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Big hands holding small hands: The role of new agricultural operating entities in farmland abandonment

Linyi Zheng

China Academy for Rural Development (CARD), School of Public Affairs, Zhejiang University, Hangzhou, China

ARTICLE INFO ABSTRACT Keywords: It is crucial to address farmland abandonment to achieve Zero Hunger according to the United Nations' sus-New agricultural operating entity tainable development goals. However, quantitative research on this topic is relatively lacking. Based on a large Panel Tobit model sample of panel data from the Chinese Family Database, this study applies a panel Tobit model to examine the Farmland abandonment relationship between new agricultural operating entities (NAOEs) and farmland abandonment. The results show Food security that NAOEs-professional operators, family farms, and agricultural cooperatives-are negatively and signifi-Sustainable development cantly associated with the ratio of abandoned farmland areas. This effect is achieved through channels such as promoting land leasing, providing technical guidance, and facilitating the sale of agricultural products. Additionally, NAOEs benefit more from China's central and western regions, mountainous areas, villages with better land tenure security, and households with poorer human resource endowments. These findings provide valuable insights for policymakers to ensure food security and promote sustainable development by cultivating various large-scale farming entities.

1. Introduction

Zero Hunger, which encompasses ending hunger, ensuring food security, and promoting sustainable agriculture, is a crucial component of the United Nations Sustainable Development Goals. However, the current state of food security and nutrition is concerning, and meeting the Zero Hunger target by 2030 presents a formidable challenge. Despite the gradual fading of the impact of the COVID-19 pandemic since 2022, the global food supply chain continues to face significant disruptions due to frequent extreme weather events, the ongoing conflict between Russia and Ukraine, and the growing prevalence of food trade protectionism (Andrianarimanana et al., 2023; Hasegawa et al., 2021; Olabisi et al., 2021; Zheng et al., 2023a). According to the State of Food Security and Nutrition in the World 2023, released jointly by the Food and Agriculture Organization of the United Nations, the World Food Programme, and other international organizations, approximately 2.4 billion people, or 29.6 % of the world's population, experienced severe food insecurity in 2022. Furthermore, the number of hungry individuals worldwide increased 735 million, reflecting an increase of 122 million since the pre-pandemic period of 2019 (FAO, 2023).

The importance of farmlands for food security and nutrition cannot be overstated. Farmland is the foundation of food production and directly or indirectly provides all food needed for human survival and development. On average, 83 % of the 697 kg of food individuals consume yearly, 93 % of the 2884 kcal consumed daily, and 80 % of the 81 g of protein consumed daily come from farmlands (FAOSTAT, 2018). However, owing to rapid industrialization and urbanization, farmland abandonment has become a major global problem (Zheng et al., 2023b). Campbell et al. (2008) estimated that, since the 20th century, the area of abandoned farmland worldwide ranged from 385 million to 472 million ha. Farmland abandonment not only wastes land resources but also has serious negative impacts on food security. Recent empirical evidence from China reveals that, in 2020, approximately 49.23 million tons of food were lost owing to farmland abandonment, which accounted for 7.36 % of total grain production that year (Wang et al., 2023).

The severe situation of farmland abandonment and its far-reaching impacts have garnered significant attention from scholars worldwide, resulting in a wealth of research. In summary, the literature on farmland abandonment focuses mainly on two aspects: driving factors and various impacts. Numerous studies have indicated that factors such as harsh terrain conditions (Han and Song, 2019; Zavalloni et al., 2021), remote geographical location (Lieskovsky and Lieskovska, 2021; Xu et al., 2019; Zhang et al., 2014), land fragmentation (Deininger et al., 2012; Zheng et al., 2023b), labor shortages (Meyfroidt et al., 2016; Xu et al., 2019), low agricultural returns (Yan et al., 2016), and imperfect land markets and land systems (Deininger et al., 2012; Zheng and Qian, 2022) all

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E-mail address: zheng01@zju.edu.cn.

contribute to farmers abandoning their farmland. Additionally, it is important to note that besides food security, farmland abandonment also exerts significant negative effects on biodiversity (Müller et al., 2013; Queiroz et al., 2014), as well as cultural and aesthetic values (Elbakidze and Angelstam, 2007; Tseng et al., 2021).

Although a few scholars have attempted to assess farmland abandonment in terms of technology, machinery, and institutions (Deng et al., 2019; Ma et al., 2022; Zheng and Qian, 2022), little is known regarding solutions for curbing farmland abandonment, especially from the perspective of agricultural operators. Only Ma and Zhu (2020) have quantified the relationship between agricultural cooperatives and farmland abandonment in China. Employing data from the 2016 China Labor-Force Dynamics Survey, they found that establishing agricultural cooperatives in villages could help reduce the likelihood of farmland abandonment by 0.8 % and the abandonment rate by 0.2 %. Although their study provides a basis for this study, it also highlights areas for further improvement. Ma and Zhu (2020) did not thoroughly investigate the relevant mechanisms and heterogeneous effects at the village and household levels, leaving some questions unanswered. Simultaneously, although the proportion of farmers who did not abandon farmlands was as high as 85 % in their data, they did not address potential censored data issues, which could skew their findings. Moreover, they focused solely on agricultural cooperatives, neglecting the roles of other agricultural operators.

