

Article

Transition Through Collaboration: New Agricultural Business Entities Can Promote Crop Rotation Adoption in Heilongjiang, China

Shengsheng Li ¹ , Xiaoyu Fan ² and Guoming Du ^{1,2,*} ¹ School of Public Administration and Law, Northeast Agricultural University, Harbin 150030, China; li_shengsheng@yeah.net² College of Economics and Management, Northeast Agricultural University, Harbin 150030, China; fanxiaoyu2017@foxmail.com

* Correspondence: duguoming@neau.edu.cn

Abstract: Crop rotation emerges as a pivotal strategy addressing the decline in cultivated land quality and degradation and alleviating food production issues. However, the effective implementation of crop rotation policies remains challenging and requires further research. With the decline of the Chinese agricultural labor force, new agricultural business entities (NABEs), which encompass agricultural cooperatives, family farms, and agribusinesses, can play a significant role in agricultural modernization. Therefore, this research assesses how well NABEs encourage smallholders to adopt crop rotation practices, unraveling the mechanisms behind them and practical implementation pathways. Using survey data (n = 798) and the Tobit model, the findings of this research indicate the positive influence of NABEs in stimulating crop rotation among smallholders. This facilitation occurs via diverse mechanisms, including suitable access to land leasing, agricultural inputs, technical assistance, and market access. Additionally, the results indicate nuanced aspects, highlighting the heterogeneous impacts of NABEs across different contexts.

Keywords: rural land degradation; food scarcities; crop rotation; new agricultural business entities; incentivization mechanisms



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1. Introduction

Food security is one of the challenges faced by global sustainable development today [1]. Since 2020, the global food supply chain has faced ongoing risks from frequent extreme weather, environmental pollution, political conflicts, and growing food trade protectionism [2,3]. Cultivated land is the foundation of agricultural production and plays a vital role in ensuring domestic and global food stability [4,5]. Hence, the sustainable and intensive utilization of cultivated land has become a new research framework in international sustainable development studies [6,7]. However, in some regions of China, the intensive use of cultivated land has significantly impacted its sustainability, leading to a decline in soil fertility [8,9].

Cultivated land is the foundation of agricultural production. Guaranteeing the sustainable production capacity of farmland is crucial for global food security. However, cultivated land is challenging due to declining fertility, and FAO data show that China's cultivated land fertility is in the middle and lower reaches of the world [5]. Chinese government soil census data show significant regional differences in cultivated land fertility. Soil organic matter levels have varied across regions, with the most noticeable decline being seen in the

northeast. For instance, between 1980 and 2010, the average soil organic matter content of the black soils in the northeast region declined by nearly 50% [10]. At the same time, soil heavy metal pollution in the surface layer of Chinese cultivated land fertility has become increasingly serious [11]. Along with increased industrialization and urbanization, heavy metal pollution in agricultural soils around large industrial areas such as the Yangtze River Delta and Pearl River Delta has become more serious [12]. Over the past two decades, China has witnessed a notable surge in the incidence of heavy metal contamination cases, with a corresponding expansion in their geographical distribution. This trend is particularly evident in cases involving lead, mercury, and cadmium [13–15].

In response to the challenges of declining farmland fertility and excessive heavy metals, the Chinese government began implementing a pilot crop rotation program for arable land in some provinces in 2016. After nearly 10 years of continuous promotion of the crop rotation project, the scope of implementation and the scale of the pilot project have continued to expand, laying a solid foundation for the regularized and institutionalized implementation of crop rotation and fallow. The pilot area has expanded from over 4 million hectares to nearly 50 million hectares, and the number of pilot provinces has increased from 9 to 24, with the scope of implementation covering China's major grain-producing areas and ecologically fragile areas. Crop rotation as a traditional agricultural production method has attracted much attention, and researchers have thoroughly explored the importance and potential of crop rotation in improving soil fertility and pollution [16,17]. Some studies have shown that crop rotation not only improves soil quality but also increases crop yield and quality [18,19]. Meanwhile, it has also been found that soil heavy metals in farmlands practicing wheat and jade crop rotation in China's two maturing areas showed an overall clean state [20].

However, despite the importance of crop rotation in the sustainable production of agriculture, it still faces the dilemma of a sharp decrease in the number of agricultural workers. The demographic structure of Chinese agriculture is undergoing significant changes, and the contradiction between smallholders and the market is highlighted. Smallholders manage only 12% of the world's land, yet they contribute 36% of the global food output. In China, this proportion is as high as 80% [21]. New agricultural business entities (NABEs), such as large-scale agribusinesses, cooperatives, and agricultural technology companies, play an important role in promoting agricultural modernization and sustainable development. On the one hand, they promote agricultural efficiency and farmers' income through large-scale and intensive production methods. On the other hand, they connect smallholders and the market through the provision of social service functions, which has become an important pillar for the development of modern agriculture in China [22]. In the long term, crop rotation on agricultural land can improve soil conditions and enhance the ecological service benefits of agricultural land, but in the short term, shifting from the previous pattern of the continuous cultivation of crops with comparative advantages to crop rotation on agricultural land may lead to a decline in the yields of agricultural products and undermine the economic efficiency of agricultural business entities. Among other things, new agricultural business entities, such as large-scale agribusinesses, cooperatives, and agricultural technology companies, can significantly improve agricultural efficiency and increase farmers' incomes through large-scale and intensive production methods. However, smallholders still rely to some extent on individual preferences and market conditions. Smallholders tend to be cautious in farming, focusing more on avoiding losses than making gains, which often hinders the adoption of crop rotation [23]. Currently, scholars recognize that NABEs help guide farmers' transformation and support their involvement in rural governance decisions [24,25]. Therefore, it is important to include the relationship between crop rotation and NABEs in research. A model should be developed to show how NABEs

encourage smallholders to join crop rotation projects, supporting their wider adoption and higher-quality development.

