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National Agricultural Green Development Pioneer Zone and Enterprise Total Factor Productivity: Empirical Evidence from Chinese Agricultural Enterprises

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Abstract. The construction of the National Agricultural Green Development Pioneer Zone represents a crucial strategic direction for promoting green transformation in agriculture and advancing high-quality agricultural development. This paper treats the green agricultural development pilot zone initiative as a quasi-natural experiment, selecting A-share agricultural listed enterprises from 2005 to 2024 as the research sample, and employs the staggered difference-in-differences (DID) method to empirically examine the impact of the green agricultural development pilot zone policy on agricultural enterprise total factor productivity (TFP). The findings reveal that: (1) The green agricultural pilot zone policy effectively enhances agricultural enterprise TFP, and this conclusion remains robust after conducting a series of robustness tests including parallel trends test, placebo test, and PSM-DID test. (2) Heterogeneity analysis demonstrates that the policy effects are more pronounced in asset-light enterprises, enterprises in central regions, and major grain-producing areas. (3) Mechanism analysis indicates that the policy operates through three pathways: increasing government subsidies, enhancing technological innovation, and promoting industrial agglomeration. This study evaluates policy effects from the enterprise micro-level perspective, providing empirical support and policy implications for China's continued advancement of green agricultural development and improvement of the agricultural support policy system.

Keywords: National Agricultural Green Development Pioneer Zone; Agricultural enterprise total factor productivity; Government subsidies; Technological innovation; Industrial agglomeration.

1. Introduction

In the current critical stage of comprehensively building a modern socialist country and accelerating the construction of an agricultural powerhouse, promoting green transformation has been incorporated as a core objective in the proposed "15th Five-Year Plan." As an essential component of China's new agricultural management system, agricultural enterprises serve not only as the core market entities for advancing agricultural modernization but also as the key force for achieving agricultural efficiency improvements . Against this backdrop, National Agricultural Green Development Pioneer Zone(hereinafter referred to as the pioneer zone), as important experimental and demonstration platforms for the nation's promotion of sustainable agricultural development, have been entrusted with the crucial task of advancing resource conservation, environmental protection, and ecological stability in accordance with local conditions [1]. In reality, China's agriculture has long been constrained by multiple factors, including low per capita production resource endowment, diminishing marginal returns on production factor inputs, and intensifying pollution emissions. To a considerable extent, the development model has remained dependent on extensive input of chemicals such as fertilizers and pesticides, with agricultural pollution emissions even surpassing traditional pollution sources such as industry[2]. This extensive development model directly constrains the improvement of agricultural enterprise total factor productivity (TFP). On the one hand, sustained high inputs lead to declining marginal output, making it difficult to improve enterprise production

[1] See the Management Measures for the National Agricultural Sustainable Development Pilot Demonstration Zones (Agricultural Green Development Pioneer Zones) (Trial)

efficiency; on the other hand, intensifying agricultural pollution brings environmental regulatory pressure and rising compliance costs, further compressing enterprises' production efficiency space. Affected by these factors, the improvement of agricultural enterprise TFP has encountered significant bottlenecks. becoming a critical practical issue constraining the sustainable economic development of agricultural enterprises. In this context, can the National Agricultural Green Development Pioneer Zone effectively assist agricultural enterprises in completing green transformation and enhancing their TFP? Through what mechanisms do pilot zone policies exert influence on agricultural enterprise TFP? These questions urgently require systematic examination.

Existing literature has explored from multiple perspectives the impact of the pioneer zone and similar regional green pilot policies on enterprise production and operations, technological innovation, and total factor productivity (TFP). Chen et al. (2021) demonstrated that low-carbon pilot policies can significantly enhance local enterprise TFP [3]. Z. Zhao et al. (2021) found that national low-carbon policy pilots can promote enterprises to achieve a win-win outcome in both economic and environmental benefits [4]. Sun et al. (2023) argued that China's agricultural green development demonstration zone policy has a significant driving effect on the growth of green patent applications by agricultural enterprises [5]. Q. Li and Z. Xiao (2020) confirmed that environmental subsidy policies have a crowding-out effect on green invention patents in heavily polluting industries [6]. Existing research predominantly focuses on the macro-level agricultural effects of green pilot policies, but systematic empirical evidence remains lacking regarding how the core policy shock of the pioneer zone affects micro-level agricultural enterprise TFP, as well as its heterogeneous characteristics and underlying mechanisms. Based on this, this paper systematically analyzes the impact of the Agricultural Green Development Pioneer Zone policy (hereinafter the pioneer zone policy) on agricultural enterprise TFP and its core transmission mechanisms.

Theoretically, the pioneer zone policy may have a positive promoting effect on agricultural enterprise TFP. From the constraint mechanism perspective, the pioneer zone provides clearer normative constraints for agricultural production activities by improving the agricultural input standards system, agricultural non-point source pollution monitoring system, and farmland pollution control standards. This helps reduce resource misallocation caused by lack of standards and insufficient regulation, improves resource allocation efficiency, and ensures the quality and effectiveness of green agricultural development [7]. From the incentive mechanism perspective, the pilot zone policy provides financial guarantees and cost compensation for the green transformation of agricultural business entities and leading enterprises through establishing and improving green ecology-oriented agricultural subsidy mechanisms and promoting credit express services. This alleviates financial constraints in the research, development, application, and diffusion of green technologies, and incentivizes enterprises to increase green investment [8]. Therefore, the pioneer zone policy is expected to promote enterprises' TFP improvement through constraint and incentive mechanisms that facilitate green innovation, optimize resource allocation, and release growth potential, thereby driving transformation from factor-driven to efficiency-driven development.

However, the pioneer zone may also have a negative inhibitory effect on agricultural enterprise TFP in the short term. According to policy requirements, agricultural business entities need to cultivate and promote new green varieties, improve agricultural product quality, and reduce the use of inputs such as fertilizers and pesticides [9]. This means enterprises must bear additional green investment and transformation costs. The traditional neoclassical economics perspective holds that environmental regulation often compresses profit margins by increasing production costs, further affecting enterprises' own profitability and investment decisions, thereby adversely impacting enterprise competitiveness [10]. Some research also suggests that agricultural subsidies do not necessarily effectively promote green agricultural development, and the effects of support measures such as credit are not significant [9]. Therefore, agricultural enterprises often need to bear additional compliance costs to meet green development requirements. If these cannot be effectively compensated through policy support, it may lead to a decline rather than improvement in enterprise TFP.

Regarding the impact of the pioneer zone policy on agricultural enterprise TFP, no unified conclusion has been reached at the theoretical level, thus requiring empirical testing. This paper selects A-share agricultural listed enterprises from 2005-2024 as the research sample and demonstrates that the pioneer zone policy has a significant promoting effect on agricultural enterprise TFP. This result remains robust after a series of robustness tests, including parallel trends test, placebo test, and difference-in-differences test. Heterogeneity analysis shows that the policy's enhancement effect is more significant in asset-light enterprises, enterprises in central regions, and enterprises in major grain-producing areas. Mechanism testing indicates that the policy can increase government subsidies, promote technological innovation, and drive industrial agglomeration. These conclusions align with the theoretical logic that green policies promote enterprise quality improvement and efficiency enhancement.

