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# Impact of demonstration zone policy on agricultural science and technology innovation: evidence from China

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As driving forces in agricultural development, science and technology, along with innovation in agricultural science and technology, are crucial to food security and socioeconomic development. The National Modern Agricultural Demonstration Zone is a major initiative of the Chinese government to promote the modernization of agriculture with Chinese characteristics and aims to improve the level of regional agricultural development through policy guidance and financial support. However, few studies have explored the impact of the National Modern Agricultural Demonstration Zone on agricultural science and technology innovation from a policy perspective. In this context, this study is based on the panel data of 696 regions in China from 2007 to 2017. Difference-in-differences is used to study the impact and mechanism of the National Modern Agricultural Demonstration Zone on agricultural science and technology innovation. The results show that the National Modern Agricultural Demonstration Zone policy can significantly improve the level of agricultural science and technology innovation, and the impact effect is more significant in regions with high fiscal autonomy, western regions, and those with better transportation infrastructure. Mechanism analysis shows that the National Modern Agricultural Demonstration Zone enhances agricultural science and technology innovation mainly through increasing financial resource allocation, improving financial support for agriculture, and increasing human capital. This study evaluates the policy effects, provides theoretical support for the public value of the National Modern Agricultural Demonstration Zone, and offers lessons for agricultural science and technology innovation in similar economies in China and worldwide.

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## Introduction

The world is facing unprecedented challenges, as global development is entering a period of strategic opportunities, risks, and uncertainties are increasing. As a basic industry of national economic importance, the stable growth of agriculture is related to the high-quality development of the national economy (Cui et al., 2022). To achieve stable and sustainable development of agriculture and to ensure the effective supply of agricultural products, science, and technology will serve as fundamental mechanisms to solve the stability and sustainability problem. Agricultural science and technology innovation is a basic means of ensuring national food security. In addition, agriculture science and technology innovation may inevitably break through resource and environmental constraints and become the decisive force that can accelerate the construction of modern agriculture. At present, China is accelerating the advancement of large agricultural countries to agricultural power leaps, mainly relying on agricultural science and technology innovation (Wang et al., 2021; Chang and Luo, 2019). As a large agricultural country with relatively insufficient per capita resources, China's need for agricultural science and technology is more urgent than ever, which highlights the need to promote science and technology progress as a fundamental measure to solve the "three rural" problem. Therefore, improving agricultural science and technology innovation is of great significance.

In recent years, agricultural science and technology in China has made rapid progress, with the contribution rate of agricultural science and technology progress exceeding 60%. Agricultural science and technology innovation has been fruitful, an achievement that could not have been achieved without the support of the Chinese government. To promote innovation in agricultural science and technology, the Chinese government has introduced a series of new policies, aimed at promoting agricultural development by creating agricultural agglomeration and scale effects in the region through financial subsidies and tax incentives (Xu et al., 2023; Guo et al., 2021). As one of the important regional agricultural policies, the National Modern Agricultural Demonstration Zone aims to promote the development of regional agriculture by exploiting the strengths of the central region and playing the role of its core demonstration and driving force to promote the modernization of China's agriculture by taking the point as a whole (Zeng and Yu, 2022). The establishment of the National Modern Agricultural Demonstration Zone is based on the application of the founding unit, consent of the local government, preliminary examination by the provincial agricultural authorities, and approval by the Ministry of Agriculture. A total of 283 demonstration zones were identified in three batches in 2010, 2012, and 2015. The construction of the National Modern Agricultural Demonstration Zone plays an important role in accelerating the transformation of traditional agriculture to modern agriculture, improving the comprehensive production region of superior agricultural products, and ensuring national food security (Zhang et al., 2015). As a core demonstration zone for agricultural reform and construction, the National Modern Agricultural Demonstration Zone aims to comprehensively promote the modernization of China's agriculture through various types of funding projects, with an inclination toward prioritizing the demonstration zone. However, can the National Modern Agricultural Demonstration Zone promote agricultural science and technology innovation? What is its influence mechanism? These questions need to be further explored.

This paper assesses the effect of the National Modern Agricultural Demonstration Zone on agricultural science and technology innovation and the mechanism of action based on the panel data of 696 regions from 2007 to 2017 using difference-in-differences. This paper makes the following four main contributions. First, the research object is more precise and valuable. Most of the National Modern Agricultural Demonstration Zone pilots are concentrated at the district and regional levels, and the data used do not provide an accurate picture of the policy effects of the demonstration area (Wu et al., 2019). This paper matches the district, region, and prefecture-level cities targeted by the National Modern Agricultural Demonstration Zone, and the data cover three batches of pilot regions. Thus, the research data and objects are more precise. Second, the research method is more reliable, and the research conclusions are more credible. Most of the existing studies on the National Modern Agricultural Demonstration Zone adopt qualitative methods for analysis and discussion (Cheng et al., 2015; Shi,2022). This paper adopts a difference-in-differences approach to assess the policy effects of the National Modern Agricultural Demonstration Zone, which can effectively reflect the policy effects of this zone. Third, the research perspective is more novel and has more academic value. The literature on the assessment of policy effects of the National Modern Agricultural Demonstration Zone is mostly focused on the ecological and environmental effects (Du et al., 2023; Ye et al., 2023), modern agricultural development (Sah et al., 2019), farmers' income level and labor force employment growth (Zeng and Yu, 2022). Less research expands the policy effects of demonstration zones in terms of agricultural science and technology innovation. Fourth, the research path is more practical and robust. Based on the literature, this paper further explores the mechanism of the role of the National Modern Agricultural Demonstration Zone in influencing agricultural science and technology innovation and provides guidance for further exertion of the effect of demonstration zones and the promotion of agricultural science and technology innovation.