The New Agricultural Operating Entity (NAOE) is a large-scale farming entity in the Chinese context; in addition to agricultural cooperatives, it also includes professional operators, family farms, and farming companies (Huang and Liang, 2018). The NAOE was proposed in contrast to traditional smallholder farmers, characterized by smallscale, semi-subsistence farming. Compared with smallholder farmers, NAOEs usually have a larger scale of operation, better material equipment conditions, and strong management capabilities. They are agricultural business organizations with commercial production and profit maximization as their main objectives. Theoretically, when NAOEs help farmers benefit from agricultural activities, farmers are less likely to abandon their farmland. According to public information reports,¹all kinds of NAOE currently operate approximately 30 % of farmland, and support 127 million farmers, increasing farmers' average annual income by over 3,500 yuan (1 dollar = 7.23 yuan). Therefore, developing various types of NAOEs, including professional operators, family farms, farming companies, and agricultural cooperatives, helps curb farmland abandonment and ensure food security, thus contributing to achieving Zero Hunger as per United Nations Sustainable Development Goals.

Given the diversity and importance of NAOEs in rural China, our study evaluates their impact of NAOE on farmland abandonment using newly released panel data from the Chinese Family Database (CFD), to enrich existing studies and provide references for other countries in order to solve the problem of farmland abandonment. Specifically, I add to the existing literature in three ways. The first is the research perspective; unlike existing studies that focus on the driving factors and various impacts of cropland abandonment, this study is one of the few to focus on the governance of farmland abandonment, especially from the perspective of various agricultural operators. The second aspect concerns the research content; I estimate whether and how NAOEs affect farmland abandonment, and its heterogeneous effects across regions, villages, and households. The third aspect concerns research data and methodology; I employ two-period nationally representative farm-level data and a panel Tobit model to address censored data issues, making estimates more accurate and realistic.

2. Background and theoretical analysis

2.1. Development of NAOE in China

Since the reform and opening-up in 1978, China has witnessed accelerated industrialization and urbanization, adjustment of its agricultural industry, and changes in the basic rural management system (Anderson and Strutt, 2014; Li, 2017). Consequently, farm households in rural China have gradually divided, with some smallholder farmers withdrawing from agricultural production, and others evolving into various types of NAOEs characterized by large-scale market-oriented operations (Huang and Liang, 2018). Smallholder farmers and various types of NAOEs constitute all agricultural operators in China.

NAOE is a general term for professional operators, family farms, farming companies, and agricultural cooperatives, as defined by the Chinese government. Table 1 presents the differences and connections between the four types of NAOEs. Among them, professional operators are agricultural operators whose family labor time is mostly spent in one agricultural industry; their income accounts for over 80 % of the total household income. Moreover, their production scale for planting or breeding is significantly larger than that of the local smallholder farmers. Family farms are agricultural operation organizations registered with local governments and engaged in large-scale, intensive, and commercialized agricultural production and operations using the family's labor as a business unit. Compared with professional operators, family farms not only require government recognition but also have higher requirements for intensification, management, and stability of production and operation. Farming companies are economic organizations that adopt modern enterprise management methods, engage in large-scale, intensive, commercialized agricultural production, and implement independent management and self-financing strategies. Compared with other NAOEs, farming companies usually have strong economic strength, advanced production technology, and modern management personnel, and have significant advantages in adapting to volatile market environments and responding to fierce international competition. Agricultural cooperatives are mutual economic organizations organized by operators of similar agricultural products and providers and users of similar agricultural production factors or services under the principles of voluntary association and democratic management and registered with the local government. Through cooperation and collaboration among farmers, agricultural cooperatives can address the inefficiencies of traditional family-based operations and achieve mutual production assistance, benefit-sharing and risk-sharing, thus promoting sustainable agricultural development.

With the strong support of the Chinese government, various types of NAOEs have developed rapidly and gradually grown into important main bodies and backbone forces for China to develop modern agriculture, ensure national food security, and drive smallholder farmers to become rich together. According to public data from China's Ministry of Agriculture and Rural Affairs,²by the end of September 2021, there were more than 3.8 million family farms nationwide, with an average of 134.3 mu (1 mu = 1/15 ha) of farmland per family farm and a total annual operating income of nearly 890 billion yuan; Simultaneously, 2.23 million agricultural cooperatives, with a total annual operating income of more than 588 billion yuan, driving nearly half of the smallholder farmers across China, and 90,000 farming companies at or above the county level, created jobs for 17 million rural households. This evidence indirectly reveals the potential impact of NAOEs on land use, agricultural production and farmers' well-being. Therefore, it is of great practical significance to investigate the role of NAOEs in reducing farmland abandonment.

¹ The data can be accessed from https://www.npc.gov.cn/npc/c30 834/202112/e0995f9916d747e38bcc7deafda97048.shtml.

² The data can be accessed from https://www.npc.gov.cn/npc/c30 834/202112/e0995f9916d747e38bcc7deafda97048.shtml.

Table 1

Comparison of various types of NAOEs in rural China.

*				
Types	Sources	Enrollment	Characteristics	Advantages
Professional operator	Smallholder farmers	No	Family labor dominates; it is engaged in farming or breeding	Specialized production
Family farm	Smallholder farmers, large professional farmers	Yes	Family labor dominates; it is engaged in farming, breeding, processing agricultural products or leisure tourism	Diversification
Farming company	Smallholder farmers, large professional families, family farms, entrepreneurs	Yes	Wage labor dominates; it is engaged in planting, breeding, processing and selling agricultural products, agricultural technology research and development	Strong capital, advanced technology, efficient management
Agricultural cooperative	Association of numerous small farmers with village collective economic organizations or new agricultural operating entities	Yes	Wage labor dominates; it is engaged in planting, breeding, processing and marketing agricultural products, and provides agricultural socialization services	Mutual assistance in production, benefit and risk sharing

Notes: The distinctions between various types of NAOEs in China and other countries, especially developed countries in Europe and the United States, are as follows: first, NAOEs are built on non-private land property rights, predominantly through leasing rather than purchasing land to expand production scale; second, NAOEs are restrained by the limited resource endowment of a larger population and less land, resulting in a relatively small land size; third, due to the geographical constraints of more mountains and fewer plains, small and medium-sized agricultural machinery dominates.