The contributions of this paper are as follows:

First, existing research on the policy effects of the pioneer zone mainly focuses on the macro level. For example, H. Lu et al. (2024) found based on county-level samples that the policy functions through two pathways: industrial agglomeration and structural optimization[7]; Z. Zhang et al. used municipal panel data to evaluate the effect of pilot zone policy on fertilizer reduction[9]. These studies mostly adopt regional or industry-wide perspectives, with few studies examining the impact of agricultural green development policy on individual enterprise production efficiency from a micro-enterprise perspective. This paper extends the research to the agricultural enterprise level, using enterprise micro-data to evaluate the micro-productivity effects of pilot zone policy, thereby expanding the research boundaries of the economic consequences of agricultural green policies.

Second, the economic effects of policy pilots have long attracted academic attention. Existing research has not deeply explored the mechanisms through which agricultural green development pilot zone policy operates. Regarding intermediary mechanisms, although existing research has separately confirmed the promoting effects of government subsidies (J. Sun et al., 2023) [11], technological innovation (Baron and Kenny, 1986) [12], and industrial agglomeration (J. Fan et al., 2014) [13] on enterprise TFP, this paper incorporates these mechanisms into a unified analytical framework to systematically examine the operational pathways of green agricultural development pilot zone policy.

Third, the "Proposal of the Central Committee of the Communist Party of China on Formulating the 15th Five-Year Plan for National Economic and Social Development" explicitly proposes the strategic requirement to "coordinate the development of scientific agriculture, green agriculture, and quality agriculture." Pilots are a benchmark-leading model tied to macro governance objectives (W. Zou, 2022) [14]. As a benchmark pilot for China's green agricultural development, the pioneer zone policy—this paper's research not only demonstrates the micro-economic effects of the policy but also provides clear policy guidance for implementing the "15th Five-Year Plan" requirements and achieving overall improvement in green agricultural development through policy diffusion driven by pilot demonstrations.

2. Literature Review

Research on policies of Agricultural Green Development Pioneer Zones. As an important pilot policy for China's agricultural green transformation, the pioneer zone policy has a profound historical context and clear institutional orientation in its formulation and implementation. Regarding the implementation effects of this policy, existing research has conducted relatively rich discussions from two levels: policy mechanisms and empirical evidence.

First, regarding the policy background and institutional design, the Agricultural Green Development Pioneer Zones, also known as the Agricultural Sustainable Development Pilot Demonstration Zones, serve as national experimental platforms for promoting agricultural green development and sustainable development, carrying the important mission of exploring green development models and demonstrating to drive national agricultural transformation [16]. In 2015, eight ministries and departments, including the then Ministry of Agriculture, the National Development and Reform Commission, and the Ministry of Science and Technology, jointly issued the National Agricultural Sustainable Development Plan (2015–2030), which for the first time explicitly proposed vigorously promoting agricultural sustainable development and officially launched the National Agricultural Sustainable Development Pilot Demonstration Zones [15].

Implementing the concept of green development, the policy focuses on three aspects: agricultural industry sustainability, resource and environmental sustainability, and rural society sustainability. It integrates various fragmented individual measures and employs five supporting mechanisms—advancing technological innovation, promoting technology application, improving legal constraints, strengthening incentive mechanisms, and establishing market price adjustment mechanisms—as policy instruments, aiming to accelerate agricultural development into a new stage of green transformation and shift agricultural production from solely pursuing output to equal emphasis on quantity and quality [11].

Second, a growing body of empirical research has examined the policy effects from both a micro and macro perspective. From the micro-behavioral level, Sun et al. (2023) showed that China's green agriculture pilot zone policy reduced corporate financial risk and promoted greater investment in innovation [5]. Z. Tan (2025) found that the establishment of pioneer zones strengthened the agglomeration of capital and talent, thereby promoting corporate green technology innovation [19]. W. Liu (2024) found that the pioneer zone policy could significantly promote the attraction of foreign investment to pilot areas through increased scientific research investment and environmental improvement [20]. Through behavioral incentives such as promoting corporate investment in innovation and strengthening capital agglomeration, the pioneer zone policy has ultimately exerted profound impacts on macro-level indicators such as total factor productivity. For example, Wu et al. (2025) found that the Agricultural Green Development Pioneer Zone policy promoted agricultural production, and that environmental regulations caused suppliers of fertilizers and pesticides to increase the supply of agricultural chemicals in anticipation of increasingly strict environmental regulations, which in the short term stimulated agricultural chemical demand [21]. Lu et al. (2024) showed that the Agricultural Green Development Pioneer Zone policy promoted both agricultural green technology progress and agricultural green technology efficiency, enhancing agricultural total factor productivity through two pathways: promoting agricultural industry agglomeration and industrial structure optimization [7]. Ma et al. (2025) found that the policy promoted cultivated land use and significantly improved ecological efficiency, facilitating agricultural technological innovation and agricultural industry modernization [22].

Research on Total Factor Productivity of Agricultural Enterprises. TFP (Total Factor Productivity of enterprises) is typically interpreted as the "residual" in total output that cannot be explained by factor inputs. It reflects the average output level per unit of various input factors in the production process, that is, the overall efficiency of converting all factor inputs into final output [23]. In recent years, micro-level productivity has been widely adopted by economists and policymakers. Productivity growth is considered a key factor driving long-term macroeconomic growth [24]. Existing research shows that total factor productivity growth of agricultural enterprises is slow. Agricultural enterprises face structural imbalances in capital and labor inputs, with more than half of enterprises facing financing difficulties, and their proportion of R&D personnel is far below the average level [25].

Scholars have conducted extensive research on factors affecting the total factor productivity of agricultural enterprises. Regarding market competition factors, Z. Zhan et al. (2021) found that industrial agglomeration contributes to total factor productivity improvement, and Giang et al. (2019) found that enterprise scale is positively correlated with total factor productivity [27,25]. Han et al. (2024) found that foreign direct investment in Chinese agriculture promotes total factor productivity improvement of foreign-invested agricultural enterprises in China, but its spillover effects have a negative impact on their total factor productivity [27]. Regarding government policy factors, Liu et al. (2020) demonstrated that government increases in R&D for agricultural development projects and technological progress enhance agricultural total factor productivity [28]. D. Li et al. (2011) found that loan interest subsidies and tax reductions significantly promote total factor productivity improvement of agricultural enterprises, while brand support effects are not significant [29]. K. Zhou (2023) argued that timely and moderate adjustments of various economic policies, maintaining policy stability and continuity, can provide a stable and predictable development environment for agricultural enterprises and effectively promote high-quality development of agricultural enterprises [30].