## Theoretical analysis and research hypothesis

**The National Modern Agricultural Demonstration Zone and Agricultural Science & Technology Innovation**. The National Modern Agricultural Demonstration Zone provides key elements for agricultural science and technology innovation through financial support effects and policy guidance mechanisms, thus promoting the level of agricultural science and technology innovation. To promote agricultural science and technology innovation, the National Modern Agricultural Demonstration Zone has established a multilevel and multichannel financial support mechanism, which contributes to the research and application of agricultural science and technology innovation projects (Xu et al., 2023). The demonstration zones provide the necessary financial support for agricultural science and technology innovation by setting up special funds, establishing agricultural science and technology innovation funds and other measures, and using financial leverage to guide the extensive participation of social capital (Qiao et al., 2019). The National Modern Agricultural Demonstration Zone also stimulates the enthusiasm and creativity of agricultural science and technology innovation through a policy-guiding mechanism that not only formulates policies and regulations in favor of science and technology innovation but also provides policy concessions such as taxation, finance, and land for science and technology innovation (Meng et al., 2018).

The National Modern Agricultural Demonstration Zone promotes the absorption and transformation of agricultural technology through policy demonstration effects and industrial agglomeration effects, providing fertile ground for improving the level of agricultural science and technology innovation. The theory of technology diffusion suggests that technological

innovation must be diffused and disseminated to realize its actual benefits. Regional policies can promote the diffusion and dissemination of advanced agricultural technologies through the establishment of science and technology innovation demonstration zones and the promotion of science and technology achievements to enhance the level of agricultural science and technology innovation in a comprehensive way (Kumar et al., 2021; Chen et al., 2022).

The National Modern Agricultural Demonstration Zone adopts preferential policies and flexible mechanisms, which can attract domestic and foreign high-quality enterprises and scientific research institutions to settle in the area. This is conducive to the absorption and transformation of advanced technologies and promotes the advancement of agricultural science and technology (Meng et al., 2018; Zeng and Yu, 2022). A sound science and technology innovation system is established under the guidance of the demonstration zone policy, and the construction of agricultural science and technology innovation infrastructure is strengthened. At the same time, demonstration zones actively guide various types of innovation subjects, such as enterprises, universities and research institutions, to participate in agricultural science and technology innovation and promote the synergistic sharing of innovation resources (Chen et al., 2022; Li et al., 2023).

On the other hand, the National Modern Agricultural Demonstration Zone views the agricultural industry chain as a link to form the agglomeration effect, improve regional production efficiency, optimize the industrial structure, and further improve the level of agricultural science and technology innovation (Wu et al., 2020; Reddy and Bantilan, 2012). The National Modern Agricultural Demonstration Zone promotes the close integration of agricultural science and technology innovation and industrial development through the establishment of industrial linkage mechanisms. It also enhances the transformation and application of scientific and technological achievements to enhance agricultural science and technology innovation in all aspects.

Overall, the construction of the National Modern Agricultural Demonstration Zone relies on projects, such as land governance and high-standard farmland construction, to demonstrate and lead the construction of local agricultural modernization. So that the advanced achievements and models in the demonstration zones can be effectively promoted, encouraging the flow of humans, capital, information, and products between urban and rural areas, further enhancing the level of regional agricultural basic equipment manufacturing and science and technology innovation. Additionally, the National Modern Agricultural Demonstration Zone enhances and strengthens the functions of agricultural demonstration zones in introducing, integrating, applying, demonstrating and promoting new varieties, technologies and equipment through the combination of industry, academia, and research. This leads to the development of numerous intensive application areas and radiation sources of applicable agricultural science and technology achievements, accelerating the transformation and application of agricultural science and technology achievements, and promoting agricultural science and technology innovation. In summary, this paper proposes Hypothesis 1:

Hypothesis 1: The establishment of the National Modern Agricultural Demonstration Zone can promote agricultural science and technology innovation.

**Mechanisms of influence**. The National Modern Agricultural Demonstration Zone can provide solid support for improving agricultural science and technology innovation by improving the allocation efficiency of financial resources and allowing resources to be used for agricultural science and technology innovation that can create the most value. Due to the policy orientation and signaling effect, agricultural demonstration zones, as an important initiative of the Ministry of Agriculture and Rural Development to support the development of agricultural modernization, convey the government's attention to agriculture, rural areas, and farmers. Similarly, financial institutions realize the potential opportunities of the demonstration zones, and they will strive to build a sounder financial service system, strengthen the allocation of financial resources in the demonstration zones, and better solve the problems of agricultural loans and insurance in the agricultural demonstration zones. Additionally, financial institutions provide the necessary support for agricultural science and technology innovation in the demonstration zones (Gine and Yang, 2009). According to resource base theory, capital is the core element of agricultural science and technology innovation, which is the foundation and guarantee of agricultural science and technology research and development, transformation, popularization and sustainable development. The demonstration zones provide diversified financial instruments and financing channels for agricultural science and technology innovation by issuing agricultural science and technology innovation bonds and setting up agricultural science and technology innovation funds to improve the allocation efficiency of financial resources in agricultural science and technology innovation (Chen et al., 2022; Reddy and Bantilan, 2012).

The National Modern Agricultural Demonstration Zone is allocated funds by the central government to support regional agricultural development and provide financial support for agricultural science and technology innovation through the financial support of agriculture. According to statistics, at present, the central government has invested more than 15 billion yuan in subsidies for the construction of the National Modern Agricultural Demonstration Zone, driving local support of approximately 12 billion yuan. Agriculture is highly dependent on the natural environment, which makes agriculture show greater vulnerability in the face of external factors such as climate change and natural disasters (Ma et al., 2022). Moreover, agricultural science and technology innovation has positive externalities and public goods attributes, which are important for the sustainable development of the agricultural sector and rural economy. Therefore, it is necessary and valuable for the government to provide financial support for agricultural science and technology innovation. The National Modern Agricultural Demonstration Zones can significantly improve the level of agricultural science and technology innovation by providing sufficient financial guarantees, government subsidies and industrial funds (Sun, 2020). Chone (1994) confirms this view that agricultural support policies from the government can promote the improvement of the level of agricultural technology (Chone, 1994).