Building on the existing literature, we develop a model to examine how NABEs encourage smallholders to adopt crop rotation and test it using econometric analysis. Subsequently, we propose optimization strategies that include both the theoretical framework and practical implementation pathways of NABE-led crop rotation initiatives. Hence, this study addresses the critical question of whether NABEs can fulfill a vital role in safeguarding national food security. The paper is structured as follows: The first section presents the introduction. The second section presents the theoretical analysis and research hypothesis, which mainly introduces the development of NABEs in China and puts forward the research hypotheses. The third section presents the research design, introducing the research method and data sources of this paper. The fourth section presents the empirical analysis that tests the impact of NABEs on crop rotation. The fifth section presents the heterogeneity analysis, which is conducted from three different perspectives. Section 6 presents the conclusion and discussion, summarizing the findings of the study and addressing the shortcomings of the study and further research options.

2. Theoretical Analysis and Research Hypothesis

2.1. Development of NABEs in China

The differentiation of China's farming households can be traced back to the reform and opening up of China in 1978. With policy changes and rapid urbanization, some farmers moved to urban jobs, while others formed NABEs focused on large-scale, market-driven farming [26]. Nevertheless, farmers with less than 2 hectares of farmland still account for about 90 percent of agricultural production in the country. According to the Chinese government's definition, NABEs encompass a diverse array of agricultural practitioners [27,28]. This includes professional farmers, family farms, agricultural enterprises, and cooperatives, among others [29]. Professional farmers are those who mainly work in one agricultural sector and earn over 80% of their household income from it. Their production scale in planting or breeding significantly surpasses that of local smallholders. However, the absence of an official certification for professional farmer status poses challenges in accurately identifying them, prompting their exclusion from this study for rigor.

Family farms, on the other hand, are locally registered agricultural operation entities that utilize family labor as a business unit to engage in large-scale, intensive, and commercialized agricultural production [30]. The high degree of specialization of family farms can even alleviate employment pressures in some countries [31]. At the same time, family farms are seen as an alternative to traditional large farms, and their small size gives them the flexibility to face multiple crises [32].

Agribusinesses represent economic organizations that adopt modern enterprise management techniques for large-scale, intensive, and commercialized agricultural production while implementing independent management and self-financing strategies. Agribusinesses, in contrast to other NABEs, generally exhibit substantial economic prowess, cutting-edge production technologies, and modern management expertise, allowing them to handle volatile market dynamics and intense global competition. Government subsidies are an important external resource for agricultural enterprises and are conducive to improving the economic benefits of agricultural enterprises [33]. Agribusiness, as a composite business subject in the modern agricultural system, has a value chain that covers multiple links, such as primary agricultural production, food deep processing, raw material supply chain management, and cold chain logistics system construction [34]. Under the new complex development pattern, these enterprises are facing multiple dynamic challenges from the natural climate and economic society [35]. In this context, the construction of sustain-

able competitiveness has become the strategic core competence of agribusiness to obtain sustainable competitive advantage [36].

Agricultural cooperatives, meanwhile, represent mutual economic entities formed by individuals engaged in similar agricultural production or utilizing similar factors of production and services, adhering to the principles of voluntary membership and democratic governance, and registered with local authorities [37]. These cooperatives help farmers work together to solve problems common in traditional family farming. By supporting each other, they can share resources, benefits, and risks, leading to more sustainable agricultural growth. With strong support from the Chinese government, various NABEs have grown and become key players in modern farming, food security, and improving small farmers' lives. Traditional agricultural marketing cooperatives are under pressure to adapt due to the global push for sustainable development (SDGs) and climate-resilient farming. Their current governance models and legal frameworks are struggling to keep up with these new challenges and emerging trends [38,39]. As of October 2023, China's Ministry of Agriculture reported nearly 4 million family farms, over 2.2 million cooperatives, and 1.07 million service organizations supporting over 91 million smallholders and covering more than 130 million hectares. Of these, 1.765 million family farms and 542,000 cooperatives grow food, accounting for 37.5 percent of the total number of NABEs. The average acreage planted by food-growing family farms is 148.8 acres, and the average acreage planted by food-growing farmers' cooperatives is 460.1 acres. The potential influence of NABEs on land utilization, agricultural productivity, and farmers' welfare is indirectly indicated by this evidence. Consequently, examining the function of NABEs in crop rotation systems holds significant importance.