Overall, existing literature has extensively studied the factors influencing total factor productivity of agricultural enterprises from multiple perspectives, including market-based and policy-based factors. However, there is currently limited analysis of the impact of the Agricultural Green Development Pioneer Zone, a key green policy, on the total factor productivity of agricultural enterprises. Therefore, this paper will use the Agricultural Green Development Pioneer Zone as a quasi-natural experiment to systematically study the policy's impact on total factor productivity of agricultural enterprises and its underlying mechanisms, filling the gaps in existing research.

3. Research Hypotheses and Design

Research Hypotheses. The National Agricultural Green Development Pioneer Zone policy represents an exogenous institutional shock to agricultural business entities. This institutional shock has both direct and indirect transmission pathways affecting the total factor productivity of agricultural enterprises.

(i) The direct promotion pathway refers to how the Agricultural Green Development Pioneer Zone policy directly affects enterprises' production factor allocation and technical efficiency through incentive-based environmental regulations and fiscal support instruments, thereby promoting enterprise total factor productivity. Based on the core logic of the Porter Hypothesis, reasonable incentive-based environmental regulations can compel enterprises to conduct technological innovation, offsetting compliance costs through innovation compensation, thus driving the improvement of enterprise total factor productivity [32]. The incentive policy instruments of pioneer zones can directly affect agricultural enterprises from four aspects—cost, financing, technology, and profitability—forming positive incentives. In terms of cost, pioneer zones directly reduce enterprise compliance costs and decrease non-productive capital occupation through fiscal subsidies and tax reductions. In terms of financing, through financial support policies such as "direct lending channels" and special green credit, they reduce enterprise financing constraints and provide long-term, stable financial support for enterprise transformation. The above cost reduction and financing support jointly construct direct relief for enterprises' internal self-constraints, helping more enterprises invest in innovation activities, thereby promoting the improvement of enterprise total factor productivity. Meanwhile, in terms of technology, pioneer zones establish technology-sharing platforms through cooperation with research institutes and leading enterprises, improve standard system platforms, and promote agricultural green technologies[2], directly lowering the threshold for enterprise technology R&D and application, thus promoting standardization of enterprise production processes and advancement of production technology. Finally, from an operability perspective, the policy promotes the cultivation of "Three Products and One Standard" and emphasizes building agricultural product brands, which aligns with brand asset theory, allowing e products to obtain market premiums and reduce price volatility risks [35], enhancing enterprise profitability stability. According to Keynes' theory of marginal efficiency of capital, stable profit expectations will enhance the marginal efficiency of enterprise capital, incentivizing enterprises to continuously expand investment scale and promote production scale expansion, thereby promoting the improvement of agricultural enterprise total factor productivity.

[2] see "Implementation Plan for Building National Agricultural Green Development Pioneer Zones to Promote Agricultural Modernization and Comprehensive Green Transformation of Demonstration Zones"

(ii) The indirect pathway refers to indirectly affecting agricultural enterprise total factor productivity through three mechanisms: policy subsidies, technological innovation, and industrial agglomeration. Policy subsidies can promote enterprise total factor productivity because financing constraints restrict the improvement of enterprise operational efficiency (S. Chen and D. Chen, 2016) [36], while policy subsidies can effectively alleviate enterprise financing constraints (Wu, 2017) [38], thereby promoting the improvement of enterprise total factor productivity. The policy subsidies of pioneer zones are mainly reflected in fiscal subsidies and green credit policies, which reduce enterprise financing constraints and operating costs, providing financial guarantees for enterprises to expand production and conduct technology R&D, consistent with conclusions in existing literature. In terms of technological innovation, pioneer zones guide enterprises to continuously conduct technological innovation by promoting green production technologies and establishing standardized production systems, facilitating green technology R&D and application, and driving the improvement of enterprise production efficiency. In terms of industrial agglomeration, based on Marshall's theory of industrial agglomeration externalities, industrial agglomeration has three major externalities: economies of scale, knowledge spillover, and optimal factor allocation [35]. Through the construction of green low-carbon agricultural industry chains and support for specialized industrial clusters [36], pioneer zones guide leading agricultural enterprises, upstream and downstream processing supporting enterprises, and agricultural socialized service institutions to concentrate in pilot areas, forming specialized agricultural industrial agglomerations. This agglomeration provides a collaborative development environment for Enterprises within the region in terms of sharing infrastructure, promoting technology diffusion, and optimizing production efficiency allocation, thereby indirectly enhancing total factor productivity.

Based on the above analysis, this paper proposes the following research hypotheses:

$H1$: The establishment of the Agricultural Green Development Pioneer Zone policy can significantly promote the improvement of total factor productivity of agricultural enterprises.

$H1a$: The Agricultural Green Development Pioneer Zone policy has a direct positive impact on the total factor productivity of agricultural enterprises within the zones;

$H1b$: The Agricultural Green Development Pioneer Zone policy promotes the improvement of total factor productivity of agricultural enterprises within the zones through three indirect pathways: policy subsidies, technological innovation, and industrial agglomeration.

4. Research Design

Model Construction. This paper uses the pioneer zone pilot as a quasi-natural experiment. Since the three batches of green development pioneer zone pilots were implemented in different years, a staggered difference-in-differences (DID) method is adopted to study the impact of the pioneer zone on the total factor productivity of agricultural enterprises. By comparing the differences in total factor productivity between agricultural enterprises in pilot areas (treatment group) and agricultural enterprises in non-pilot areas (control group) before and after the green development pioneer zone pilot, the net policy effect of the pilot can be identified. Following the common research approach of Zhao Zhenzhi et al. (2021) [4] and Li et al. [39] for similar green pilot policies, the following model is constructed:

$$TFP\_OP_{i,t} = \beta_0 + \beta_1 TREAT_i \times POST_{i,t} + \rho X_{it} + \mu_i + \lambda_t + \varepsilon_{i,t} \quad (1)$$

Where, $TFP\_OP_{i,t}$ represents the total factor productivity of agricultural enterprise i in year t. $TREAT_i$ is a grouping dummy variable representing the pioneer zone pilot. It takes the value of 1 if the agricultural enterprise belongs to a pilot area, and 0 otherwise. $POST_{i,t}$ s a policy timing dummy variable, taking the value of 1 for the year in which the enterprise's region becomes a pilot area and all subsequent years, and 0 for prior years. $TREAT_i \times POST_{i,t}$ is the core explanatory variable, defined as the interaction term between $TREAT_i$ and $POST_{i,t}$. X_{it} represents a set of selected control variables. μ_i and λ_t denote individual fixed effects and time fixed effects, respectively, and $\varepsilon_{i,t}$is the random error term. The coefficient of $TREAT_i \times POST_{i,t}$captures the net policy effect of the pioneer zone pilot, reflecting the impact of the pioneer zone policy on the total factor productivity of agricultural enterprises. If this coefficient is positive, the research hypotheses of this paper are supported. To address potential cross-sectional heteroskedasticity, all models in this paper are estimated using robust standard errors clustered at the enterprise level.