The National Modern Agricultural Demonstration Zone can comprehensively improve the quality and scientific and cultural level of most farmers and provide human capital to enhance the level of agricultural science and technology innovation through various forms of training. On the one hand, through industrial agglomeration, demonstration zones can not only form a labor market and improve the match between the labor force and market demand but also stimulate the employment growth of the rural labor force (Zeng and Mei, 2022). Industrial agglomeration can improve the income level of residents (He et al., 2020; Kline and Moretti, 2014), which is key to the enhancement of regional human capital. On the other hand, demonstration zones are at the forefront in the construction of their own public service platforms, and the high-quality public service capability of demonstration zones, the sound infrastructure, and the

development prospects brought about by governmental support play an important facilitating role in attracting humans and new farmers (Gong, 2021). The National Modern Agricultural Demonstration Zone should carry out new agricultural management main body leader rotation training and young farmer training programs, guide the participation of various types of business subjects, and accurately cultivate numerous new professional farmers for agricultural science and technology innovation to lay a solid foundation for humans. In summary, Hypothesis 2 can be formulated:

Hypothesis 2: The National Modern Agricultural Demonstration Zone enhances regional agricultural science and technology innovation by improving the allocation of financial resources, increasing the level of financial support to agriculture, and improving regional human capital.

**Heterogeneity analysis**. Fiscal autonomy enables local governments to manage their economies autonomously, which can influence the flexibility of government expenditure structures and give full play to the policy effects of the National Modern Agricultural Demonstration Zone. On the one hand, during the construction of the National Modern Agricultural Demonstration Zone, local governments can support the construction and development of the demonstration zone by increasing financial input. Local fiscal autonomy can provide more financial support and resource guarantees, which is conducive to the demonstration zones achieving better results in agricultural science and technology innovation, industrial upgrading, and farmers' income increase (Okoh et al., 2022). On the other hand, fiscal autonomy can realize regional economic development and the optimal allocation of financial resources, improve the construction of agricultural infrastructure and the environment of agricultural economic development, and provide a more solid foundation for the development of agricultural science and technology innovation (Sun, 2020).

In general, the current agricultural demonstration zones have achieved relatively fast growth and remarkable results in basic equipment manufacturing, modernized management level, and agricultural output level, but the imbalance in regional development of the demonstration zones is still prominent (Wang et al., 2020), which is fundamentally due to the vast differences in China's level of economic development. Compared with the eastern region, the central and western regions of China are more in need of advanced agricultural production factors such as humans, capital, technology, and information brought by the demonstration zone policy. Therefore, the agglomeration effect and scale effect brought by agricultural demonstration zones provide more convenient financial capital and more abundant social capital and human capital for agricultural science and technology innovation in the western region (Nelson and Phelps, 1966). The marginal contribution of demonstration zones to agricultural science and technology innovation in the central and western regions is greater.

Agricultural science and technology innovation not only requires a high level of human input, capital support, and policy guidance but also cannot be separated from the free flow of innovation factors between regions. The facilitation of transportation facilities can effectively reduce the flow cost of innovation factors, break the constraints of spatial geographic location on innovation factors and various types of resources, promote the sharing of knowledge and technology among groups, and promote technological progress (Liu et al., 2019). As far as the direct effect is concerned, transportation infrastructure improves regional accessibility, which is conducive to the exchange of regional funds, information, and humans, and the advantages of agricultural demonstration zones can be better utilized, which plays a significant role in promoting agricultural science and technology innovation. In terms of indirect effects, transportation facilities can greatly improve the innovation environment of the demonstration area, attract social capital and human concentration, and give full play to the multiplier effect of transportation facilities, helping to enhance agricultural science and technology innovation (Wang et al., 2019). Therefore, demonstration zones with good transportation infrastructure are more conducive to the concentration of capital and humans, which in turn promotes agricultural science and technology innovation. In summary, Hypothesis 3 can be formulated:

Hypothesis 3: There are differences in the effects of the establishment of the National Modern Agricultural Demonstration Zone on agricultural science and technology innovation, with more significant effects in regions with higher fiscal autonomy, in the western region, and in regions with better transportation infrastructure.

## Study design

**Sample selection and data sources**. This paper studies the impact of the National Modern Agricultural Demonstration Zone on agricultural science and technology innovation based on panel data from 696 regions from 2007–2017. This paper uses the establishment of the National Modern Agricultural Demonstration Zone as a quasi-natural experiment, with 283 regions in three batches in 2010, 2012, and 2015 as the experimental group and other regions as the control group, and uses difference-in-differences to assess the effect of agricultural demonstration zones on agricultural science and technology innovation. The relevant data were obtained from the China Science and Technology Statistical Yearbook, the National Bureau of Statistics, the China Rural Statistical Yearbook, the CSMAR database, and the China Banking and Insurance Regulatory Commission. Since there were missing values in the region-level data, this paper used the linear trend of the data and used the linear interpolation method to fill in the missing parts in the middle of each year.