2.2. Potential channels for NAOEs to curb farmland abandonment

Farmland abandonment results from the combined effects of multiple factors, including natural, economic, social, cultural, institutional, and technological factors (Díaz et al., 2011; Meyfroidt et al., 2016; Müller et al., 2013). In the Chinese context, numerous studies have shown that farmland abandonment among farmers is mainly due to poor land leases (Zheng and Qian, 2022), insufficient labor (Ma et al., 2022; Xu et al., 2019), low productivity (Yan et al., 2016), and difficulties in selling agricultural products (Han and Song, 2019). Fortunately, various types of NAOEs can theoretically help farmers break the above restrictions by promoting land leases, increasing the adoption of machinery, strengthening technical guidance, and assisting in agricultural product sales, thus curbing farmland abandonment (Fig. 1).

First, NAOEs can help reduce abandoned farmland by promoting land leases. Compared with smallholder farmers, NAOEs tend to have a higher demand for land and operate more land areas, making it easier to obtain economies of scale. Thus, NAOEs create demand for land and establish a platform for land trading (Ito et al., 2016). Therefore, when farmers do not want to cultivate their farmland, they can rent it to the NAOE instead of leaving it unproductive. Furthermore, previous studies indicate that farmers can receive higher land rents by renting farmland to NAOEs rather than nearby smallholders (Fu et al., 2022; Qiu et al., 2020). Consequently, the emergence of NAOEs can create conditions and incentives for farmers to rent their farmland, thereby reducing the probability of farmland abandonment (Liu et al., 2023). Based on this, I propose the following hypothesis:

Hypothesis 1: NAOEs promote farmers' land leases, reducing the likelihood of farmland abandonment.

Second, NAOEs can curb farmland abandonment through increased adoption of agricultural machinery. Various types of NAOEs, with their

superior economic strength compared to smallholder farmers, typically purchase a variety of agricultural machinery and equipment covering all aspects of crop cultivation, planting, and harvesting to meet the needs of mechanized agricultural production and further improve agricultural productivity (Ma et al., 2022). Therefore, when an NAOE's agricultural machinery is idle, nearby farmers can also rent it or purchase their agricultural machinery services for agricultural production. Moreover, when farmers realize that an NAOE's certain agricultural machinery equipment is more cost-effective, they may also imitate them and purchase this type of agricultural equipment independently (Liu et al., 2022). By using agricultural machinery, farmers can effectively alleviate the shortage of labor in agricultural production, thereby reducing the occurrence of abandoned farmland (Zheng et al., 2023b). Therefore, I propose the following hypothesis:

Hypothesis 2: NAOEs increase farmers' adoption of agricultural machinery, reducing the likelihood of farmland abandonment.

Third, NAOEs can strengthen their technical guidance for curbing farmland abandonment. NAOEs possess a more contemporary business management philosophy and superior production technology than smallholder farmers, thus effectively using resource factors. Consequently, the agricultural productivity of these entities is relatively high (Huang and Liang, 2018). Owing to NAOE's unique technological advantages, the Chinese government has successively issued a series of documents, such as the Opinions on Accelerating the Construction of a Policy System for Fostering New Agricultural Operating Entities, the Opinions on Promoting the Organic Connection between Smallholder Farmers and Modern Agricultural Development, and the Notice on Implementing Actions to Enhance New Agricultural Operating Entities, encouraging NAOEs to drive the development of smallholder farmers (Zheng et al., 2023b). In this scenario, nearby smallholder farmers can receive agricultural technical guidance from NAOEs, enabling them to



Fig. 1. Analytical framework.

improve their agricultural skills through learning and imitation (Li, 2017). Applying advanced agricultural technologies can significantly increase agricultural productivity, potentially reducing farmers' likelihood of abandoning farmland due to farming challenges. Thus, I postulate the following hypothesis:

Hypothesis 3: NAOEs provide technical guidance to farmers, reducing the likelihood of farmland abandonment.

Finally, NAOEs can reduce farmland abandonment by helping farmers sell their produce. NAOEs have greater bargaining power in the agricultural market than smallholder farmers. They effectively organize agricultural production activities according to market demand and market their products through multiple channels, including e-commerce and live broadcasting of agricultural products. This approach has enabled them to commercialize agricultural products and obtain more stable economic returns (Huang and Liang, 2018). Consequently, with the aid and influence of NAOEs, farmers are likely to diversify their agricultural product sales channels, thus alleviating the challenges they face in selling agricultural products to various extents (Tadesse et al., 2019). Farmers can ensure their farm income when most agricultural products enter the market, making it less likely for them to abandon their farmland (Ma and Zhu, 2020). This is because when agricultural products cannot be transformed into income-generating commodities, they negatively affect farmers' enthusiasm for farming. Based on this understanding, the final hypothesis is proposed as follows:

Hypothesis 4: NAOEs help farmers sell their agricultural products, reducing the likelihood of farmland abandonment.