2.2. Potential Channels for NABEs to Promote Crop Rotation

Several factors limit farmers' participation in crop rotation pilot projects. Different types of NABEs help reduce the challenges farmers face by supporting land rentals, improving access to machinery, providing technical assistance, and helping to market their products. This, in turn, helps prevent farmland abandonment. Furthermore, these new agricultural business entities, inherently linked to smallholders, serve as vital intermediaries in assisting smallholders in adopting crop rotation practices (Figure 1).

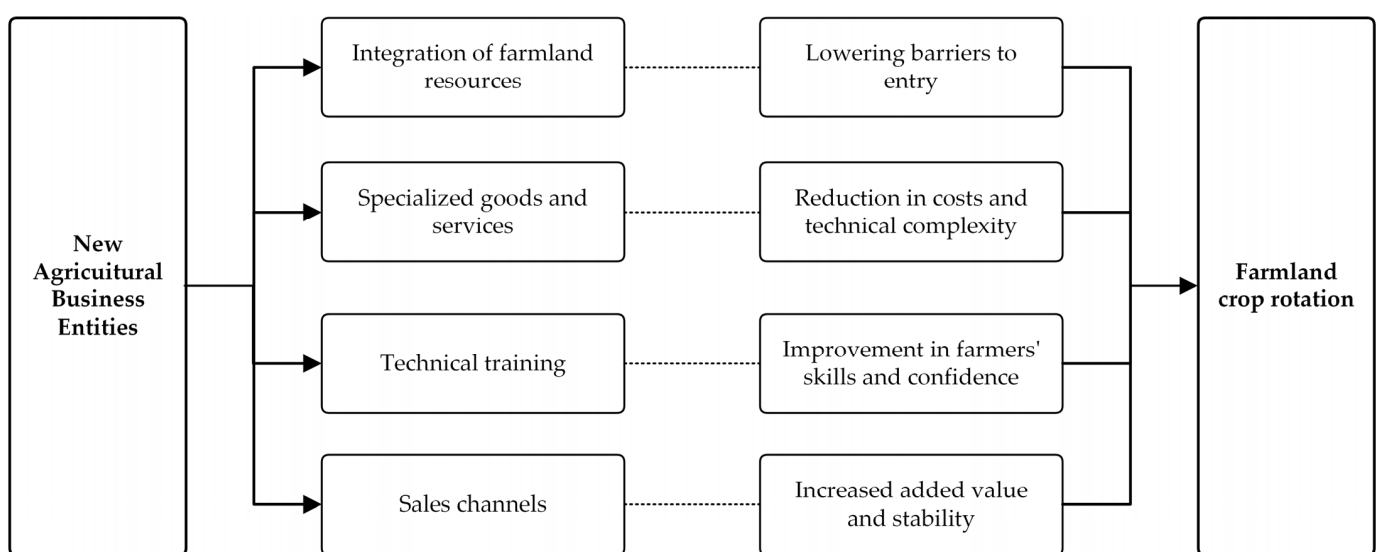


Figure 1. Potential channels for NABEs to promote crop rotation.

First, NABEs can incentivize farmers to participate in crop rotation pilot projects by facilitating the integration of farmland resources. Social interaction theory states that

farmers' agricultural production decisions are not independent and will be influenced by other production subjects around them and that in long-term social interactions, farmers have formed a stable network of social relationships among themselves, and their behavioral decisions are easily influenced by the farmers around them [40]. The "small and scattered" nature of smallholder farming makes it hard for them to meet the scale required by crop rotation policies, and unorganized farmers often struggle to access related subsidies. Whether it is leasing the fragmented farmland to an agricultural company, transferring the farmland with the help of an agricultural co-operative, or uniting several farmers to form a family farm, NABEs can cope with the problems of a small farmland size and haphazard distribution. In addition, NABEs have the economic strength to carry out land improvement. NABEs provide a feasible way to integrate farmland resources, which not only helps them meet the requirements for participation in the crop rotation pilot project but also makes it easier to obtain economies of scale. Therefore, when farmers have difficulties meeting the requirements for participation in crop rotation projects, they can use the help of NABEs to meet the requirements and, at the same time, improve their returns. In addition, policy advocacy and the demonstration of successful cases may shape farmers' positive perceptions of new agricultural models in the future, further enhancing their motivation to participate in land transfer. Based on this, the first hypothesis of this study is proposed.

Hypothesis (H1): *NABEs can help integrate farmland resources, reduce barriers to joining crop rotation pilot projects, and boost farmers' motivation to participate.*

Second, NABEs can incentivize farmers to participate in crop rotation pilot projects by providing agricultural materials. Crop rotation is a type of cultivation that breaks farmers' cultivation inertia. Farmers face the dilemma of "machinery mismatch" when trying out new cropping patterns and need to buy or improve equipment to cope with the new demands [41,42]. Compared to smallholders, various types of NABEs have superior economic power and are able to update their agricultural machinery and equipment in time to cope with new crop varieties [43]. At the same time, large-scale production allows NABEs to have higher bargaining power when purchasing agricultural materials such as seeds, pesticides, and fertilizers, with correspondingly lower production costs. On the one hand, new agricultural business entities are helpful in enabling farmers to use improved seeds and higher-quality fertilizers in agricultural production [44].

On the other hand, farmers with a relatively high degree of planting specialization can significantly improve their productivity by adopting agricultural green production technologies [45]. In addition, when farmers realize the cost advantage of NABEs in production, it may trigger the establishment of new NABEs. Based on this, the second hypothesis of this study is proposed.