**Model setting and variable definition**. To verify the impact of the National Modern Agricultural Demonstration Zone on agricultural science and technology innovation, the following basic econometric model was set up, drawing on the study by Zhao and Yu (2022):

$$ATI_{it} = \beta_0 + \beta_1{}^{*}DID_{it} + \beta_2{}^{*}Controls + \gamma_i + \mu_t + \varepsilon_{it} \quad (1)$$

To verify the intrinsic mechanism of the National Modern Agricultural Demonstration Zone affecting agricultural science and technology innovation, models (2) and (3) were constructed to test the influence mechanisms of financial capital allocation, financial support to agriculture, and human capital, drawing on the study of Wen and Ye (2014).

$$Finance_{it}/Government_{it}/Human_{it} = \alpha_0 + \alpha_1{}^{*}DID_{it} + \alpha_2{}^{*}Controls + \gamma_i + \mu_t + \varepsilon_{it} \quad (2)$$

$$ATI_{it} = \gamma_0 + \gamma_1{}^{*}DID_{it} + \gamma_2 Finance_{it}/Government_{it}/Human_{it} + \gamma_3{}^{*}Controls + \gamma_i + \mu_t + \varepsilon_{it} \quad (3)$$

where $i$ and $t$ represent the region and year, respectively; $ATI_{it}$ represents the agricultural science and technology innovation of region $i$ in period $t$; and $DID_{it}$ indicates whether region i is set up as a demonstration area in period t. If set up as a demonstration area, the value is 1; otherwise, it is 0. $Finance_{it}/Government_{it}/$

**Table 1 Agricultural Science and Technology Innovation Evaluation Index System.**

| Tier 1 indicators | Secondary indicators | Measurement method | Indicator direction |
|---|---|---|---|
| Agricultural Science and Technology Innovation Environment | Economic level | Disposable income of rural residents | + |
| | Infrastructure | Rural fixed asset investment | + |
| Agricultural science and technology innovation support | Human support | Average number of students in higher education | + |
| | Information foundation | Number of cell phones | + |
| Agricultural science and technology innovation input | Capital investment | R&D expenditure* (Total agricultural output / Regional GDP) | + |
| | Human input | R&D researcher full-time equivalent* (Total agricultural output / Regional GDP) | + |
| Agricultural science and technology innovation output | Science and technology achievements | Total power of agricultural machinery | + |
| | | Number of green patent applications per 10,000 people | + |
| | Economic benefits | Value added to agricultural output | + |

Note: Measured according to the entropy value method.

$Human_{it}$ are mediating variables, representing financial resource allocation, financial support to agriculture, and human capital of region $i$ in period $t$; Controls denote control variables; $\gamma_i$ represents individual fixed effects of region, $\mu_t$ represents time fixed effects, and $\varepsilon_{it}$ is the error term.

*Dependent variable*. Agricultural Science and Technology Innovation (ATI). Agricultural science and technology innovation refers to a series of closely articulated processes of recombining production factors and promoting technological development, such as the research and development, promotion and application of new varieties and new production methods. Therefore, agricultural science and technology innovation is a systematic system, and a single measure is not a good measure. Thus, this paper draws on the studies of Wu et al. (2020) and Hua and Pan (2022) and adopts the entropy value method to measure the level of agricultural science and technology innovation by integrating the four aspects of the agricultural science and technology innovation environment, innovation support, innovation input, and innovation output. (1) The agricultural science and technology innovation environment includes the regional economic development level and infrastructure, and the disposable income and fixed asset investment of rural residents provide the basis for agricultural science and technology innovation. (2) Agricultural science and technology innovation support includes human support and an information base, and the average number of higher education students and cell phones provide the necessary support for agricultural science and technology innovation. (3) Agricultural science and technology innovation input includes capital input and personnel input. Agricultural science and technology innovation is a long-term and risky process, and sufficient personnel and capital input are important guarantees that the process is successful. (4) Agricultural science and technology output includes science and technology achievements and economic benefits. The wide application of agricultural mechanization and the increase in the number of patent applications are important indicators of science and technology achievements, and the increased value of agricultural output is the visualization of economic benefits. The entropy value method is used to measure the level of agricultural science and technology innovation, and finally, the agricultural science and technology innovation evaluation index system is obtained, as shown in Table 1.

*Independent variable*. National Modern Agricultural Demonstration Zone (DID). There are three main batches of national modern agricultural demonstration areas. The first batch of 52 national modern agricultural demonstration areas was identified by the Ministry of Agriculture in 2010. The Ministry of Agriculture identified 101 regions as the second batch of demonstration areas in 2012, and 157 regions were identified as the third batch of demonstration areas in 2015. According to the criteria of whether the region is in the demonstration areas and the year, if the region is in the first batch of demonstration areas and the year is in 2010 or after the year is 1; otherwise, it is 0. If the region is in the second batch of demonstration areas and the year is in 2012 or after the year, it is 1; otherwise, it is 0. If the region is in the third batch of demonstration areas and the year is after 2015, it is 1; otherwise, it is 0.

*Mediating variables*. (1) Financial resource allocation (Finance), the logarithm of the stock of financial institutions in the current year is used to measure local financial resource allocation, and the relevant data come from the China Banking and Insurance Regulatory Commission. (2) Financial support for agriculture (Government), due to the availability of data during the study period, the ratio of financial expenditure on agriculture, forestry, and water affairs to agricultural GDP is used to measure the level of financial support for agriculture. (3) Human capital (Human), education is the main path of human capital behavior and development. We used the average number of years of education of residents to measure the level of regional human capital. The level of human capital = the number of people with a general undergraduate degree or above/the region's resident population.

*Control variables*. Referencing existing studies, the ratio of gross domestic product of primary industry to regional GDP (GGDP), total agricultural machinery power (Power), fixed asset investment to regional GDP (Fixed), the sum of resident savings and year-end loan balance of financial institutions to regional GDP (Load), and general fiscal budget revenue and expenditure to regional GDP (Budget) are the main influencing factors. Therefore, the above variables are chosen as control variables in this paper.