Variable Definitions. Existing studies commonly use the OP and LP methods to estimate TFP, as these approaches can avoid the estimation bias introduced by OLS regression. This paper adopts the OP method proposed by Olley & Pakes (1996) to measure the total factor productivity of agricultural enterprises. This method uses the firm's current period investment as a proxy variable for unobservable productivity shocks, and simultaneously incorporates a firm survival probability model, effectively addressing two major endogeneity problems inherent in OLS estimation: simultaneity bias and sample selection bias. The economic significance of TFP lies in its ability to reflect an agricultural enterprise's level of technological progress, production management efficiency, resource allocation capacity, and green production capability, making it a core indicator for measuring the productive efficiency and high-quality development of agricultural enterprises. The higher the value, the stronger the firm's output capacity under the same factor inputs, and the higher its overall production efficiency.

The variable specifications in this paper draw on Z. Zhao et al.'s (2021) research on similar green pilot policies and enterprise total factor productivity, J. Sun et al.'s (2023) study on the impact of policies on the total factor productivity of agricultural enterprises, and are further adjusted with reference to related literature on the effects of other policies on agricultural enterprise TFP [4,11]. The selected control variables include: firm size (*Size*), asset-liability ratio (*Lev*), return on assets (*ROA*), ownership type (*SOE*), quick ratio *(Quick*), fixed asset ratio (*Fixed*), operating revenue growth rate (*Growth*), board size (*Board*), equity concentration (Top 1), and firm age (*FirmAge*). The definitions of each variable are presented in Table 1.

Table 1. Variables

Variable notation	Variable name	Definition
TFP_OP	Total factor productivity	Total factor productivity of agricultural enterprises, measured using the OP (Olley–Pakes) method
TREAT_POST	Pioneer zone pilot impact	*TREAT* equals 1 if the enterprise is located in a pilot city, and 0 otherwise; *POST* equals 1 for the year of pilot approval and subsequent years, and 0 otherwise; their interaction term serves as the core measure of policy effect
Size	Enterprise size	Natural logarithm of total assets at year-end
Lev	Asset–liability ratio	Total liabilities divided by total assets
ROA	Return on assets	Net profit divided by average total assets
SOE	Ownership nature	Equals 1 for state-owned enterprises (SOEs), and 0 otherwise
Quick	Quick ratio	Quick assets divided by ending current liabilities
Fixed	Fixed asset ratio	Ending net fixed assets divided by ending total assets × 100%
Growth	Revenue growth rate	(Current-period total revenue − previous-period total revenue) divided by previous-period total revenue × 100%
Board	Board size	Number of board members plus 1, taken in natural logarithm
Top1	Ownership concentration	Shareholding ratio of the largest shareholder
FirmAge	Firm age	Current year − establishment year + 1, taken in natural logarithm

Data Description. This paper selects A-share agricultural listed enterprises from 2005 to 2024 as the initial research sample. The chosen time span covers the implementation cycle of the pioneer zone policy (2017–2023) and encompasses both the pre-policy and post-policy periods. The enterprise financial data and corporate governance data used in this paper are sourced from the CSMAR and

Wind databases, while the list of pioneer zone pilot areas is drawn from official announcements published on the website of the Ministry of Agriculture and Rural Affairs. These data sources are widely recognized as authoritative in domestic academic research, ensuring the authenticity and reliability of the data.

Following the Industrial Classification for National Economic Activities (GB/T 4754) standard [41], this paper retains only the following nine categories of industries related to agriculture and agricultural product processing: agriculture, forestry, animal husbandry, and fishery; agricultural and sideline food processing; food manufacturing; manufacture of wine, beverages, and refined tea; textile industry; manufacture of leather, fur, feathers, and related products and footwear; wood processing and manufacture of wood, bamboo, rattan, palm, and straw products; furniture manufacturing; and pharmaceutical manufacturing. Given certain deficiencies in database coverage, the initial sample is further processed as follows: 1) enterprises that were placed under ST or *ST designation during the sample period are excluded; 2) enterprises with missing values in key variables are excluded; 3) enterprises that changed their registered domicile are excluded; 4) observations where core financial indicators such as total assets, net fixed assets, and operating revenue are zero or negative are excluded. After screening, the final sample consists of 819 continuously operating agricultural enterprises over the period 2005–2024, yielding a total of 7,684 observations.

Descriptive Statistics. Table 2 presents the mean, standard deviation, minimum, maximum, and number of observations for all variables. The mean value of agricultural enterprise total factor productivity (*TFP_OP*) is 6.492, with a minimum of 3.553 and a maximum of 9.576, indicating considerable variation in productivity levels across agricultural enterprises. The mean value of the pioneer zone policy shock (*Treat_Post*) is 0.292, suggesting that approximately 29.2% of the observations belong to the treatment group in the post-policy period, which satisfies the grouping requirements of the staggered difference-in-differences method. The standard deviation of this variable is 0.455, indicating significant temporal and cross-sectional variation in policy exposure within the sample period, providing a solid basis for identifying the policy effect in this study. The statistical characteristics of other variables align with the operational realities of listed agricultural enterprises, with no extreme outliers present.

Table 2. Descriptive statistics

Variable	Mean	SD	Min	Max	N
TFP_OP	6.492	0.720	3.553	9.576	7684
Treat_Post	0.292	0.455	0.000	1.000	7684
Size	21.881	1.039	19.415	26.424	7684
Lev	0.352	0.188	0.028	0.910	7684
ROA	0.047	0.071	-0.556	0.222	7684
SOE	0.280	0.449	0.000	1.000	7684
Quick	2.439	3.074	0.121	33.841	7684
Fixed	0.231	0.127	0.001	0.807	7684
Growth	0.125	0.365	-0.668	5.076	7193
Board	2.122	0.195	1.609	2.708	7684
Top1	0.344	0.143	0.075	0.758	7684
FirmAge	2.923	0.349	1.099	3.850	7684

5. Empirical Results and Analysis

Baseline Regression Analysis. To test Hypothesis H1, a fixed effects model is employed to examine the relationship between the pioneer zone policy and agricultural enterprise total factor productivity. The regression results are presented in Table 3. Column (1) reports a univariate regression including only the core explanatory variable *Treat_Post*, which yields a coefficient of 0.193, statistically significant at the 1% level. This preliminary result suggests a clear positive association between the pioneer zone policy and agricultural enterprise total factor productivity. Column (2) builds on Column

(1) by controlling for year fixed effects, industry fixed effects, and firm fixed effects, thereby eliminating heterogeneous shocks at the industry level and the influence of annual macroeconomic policies. The coefficient on *Treat_Post* remains positive and significant at the 1% level. Column (3) adds firm-level control variables—including firm size, asset-liability ratio, and return on assets—to the specification in Column (1), and the coefficient on *Treat_Post* continues to be positive and significant at the 1% level.

