Journal of Rural Studies 119 (2025) 103759

Contents lists available at ScienceDirect

Journal of Rural Studies

journal homepage: www.elsevier.com/locate/jrurstud

Of nothing comes nothing: the impact of agricultural comparative return on cropland abandonment

Linyi Zheng [a], Songqing Jin [b], Liufang Su [c,*]

[a] China Academy for Rural Development (CARD), School of Public Affairs, Zhejiang University, Hangzhou, 310058, Zhejiang, China
[b] Department of Agricultural, Food and Resource Economics, Michigan State University, East Lansing, 48824, Michigan, USA
[c] Rural Revitalization Laboratory, Key Laboratory of Philosophy and Social Sciences of Guangdong Province, College of Economics and Management, South China Agricultural University, Guangzhou, 510642, China

ARTICLE INFO

JEL classification:
O13
Q15
R14

Keywords:
Agricultural comparative return
Panel high-dimensional fixed-effects model
Cropland abandonment
Food security
Sustainable agricultural development

ABSTRACT

Cropland abandonment exerts far-reaching consequences for food security and sustainable agricultural development. However, while it is generally believed that low agricultural comparative return (ACR) is the main cause of cropland abandonment, the magnitude of such effects and their underlying mechanisms are not well understood. On the basis of constructing a mathematical model and analysis framework, we adopt a panel high-dimensional fixed-effects model to investigate the impact of ACR on cropland abandonment. Employing a large-scale farm-level panel data from Chinese Family Databases during 2015–2021, we find that ACR has a positive impact on the proportion of abandoned cropland area to total cropland area, with an average coefficient of 0.016. This effect is mainly achieved through reductions in long-term land investment, agricultural capital input, and agricultural labor input. Nevertheless, it is also moderated by the effects of rural factor markets and government agricultural subsidies. In particular, the agricultural machinery market, the land rental market and the level of agricultural subsidies can weaken ACR's negative impact on land use. Our findings also reveal that ACR is not harmful to households in northeastern and central China or major grain producing areas, while it harms others. Overall, this study provides a better understanding of the quantitative relationship between ACR and cropland abandonment in rural China, and valuable insights for other developing countries in formulating targeted measures to curb cropland abandonment in low ACR situations.

1. Introduction

Land produces a wide array of foods, making it a key contributor to global sustenance. As the world's population continues to grow at a rapid pace and its consequent increased food demand, the protection and responsible use of limited land resources is emerging as a universal challenge for humanity (Stehfest et al., 2019). Nevertheless, cropland abandonment is widespread in both developing and developed countries and has transformed into a global economic and social concern (Blair et al., 2018; Deng et al., 2019; Ito et al., 2016; Ojha et al., 2022; Zavalloni et al., 2021). A recently published study, drawing upon ESA-CCI land-cover time series data, reveals that an alarming 1.01 million hectares of cropland were abandoned globally between 1992 and 2020, equivalent to an average of 36,000 ha of cropland being abandoned each year (Zheng et al., 2023b). The expansion of cropland abandonment not only heightens public concern about food security, but also undermines sustainable agricultural development (Guo et al., 2023; Wang et al., 2023). In certain instances, cropland abandonment may yield certain environmental benefits, such as increased carbon sequestration and regeneration of forest ecosystems (Kuemmerle et al., 2011; Zheng et al., 2023b). However, due to the escalating impact of the COVID-19 pandemic, extreme weather events, and the ongoing conflict between Russia and Ukraine on global food security (Andrianarimanana et al., 2023; Zheng, 2024a), the detrimental effects of cropland abandonment on agriculture have gradually intensified in recent years. In this regard, it is of critical importance to explore the multiple drivers of cropland abandonment, with a view to enhancing targeted management of cropland abandonment and thus ensuring food security.