**Descriptive statistical analysis**. Table 2 shows the results of descriptive statistics of variables, and a comparison with previous literature reveals that the mean and standard deviation of variables in the sample are similar to previous studies. DID is a dummy variable for the National Modern Agricultural Demonstration Zone policy. ATI is agricultural science and technology innovation with a mean value of 0.106, and the maximum and minimum values are 0.562 and 0.011, respectively, indicating that

**Table 2 Descriptive statistics of each variable.**

| Variable category | Variables | Variable meaning | Sample | Average | Standard | Median | Minimum | Maximum |
|---|---|---|---|---|---|---|---|---|
| Dependent variable | DID | National Modern Agricultural Demonstration Area | 4371 | 0.077 | 0.266 | 0 | 0 | 1 |
| Independent variable | ATI | Agricultural Science and Technology Innovation | 4371 | 0.106 | 0.085 | 0.077 | 0.011 | 0.562 |
| Mediating variables | Finance | Financial resource allocation | 3867 | 3.924 | 0.858 | 3.988 | 0 | 6.828 |
| | Government | Financial support for agriculture | 4314 | 3.985 | 0.911 | 4.132 | 0.46 | 5.892 |
| | Human | Human capital | 3362 | 1.387 | 1.538 | 0.911 | 0.004 | 12.764 |
| Control variables | GGDP | Proportion of primary industry output in regional GDP | 4371 | 0.207 | 0.132 | 0.183 | 0.007 | 0.752 |
| | Power | Logarithm of the total power of agricultural machinery | 4371 | 11.64 | 2.508 | 12.29 | 3.1 | 14.86 |
| | Fixed | Ratio of fixed asset investment to regional GDP | 4371 | 0.844 | 0.572 | 0.701 | 0.03 | 5.897 |
| | Load | Sum of loan balances as a percentage of regional GDP | 4371 | 1.456 | 0.868 | 1.293 | 0.024 | 29.22 |
| | Budget | Ratio of general budget revenue and expenditure to regional GDP | 4371 | 0.34 | 0.314 | 0.241 | 0.008 | 2.875 |

**Table 3 Benchmark regression analysis.**

| Variables | ATI | |
|---|---|---|
| | (1) | (2) |
| DID | 0.057*** | 0.036*** |
| | (17.47) | (10.38) |
| GGDP | | −0.135*** |
| | | (−9.09) |
| Power | | 0.006*** |
| | | (33.26) |
| Fixed | | 0.014*** |
| | | (10.23) |
| Load | | 0.017*** |
| | | (11.71) |
| Budget | | −0.001 |
| | | (−0.18) |
| Region | Yes | Yes |
| Year | Yes | Yes |
| _cons | 0.320*** | 0.171*** |
| | (15.08) | (6.89) |
| *N* | 4334 | 4277 |
| Adj-$R^2$ | 0.794 | 0.853 |

Note: The numbers in parentheses are the t values of the two-tailed test, *** denote significance levels at 1%, respectively.

the current level of agricultural science and technology innovation in China is low and that regional differences are large. The individual differences of the main control variables are also relatively obvious, and overall, the sample has good differentiation.

## Empirical results

**Analysis of benchmark empirical results**. The effect of the National Modern Agricultural Demonstration Zone on agricultural science and technology innovation is tested based on a benchmark regression model. The estimation results are shown in Table 3, with each column controlling for region-fixed effects and time-fixed effects. The two models in Table 3 have a progressive relationship, in which model (1) only controls for the "region-time" fixed effects, and the coefficient estimate of the pilot policy is 0.057, which is significantly positive at the 1% level. The coefficient estimate of the pilot policy is 0.036 after the inclusion of control variables in the model (2), and although the coefficient decreases, it is still significantly positive at the 1% level. The above results indicate that compared with the regions that were not selected for the demonstration zone policy, the level of agricultural science and technology innovation in the regions that were selected for the agricultural demonstration zone increased by 3.6%. With the promotion of the National Modern Agricultural Demonstration Zone policy, agricultural science and technology innovation obtains a richer allocation of innovation resources and preferential policies, which significantly improves the level of regional agricultural science and technology innovation. Thus, Hypothesis 1 is verified.

**Parallel trend test**. The use of the double difference model presupposes that the experimental group has the same trend of change as the control group before the policy implementation, and this paper draws on the treatment of Alder et al. (2016) to test the agricultural science and technology innovation in the year of the policy shock and the year before for each region and

constructs the following econometric model:

$$ATI_{it} = \theta_0 + \theta_1 * DID_{it}^{-5} + \theta_2 * DID_{it}^{-4} + \ldots + \theta_{11} * DID_{it}^{5} + \theta_2 * Controls + \gamma_i + \mu_t + \varepsilon_{it} \quad (4)$$

where $DID_{i,t\pm n}$ represents the dummy variable for the policy of the agricultural demonstration area. When the treatment group regions in the nth year before being approved for the pilot, $DID_{i,t-n}$ takes the value of 1; otherwise, it takes the value of 0. When the treatment group regions are in the nth year after the approval of the pilot, the $DID_{i,t+n}$. The other variables are consistent with model (1), and Fig. 1 presents the results of the parallel trend test. The results show that before being approved for the demonstration zone policy, the parameters $\theta_1$, $\theta_3$, $\theta_4$ of the model are insignificant, but the $\theta_5$ estimates are positive and significant, probably because the demonstration zone policy has an anticipatory effect and the approval of the demonstration zone requires an application to the Ministry of Agriculture and Rural Affairs in advance. Given this, the region will take further measures to promote agricultural development to be qualified as a demonstration zone. After the approval of the demonstration zone policy, the agricultural science and technology innovation in the demonstration zone was significantly positive and achieved rapid growth in the fourth and fifth years, indicating that the demonstration zone policy has a lag.