Column (4) presents the core baseline regression results of this paper. After simultaneously incorporating all control variables, industry fixed effects, year fixed effects, and firm fixed effects, the coefficient on *Treat_Post* is 0.133 and remains statistically significant at the 1% level. This result indicates that the implementation of the pioneer zone policy has significantly enhanced the total factor productivity of enterprises within the designated zones. Specifically, the policy has led to an average increase of 0.133 units in the total factor productivity of agricultural enterprises in the pilot areas, providing strong empirical support for the core research hypothesis of this paper.

Table 3. Baseline Regression Analysis

	(1)	(2)	(3)	(4)
VARIABLES	*TFP_OP*	*TFP_OP*	*TFP_OP*	*TFP_OP*
Treat_Post	0.193***	0.129***	0.164***	0.133***
	(4.275)	(3.039)	(5.835)	(3.627)
Size			0.403***	0.297***
			(20.451)	(9.297)
Lev			0.497***	0.207**
			(4.536)	(2.116)
ROA			1.884***	1.395***
			(9.342)	(7.529)
Quick			-0.009*	-0.002
			(-1.869)	(-0.451)
Fixed			-0.688***	-0.577***
			(-5.108)	(-5.476)
Growth			0.100***	0.188***
			(3.428)	(6.608)
Board			-0.204***	0.009
			(-2.966)	(0.136)
Top1			-0.054	-0.070
			(-0.497)	(-0.391)
FirmAge			0.074	0.126
			(1.302)	(0.523)
SOE			0.062	-0.165***
			(1.420)	(-3.575)
Constant	6.533***	5.883***	-2.254***	-0.498
	(189.411)	(38.772)	(-4.872)	(-0.603)
Observations	4,776	4,776	4,776	4,776
R-squared	0.018	0.221	0.540	0.428
Year FE	NO	YES	NO	YES
Firm FE	NO	YES	NO	YES

Note: 1) ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. 2) All regressions are estimated using heteroskedasticity-robust standard errors. 3) t-statistics are reported in parentheses. All subsequent tables follow the same notation conventions

Robustness Checks. To ensure the robustness of the baseline regression results, this paper examines the identification validity of the difference-in-differences model by conducting parallel trends tests, placebo tests, and PSM-DID tests.

Parallel Trends Test. The core identification assumption of the difference-in-differences model is that the treatment and control groups must satisfy the parallel trends assumption prior to the policy shock. That is, the trends in total factor productivity of agricultural enterprises within the Agricultural Green Development Pioneer Zones and those outside the zones should remain consistent before policy implementation. Following the specification of Sun et al. [5], the following regression model is constructed to conduct the parallel trends test:

$$TFP\_OP_{i,t} = \sigma + \sum_{\tau=-5}^{5} \theta_\tau Policy_{i,t-\tau} + \rho X_{i,t} + \gamma_t + \mu_i + \varepsilon_{i,t} \tag{2}$$

where $Policy_{i,t-\tau}$ represents the relative time dummy variable. If the region where enterprise i is located was approved as an the pioneer zone pilot in year $t-\tau$, the variable takes the value of 1; otherwise, it equals 0. $X_{i,t}$ denotes a series of firm-level control variables, $\gamma_t$represents year fixed effects, μ_i captures firm fixed effects, and $\varepsilon_{i,t}$ is the random error term. This paper uses the year prior to policy implementation as the baseline period. By testing the significance of the dynamic estimation coefficients in each period, we assess whether the parallel trends assumption holds. The dynamic effect trends are illustrated in Figure 1. The regression results show that the solid line represents the point estimates of the policy's dynamic effects in each period, while the upper and lower dashed lines indicate the 95% confidence intervals of the coefficients. The results reveal that in all window periods before the implementation of the pioneer zone policy, the 95% confidence intervals of the coefficients include zero, and the policy effects are not significant. This indicates that there was no difference in total factor productivity between treatment and control group enterprises prior to the policy shock, confirming that the parallel trends assumption holds and the identification premise of the difference-in-differences model is valid. After policy implementation, the coefficients gradually shift from negative to positive and continue to rise, reflecting that the promotional effect of the pioneer zone policy on agricultural enterprise total factor productivity exhibits some lag and is progressively released over time.

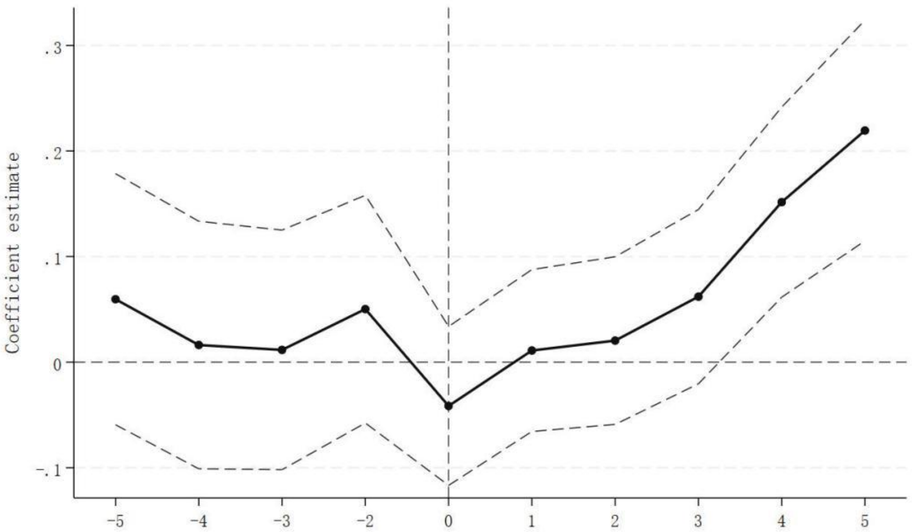

Fig. 1 Parallel Trends Test

Placebo Test. This paper employs a placebo test based on random assignment. The placebo test can verify whether other unobservable factors interfere with the difference-in-differences model, ensuring that the identified policy effect is indeed generated by the pioneer zone policy. The specific method is as follows: from the full sample, we randomly draw a sample with exactly the same number of observations as the actual pilot regions to serve as the pseudo-treatment group. The remaining samples constitute the pseudo-control group. We then construct the same policy shock interaction term and re-estimate the baseline regression model. By repeating the random sampling and simulation 500 times, we enhance the credibility of the test results. This yields 500 estimated coefficients for the pseudo-policy shocks.

Figure 2 presents the distribution of coefficients from the placebo test. The results show that the pseudo-policy coefficients obtained from 500 random simulations are primarily concentrated around zero, exhibiting an approximately normal distribution overall, which differs significantly from the true policy effect coefficient obtained in the baseline regression. Based on this, we can rule out the possibility that the regression results are driven by random factors or omitted variables.