3. Research design

3.1. Data sources

The data employed in this study were obtained from the 2017 and 2019 Chinese Family Databases (CFD), which are available on the website (source: https://ssec.zju.edu.cn/sites/main/template/news. aspx?id = 51027) for public applications. The survey was led by Zhejiang University and implemented in conjunction with other Chinese universities, such as Anhui University and Fujian Agriculture and Forestry University. To ensure the national representativeness of the dataset, the survey adopted a sampling method that used a combination of stratified, three-stage, and proportional population size (PPS) sampling to collect data from farm households and village directors (grassroots leaders) in 29 provinces (excluding Xinjiang and Xizang) across the country. Given the focus of this study, I excluded households without farmland from data cleansing. Meanwhile, I retained key variables including NAOE, farmland abandonment, land leases, agricultural machinery, technical guidance, sales of agricultural products, individual characteristics of household heads, and family characteristics. Additionally, I deleted observations with missing information from these variables. Finally, I obtained unbalanced panel data over two periods with a sample of 15,680 farm households for the estimation. Of these, 1,438 farm households reported abandoning farmland, whereas the remaining 14,242 did not, accounting for 9.17 % and 90.83 %, respectively.

3.2. Empirical strategy

As indicated previously, the vast majority of farm households in the sample used in this study did not abandon their farmland, implying that the dependent variable is truncated and restricted, so that the Ordinary Least Squares (OLS) estimate with a censored dependent variable may be inconsistent and biased. To avoid this, Tobin (1958) proposed a Tobit model with Maximum Likelihood Estimation (MLE) to address censored dependent variables. The Tobit model, also known as the restricted dependent variable model and the sample selection model is a model in which the dependent variable takes the value if it satisfies certain constraints. Furthermore, panel data for which some dependent variable

observations are compressed to a single point can be fitted using a panel Tobit model. Thus, I used a panel Tobit model that accounts for the distributional characteristics of the dependent variable and the type of panel data. Note that there are two types of panel Tobit models: fixed effects and random effects; however, Tobit models with unconditional fixed effects tend to be biased. Therefore, I followed the research of Shuai and Fan (2020) and adopted a random effects model for maximum likelihood estimation. Specifically, assuming that the panel data has J farm households and T periods, the panel Tobit model can be specified as follows:

$$Y_{vjt}^{*} = \alpha_0 + \alpha_1 NAOE_{vt} + \beta Z_{vjt} + \varepsilon_{vjt}$$
⁽¹⁾

$$Y_{vjt} = \begin{cases} Y_{vjt}^*, Y_{vjt}^* \ge 0\\ 0, Y_{vjt}^* < 0 \end{cases} j = 1, \dots, J \text{ and } t = 1, \dots, T$$
(2)

$$\varepsilon_{vit} N(0, \sigma 2)$$
 (3)

where *j* denotes the farm household, *v* denotes the village, and *t* denotes the year. Y_{vit}^* indicates potential farmland abandonment, whereas Y_{vit} is actually occurred; the latter is the dependent variable in this study, which is specifically defined as the ratio of abandoned farmland area to total farmland area in year t for farm household j in village v, and takes a value between 0 and 1. When the value of Y_{vit} is greater than or equal to 0, the actual observation is considered, and vice versa, the observation is left-truncated to zero. Regarding the core independent variable, using NAOE at the household level is prone to self-selection, resulting in biased estimates. Therefore, I use NAOE at the village level to investigate its impact on farmland abandonment. Specifically, NAOE represents the four types of NAOEs, including professional operators, family farms, agricultural cooperatives, and farming companies. When there are one or more types of NAOEs in a village, it takes the value of 1, and vice versa, it takes the value of 0. α_0 is the intercept term, α_1 and β are the parameters to be estimated, and ε_{vit} is the random disturbance term.

Additionally, Z_{vjt} is a series of control variables that may affect farmers' farmland abandonment behavior. Based on prior literature and data availability, the control variables selected in this study include individual characteristics, such as the gender of the head of household (Ma and Zhu, 2020), age and its square (Zhang et al., 2014), and educational status (Deininger et al., 2012), as well as family characteristics such as dependency ratio (Zheng and Qian, 2022), family size (Zavalloni et al., 2021), off-farm employment (Xu et al., 2019), land size (Wang et al., 2023), land fragmentation (Zheng et al., 2023b), and agricultural assets (Deng et al., 2019). These control variables also help alleviate the endogeneity problem caused by omitted variables.

3.3. Sample characteristics and descriptive statistics

Table 2 provides the definitions and descriptions of the selected variables. For the dependent variable, the average abandoned farmland for each sample farmer accounted for 4.3 % of the total farmland area. With regard to the core independent variable, approximately 67 % of the sampled villages nationwide had various types of NAOEs, such as professional operators, family farms, agricultural cooperatives, and farming companies. Concerning individual characteristics, approximately 85 % of the heads of households in the survey sample were male. The mean age of heads of households was approximately 54, and only 12 % of them had attended high school. Regarding household characteristics, the average dependency ratio of the sample farmers was 34.9 %. On average, each sample farm household comprised approximately four family members, one-fifth of whom were engaged in non-farm work. The sample farmers had poor land endowments, with an average household of 5.6 plots and less than 3 mu of farmland per household member. Additionally, the survey showed that each sample farmer owned approximately 5,000 farm assets.

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Table 2

Variable definitions and descriptive statistics (N = 15,680).

