–2020 fiscal year was approximately 472 million tons, which was equivalent to only 70% of China's food consumption during the same period.

[2] As per the "National Agricultural Comprehensive Development Plan for High Standard Farmland Construction (2011–2020)," the northeast region of China plans to construct 93.85 million mu of high-standard farmland, the Huang-Huai-Hawe region plans to construct 119.6 million mu, the middle and lower reaches of the Yangtze River region plans to construct 66.55 million mu, and other non-grain producing regions plan to build 120 million mu of high-standard farmland.

[3] The spillover effect is a valid concern in this study as increased economic activity in the neighboring county may impact the control county, thus affecting the estimated effects. Furthermore, the direction of this effect is not clear-cut. Positive spillovers may result from general equilibrium effects, while negative spillovers may result from inputs such as labor, capital, and fertilizer being diverted from the neighboring county to the Basic Farmland Construction county.

[4] The policy adjustments in the following years include the "National Land Consolidation Plan (2011–2015)" issued in 2013, the "Notice on Further Improving the Work of Delineating Permanent Basic Farmland" issued by the State-Owned Assets Supervision and Administration Commission of the State Council in 2014, and the "Reply on the National Land Consolidation Plan (2016–2020)" issued in 2016.

[5] We excluded data prior to 2000 to reduce confounding effects from other early policies. Data after 2015 was not authorized for use.

[6] The policy was established in 2006, and a certain preparation period was required from policy issuance to implementation. Therefore, the starting time of the policy in the model is defined as 2007.

[7] A potential concern regarding Figure 2 is the presence of a preexisting increasing trend from 2015 to 2017, despite the statistically insignificant estimates. The following analysis based on household-level data will alleviate this concern by demonstrating that there is no apparent preexisting trend when estimating the flexible model using a large sample of household-level data (refer to Figure 3).

[8] The sample size varies across columns in Table 3 due to missing observations for dependent variables in columns 2–5. These missing observations primarily occurred in the early years of the sample period. Moreover, the missing observations are approximately balanced between the treated and comparison counties. For instance, out of the 260 missing values in Column 2, 136 come from the treated countries, while 124 come from the comparison counties.

[9] We did not use household-level estimates in the cost–benefit analysis because only some of the villages in the Basic Farmland Construction counties implemented the policy, while all households in the household-level study were selected from villages that implemented the policy.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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