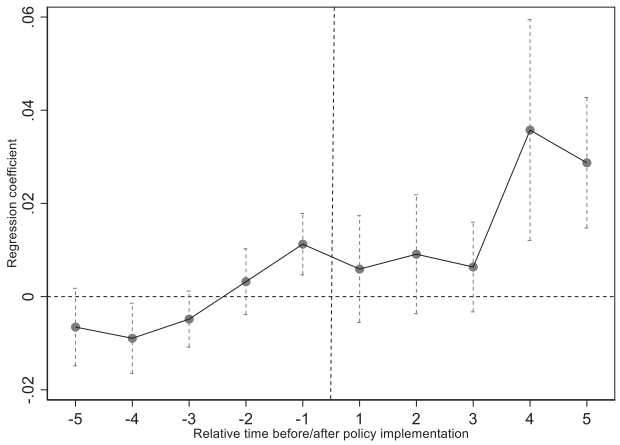


**Fig. 1** Parallel trend test chart.

**Robustness test**

*Replace the explanatory variables*. The level of agricultural mechanization is an expression and a measure of the degree of use, the size of the role, and the effect of the use of machines (equipment) in agriculture. Agricultural mechanization is the visual display of agricultural science and technology innovation in equipment. At the same time, differences in the total power of the agricultural machinery needed in different regions of arable land areas were explained. In this paper, we use the ratio of the total power of agricultural machinery in the region to the area of cultivated land in the region to measure the innovation of agricultural science and technology. The regression results are shown in column (1) of Table 4, and the promotion effect of agricultural demonstration areas on agricultural science and technology innovation remains significant after replacing the measurement of the explanatory variables, which proves the robustness of the underlying regression results.

*Excluding samples*. Compared with general prefecture-level cities, municipalities directly under the central government and provincial capitals are significantly different from other regions in terms of taxation, financial support, and transportation infrastructure, and the abovementioned advantages are important factors that influence agricultural science and technology innovation. To exclude their influence, the samples of municipalities that fall directly under the central government and provincial capitals were removed from this study for subsample testing. The regression results are shown in column (2) of Table 4. At this point, the coefficient value of demonstration zones on agricultural science and technology innovation is 0.009, which is significant at the 1% confidence level, again verifying Hypothesis 1. Notably, after excluding municipalities that fall directly under the central government and provincial capitals, the estimated coefficient of DID decreases to a certain extent compared with the base regression, indicating that the effect of demonstration zone policies on agricultural science and technology innovation in municipalities that are directly under the central government and provincial capitals is more significant.

*Excluding other policies*. In 2001, six ministries and commissions, including the Ministry of Science and Technology and the Ministry of Agriculture, officially launched the pilot construction of national agricultural science and technology parks. Agricultural science and technology parks are a new model of market-oriented, science and technology-supported, and enterprise-led modern agricultural construction that overlaps with the National Modern Agricultural Demonstration Zone in terms of development philosophy and

**Table 4 Robustness tests.**

| | (1) Replacement variables | (2) Excluding samples | (3) Excluding policies | (4) Placebo test | (5) PSM-DID | (6) CSDID |
|---|---|---|---|---|---|---|
| DID | 56.342** | 0.009*** | 0.016*** | | 0.045*** | 0.010*** |
| | (2.23) | (2.73) | (4.58) | | (8.36) | (4.28) |
| Treat*2010 | | | | 0.010 | | |
| | | | | (1.37) | | |
| Controls | Yes | Yes | Yes | Yes | Yes | Yes |
| Region | Yes | Yes | Yes | Yes | Yes | Yes |
| Year | Yes | Yes | Yes | Yes | Yes | Yes |
| _cons | −968.968*** | 0.054*** | −0.036*** | 0.327*** | 0.289*** | 0.038*** |
| | (−19.10) | (2.60) | (−8.37) | (13.40) | (9.85) | (8.33) |
| *N* | 4164 | 4017 | 3780 | 4209 | 4209 | 4277 |
| Adj-$R^2$ | 0.698 | 0.911 | 0.862 | 0.951 | 0.931 | - |

Note: The numbers in parentheses are the t values of the two-tailed test, ***, **, denote significance levels at 1%, 5%, respectively.

**Table 5 Analysis of impact mechanisms.**

| | (1) Finance | (2) ATI | (3) Government | (4) ATI | (5) Human | (6) ATI |
|---|---|---|---|---|---|---|
| DID | 0.160*** | 0.037*** | 0.359*** | 0.024*** | 0.413*** | 0.037*** |
| | (3.12) | (10.16) | (12.06) | (7.23) | (6.88) | (9.30) |
| Finance | | 0.007*** | | | | |
| | | (8.02) | | | | |
| Government | | | | 0.040*** | | |
| | | | | (27.83) | | |
| Human | | | | | | 0.001 |
| | | | | | | (0.28) |
| Sobel test | $Z = 4.561$, $p < 0.01$ | | $Z = 8.445$, $p < 0.01$ | | $Z = 13.362$, $p < 0.01$ | |
| Controls | Yes | Yes | Yes | Yes | Yes | Yes |
| Region | Yes | Yes | Yes | Yes | Yes | Yes |
| Year | Yes | Yes | Yes | Yes | Yes | Yes |
| _cons | 4.430*** | 0.173*** | 0.087 | 0.200*** | 1.801*** | 0.179*** |
| | (14.50) | (6.58) | (0.29) | (8.45) | (12.84) | (7.17) |
| *N* | 3867 | 3867 | 4314 | 4314 | 3362 | 3362 |
| Adj-$R^2$ | 0.468 | 0.849 | 0.838 | 0.884 | 0.939 | 0.846 |

Note: The numbers in parentheses are the t values of the two-tailed test, ***denote significance levels at 1%, respectively.

policy objectives. By the first half of 2015, a total of 158 national agricultural science and technology parks had been established in six batches across the country. Among them, the fourth, fifth, and sixth batches were built in 2012, 2013, and 2015, respectively, and there exist some regions with the dual identities of science and technology parks and demonstration zones at the same time, making it difficult to distinguish which policy actually promotes the development of their modern agriculture. To remove the influence of national agricultural science and technology parks, this paper excludes the regions with the "status" of national agricultural science and technology parks and re-estimates the double difference to obtain the pure policy effect of demonstration zones. The regression results are shown in column (3) of Table 4, where the coefficient of the National Modern Agricultural Demonstration Zone on agricultural science and technology innovation is estimated to be 0.016 and is significantly positive at the 1% level. The results suggest that the increase in agricultural science and technology is brought about by the National Modern Agricultural Demonstration Zone.