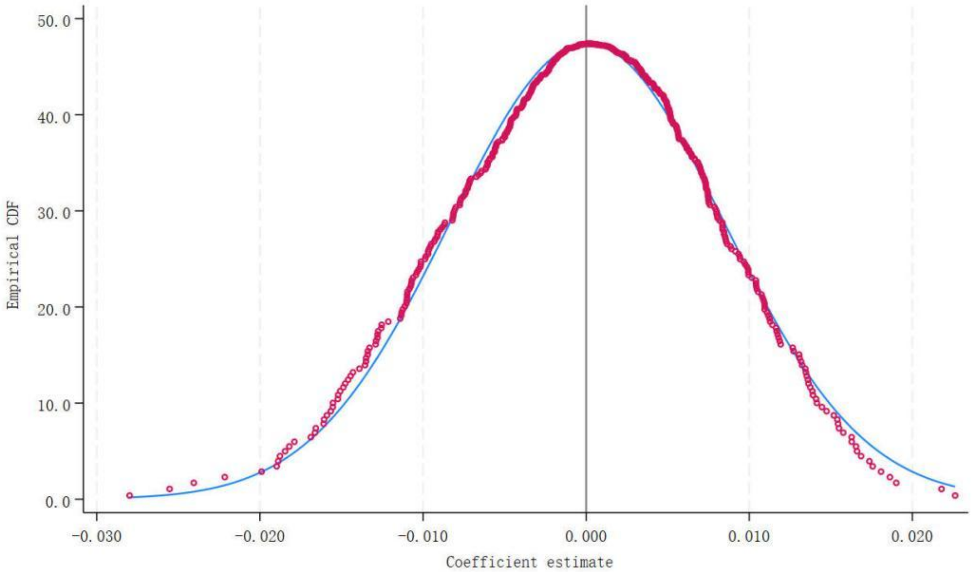

Fig. 2 Placebo Test

Placebo Test. The establishment of Agricultural Green Development Pioneer Zones is not entirely random. Factors such as a region's green development orientation, economic level, and agricultural foundation all influence whether that region can become a pilot area. This leads to differences between the treatment and control sample groups, resulting in sample self-selection bias. This endogeneity problem interferes with the accurate identification of the net policy effect in the baseline regression. Propensity Score Matching (PSM) mitigates endogeneity issues by matching treatment group samples with control group samples that have highly similar characteristics, so that the two groups differ only in the single factor of "whether they are affected by the policy shock." Therefore, this paper adopts the PSM-DID method to verify the robustness of the baseline regression. The specific method is as follows: the included variables are used as matching covariates and explanatory variables, with whether an enterprise belongs to the treatment group as the dependent variable. A Logit model is constructed to estimate each sample's propensity score for being within an Agricultural Development Pioneer Zone. Using 1:1 nearest neighbor matching, each treatment group enterprise is matched with a control group enterprise with the closest propensity score, completing the sample matching. Based on this, the difference-in-differences regression is re-conducted to eliminate the interference of inherent sample differences on policy effect identification. The results are shown in Table 4.

In columns (1) through (4), under different model specifications, the coefficients of Treat×Post are all significantly positive at the 1% level. Among them, column (4) represents the model that incorporates all firm-level control variables while controlling for both firm fixed effects and year fixed effects. The regression coefficient of Treat×Post is 0.133. This result indicates that after excluding other confounding factors, the implementation of the pioneer zone policy significantly increases the total factor productivity of treatment group enterprises by 13.3 units compared to the control group, which validates the research hypothesis of this paper.

Table 4. Placebo Test

	(1)	(2)	(3)	(4)
VARIABLES	TFP_OP	TFP_OP	TFP_OP	TFP_OP
Treat_Post	0.193***	0.129***	0.164***	0.133***
	(4.275)	(3.039)	(5.835)	(3.627)
Size			0.403***	0.297***
			(20.451)	(9.297)
Lev			0.497***	0.207**
			(4.536)	(2.116)
ROA			1.884***	1.395***
			(9.342)	(7.529)
Quick			-0.009*	-0.002
			(-1.869)	(-0.451)
Fixed			-0.688***	-0.577***
			(-5.108)	(-5.476)
Growth			0.100***	0.188***
			(3.428)	(6.608)
Board			-0.204***	0.009
			(-2.966)	(0.136)
Top1			-0.054	0.070
			(-0.497)	(-0.391)
FirmAge			0.074	0.126
			(1.302)	(0.523)
SOE			0.062	-0.165***
			(1.420)	(-3.575)
Constant	6.533***	5.883***	-2.254***	-0.498
	(189.411)	(38.772)	(-4.872)	(-0.603)
Observations	4,776	4,776	4,776	4,776
R-squared	0.018	0.221	0.540	0.428
Industry FE	NO			
Year FE	NO	YES	NO	YES
Number of stkcd		768		768
Firm FE		YES	NO	YES

6. Further Analysis

Heterogeneity Analysis. The baseline regression results verify the average promotional effect of the pioneer zone policy on the total factor productivity of agricultural enterprises. However, for agricultural enterprises with different operational characteristics and regional environments, the policy effects may vary. Therefore, this paper conducts heterogeneity analysis from three perspectives: enterprise asset intensity, regional location, and whether the enterprise is located in a major grain-producing area.

Heterogeneity by Asset Intensity. Agriculture-related enterprises can be classified into two categories: asset-heavy and asset-light. Asset-heavy agricultural enterprises primarily rely on fixed assets as production materials, such as planting and breeding greenhouses, agricultural machinery and equipment, and processing workshops. Asset-light agricultural enterprises mainly depend on human resources, distribution channels, and brands as production materials, with a low proportion of fixed assets and weak dependence on equipment and facilities. Generally speaking, agricultural enterprises with different asset intensities have different needs and are affected differently by policies. Asset-heavy enterprises face high costs for fixed assets and equipment procurement, with long replacement and upgrade cycles. Therefore, after the implementation of this policy, they may not experience rapid improvements in production efficiency in the short term, and the conversion of policy effects also requires a longer cycle. In contrast, asset-light enterprises upgrade and transform more quickly, with more flexible investment decisions. The policy subsidies they receive can be rapidly deployed into operations to release efficiency gains, thereby converting policy dividends into improvements in total factor productivity more rapidly.

The verification of this conjecture is shown in Table 5. Columns K1 and K2 demonstrate that the promotional effect of the pioneer zone policy exhibits significant differences based on asset structure. The policy's effect on improving the total factor productivity of asset-light agricultural enterprises is significantly positive at the 1% statistical level, while the policy effect on asset-heavy agricultural enterprises does not pass the statistical significance test. This result validates the conjecture of this paper and further confirms the robustness of the impact mechanism constructed in this study.