There is widespread academic discussion about why farmers abandon cropland. A growing body of scholarly literature indicates that cropland abandonment is primarily attributed to the following factors: (1) adverse natural conditions, such as remote mountainous areas (Hong

* Corresponding author.
E-mail addresses: zheng01@zju.edu.cn (L. Zheng), jins@msu.edu (S. Jin), lfsu@scau.edu.cn (L. Su).

https://doi.org/10.1016/j.jrurstud.2025.103759
Received 12 October 2024; Received in revised form 29 May 2025; Accepted 22 June 2025
Available online 25 June 2025

et al., 2024), fragmented land (Deininger et al., 2012; Zheng et al., 2023a), and poor soil fertility (Ojha et al., 2022); (2) unfavorable economic conditions, such as non-agricultural employment (Zheng, 2024b) and low agricultural income (Zavalloni et al., 2021); (3) inadequate institutional arrangements, such as insecure land tenure (Zheng and Qian, 2022) and limited land transfer rights (Deininger et al., 2012). Notably, economic factors, particularly low farm incomes, have been identified as the primary cause of farmers' decision to abandon cropland (Guo et al., 2023; Wang et al., 2022). However, it is important to note that the level of agricultural income is a relative concept due to differences in the frame of reference, and it is more specific to low agricultural comparative returns (Wang et al., 2023). Provided that other conditions remain constant, farmers' decision to abandon cropland depends primarily on the level of agricultural comparative return (ACR), which is widely recognized as the most critical economic factor in the Chinese context (Zhang et al., 2019). For a rational farmer, if their agricultural income and non-agricultural wage income are both relatively low, they are unlikely to abandon cropland for survival; conversely, if non-agricultural wage income is higher or even substantially higher than agricultural income, then they are highly likely to abandon cropland (Ma and Zhu, 2020).

Regrettably, despite the recognition by a subset of academics that ACR plays a pivotal role in instigating cropland abandonment (Wang et al., 2023), there is a notable lack of literature that directly investigates whether and how ACR triggers cropland abandonment, perhaps due to the fact that ACR is a counterfactual state, making it challenging to measure. For most developing countries, increasing agricultural income beyond non-agricultural wage income is not an easy task; especially in the context of rural-urban transformation, low ACR is likely to persist for an extended period. As the world's largest developing country, it is an undeniable fact that China's agricultural income is currently lower than non-agricultural wage income. According to the National Bureau of Statistics of China, since 2015, Chinese farmers' non-agricultural wage income has superseded agricultural income as the primary source of household income. In recent years, the influx of rural workers to urban areas for employment has escalated every year, reaching a total of 297.53 million by 2023. It also suggests that the gap between agricultural and non-agricultural earnings may persist and widen, with higher non-agricultural earnings acting as a catalyst for rural-urban migration (Zheng, 2024b). Concurrently, the issue of cropland abandonment in rural China is not encouraging. According to the Chinese Social Survey (CSS), the proportion of farmers abandoning cropland has risen from 9.80 % in 2011 to 12.35 % in 2021. The aforementioned preliminary evidence suggests an underlying positive correlation between ACR and cropland abandonment, but the extent to which ACR will induce farmers to abandon cropland remains to be further empirically examined.

In light of the above considerations, this study will seek to examine the main factors contributing to cropland abandonment by conducting an empirical analysis of the impact of ACR on cropland abandonment. Compared with the existing literature, the potential marginal contributions to this study mainly include the following three aspects. Firstly, we take the lead in developing an analytical framework to elucidate how ACR affects cropland abandonment, and our empirical design aligns well with theoretical derivation, thereby addressing the limitations of previous studies that only indirectly mention ACR. More importantly, we adopt a measurement approach for ACR using the value of the previous year and off-farm wage income at the village level. This effectively addresses endogenous issues caused by reverse causality and enables us to obtain unbiased estimation results. Secondly, using panel tracking data from Chinese Family Databases with national representation, the panel high-dimensional fixed-effects model will be employed to assess the overall effects, mechanisms, and heterogeneous effects of ACR on cropland abandonment, thereby enabling a comprehensive investigation of the relationship between ACR and cropland abandonment. Thirdly, starting from agricultural subsidies, agricultural machinery markets and land rental markets, we focus on land use change in the context of rural-urban transformation, and explore the governance strategies of abandoned cropland under the situation of low ACR, so as to contribute Chinese solutions to food security based on land protection in developing countries.