Variables	Definition	Mean	SD	Min	Max
Farmland abandonment	Ratio of abandoned farmland area to total farmland area (0–1)	0.043	0.154	0	1
New agricultural operating	Is there a professional operator, family farm, agricultural cooperative, or farming company in the	0.670	0.470	0	1
entities	village? (yes $= 1$, no $= 0$)				
Gender	Is the head of the household male? (yes $= 1$, no $= 0$)	0.849	0.358	0	1
Age	Age of the head of household	53.603	10.674	16	69
Education	Did the head of the household attend high school? (yes $= 1$, no $= 0$)	0.120	0.324	0	1
Dependency ratio	Dependency ratio of children and the elderly (0–5)	0.349	0.478	0	5
Family size	Number of family members	3.642	1.708	1	13
Off-farm employment	Ratio of off-farm employment in the household (0-1)	0.222	0.296	0	1
Land size	Household farmland area per capita (mu)	2.982	6.089	0.001	360
Land fragmentation	Number of farmland plots	5.601	6.083	1	120
Farm assets	Value of domestic livestock and machinery (unit: yuan)	5010.964	20350.150	0	500,000

3.4. Descriptive statistics on NAOE and farmland abandonment

Before conducting the formal econometric analysis, I drew group bars and scatter charts to explore the relationship between NAOE and farmland abandonment. Fig. 2 shows the results obtained using CFD. The bar chart on the left shows that in both 2017 and 2019, the ratio of abandoned farmland areas in villages with NAOEs was lower than that in villages without NAOEs. Moreover, from 2017 to 2019, regardless of whether villages had NAOEs, the ratio of abandoned farmland areas increased. Additionally, the scatter chart on the right shows that farmland abandonment negatively correlates with NAOE. The above evidence suggests that the development of NAOEs may help curb the expansion of farmland abandonment.

4. Impact of NAOE on farmland abandonment

4.1. Main results

Table 3 presents the estimates using panel Tobit models. Column (1) includes no control variables. On this basis, columns (2) and (3) accumulate individual characteristics and family characteristic variables, respectively. Note that the estimated coefficients are not straightforward for the panel Tobit model. Therefore, I calculated and reported the results of the average marginal effects for a better interpretation. In all three models, the estimated coefficients for NAOE are -0.013, significant at the 1 % level. This suggests that omitted variables are unlikely to disturb the above estimates. Regardless of the inclusion of control variables, NAOE always has a significant inhibitory effect on farmland abandonment. Specifically, owing to the presence of NAOE in villages, the ratio of abandoned farmland areas in rural China decreased by 1.3 %. The average abandonment ratio over the sample period is 4.3 %, which means that from 2017 to 2019, the presence of NAOE is to reduce farmland abandonment by approximately 30.2 % (1.3/4.3 × 100).

Among the control variables, male household heads are less likely to abandon their farmland, possibly because they are generally more physically energetic than women. Age and its squared coefficients share an inverse and significant relationship, implying a nonlinear relationship between the age of the household head and farmland abandonment. Specifically, before the age 50 years (-0.007/(-2 \times 0.00007)), the probability of householders abandoning farmland decreases due to increased energy and experience. Once they reach or exceed this age, their likelihood of abandoning farmland increases because of reduced physical fitness (Zhang et al., 2014). Education appears to negatively affect farmland abandonment, suggesting that more educated household heads have better agricultural management skills than less educated ones and are therefore less likely to abandon their farmland (Zheng et al., 2023b). The dependency ratio significantly exacerbates farmland abandonment, whereas family size significantly reduces farmland abandonment. These findings indicate that labor-poor households are more likely to abandon their farmland (Zheng and Qian, 2022). The variable representing off-farm employment positively affects farmland

abandonment, which is consistent with the findings of Xu et al. (2019). The negative and significant coefficient of land size implies that farmers with more farmland resources do not easily abandon their farmland. This is probably because income from these farmland areas can sustain their livelihoods (Wang et al., 2023). The coefficient of land fragmentation is positive and significant, suggesting that more fragmented plots are more likely to abandon farmland due to high agricultural production costs (Zheng et al., 2023b). The results show that farm assets significantly reduce farmers' farmland abandonment. This can be explained by the fact that households with more farm assets have higher agricultural productivity and enthusiasm for agriculture, and are, therefore, less likely to abandon farmland (Deng et al., 2019).

4.2. Robustness checks

I performed various additional robustness checks to confirm the reliability of the previous estimates. The corresponding estimates are listed in Table 4.

First, I re-estimated Equation (2) by replacing the original NAOE dummy variable with the logarithm of the NAOE number. Column (1) shows that after redefining the core independent variable, NAOE still contributes to reducing the occurrence of farmland abandonment by farmers. Moreover, the greater the number of NAOE in villages, the less likely farmers are to abandon their farmlands. This estimate somewhat alleviates the endogeneity problem caused by measurement errors.

Second, referring to Zheng and Qian (2022), I further used the logarithm of the abandoned farmland area to replace the abandoned farmland ratio. As shown in column (2), regardless of whether the dependent variable is replaced, the estimated coefficient of NAOE is significantly negative at the 1 % level. This finding is consistent with that in Table 3, which once again demonstrates NAOE's positive role in reducing farmland abandonment.

Third, I applied the panel random effects model instead of the panel Tobit model without considering the truncation feature of the dependent variable observations. Column (3) indicates a slight decrease in the estimated coefficient for NAOE compared with column (3) of Table 3. However, it remains significantly negative at the 1 % level, indicating that previous estimates are robust and that the Tobit model is not undervalued.

Fourth, although the data in this study are primarily a sample of farm households, they are theoretically unlikely to be NAOEs under CFD's sampling strategy. However, to rule out this suspicion, I also tried to employ a sample of smallholder farmers with a farming area of less than 25 mu for a robust estimation³ when CFD could not identify whether the samples were NAOEs. Column (4) shows that NAOE still significantly reduces farmland abandonment.

Finally, I considered the village traffic and economy variables in

³ Whether the farming area is more than 25 mu is an important criterion for distinguishing large-scale farmers in China's third national agricultural census.



Fig. 2. Correlation between NAOE and farmland abandonment.

Table 3	
NAOE and farmland abandonment: Baseline results.	