Hypothesis (H2): *NABEs provide key agricultural resources, such as materials and machinery rentals, which can help to lower the cost and technical challenges of crop rotation, encouraging farmers to join pilot crop rotation programs.*

Third, NABEs can provide technical guidance. Crop rotation requires farmers to master the habits and field management practices of new species. Smallholders are not only characterized as "rational economic beings" but also as "socialized" with close interaction with the outside world during the agricultural production process and with a stronger ability to acquire information and learn. NABEs have more modern business management concepts, superior production techniques, and relatively high agricultural productivity compared to smallholders [26]. The impact of NABEs on smallholders is mainly reflected

in the following three aspects: first, some behaviors of NABEs have a guiding effect on other smallholders [44]. For example, actions taken by NABEs in controlling pests and diseases may be quickly absorbed and adopted by smallholders, especially for the increasing number of part-time farmers who are unable to rationally allocate their time between agricultural and non-agricultural labor. Second, NABEs, with rural collective economic organizations, have taken the initiative to seek help from the government to match farmers' needs and provide technical guidance, forming a service station model. Third, NABEs can provide smallholders with different socialized services before, during, and after production to make up for the technical shortcomings of smallholders in cultivation and harvest prevention. Due to the unique technical advantages of NABEs, the Chinese government has issued a series of documents, such as the Opinions on Accelerating the Construction of a Policy System for Cultivating NABEs, the Opinions on Promoting the Organic Connection between Smallholders and Modern Agricultural Development, and the Circular on the Implementation of the Compulsory Actions for NABEs to encourage the development of small farmers driven by NABEs [46]. In this case, smallholders in the neighborhood can receive agricultural technical guidance on new species from NABEs, reducing the likelihood that farmers will not be able to participate in crop rotation projects due to agricultural challenges. Based on this, the third hypothesis of this study is proposed.

Hypothesis (H3): *NABEs provide training and on-site guidance on crop rotation systems to farmers and motivate them to join the crop rotation pilot.*

Fourth, NABEs can incentivize farmers to participate in the crop rotation pilot by helping them sell their agricultural products. The agricultural production and marketing system is the sum of the organizational system and structural form of agricultural production, operation, trading, management, and service, and it is also the direction and path to realize the transformation and upgrading of the agricultural industry. While traditional smallholders have limited marketing channels, NABEs have more bargaining power than smallholders in the agricultural market. In accordance with market demands, they efficiently structure their agricultural production endeavors and market their produce via numerous avenues, encompassing e-commerce and live-streaming sessions dedicated to agricultural goods. This methodology allows them to successfully bring their agricultural products to market and achieve more consistent financial gains. Therefore, with the help and influence of NABEs, farmers may be able to diversify the channels through which they market their agricultural products, thereby mitigating, to varying degrees, the challenges they face in marketing their agricultural products [47]. Based on this, the fourth hypothesis of this study is proposed.

Hypothesis (H4): *NABEs leverage market advantages to connect rotational crops with specialized procurement and marketing channels, increasing their value and sales stability. This encourages more farmers to take part in crop rotation.*

3. Materials and Methods

3.1. Data Sources and Study Area

This study uses survey data from farm households collected in August 2023. Heilongjiang Province was chosen as the study area mainly because the province is rich in agricultural resources and is an important food production base in China. Heilongjiang's main crops are dominated by staple plants such as soybeans, maize, and rice. In contrast, at the national level, Heilongjiang's soybean cultivation area ranks first in the country, and its rice cultivation area ranks second in the country. Moreover, Heilongjiang Province

has been vigorously implementing agricultural green development measures such as crop rotation since 2016 and has achieved certain results, showing that it has more than sufficient practical experience; therefore, the selection of farmers located in Heilongjiang Province for fieldwork is quite representative and exemplary.

To select the research area, we considered the differences in natural resources, socio-economic conditions, and agricultural development across counties in Heilongjiang Province. Based on expert recommendations from the Provincial Department of Agriculture, eight counties (cities and districts) were chosen: Aihui District, Bayquan County, Jixian County, Nehe City, Nenjiang City, Sunwu County, Wangkui County, and Zhaodong City. The sample counties are distributed in several climatic divisions of Heilongjiang Province, with typical economic structures and agricultural development.

The research program involved selecting 2–3 townships within each sample county using the number of registered NABEs per township as weights. Among the selected townships, 2–3 administrative villages were randomly selected based on the list of administrative villages. In each administrative village, 15–20 so-called smallholders were randomly selected for interviews based on the list of farming households after excluding households not engaged in agricultural production and households that were managers of any kind of NABEs.

Throughout the study, a total of 798 farm households were collected for follow-up survey data. The research activity received permission and support from the author's affiliated institution. All respondents were informed of and agreed to the purpose of data use and the anonymization process prior to receiving the questionnaire. At the same time, questions that could indirectly identify individuals (e.g., precise plot locations, specific values of annual household income, etc.) were avoided in the questionnaire design to protect respondent privacy. All open-ended question responses were semantically desensitized.