The remainder of the study is structured as follows. Section 2 discusses how ACR affects cropland abandonment. Section 3 introduces the data, selected variables and empirical strategy, and describes the descriptive statistics of the samples employed. Section 4 presents empirical findings on the impacts and mechanisms of ACR on cropland abandonment. Section 5 provides an analysis of the heterogeneous effects observed. Section 6 concludes with policy implications and research outlooks.

2. Theoretical analysis and research hypothesis

2.1. The effect of ACR on cropland abandonment

Dualistic economic theory suggests that the higher wage benefits in modern industrial sectors compared to traditional agricultural sectors induce large numbers of agricultural laborers to continuously migrate to urban areas (Lewis, 1954). Changes in the allocation of labor factors also lead to the reconfiguration of land resources by farmers. In order to analyze the impact of ACR on farmers' cropland abandonment behavior clearly, this study constructs the following theoretical model. Suppose the efficiency of agricultural production technology is A, and the inputs of labor, land, and capital are L_f, N_f, K_f, respectively. Using the technique of Chari et al. (2021) and Adamopoulos and Restuccia (2014) for agricultural production, the corresponding production function can be expressed as follows:

$$Y = f(N_f, L_f, K_f) = A^{1-\partial}\left(N_f^{\alpha} L_f^{\beta} K_f^{\gamma}\right)^{\partial} \tag{1}$$

$$\alpha + \beta + \gamma = 1, \partial < 1$$

where Y is the output of agricultural production. ∂ represents the scale return of agricultural production, and $\partial < 1$ indicates decreasing returns to scale. This inequality condition is based on the claim in most literature that increasing returns to scale in agricultural production do not exist at all except in some very special cases (Berry and Cline, 1980; Binswanger et al., 1995; Johnson and Ruttan, 1994). In developing countries in particular, diminishing returns to scale are more common. α, β, and γ measure the relative importance of land, labor, and capital respectively, while $\partial\alpha$, $\partial\beta$, and $\partial\gamma$ represent the output elasticity of land, labor, and capital respectively. Meanwhile, it is assumed that the agricultural production function satisfies the Inada conditions (Inada, 1963), that is $f'(0) = \infty, f'(\infty) = 0, f'(x) > 0, f''(x) < 0$, where $f'(\cdot)$ and $f''(\cdot)$ denote the first derivative and the second derivative, respective, and x can refer to either L_f, N_f or K_f.

The agricultural household model, with the dual constraints of labor and land, aiming to maximize income π, can be demonstrated as follows:

$$\underset{N_f, L_f, K_f}{Max}\ \pi = pf(N_f, L_f, K_f) - uK_f + rN_r + wL_n + T(N_f) \tag{2}$$

$$s.t.\quad N_f + N_r \le \bar{N} \quad L_f + L_n \le \bar{L}$$

where p is the price of agricultural products. r, w, and u represent land rent, labor wages, and capital interest rates, respectively. Additionally, L_n signifies the number of non-agricultural employment labor force while N_r denotes the area of land transferred-out. $\bar{N}$ indicates household land resource constraints and $\bar{L}$ refers to household labor force constraints. Furthermore, $T(N_f)$ symbolizes government subsidies to farmers for agricultural production, which are calculated according to the land area cultivated by farmers (N_f). Based on equation (2), we take the first order derivative for L_f, N_f and K_f yields respectively (see

Appendix A for more details of the derivation):

$$\frac{\partial \pi}{\partial N_f} = p f'_{N_f} - r + \frac{\partial T(N_f)}{\partial N_f} = 0 \tag{3}$$

$$\frac{\partial \pi}{\partial L_f} = p f'_{L_f} - w = 0 \tag{4}$$

$$\frac{\partial \pi}{\partial K_f} = p f'_{K_f} - u = 0 \tag{5}$$

The core essence of the decline in comparative agricultural returns is reflected in the decrease in agricultural income and the increase in non-agricultural income. The decline in agricultural income can be attributed to a reduction in grain profits, often caused by a decrease in agricultural product prices or an increase in input costs. Therefore, the analysis of the impact of declining comparative agricultural returns can be conducted from three aspects: decreasing agricultural product prices, increasing input costs, and rising non-agricultural income.