	Ratio of abandoned farmland area to total farmland area			
	(1)	(2)	(3)	
NAOE	-0.013***	-0.013***	-0.013***	
	(0.004)	(0.004)	(0.004)	
Gender		-0.022^{**}	-0.013^{**}	
		(0.006)	(0.006)	
Age		-0.007***	-0.007***	
		(0.001)	(0.001)	
Age ²		0.00008***	0.00007***	
		(0.000)	(0.000)	
Education		-0.014**	-0.016**	
		(0.007)	(0.007)	
Dependency ratio			0.017***	
			(0.005)	
Family size			-0.004**	
			(0.001)	
Off-farm employment			0.037***	
			(0.008)	
Land size			-0.003***	
			(0.001)	
Land fragmentation			0.004***	
			(0.000)	
Farm assets (log)			-0.004***	
			(0.001)	
Mean of dependent variable	0.043	0.043	0.043	
Observations	15,680	15,680	15,680	
Log likelihood	-4937.216	-4904.019	-4738.085	

Notes: ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively; Delta-method standard errors are presented in parentheses.

conjunction with the availability of data to mitigate the interference of such omitted variables at the village level. Column (5) confirms that accounting for these village-level variables, the inverse association between NAOE and farmland abandonment persists.

In conclusion, the above analyses from different perspectives support the baseline estimates in Table 3 for various dimensions, confirming the negative relationship between NAOE and farmland abandonment.

4.3. Endogeneity discussion

Endogeneity problems caused by measurement bias and missing variables can be avoided by replacing the core independent variable and adding control variables. However, whether there is an endogeneity problem due to selection bias in this study is worthy of further discussion. To this end, I used a propensity score matching (PSM) approach to re-estimate the impact of NAOE on farmland abandonment. To obtain accurate estimates, I employed three commonly used matching methods: nearest neighbor (NN) matching within caliper (n = 4, r = 0.05), radius matching (r = 0.05), and kernel matching (bandwidth = 0.03). Results in Table 5 show that the average treatment effect (ATT) for NAOE remains positive and significant regardless of the matching method used. This indicates that our findings are highly consistent with previous estimates, even in the face of a potential selection bias.

4.4. Mechanism analysis

We further explored the underlying mechanisms after confirming the negative correlation between NAOE and farmland abandonment. As noted earlier, I examined the effects of NAOE on land leases, machinery adoption, technical guidance, and the sale of agricultural products to uncover the channels through which NAOE affects farmland abandonment. Specifically, land leases were defined as whether farmers rented out the land (yes = 1, no = 0). Machinery adoption was defined as whether farmers adopted machinery for agricultural production (yes = 1, no = 0). Technical guidance was defined as whether farmers received technical guidance on agricultural production (yes = 1, no = 0). Agricultural product sales were defined as whether farmers sold agricultural products (yes = 1, no = 0).

Table 6 provides the estimates of the mechanism analysis. The results show that NAOE significantly increases the likelihood of farmers leasing land, obtaining technical guidance and selling agricultural products. To be specific, column (1) shows that farmers are 6.3 % more likely to rent out their land in villages with NAOEs than those without NAOEs; thus, Hypothesis 1 is confirmed. The likely reason is that NAOEs tend to be market-oriented; their demand for land is relatively high; therefore, farmers with idle farmland are more likely to rent out. As shown in

Table 4

NAOE and farmland abandonment: Robustness checks.

	Replacing X	Replacing Y	Replacing model	Replacing sample	Adding variables
	(1)	(2)	(3)	(4)	(5)
NAOE		-0.032***	-0.010***	-0.011***	-0.010**
Number of NAOEs (log)	-0.010*** (0.002)	(0.010)	(0.003)	(0.004)	(0.004)
Village traffic					-0.008***
Village economy					(0.003) -0.007*** (0.002)
Control variables	Yes	Yes	Yes	Yes	Yes
Observations	15,680	15,680	15,680	14,499	15,060
Log likelihood	-4729.330	-5999.595	_	-4553.720	-4522.883
R-squared	_	_	0.027	_	_

Notes: ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively; Delta-method standard errors and robust standard errors are presented in parentheses. Village traffic is measured by the number of roads from the village to the county, while the village economy is gauged by the annual disposable income per capita, scored from 1 (less than 1,000 yuan) to 9 (more than 50,000 yuan).

Table 5

NAOE and farmland abandonment: PSM estimates.

PSM methods	Ratio of abandoned farmland area to total farmland area		ATT	S.D.	T-value	Common support	
	Treat	Control				Treat	Control
NN matching within caliper ($n = 4$, $r = 0.05$)	0.040	0.048	-0.008***	0.003	-2.82	10,498	5178
Radius matching ($r = 0.05$)	0.040	0.049	-0.009***	0.003	-3.47	10,498	5178
Kernel matching (bandwidth $=$ 0.03)	0.040	0.050	-0.010***	0.003	-3.64	10,496	5178

Notes: ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Table 6

NAOE and farmland abandonment: Mechanism analysis.