Heterogeneity by Regional Location. Enterprises in different regions of China experience variations in policy implementation effects due to the heterogeneity of regional development levels and market environments. This paper follows the regional classification standards issued by the National Bureau of Statistics, dividing agricultural enterprises in 31 provinces (autonomous regions and municipalities) nationwide into eastern, central, and western regions [42].

As shown in columns R1-R3 of Table 5, the interaction term coefficient for the central region group is 0.193, significantly positive at the 5% statistical level; the interaction term coefficient for the eastern group is 0.082, weakly significant at the 10% statistical level; the interaction term coefficient for the western group is 0.103 and does not pass the statistical significance test. This indicates that the promotional effect of the pioneer zone policy exhibits the characteristic of "strongest in the central region, followed by the eastern region, and insignificant in the western region." Possible explanations include: (i) The agricultural industry in the central region is a core pillar of the regional economy. Local governments attach greater importance to the policy, implement it more vigorously, have more comprehensive supporting policies, and allocate policy resources more favorably, resulting in a more prominent promotional effect. (ii) The eastern region has a high level of economic development, but agriculture accounts for a relatively low proportion of the regional economy. The resource allocation and targeting of the policy are weaker than in the central region, resulting in a weakly significant policy effect.(iii) Agricultural industry development in the western region is relatively weak, local fiscal capacity is limited, and enterprise technological levels and transformation capabilities are relatively insufficient, making it difficult to fully absorb the policy support benefits, preventing the policy's promotional effect from manifesting effectively.

Heterogeneity by Major Grain-Producing Areas. Major grain-producing areas and non-major grain-producing areas exhibit distinct regional characteristics in agricultural green development levels. Based on the province where enterprises are registered and according to the standards defined in the "National Medium and Long-term Food Security Plan (2008-2020)" issued by the State Council, sample enterprises are divided into major grain-producing provinces and non-major grain-producing provinces [43]. As shown in columns G1 and G2 of Table 5, the interaction term coefficient for the major grain-producing area group is 0.114, significantly positive at the 5% statistical level; the interaction term coefficient for the non-major producing area group is 0.059 and does not pass the statistical significance test. This indicates that the promotional effect of the green development pioneer zone policy is mainly concentrated in major grain-producing areas, with no significant impact on agricultural enterprises located in non-major grain-producing areas. A possible explanation is that major grain-producing areas bear the strategic function of national food security and have already formed mature intensive and large-scale production layouts. The policy transmission chain in this group is smoother, government implementation efficiency is higher, and they can provide targeted policy support to agricultural enterprises and precisely match the factor demands for their transformation and upgrading. In contrast, the agricultural industry accounts for a relatively low proportion of industrial development in non-major producing areas, and the alignment between policy supply and actual enterprise needs is low, making it difficult for the policy's promotional effect on enterprise total factor productivity to manifest effectively.

Table 5. Heterogeneity Analysis

	Capital intensity		Regional location			Major grain-producing area	
	K1	K2	R1	R2	R3	G1	G2
	Heavy asset	Light asset	Eastern	Central	Western	Major grain-producing area	Non-major grain-producing area
VARIABLES	TFP_OP	TFP_OP	TFP_OP	TFP_OP	TFP_OP	TFP_OP	TFP_OP
Treat_Post	0.029	0.159***	0.082*	0.193**	0.103	0.114**	0.059
	(0.794)	(2.828)	(1.841)	(2.476)	(1.123)	(2.207)	(1.148)
Size	0.245***	0.335***	0.297***	0.262***	0.305***	0.250***	0.315***
	(6.814)	(9.096)	(8.716)	(4.907)	(6.376)	(6.809)	(9.241)
Lev	0.165*	0.165	0.191	0.442**	0.223	0.416***	0.121
	(1.654)	(1.079)	(1.589)	(2.531)	(1.547)	(3.483)	(1.000)
ROA	1.166***	1.651***	1.344***	1.674***	1.654***	1.775***	1.361***
	(6.686)	(6.628)	(7.250)	(3.904)	(5.351)	(6.226)	(7.214)
Quick	-0.018**	0.001	-0.001	-0.010	-0.014	-0.006	-0.001
	(-2.105)	(0.260)	(-0.122)	(-1.294)	(-1.171)	(-0.971)	(-0.189)
Fixed	-0.500***	-1.373***	-0.571***	-0.834***	-0.915***	-0.758***	-0.608***
	(-3.832)	(-4.478)	(-3.964)	(-3.519)	(-4.707)	(-5.475)	(-4.202)
Growth	0.197***	0.193***	0.192***	0.168***	0.220***	0.189***	0.208***
	(8.138)	(6.656)	(5.848)	(3.717)	(6.001)	(5.525)	(7.584)
Board	0.197***	0.048	0.104	0.223	0.109	0.252***	0.021
	(3.041)	(0.464)	(1.539)	(1.404)	(0.936)	(2.627)	(0.296)
Top1	-0.254	-0.122	-0.026	-0.114	-0.358	-0.168	-0.184
	(-1.116)	(-0.468)	(-0.123)	(-0.277)	(-1.276)	(-0.609)	(-0.875)
FirmAge	0.128	0.511**	0.622***	-0.245	-0.083	0.159	0.426*
	(0.514)	(2.164)	(2.907)	(-0.527)	(-0.233)	(0.648)	(1.881)
SOE	-0.007	-0.127*	-0.056	-0.174**	-0.004	-0.100*	-0.048
	(-0.215)	(-1.850)	(-1.027)	(-2.204)	(-0.049)	(-1.885)	(-0.816)
Constant	0.113	-2.143**	-1.856**	0.578	-0.503	-0.206	-1.603*
	(0.121)	(-2.354)	(-2.134)	(0.484)	(-0.399)	(-0.246)	(-1.828)
Observations	3,669	3,524	4,416	1,391	1,386	3,004	4,189
R-squared	0.518	0.455	0.466	0.521	0.602	0.517	0.496
Number of stkcd	589	616	533	147	139	342	479
Firm FE	YES	YES	YES	YES	YES	YES	YES

7. Mechanism Analysis

The theoretical analysis above suggests that the pioneer zone enhances the total factor productivity of agricultural enterprises through two pathways: policy dividends and industrial agglomeration. Drawing on Baron and Kenny's research using enterprise financing constraints and enterprise innovation as mediating mechanisms affecting enterprise total factor productivity [12], and J. Sun et al.'s research using financing constraints and policy subsidies as mediating mechanisms affecting enterprise total factor productivity [45], this paper proposes sub-hypotheses that the pioneer zone policy's enhancement of enterprise total factor productivity can be verified through three indirect transmission mechanisms: government subsidies, technological innovation, and industrial agglomeration.