*Placebo test*. Due to its small sample, this paper removes the first batch of samples to present the research results more accurately. The second and third batches of policies were implemented in 2012 and 2015, respectively. The paper selects 2010 as the second and third batches of policy implementation points for the placebo test, and the results are shown in column (4) of Table 4. Treat*2010 has a positive effect but is not significant, indicating that there is no policy effect before the implementation of the second and third batches of policies. The results of the study are credible.

*Propensity Score Matching-Difference-in-differences (PSM-DID)*. According to the application requirements for demonstration zones announced by the Ministry of Agriculture and Rural Development, the mechanization level and infrastructure of the declared regions must meet certain conditions, so the regions that set up demonstration zones have a "self-selection effect". To avoid the effect of self-selection on the results, the propensity score matching method is chosen, and the non-demonstration areas that are most similar to the demonstration areas are selected as the control group for testing. The control variables of this paper are selected as the matching variables by the study of Zhao and Yu (2022), and hypothesis testing is conducted by using the "kernel matching" method. The matched samples are used to study the impact of demonstration zones on agricultural science and technology innovation. The results are shown in column (5) of Table 4, where the estimated coefficient of DID is 0.045 and is significantly positive at the 1% level. The robustness of the benchmark regression results is again illustrated.

*Callaway–Sant'anna time-varying-treatment difference-in-difference (CSDID)*. In this article, two-way fixed effects of region and time are added to the baseline regression. Considering that the late treatment group, which is later affected by the treatment effect in the multiperiod DID, has already included the treatment effect of the early treatment group, this may cause estimation bias in the two-way fixed effects model (Goodman-Bacon, 2021). Drawing on the methodology of Callaway and Sant'Anna (2021), a "heterogeneity-robust" estimator was calculated to better estimate the average treatment effect of the multiperiod DID. The results are shown in column (6) of Table 4, and the estimated coefficients are significantly positive, in line with the previous section.

## Further analysis

**Impact mechanism test**. The influence paths of the National Modern Agricultural Demonstration Zone that affect agricultural science and technology innovation have been described in the previous section, and this section tests the influence mechanisms of financial resource allocation, financial support to agriculture, and human capital. Referring to the mediation test method of Wen and Ye (2014), first, the impact of the establishment of the National Modern Agricultural Demonstration Zone on the mediating variables is tested according to model (2). In columns (1) (3) (5) of Table 5, it is shown that the National Modern Agricultural Demonstration Zone helps to improve the regional financial asset allocation ($\alpha_1 = 0.160$), improve the level of financial support to agriculture ($\alpha_1 = 0.359$), and improve human capital in demonstration areas ($\alpha_1 = 0.413$). Second, following model (3) to test the influence played by mediating variables, from columns (2) (4) (6) of Table 5, the coefficient estimates of the National Modern Agricultural Demonstration Zone on agricultural science and technology innovation are 0.037, 0.024 and 0.037, respectively, after adding mediating variables, which are all significantly positive at the 1% level, although they are lower than the estimated values of the underlying regression coefficients.

**Table 6 Heterogeneity analysis.**

| | Fiscal autonomy | | Region | | Transportation infrastructure | |
|---|---|---|---|---|---|---|
| | Low | High | East | West | Low | High |
| | (1) | (2) | (3) | (4) | (5) | (6) |
| DID | 0.004** | 0.021*** | 0.014*** | 0.032*** | −0.003 | 0.012*** |
| | (1.98) | (7.22) | (5.21) | (11.34) | (−0.61) | (3.03) |
| Controls | Yes | Yes | Yes | Yes | Yes | Yes |
| Region | Yes | Yes | Yes | Yes | Yes | Yes |
| Year | Yes | Yes | Yes | Yes | Yes | Yes |
| _cons | −0.045*** | −0.076*** | 0.236*** | −0.055*** | 0.070*** | 0.086*** |
| | (−15.02) | (−5.76) | (23.53) | (−11.32) | (8.42) | (5.17) |
| Surtest | 0.062, $P < 0.01$ | | 0.018, $P < 0.05$ | | - | |
| *N* | 2883 | 2816 | 2734 | 1580 | 1077 | 1131 |
| Adj-$R^2$ | 0.817 | 0.891 | 0.796 | 0.632 | 0.893 | 0.850 |

Note: The numbers in parentheses are the t values of the two-tailed test, ***, **,denote significance levels at 1%, 5%, respectively.

Sobel was further used to test the mediating effect, and the results in the table show that they all passed the test. Hypothesis 2 is verified. The above results show that financial resource allocation, financial support for agriculture, and human capital play a partial intermediary role in the process of influencing agricultural science and technology innovation in the national modern agricultural demonstration zones.

### Heterogeneity analysis

*Fiscal autonomy*. Drawing on the study of Gao (2012), this paper adopts revenue within the general budget of local finance to measure fiscal autonomy, divides the sample into a low fiscal autonomy group and a high fiscal autonomy group according to the median, and further conducts the grouping test. The results are shown in columns (1) and (2) of Table 6. Based on the grouping regression results, the regression coefficient of the national modern agricultural demonstration zones on agricultural science and technology innovation in the sample with high fiscal autonomy is 0.021, which is significantly positive at the 1% level. In the sample with lower fiscal autonomy, the regression coefficient is 0.004, which is significantly positive at the 5% level. Further testing of the difference in coefficients between groups shows that the regression of the high fiscal autonomy group is significantly higher than that of the low fiscal autonomy group. Therefore, the study concludes that a high level of fiscal autonomy can effectively play the policy guidance effect and financial support effect of the National Modern Agricultural Demonstration Zones and better help agricultural science and technology innovation (Yang et al., 2021).