3.2. Empirical Strategy

The initial examination of the research data indicated that farmers face challenges in utilizing their entire farmland for the crop rotation program, thus limiting the dependent variable in this study. Specifically, the proportion of farmland participating in crop rotation to the total farmland area falls within the range of 0 to 1. Consequently, the application of Ordinary Least Squares (OLS) estimation with a truncated dependent variable may result in inconsistency and bias. To address this issue, Tobin introduced a method involving the construction of a Tobit model through maximum likelihood estimation (MLE). It is crucial to acknowledge the existence of two Tobit model variations: fixed effects and random effects. However, unconditional fixed-effects Tobit models are prone to bias. Therefore, in this paper, we opted for a random-effects model for maximum likelihood estimation. The specific formulation of the model is outlined below.

$$Y_{ij}^* = \alpha_0 + \alpha_1 NABE_j + \beta Z_{ij} + \varepsilon_{ij} \quad (1)$$

$$\varepsilon_{ij} \sim N(0, \sigma^2) \quad (2)$$

$$Y_{ij} = \begin{cases} Y_{ij}^*, & Y_{ij}^* \geq 0 \\ 0, & Y_{ij}^* < 0 \end{cases} \quad (3)$$

where i denotes a farm household, and j denotes a village. Y_{ij}^* denotes potential crop rotation. Y_{ij} is the actual occurrence of crop rotation, which is also the dependent variable in this study, specifically defined as the ratio of the area of crop rotation of farm households i in village j to the total area of farmland in that year, taking values between 0 and 1.

Regarding the core independent variable, the use of NABEs at the household level is prone to self-selection, which can lead to biased estimates. Therefore, NABEs at the village level were used to examine their impact on crop rotation. Specifically, NABEs consist of three main actors: family farms, agricultural co-operatives, and agricultural companies. NABEs also include professional operators. α_0 is the intercept term, α_1 and β are the parameters to be estimated, and ε_{ij} is the random perturbation term obeying a Sigma-squared normal distribution with a mean of 0 variance. In addition, Z_{ij} represents a range of control variables that may influence farmers' farm abandonment behavior. Based on the existing literature and data availability, shown in Table 1, the control variables selected for this study include individual characteristics such as gender, age, education, family size, agricultural labor, agricultural income, farmland area, farmland blocks, and machines [48–50].

Table 1. Descriptive statistics.

Variables	Descriptive	Min	Max	Mean	SD
Crop rotation	Proportion of crop rotation area to total cultivated area	0	1	0.171	0.274
NABEs	Are there NABEs in village? (yes = 1; no = 0)	0	1	0.209	0.407
Gender	Gender of head of household (M = 1; F = 0)	0	1	0.901	0.298
Age	Age of head of household (years)	24	81	53.686	9.792
Education	Duration of education of head of household (years)	0	16	7.028	3.029
Family size	Number of persons in household	1	7	3.850	3.359
Agricultural labor	Proportion of household farm labor	1	7	2.255	1.634
Agricultural income	Proportion of household farm income	0.307	0.862	0.633	0.477
Farmland area	Area of household farmland (hectares)	0.602	4.130	1.981	0.542
Farmland blocks	Number of blocks of farmland owned by household	1	82	9.109	1.981
Machines	Number of machineries owned by household	0	48	3.484	3.157

4. Results and Discussion

4.1. Impact of NABEs on Crop Rotation

In Table 2, the outcomes of the estimations utilizing the Tobit models are presented. Model 1 does not contain control variables, Model 2 adds personal characteristics of the head of household variables, and Model 3 further adds household characteristic variables. The estimated coefficients on the NABEs are significant at the 1% level in all three models. This suggests that NABEs exhibit a driving effect on crop rotation projects regardless of the inclusion of control variables. Specifically, the proportion of farmers participating in crop rotation projects is 13.9 percent higher in villages with NABEs than in other villages. Among the control variables, male household heads showed higher motivation to rotate crops, and the coefficient of age was not significant. This is different from previous studies that concluded that farmers would be reluctant to change the status quo because of physical decline due to aging [51]. The reason for this may be the aging population exhibited throughout the northeast region, and a clear break in the age of household heads was also found during the research. The coefficient on the control variable of education was positive and significant, suggesting that better-educated household heads have better agricultural management skills than those with lower levels of education and therefore have a higher likelihood of participating in the crop rotation program [28]. The coefficients of family size and agricultural labor are not significant, probably because agricultural production in Northeast China is not limited to family members, and a large number of agricultural workers are involved in the busy season. Interestingly, the coefficient of agricultural income is also not significant, which means that agricultural income does not affect the motivation of farmers to participate in the crop rotation project. The reason for this is that some smallholders have a high degree of part-time employment, and the income from agriculture

does not affect the production decisions of the farmers [34]. The coefficient of farmland area is positive and significant at a 1% level, which is due to the fact that farmers with large farmland areas have a greater advantage in participating in the crop rotation project and are more likely to be eligible for the pilot program issued by the government [29]. On the contrary, the coefficient of farmland blocks is negative and significant, which may be due to the increase in the cost of farmland management as a result of the fragmentation of plots [51]. Meanwhile, the negative and significant coefficients for machines can be explained by the specialized nature of farm machinery, with differences between machinery used for harvesting maize and machinery used for harvesting soya beans. As a result, farmers with a high proportion of mechanical cultivation will need to equip themselves with new farm machinery if they plant new crops, which will undoubtedly increase the cost of participating in the crop rotation program.