Land lease	Machinery adoption	Technical guidance	Products sale
(1)	(2)	(3)	(4)
0.063*** (0.006)	-0.003 (0.005)	0.041*** (0.006)	0.023** (0.009)
Yes	Yes	Yes	Yes
15,680 0.095	13,713 0.686	13,679 0.030	13,491 0.071
	Land lease (1) 0.063*** (0.006) Yes 15,680 0.095	Land Machinery lease adoption (1) (2) 0.063*** -0.003 (0.006) (0.005) Yes Yes 15,680 13,713 0.095 0.686	$\begin{tabular}{ c c c c c c } \hline Land & Machinery & Technical guidance \\ \hline \\ $

Notes: ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively; Robust standard errors are presented in parentheses. For consistency, all models here are panel random effects models.

column (3), NAOE increases farmers' access to technical guidance by 4.1 %, possibly due to its technical advantages and assistance. Thus, Hypothesis 3 is confirmed. As farmers' agricultural skills improve, their agricultural productivity increases accordingly, making them less likely to abandon their farmland. As demonstrated in column (4), NAOE is significantly associated with a 2.3 % increase in the probability of sales of agricultural products, supporting Hypothesis 4. This is mainly due to NAOE's diversified sales channels, which indirectly help farmers solve the problem of difficult sales of agricultural products. Unblocking farmers' sales channels for agricultural products makes them less likely to abandon farmland due to insufficient income from difficult sales. However, the results in column (2) indicate that NAOE has an insignificant impact on farmers' adoption of machinery. Thus, Hypothesis 2 is not supported. One possible explanation is that agricultural production is seasonal, and if a season is missed, it leads to lower yields. Therefore, NAOE's machinery is mainly used for domestic agricultural production and has a smaller radiation effect on other agricultural operators.

4.5. Further discussion

Different types of NAOEs have different survival logic and

comparative advantages; therefore, their impact on farmland abandonment may differ. Consequently, I separately investigated the basic situation of farmers abandoning their farmland under a certain NAOE in their village. As illustrated in Fig. 3, apart from farming companies, the other three types of NAOEs, including professional operators, family farms, and agricultural cooperatives, negatively impact farmland abandonment. A possible reason for this is that compared with other types of NAOEs, agricultural companies are more profit-oriented, especially those from outside the village, who usually prioritize maximizing their profits when making decisions (Huang and Liang, 2018). Additionally, agricultural cooperatives have the most prominent inhibitory effect on farmland abandonment, possibly due to the close link between agricultural cooperatives and smallholder farmers (Ma and Zhu, 2020). Conversely, professional operators have the weakest inhibitory effect on



Fig. 3. NAOE and farmland abandonment: Analysis based on different NAOE types. Notes: In all models, the control group for a particular type of NAOE is smallholder farmers.

farmland abandonment, potentially due to their relatively small-scale operations and lack of significant radiation capacity.

5. Heterogeneous effects of NAOE on farmland abandonment

I previously demonstrated a negative correlation between NAOE and farmland abandonment. However, owing to obvious differences between regions, villages, and households in rural China, whether this relationship is established remains to be explored. Given this, I analyzed the heterogeneous effects of NAOE on farmland abandonment using the macro-*meso*-micro dimensions mentioned above.

5.1. Variance results by different regions

In addition to the direct influence of the control variables in Table 3, NAOE's effect on farmland abandonment may be moderated by other factors, particularly geographic and topographical characteristics. Considering the increasing level of China's economic development from west to east, as well as the geographical differences between the eastern, central, and western regions, I employed subsamples of the three regions for estimation according to the division criteria of the National Bureau of Statistics of China.⁴ Simultaneously, farmers' land-use behavior varies greatly due to the difficulty of agricultural production in mountains and plains (Xu et al., 2019). Therefore, subsamples under both terrain conditions were used for the estimation.

Fig. 4 plots the grouped regression results based on Equation (1). The figure on the left shows that the estimated coefficients of NAOE in central and western China are negative and significant, while those in the eastern region are insignificant. One possible reason is that the eastern region is the most economically developed, local NAOE numbers tend to be saturated, and their marginal effect on farmland abandonment is slightly insufficient. Conversely, NAOE numbers in the central and western regions are relatively small. Therefore, in the context of rural–urban labor migration, NAOEs are more needed to operate idle farmland. On the right side of the figure, we can observe that NAOE mainly has a significant inhibitory effect on farmland abandonment in mountainous areas, but not in plain areas. This may be explained by the fact that farmland in the plains is less difficult and easier to cultivate than in the mountains; thus, even without NAOE, smallholder farmers in the surrounding areas will likely lease unused farmland.

5.2. Variance results by different villages

Like other developing countries, land tenure insecurity is prominent in rural China. In China, the source of land tenure insecurity is land redistribution among village farmers due to population changes under the Household Responsibility System. To improve land tenure security, the Chinese government has repeatedly prohibited land redistribution and introduced two landmark reforms. The first is the *Property Law of the People's Republic of China*, introduced in 2007, which directly treated farmers' land rights as more exclusive property rights rather than creditors' rights. The second is a new round of land certification implemented nationwide in 2013, which required farmers to legally issue land certificates (Zheng and Qian, 2022). As such, I discussed the heterogeneous effects, focusing on whether villages have carried out land certification and distribution since 2013 and 2007, respectively.

Fig. 5 presents the estimated results for different security rights. As shown on the left, NAOE helps curb farmland abandonment in villages with certified land but has little effect on villages without certified land. As shown on the right, NAOE reduces farmland abandonment in villages where land redistribution has not occurred in the past but has no impact on villages where it has occurred. This may be because villages that have not been redistributed or certified are generally more secure regarding land tenure. Consequently, NAOEs prefer to operate on an agricultural scale in such villages, which prevents farmers from abandoning their farmland.