*Geographical location*. According to the division of China's regions by the National Bureau of Statistics, the regions were divided into eastern, central, and western regions according to the provinces where they were located, and group tests were conducted. According to the previous analysis, compared with the western region, the central and eastern regions have obvious advantages in terms of economic development levels and industrial structures. Therefore, the agricultural science and technology innovation effect of the demonstration zones is further analyzed with the subgroups of the central and eastern regions and the subgroups of the western regions. The results, as shown in columns (3)–(4) of Table 6, indicate that the National Modern Agricultural Demonstration Zones have positively promoted agricultural science and technology innovation, regardless of the region. The test of differences between groups concludes that the coefficient estimate of the demonstration zone policy on agricultural science and technology innovation in the western region is larger and significantly different. As discussed earlier, the western region is more in need of financial support and favorable conditions brought by the demonstration zones, and thus, the demonstration zones have a greater marginal contribution to agricultural science and technology innovation in the western region.

*Transportation infrastructure*. Drawing on the study of Wang et al. (2019), the level of transportation infrastructure construction was measured by the total number of road miles per unit of land area in each province, and the sample was divided into a high-level group and a low-level group of transportation infrastructure with a median. The results were tested in groups as shown in columns (5)–(6) of Table 6. The high level of transportation infrastructure improves the advantageous role of agricultural demonstration areas, and the significant effect of transportation infrastructure on the innovation effect of agricultural demonstration areas also verifies the multiplier effect of transportation infrastructure on agricultural science and technology innovation. Summarizing the above analysis, hypothesis 3 is tested.

## Discussion and conclusions

The National Modern Agricultural Demonstration Zone is an important initiative that enhances agricultural science and technology innovation and assists in rural revitalization. This study focuses on examining the effectiveness of the construction of the National Modern Agricultural Demonstration Zone, assessing the level of agricultural science and technology innovation in the districts and counties where the demonstration zone is located. In addition, it refines the knowledge of replicable and extendable construction models to provide references for the modernization of China's agricultural and rural areas. It also offers insight into the Chinese experience in the agricultural development of other similar economies around the globe. Based on the panel data of 696 regions in China from 2007–2017, this paper uses difference-in-differences to study the impact and mechanism of action of the demonstration zone construction on agricultural science and technology innovation.

The results show that (1) the National Modern Agricultural Demonstration Zone can enhance agricultural science and technology innovation, and the results remain robust after a series of robustness tests. The findings of this paper are consistent with those of Wu et al. (2019), both of which concluded that agricultural demonstration zones can play a policy-driven role in rationalizing the allocation of agricultural production factors and improving agricultural technology. (2) The National Modern Agricultural Demonstration Zone can enhance regional financial capital allocation, financial support for agriculture, and human capital stock,

which are the necessary elements for agricultural science and technology innovation, due to policy orientation and financial support. Similarly, Li et al.,(2023) analyzes the spatial distribution and innovation efficiency of China's national agricultural science and technology parks and concludes that innovation support from agricultural science and technology parks, demonstration, and promotion can optimize the efficiency of the allocation of science and technology resources and improve agricultural science and technology innovation. Kumar & Joshi (2018) argues that as climate change continues to intensify, a lack of technology, finance, and credit availability places significant constraints on agricultural performance. (3) The positive impact of demonstration zones on agricultural science and technology innovation is more significant in western regions with high fiscal autonomy and better transportation infrastructure. Li et al.,(2023) also concludes that agricultural science and technology parks should be focused on northeastern and northwestern China to exploit the supportive effects of agricultural policies in slower-developing regions.

## Policy implications

Based on the above conclusions, the following policy suggestions are put forward to better illustrate the advantageous role of agricultural demonstration zones, enhance the level of agricultural science and technology innovation, and realize the modernization of agricultural construction.

First, at the current new stage of China's comprehensive rural revitalization, it is necessary to further grasp the mechanism of the role of agricultural demonstration in agricultural science and technology innovation. Local governments should combine fiscal autonomy to implement differentiated and personalized support services, increase financial support, cultivate and provide farmers with professional development, assist agricultural demonstration zones to better aid and benefit agriculture, and fully realize the significant role of agricultural demonstration zones.

Second, the western region should continue to strengthen the construction of the National Modern Agricultural Demonstration Zones. Promoting the effect of agricultural science and technology innovation is critical. Thus, the government should increase the density of the construction of demonstration zones and provide greater financial support from financial institutions to aid the region in enhancing agricultural science and technology innovation, facilitating agricultural modernization.

Third, the construction of the transportation infrastructure in the agricultural region should continue to be promoted. Transportation is an important infrastructure factor that supports regional economic development and is especially significant for the development of agricultural regions. The government should set up special funds to improve the rural road access conditions in the demonstration area, help the area realize industrial agglomeration, human interaction, and technology exchange, and better promote agricultural science and technology innovation.

## Data availability

The study used primary data and the author has attached the dataset as a supplementary file to this submission.

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## Author contributions

NW contributed to the conception or design of the work. NW & DC contributed to the acquisition, analysis, or interpretation of data for the work. NW & DC contributed to draft the work or revising it critically for important intellectual content. All authors read, revised, and approved the final manuscript.

## Competing interests

The authors declare no competing interests.

## Ethical approval

This article does not contain any studies with human participants performed by any of the authors.

## Informed consent

This article does not contain any studies with human participants performed by any of the authors.

## Additional information

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