Table 2. NABEs and crop rotation: Baseline results.

Variables	Model 1	Model 2	Model 3
NABEs	0.219 *** (0.047)	0.178 *** (0.047)	0.139 *** (0.050)
Gender		0.205 *** (0.071)	0.159 ** (0.073)
Age		0.001 (0.002)	0.002 (0.002)
Education		0.018 *** (0.006)	0.014 ** (0.007)
Family size			0.005 (0.019)
Agricultural labor			−0.028 (0.059)
Agricultural income			−0.052 (0.058)
Farmland area			0.235 *** (0.047)
Farmland blocks			−0.004 * (0.003)
Machines			−0.092 * (0.063) *
Observations	798	798	780
Log-likelihood	−580.003	−570.137	−545.683

***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively. Standard errors are presented in parentheses.

4.2. Robustness Checks

Additional robustness tests are required to ensure the truthfulness and reliability of the empirical results above. Table 3 shows the results of the robustness tests under different methods. First, with reference to Zheng and Qian [52], Model 4 adjusts the dependent variable in the baseline regression model from crop rotation proportion to crop rotation area, and the results still indicate that NABEs have a driving effect on smallholders' participation in crop rotation projects. This estimation mitigates, to some extent, the endogeneity problem caused by measurement error. Second, Model 5 recalculates the value by replacing the original NABE dummy variable with the number of NABEs, and the results show that the estimated coefficients of NABEs are significant regardless of whether or not the independent variables are replaced. This result is consistent with the results of the baseline regression, again demonstrating the positive effect of NABEs in driving smallholders' participation in crop rotation projects. Thirdly, Model 6 uses the Probit

model instead of the Tobit model without considering the truncated characteristics of the observations of the dependent variable. The results show that the estimated coefficients are still significant, which indicates that the previous estimates are robust and the Tobit model is not underestimated.

Table 3. NABEs and crop rotation: robustness checks.

Variables	Model 4	Model 5	Model 6
NABEs	69.955 * (40.289)		0.216 * (0.127)
Number of NABEs (log)		0.079 ** (0.041)	
Control variables	YES	YES	YES
Observations	780	780	780
R-squared			0.795

** and * denote significance at the 5% and 10% levels, respectively. Standard errors are presented in parentheses.

4.3. Mechanism Analysis

After showing that NABEs encourage smallholder participation in crop rotation, this section tests the previously proposed hypotheses to explore the underlying mechanisms. This study examines how NABEs influence smallholder participation in crop rotation by looking at four key areas: farmland transfer, access to farm materials, technical guidance, and product marketing through NABEs (all measured as yes = 1; no = 0). Table 4 shows that NABEs significantly help motivate farmers to join crop rotation projects. The high R-squared values indicate that the models fit well and explain the relationships effectively. Notably, Model 7 indicates that NABEs have a strong positive impact on farmland integration (coefficient of 0.295, significant at the 1% level), supporting the idea that NABEs lower participation barriers and boost farmer involvement in crop rotation [40]. The study found that in villages with a high level of NABE development, the transfer of farmland is generally smooth and transparent, and the transfer price is very stable. In other areas, the transfer of farmland is prone to be hindered [42]. Model 8 shows that NABEs have a significant positive impact on the supply of farm materials, with a coefficient of 0.032, which is significant at the 5 percent level. This verifies the hypothesis of H2 that rotation-specific farm materials, farm machinery rental, and technical support provided by NABEs may reduce the cost and difficulty of farmers' implementation of crop rotation, thus motivating them to participate in the crop rotation pilot. The results of Model 9 also support the hypothesis of H3, where NABEs have a significant positive impact on technical training, with a coefficient of 0.025, and is significant at the 5 percent level. This suggests that the training and on-site guidance on crop rotation systems provided by NABEs may have indeed improved farmers' skills and confidence, which in turn motivated them to join the on-farm crop rotation pilot [26,44]. Hypothesis H4 was tested by Model 10, where NABEs had a significant positive impact on marketing channels, with a coefficient of 0.023 and significance at the 5 percent level. This suggests that the sourcing and specialized marketing channels for rotational crop produce matched by NABEs using market advantages may have enhanced the value addition and marketing stability of the products, thus motivating farmers to participate in the practice of rotating crops [47].

Table 4. NABEs and crop rotation: mechanism analysis.

Variables	Model 7	Model 8	Model 9	Model 10
NABEs	0.295 *** (0.069)	0.032 ** (0.042)	0.025 ** (0.023)	0.023 ** (0.030)
Control variables	YES	YES	YES	YES
Observations	778	773	764	762
R-squared	0.915	0.823	0.678	0.746

*** and ** denote significance at the 1% and 5% levels, respectively. Standard errors are presented in parentheses.

5. Heterogeneous Effects of NABEs on Crop Rotations

The previous section confirmed the driving effect of NABEs on crop rotation projects. However, it remains to be explored whether this mechanism is valid due to the differences in the membership of NABEs, the differences in individual farmers, and the existence of geographical and climatic differences. Therefore, this section will analyze the heterogeneous effects of NABEs on the driving effect of crop rotation projects from the three dimensions of the acting subject, the acting object, and the acting environment.