Firstly, we analyze the impact of the decrease in the ACR caused by the decline in agricultural product prices on land allocation. Equation (3) can be rewritten as:

$$p f'_{N_f} = r - \frac{\partial T(N_f)}{\partial N_f} \tag{6}$$

Assuming that government subsidies are implemented according to a fixed per acre subsidy standard, $\frac{\partial T(N_f)}{\partial N_f}$ is a constant that remains unchanged. In the event of a decrease in p, equation (6) can only be maintained by increasing f'_{N_f} while keeping r constant. Moreover, considering $f''(x) < 0$ implies that N_f will exhibit a decline. This derivation can be proved by the total differentiation of equation (6) shown in Appendix B.

Next, we turn to discuss the impact of the decrease in ACR due to higher input costs on land allocation. The input costs increase, that is, u in equation (5) increases. To ensure that equation (5) still holds true while p remains unchanged, it is necessary to increase f'_{K_f} and correspondingly decrease K_f. This derivation can be proved by the total differentiation of equation (5) shown in Appendix C. We further expand equation (6) in a specific manner (see Appendix D for more details of the derivation):

$$pA^{1-\partial}\alpha\partial N_f^{\alpha\partial-1} L_f^{\beta\partial} K_f^{\gamma\partial} = r - \frac{\partial T(N_f)}{\partial N_f} \tag{7}$$

Under the condition of holding other factors constant, a decrease in K_f necessitates a corresponding decrease in N_f to maintain equation (7). This derivation can be demonstrated by the total differentiation of equation (7) shown in Appendix E.

Lastly, the decline in ACR may also be due to an increase in non-agricultural income, which is reflected in the rise of wages for non-agricultural employment (w). In order to maintain equation (4) while w increases and other factors remain constant, it is necessary to increase f'_{L_f} and decrease L_f accordingly. This derivation can be proved by the total differentiation of equation (4) shown in Appendix F. Furthermore, it can be inferred that a decrease in L_f requires a corresponding decrease in N_f to ensure the validity of equation (7).

In conclusion, it can be inferred that a decline in ACR will lead to a reduction in land use. Ideally, farmers would opt to rent their surplus cropland out to generate rental income. However, due to the homogeneous factor allocation logic among farmers in the same land rental market, when farmers collectively decide to transfer their croplands, an oversupply situation arises. Consequently, farmers may face the dilemma of transferring their land with zero rent. To mitigate losses from potential damage beyond crop yields, farmers are more likely to abandon their croplands. Alternatively, imperfect land rental markets and high transaction costs for land rental may lead to cropland abandonment. Therefore, we propose the first research hypothesis as follows.

Hypothesis 1. A decrease in ACR increases the farmers' cropland abandonment.

2.2. The mediation mechanism of ACR affecting cropland abandonment

Based on the previous analysis, it becomes evident that the decline in ACR can be manifested by a decrease in p, coupled with an increase in u and w. To attain equilibrium conditions as stated in equations (4) and (5), it is imperative to augment f'_{L_f} and f'_{K_f}, while correspondingly diminishing L_f and K_f. In this scenario, combining equation (7) reveals that the decrease in L_f and K_f will further result in a decrease in variable N_f. This can also be explained by the complementary relationship between labor and capital with land (Chari et al., 2021; Sazama and Davis, 1973). Therefore, it can be inferred that a decrease in ACR reduces capital and labor inputs in agricultural production, which have been proved by previous studies to exert a negative relationship with cropland abandonment (Chen et al., 2025; Deininger et al., 2012; Zheng, 2024b).