Therefore, to verify the rationality of the hypotheses, a mediation effect model is constructed based on the baseline regression model as follows:

$$M_{\mathrm{it}} = \varphi_0 + \varphi_1 Treat_{\mathrm{i}} \times Post_{\mathrm{it}} + \varphi \sum \mathrm{Control}_{\mathrm{it}} + \sum \mathrm{Year} + \sum \mathrm{Firm} + \varepsilon_{\mathrm{it}} \tag{3}$$

Where M represents the mediating variable, and other variables are consistent with the previous text. The mediating variables include: (i) Government subsidies (s*ub2*). Following H. Luo et al.'s [44] measurement method for government subsidies, the logarithm of annual government subsidies obtained by enterprises is used in the empirical analysis. (ii) Technological innovation (*Patent*). Following Wagner's [46] measurement method for enterprise technological innovation, the total number of patent applications filed by the enterprise in the current year is selected as the measurement indicator for enterprise innovation. (iii) Industrial agglomeration (*coagg*). Following J. Sun et al.'s [45] measurement method for industrial agglomeration, the location quotient method is used to analyze the degree of agglomeration.

The mechanism test results are shown in Table 5. Column (1) presents the results for the government subsidy mechanism (*sub2*). The Treat_Post coefficient is 0.001, significant at the 1% level, indicating that enterprises in the treatment group received significantly increased policy subsidies after policy implementation. This demonstrates that the pioneer zone policy transmits resource support to target agricultural enterprises through fiscal subsidies, special funds, and other measures, which can alleviate enterprise financing pressure and operating costs, thereby enhancing total factor productivity. Column (2) shows the results for the technological innovation mechanism (*Patent*). The *Treat_Post* coefficient is 0.193, significant at the 5% level, indicating that the policy's incentive effect on enterprise technological innovation is significant, with the patent output level of treatment group enterprises significantly higher than that of the control group. This result is consistent with the earlier assertion that the pioneer zone policy activates innovation momentum by helping enterprises transform and upgrade, providing technology promotion channels and innovation platforms, aligning with the expected hypothesis. Technological innovation can drive the transformation and upgrading of agricultural production methods and improve resource allocation efficiency, serving as the dominant transmission channel affecting enterprise total factor productivity in the policy dividend pathway. Combining theoretical analysis and empirical results, the pioneer zone policy enhances the total factor productivity of agricultural enterprises by increasing policy subsidies and incentivizing enterprise technological innovation to release policy dividends.

Column (3) presents the industrial agglomeration mechanism, with a Treat_Post coefficient of 0.137, significant at the 1% level, indicating that policy implementation has significantly enhanced the agglomeration level of agricultural enterprises within the region. The results demonstrate that the policy has optimized the industrial spatial layout, guiding upstream and downstream supporting resources to concentrate in the pioneer zones, forming large-scale industrial cluster effects, which aligns with the earlier analysis that industrial agglomeration reduces transaction costs among enterprises, promotes knowledge spillovers, and optimizes factor allocation. In summary, the pioneer zone policy can promote the enhancement of total factor productivity of agricultural enterprises through three indirect mechanisms: increasing policy subsidies, promoting enterprise technological innovation, and strengthening industrial agglomeration of agricultural enterprises within the region. Thus, *H1b* is verified.

Table 5. Mechanism Analysis

	(1)	(2)	(3)
VARIABLES	*sub2*	*Patent*	*coagg*
Treat_Post	0.001***	0.193**	0.137***
	(2.695)	(2.327)	(3.693)
Size	-0.001***	0.157**	0.027
	(-2.715)	(2.234)	(0.489)
Lev	0.001	0.032	0.031
	(0.853)	(0.136)	(0.225)
ROA	0.005**	0.267	0.403*
	(2.208)	(0.736)	(1.719)
Quick	-0.000	0.016	0.001
	(-0.467)	(1.268)	(0.328)
Fixed	0.003	0.719**	-0.110
	(1.519)	(2.317)	(-0.553)
Growth	-0.000	-0.017	-0.009
	(-1.329)	(-0.456)	(-0.716)
Board	0.000	-0.278	0.095*
	(0.160)	(-1.484)	(1.674)
Top1	-0.000	0.589	0.031
	(-0.145)	(0.952)	(0.186)
FirmAge	-0.002	0.269	0.004
	(-0.456)	(0.482)	(0.013)
SOE	-0.001	-0.128	-0.106***
	(-0.683)	(-0.724)	(-3.204)
Constant	0.037**	-2.556	2.124*
	(2.404)	(-1.162)	(1.775)
Observations	3,724	3,724	3,724
R-squared	0.030	0.025	0.065
Firm FE	YES	YES	YES
Year FE	YES	YES	YES

8. Conclusions and Recommendations

Against the backdrop of comprehensively advancing agricultural modernization and green sustainable development transformation, enhancing the total factor productivity of agricultural enterprises is an important objective for implementing the "15th Five-Year Plan" for agricultural development. This paper selects A-share listed agricultural companies from 2005 to 2024 as research samples and uses a staggered difference-in-differences model to empirically verify that the pioneer zone policy can effectively enhance the total factor productivity of agricultural enterprises through two pathways: releasing policy dividends and promoting industrial agglomeration. The research conclusions not only provide empirical evidence for evaluating the micro-level effects of agricultural green pilot policies but also offer useful policy references for continuously optimizing agricultural support policies and advancing green sustainable agricultural development in the new era.

Based on the above research conclusions, the following policy recommendations are proposed: First, increase fiscal subsidies. The fiscal subsidies of the pioneer zone policy are an important institutional arrangement for alleviating the cost pressures on agricultural enterprises' existing business operations under green transformation demands. Agricultural machinery purchase subsidies, green technology rewards, and insurance premium subsidies for important agricultural products can effectively improve enterprise financial conditions. According to this study's findings, policy subsidies should prioritize major grain-producing areas and asset-light enterprises. Therefore, it is necessary to optimize the fiscal fund support structure, establish differentiated subsidy mechanisms, and avoid inefficient fund allocation. Second, fully leverage the role of technological innovation, continuously promote green technology and equipment transformation, and incentivize enterprise technological innovation. In addition to providing a favorable external environment through technology support and innovation technology subsidies, policies should focus on attracting high-quality talent and providing talent support policies to help enterprises conduct independent innovation. Especially for capital-intensive, large-scale agricultural enterprises with stronger innovation transformation capabilities, it is necessary to accelerate the establishment of green technology promotion and transformation platforms to build a long-term mechanism for green development through technological innovation. Third, optimize industrial layout and infrastructure, guide factor agglomeration, and amplify industrial agglomeration effects. The government should cultivate regional characteristic agriculture according to local conditions, accelerate the completion of infrastructure construction such as farmland water conservancy, focus on promoting the formation of large-scale industrial clusters in central regions and major grain-producing areas, develop supporting agricultural industrial chains, and avoid scattered layouts. Comprehensively enhance the total factor productivity of agricultural enterprises through industrial agglomeration effects.

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