5.1. Different Members of NABEs

After years of development, NABEs in China have differentiated into various forms. Among them, agricultural cooperatives, family farms, and agribusinesses are the best known. Specifically, agricultural cooperatives are the most widespread presence, spreading across villages in agriculturally developed areas [37]. Family farms, on the other hand, have been emerging in recent years and have performed well in rural tourism, specialty agricultural development [30]. Agribusinesses are the largest and most regulated presence among NABEs, and they often drive the economic development of a region [36]. Therefore, this section focuses on different types of NABEs to analyze the heterogeneity of their role in driving crop rotation projects.

The data analysis results in Table 5 show that three different types of NABE subjects (agricultural cooperatives, family farms, and agribusinesses) all play a significant driving role in crop rotation projects, but with different effects. Among them, the driving effect on agricultural cooperatives (Model 11) is the most significant, and the driving effect on family farms (Model 12) and agribusinesses (Model 13) is weaker. The reason for this is closely related to the differences in the organizational characteristics and business models of the three types of subjects. Multiple farmers usually form agricultural cooperatives with the help of village collectives and have strong collective and organizational characteristics. Such organizational characteristics enable cooperatives to integrate resources better, share information and risks, and thus be more likely to be supported and influenced by external organizations like NABEs. Family farms, which are family-based, have a relatively smaller scale of operation and a more flexible decision-making process but may also have limited resources to utilize the support provided by NABEs fully. Agribusinesses usually have a larger scale of operation and greater economic strength, and their internal management and operations are more standardized and professionalized. However, as enterprises seek to maximize economic benefits, they may have different expectations and needs for support from NABEs. As a result, agricultural cooperatives show the greatest drive for smallholders' participation in crop rotation projects.

Table 5. Heterogeneous effects of NABEs on crop rotation: different members of NABEs.

Variables	Model 11	Model 12	Model 13
NABEs	0.132 *** (0.052)	0.078 * (0.061)	0.078 *** (0.055)
Control variables	YES	YES	YES
Observations	533	464	136

*** and * denote significance at the 1% and 10% levels, respectively. Standard errors are presented in parentheses.

5.2. Different Families

Agricultural production is typically directly influenced by both the quantity and quality of household labor, constrained by the availability of land resources. Notably, during the urban–rural transition phase, the scarcity of agricultural labor stemming from off-farm employment and the aging population frequently poses a widespread challenge for developing countries in adopting innovative agricultural technologies. With this consideration in mind, the authors investigate the heterogeneous effects of NABEs in driving smallholders' participation in crop rotation projects under labor quantity conditions. Specifically, households are divided into a group with a larger number of working members and a group with a smaller number of working members depending on whether they have more working-age members than the average number of working members in the entire sample. Table 6 shows the estimation results for the number of laborers. Model 14 and Model 15 show that there is a difference in the role of NABEs in driving the participation of smallholders in crop rotation projects. That is, NABEs are more effective and significant in driving households whose number of agricultural laborers in the household is less than the sample mean. This confirms, to some extent, the substitution effect of NABEs on household labor. Households with sufficient labor have an inherent advantage in crop rotation, whether it is planting new crops, using new farm machinery, or raising the capital needed for agricultural production. On the contrary, due to a lack of labor, many households conservatively maintain the status quo in agricultural production. The emergence of NABEs, however, has given households lacking labor another option. Farmers can transfer land, obtain farm materials and technical guidance, and sell agricultural products as NABEs help them realize their agricultural production plans. As a result, NABEs show a more effective and significant driving effect on households with even less family agricultural labor.

Table 6. Heterogeneous effects of NABEs on crop rotation: different families.

Variables	Model 14	Model 15
NABEs	0.157 ** (0.056)	0.059 * (0.114)
Control variables	YES	YES
Observations	566	214

** and * denote significance at the 5% and 10% levels, respectively. Standard errors are presented in parentheses.

5.3. Different Climatic Conditions

Apart from the immediate impacts of the control variables presented in Table 3, the influence of NABEs on crop rotation might be influenced by various other factors, notably geographical and topographical attributes. Considering that the main grain-growing area in Heilongjiang Province is the plains, the large latitudinal span leads to significant differences in temperature. Therefore, in this study, heterogeneity was studied from the cumulative temperature perspective by dividing Heilongjiang Province into six cumulative temperature zones based on the active cumulative temperatures with mean daily temperatures ≥ 10 °C. The sixth cumulative temperature zone is not included in the study area of this paper due to