Especially for investments that take a long time to show returns, such as those related to improving land quality, including investments in straw and manure returns, the costs are high and the effectiveness period is long. Therefore, in situations where ACR decreases, farmers are even less likely to implement these types of investments. However, in the long run, the lack of these investments would degrade land quality and subsequently decrease agricultural productivity (referred to as A) (Zhang et al., 2023). According to equation (7), it can be inferred that when other factors remain constant, the decrease in A leads to a decrease in N_f thus promoting cropland abandonment. To sum up, we propose the following hypotheses:

Hypothesis 2-1. A decline in ACR leads to cropland abandonment through reduced long-term land investment.

Hypothesis 2-2. A decrease in ACR results in cropland abandonment through reduced agricultural capital input.

Hypothesis 2-3. A decline in ACR leads to cropland abandonment through reduced agricultural labor input.

2.3. The moderation mechanism of ACR affecting cropland abandonment: A dual perspective of market development and government subsidies

The above two hypotheses may not necessarily hold true, as there may be certain influential factors that hinder the mechanism of ACR affecting cropland abandonment or affecting ACR itself. We therefore attempt to further identify these powerful moderating factors. Generally speaking, the development of the agricultural machinery market and the land rental market, as well as government subsidies, can all play an effective role in moderating the impact of ACR on cropland abandonment, with the former two from the market perspective and the latter from the government perspective. Thus, we discuss these moderating effects further from the dual perspectives of market and government based on the theoretical framework mentioned above.

2.3.1. The role of agricultural machinery market and land rental market

One of the mechanisms through which ACR induces cropland abandonment is off-farm labor migration, resulting in insufficient agricultural labor. However, if there is an external force that can address this issue, it can weaken the positive impact of ACR on cropland abandonment. This external force should be able to effectively address the problem of imbalanced allocation between land and labor. The development of the agricultural machinery market and the land rental market have the potential to address this problem. The former involves

replacing labor with machinery to compensate for labor shortages, while the latter involves reallocating land resources by transferring them to households with more agricultural labor.

First, the moderating role of the agricultural machinery market on cropland abandonment resulting from the reduction of ACR is dissected. On the one hand, agricultural machinery can be perceived as an input factor in the short run, denoted as part of K_f. As a production factor, agricultural machinery affects cropland abandonment through two moderating pathways: (1) Serving as a substitute factor for labor input, the presence of agricultural machinery can alleviate the issue of inadequate agricultural workforce and ensure that N_f does not experience significant or even any decline due to reduced ACR, thereby assisting in mitigating cropland abandonment; (2) As a complementary factor to land, agricultural machinery drives farmers to expand operational scales to achieve economies of scale (Feder et al., 1985; Takeshima et al., 2020), thereby reducing cropland abandonment. On the other hand, in the long run, when agricultural machinery incorporates breakthrough technological innovations, it helps reduce resource waste, improve land quality, and optimize planting cycles, thereby enhancing total factor productivity A (Cui, 2023; Ma et al., 2022). Similarly, an increase in A leads to an increase in f'_{N_f}, further promoting an increase in N_f, thus helping to prevent cropland abandonment.

Next, we focus on the moderating role of the land rental market on cropland abandonment resulting from the reduction of ACR. In equation (2), land rent r can be defined as a function of the development level z of the land rental market, where a more mature and standardized land rental market corresponds to a higher value of z. The advancement of the land rental market development level facilitates the following mechanisms: From the lessor's perspective, it promotes the transition of land from informal and relationship-based transactions to market-oriented transactions, thus reducing the probability of zero-rent arrangements and elevating rent level (Tang et al., 2019; Zheng et al., 2025); From the lessee's perspective, a well-developed land rental market can decrease transaction cost, enhance contractual stability, and encourage acceptance of higher rent (Li and Ito, 2021). Thus, $\frac{\partial r}{\partial Z} > 0$ can be obtained. Based on equation (2), we take the first order derivative with respect to N_r yields:

$$-pA^{1-\partial}\alpha\partial(\overline{N-N_r})^{\alpha\partial-1}L_f^{\beta\partial}K_f^{\gamma\partial}+r-s=0 \tag{8}$$

where $s = \frac{\partial T(N_f)}{\partial N_f}$. Equation (8) can be rewritten as:

$$r=pA^{1-\partial}\alpha\partial(\overline{N-N_r})^{\alpha\partial-1}L_f^{\beta\partial}K_f^{\gamma\partial}+s \tag{9}$$