5.3. Variance results by different households

Given the conditions of land resources, household human resource endowments—the quantity and quality of labor—usually have a direct impact on agricultural production. Particularly in the rural–urban transformation process, the shortage of agricultural labor due to offfarm employment and aging is often a common challenge for farmland abandonment in developing countries. For such consideration, following Zheng et al., (2023b), I examined the heterogeneous effects of NAOE on farmland abandonment under labor quantity and quality conditions. Specifically, based on whether the number of working-age members in the household was greater than the average of the whole sample, it was divided into a group with more workers and a group with fewer workers. According to whether the health status of the working-age members of the household was better than the average of the whole sample, it was divided into a better than the average of the whole sample, it was divided into a better than the average of the whole sample, it was

Fig. 6 shows the estimated results for various human resource endowments. Regarding the labor quantity grouping, NAOE exerts a significant inhibitory effect on farmland abandonment in both groups. However, this effect is slightly stronger in the group with fewer workers than that with more workers. For the labor quality grouping, the NAOE coefficients in both groups are negative and significantly different from zero. However, the impact appears slightly higher in the poorer health group than in the better health group. These findings suggest that farmers with inferior human resources benefit more from the NAOE than those with superior human resources. Nevertheless, this disparity in human resources has largely disappeared, possibly due to the rapid spread of social services in agriculture (Qing et al., 2023).

6. Conclusions and discussion

6.1. Conclusions

In the rural–urban transformation, many rural workers constantly migrate to cities to participate in secondary and tertiary industries, leading to a growing concern about farmland abandonment. This could challenge local food security, as less farmland is used for food production. To eradicate hunger, ensure food security, promote sustainable agriculture, and ultimately achieve the global Sustainable Development Goals, it is essential to contain abandoned farmlands, strengthen farmland quantity protection and promote the sustainable use of farmlands. Against this background, this study empirically investigates the impacts, underlying mechanisms, and heterogeneous effects of NAOE on farmers' farmland abandonment from the perspective of agricultural operators, using the 2017 and 2019 CFD and panel Tobit Models.

The empirical results reveal that the cultivation of NAOEs in villages could help deter farmers from abandoning their farmland; this estimate remained valid after a series of robustness checks. Specifically, due to the role of NAOE, the ratio of abandoned farmland area to total farmland area in rural China has decreased by approximately 30 % in two years. Compared with farming companies, the contributions of the other three types of NAOEs, such as professional operators, family farms, and agricultural cooperatives, are more significant. The mechanism tests imply that NAOEs have significantly reduced the incidence of farmland abandonment by facilitating land leasing, providing technical guidance, and promoting the sale of agricultural products. However, the mechanism for adopting agricultural machinery has not been established. Heterogeneity analysis further indicates that the effects of NAOEs on farmland abandonment vary significantly across regions, villages, and households. At the regional level, NAOEs mainly inhibit the abandonment of farmland in central and western China and mountainous areas.

⁴ https://www.stats.gov.cn/zt_18555/zthd/sjtjr/dejtjkfr/tjkp/202302/t 20230216 1909741.htm#:~:text=%.



Fig. 4. NAOE and farmland abandonment: Regional heterogeneity.



(a) Land certification grouping

(b) Land redistribution grouping

Fig. 5. NAOE and farmland abandonment: Village heterogeneity.

At the village level, NAOEs mainly benefit villages that have not reallocated land and have certified land. At the household level, NAOE's effect on households with poorer human resource endowments is slightly higher than that of households with better human resource endowments.

6.2. Policy implications

Sustainable development is an eternal proposition in human society. From a developmental perspective, using limited and scarce land resources to feed a growing population is a practical challenge for countries worldwide. In this regard, our findings have significant implications for policymakers. First, various types of NAOEs should be established to eliminate the driving mechanisms behind farmers' farmland abandonment. In particular, other countries can develop one or more types of NAOEs according to their conditions and make full use of their positive roles in promoting land leasing, providing technical guidance and facilitating the sale of agricultural products. Confronted with an aging rural population and an escalating rural exodus, the question of who will cultivate land in China is becoming increasingly critical. There is also an urgent need to vigorously establish various types of NAOE to ensure food security, especially to support returning migrant workers in establishing NAOEs. Second, it is imperative to enhance farmers' access to agricultural machinery to alleviate labor shortages in agricultural production. Notably, NAOEs cannot provide mechanical services to farmers, possibly due to the constraints of the farming season. Therefore, I recommend fostering agricultural social service organizations, increasing subsidies for agricultural machinery, and enhancing the agricultural social service market to meet the future needs of farmers. Third, countries should focus on the heterogeneity of



(a) Labor quantity grouping

(b) Labor quality grouping

Fig. 6. NAOE and farmland abandonment: Household heterogeneity.

regions, villages, and households to devise targeted solutions to curb farmland abandonment. At the regional level, emphasis should be placed on addressing the issue of farmland abandonment in the lessdeveloped and mountainous regions. From a village perspective, enhancing the security of property rights is crucial for preventing negative impacts on farmland abandonment. Supporting smallholder farmers, especially those with limited human capital, is essential to this strategy.

6.3. Research deficiencies and prospects

Owing to research focus and data limitations, future research can be further developed in the following areas. First, a comparison of NAOEs across countries is needed to identify similarities and differences. Although NAOE is a specific term defined by the Chinese government for professional operators, family farms, farming companies, and agricultural cooperatives, these agricultural operating entities can be found in other countries as well (Candemir et al., 2021; Klepac and Hampel, 2017; Lowder et al., 2021). Second, this study focuses on the role of NAOEs in farmland abandonment from a micro-household perspective. Therefore, future studies can provide more empirical evidence from higher macro levels, such as counties, cities, and provinces. Third, there is a need to investigate the additional impacts of NAOEs on land use, such as land productivity, land intensification, and land-scale management. A comprehensive assessment of the impact of NAOEs on land use will enable a detailed examination of the benefits and disadvantages for smallholder farmers and NAOEs, as well as the design of complementary and mutually reinforcing agricultural development policies.

CRediT authorship contribution statement

Linyi Zheng: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The author declares that he has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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