its reduced sample size and unrepresentative nature. Table 7 demonstrates the differences between the different cumulative temperature zones. Within expectation, the results of the first cumulative temperature zone (Model 16) and the fifth cumulative temperature zone (Model 20) are not significant. The reason for this is that crop rotation programs on local farmland are not attractive to smallholders. In the first Jaeger belt, maize is a uniquely dominant crop with high yields and a well-established support service and industry. In addition, the subsidy funds provided by the crop rotation project can hardly make up for the loss of planting soybeans, so it is difficult to change the habits formed by growing maize in the region for a long time with only the help of crop rotation projects and NABEs. The reasons for the lack of a significant driving effect in the fifth temperate zone are similar to those in the first temperate zone, except that the dominant crop in the region is soybeans. In the second temperate zone (Model 17), on the other hand, NABEs show a significant driving effect on smallholders' participation in crop rotation programs. In this region, the difference in opportunity costs between growing soybean and growing maize is smaller, the subsidy funds provided by crop rotation projects are more attractive to smallholders, and the various types of assistance provided by NABEs further encourage smallholders to participate in crop rotation projects. The driving effect of NABEs on smallholders' participation in crop rotation in the third cumulative temperature belt (Model 18) and the fourth cumulative temperature belt (Model 19), although significant, is much less strong than that shown in the second cumulative temperature belt (Model 17). This may be due to the fact that the development of NABEs in these regions has not been favorable due to inaccessibility and population loss. It was found through the research that NABEs in the region are numerically small, and there is not a single NABE in some villages. In addition, due to the lack of relevant management personnel, the daily operation of NABEs is plagued with problems, especially those related to policies and funding.

Table 7. Heterogeneous effects of NABEs on crop rotation: different climatic conditions.

Variables	Model 16	Model 17	Model 18	Model 19	Model 20
NABEs	0.063 (0.019)	0.453 *** (0.115)	0.056 ** (0.080)	0.117 * (0.101)	0.131 (0.114)
Control variables	YES	YES	YES	YES	YES
Observations	97	296	193	127	58

***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively. Standard errors are presented in parentheses.

6. Conclusions and Policy Implications

6.1. Conclusions

The decline in farmland fertility and the significant loss of agricultural labor pose dual threats to food security. To end hunger, ensure food security, and support sustainable farming, it is important to protect soil fertility and use farmland wisely. Crop rotation, however, is a key strategy to address rural land degradation and alleviate food shortages, and it is facing challenges in its wide-scale promotion. In this context, this study examines the impacts, intrinsic mechanisms, and heterogeneous effects of NABEs to drive smallholders' participation in crop rotation programs based on the perspective of agricultural business entities, utilizing survey data targeting Heilongjiang Province. The results show that NABEs are able to drive smallholders to participate in crop rotation programs with robustness. Specifically, farmers' participation in crop rotation increased by 13.9% due to the presence of NABEs. Mechanism tests showed that NABEs make it easier for smallholders to join crop rotation projects by helping with farmland integration, providing farm supplies, providing technical support, and carrying out product marketing. This

support encourages their participation. A heterogeneity analysis further showed that agricultural cooperatives had the most significant driving effect on smallholders' participation in crop rotation projects, while family farms and agribusinesses had a weaker driving effect. In addition, NABEs were more effective and significant in driving households with a number of household agricultural laborers smaller than the sample mean. At the regional level, NABEs mainly play a leading role in the second, third, and fourth cumulative temperature zones.

6.2. Policy Implications

From the perspective of sustainable development, the findings of this study have important implications for policymakers. Safeguarding limited and scarce land resources from degradation and feeding a growing population in a complex environment is a real challenge for countries around the world. First, governments should encourage and support the establishment of various types of NABEs to engage smallholders in crop rotation programs to restore farmland fertility and secure food production. Other countries can also develop various types of NABEs according to their local conditions, giving full play to their positive roles in promoting the integration of farmland resources, providing agricultural materials, offering technical guidance, and promoting the marketing of agricultural products. Secondly, in the face of the aging rural population and the aggravation of the rural exodus, resulting in the shortage of agricultural labor and management personnel, there is an urgent need to establish various types of rural tertiary industries to attract migrant farmers to return to their hometowns. At the same time, an agricultural socialized service system mainly based on agricultural machinery leasing should be developed to alleviate the labor shortage problem in agricultural production. Thirdly, the government should focus on the differences between agricultural business entities and between regions to develop targeted solutions.

6.3. Research Shortcomings and Prospects

Due to the limitations of the research focus and data, this study only focuses on the system mainly characterized by single-crop cultivation in Heilongjiang Province. At the same time, the selection of survey instruments gives priority to objective indicators instead of adopting the more widely used Likert scale method. Future research should expand the diversity of crop types and integrate psychometric scales to capture subjective environmental perceptions, especially where there are more areas of high agroecological complexity. In addition, although NABEs is a special term for a series of agricultural management subjects under the Chinese discourse system, these subjects can also be found in other countries [53,54], so further expanding the scope of the study to other countries and regions is also a direction that can be followed in subsequent research.

This study verified that new agricultural business entities can promote smallholder farmers' participation in the farmland rotation project and increase the rotation proportion. In the process of agricultural modernization, the rise in new agricultural business entities may indeed have a certain crowding-out effect on smallholders, who may become "marginal persons" in modern agriculture or suffer from interest losses [23,24]. This crowding-out effect may stem from the advantages of new agricultural management bodies in terms of access to resources, market competition, and the adoption of technology, making smallholders face greater pressure and challenges in agricultural production [27]. However, it is important to recognize the fundamental position of smallholders in agricultural production and the importance of their organic linkage with modern agricultural development. Future research will need to focus on how to guide cooperation and alliances among smallholders and between smallholders and new agricultural management bodies to form

communities of interest and achieve resource sharing, as well as the complementarity of advantages and risk sharing.

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