According to equation (9), taking the partial derivative of the first order with respect to r, we can get:

$$\frac{\partial r}{\partial Nr}=-pA^{1-\partial}\alpha\partial(\alpha\partial-1)(\overline{N-N_r})^{\alpha\partial-2}L_f^{\beta\partial}K_f^{\gamma\partial}>0 \tag{10}$$

Thus, $\frac{\partial Nr}{\partial r}>0$ can be obtained. In order to verify the moderating role of the land rental market on cropland abandonment, we identify $\frac{\partial Nr}{\partial Z}$ as follows:

$$\frac{\partial Nr}{\partial Z}=\frac{\partial Nr}{\partial r}\cdot\frac{\partial r}{\partial Z}>0 \tag{11}$$

This indicates that with the development of land rental markets, farmers tend to rent out land they are unwilling to cultivate due to low ACR rather than abandon it. Therefore, we propose the following hypotheses.

Hypothesis 3-1. The development of agricultural machinery market curbs cropland abandonment caused by ACR reduction.

Hypothesis 3-2. The development of land rental market reduces cropland abandonment due to reduced ACR.

2.3.2. The role of government agricultural subsidies

Government subsidies for agricultural production play a crucial role in China. According to statistical data, China's subsidies for safeguarding cropland encompass 220 million farming households and nearly 1.3 billion mu of contracted land, with an average subsidy amounting to approximately 95 yuan per mu and approximately 564 yuan per household.[1] This inclusive approach effectively boosts farmers' incomes, facilitates the transition of supportive agricultural policies from "yellow box" to "green box", and expands the policy space for promoting agricultural development and augmenting farmers' earnings. Consequently, we aim to reveal the moderating role of government agricultural subsidies in mitigating cropland abandonment caused by reduced ACR.

Here, we discuss agricultural subsidies linked to production. Since 2015, China has linked the decoupled direct subsidies to farmland fertility conservation, explicitly excluding abandoned cropland from subsidy eligibility. As subsidies are contingent on agricultural production, they generate a production incentive effect, directly shaping land resource allocation. However, as an income-raising policy, agricultural subsidies also induce an income effect, indirectly affecting land allocation by altering labor allocation through leisure consumption. To disentangle these dual effects, we introduce the utility function of farmers, that is $U = U(\pi, L)$, where π is income and L is leisure time. To simplify the analysis, we disregard land renting out, which complicates subsidy implementation due to regional variations in criteria, e.g., subsidies based on contracted area versus actual cultivated area, and simplify income π shown in equation (2) as:

$$\pi = pf(N_f, L_f, K_f) - uK_f + wL_n + N_f \cdot s \tag{12}$$

The land constraint condition is $N_f \le \bar{N}$, and the area of abandoned land is $D = \bar{N} - N_f$. By considering leisure, the time constraint condition can be expressed as $L_f + L_n + L = \bar{L}$. Land and labor are allocated to maximize utility:

$$MaxU = U\left(pf(N_f, L_f, K_f) - uK_f + wL_n + N_f \cdot s, T - L_f - L_n\right) \tag{13}$$

$$s.t. \quad N_f \le \bar{N},$$

We introduce Lagrangian multiplier $\lambda \ge 0$ to construct Lagrangian function as follows:

$$\mathscr{L} = U\left(pf(N_f, L_f, K_f) - uK_f + wL_n + N_f \cdot s, T - L_f - L_n\right) + \lambda\left(\bar{N} - N_f\right) \tag{14}$$

Based on equation (14), taking the first order derivative with respect to N_f and L_f , respectively, we can get:

$$\frac{\partial \mathscr{L}}{\partial N_f} = U_\pi \cdot \left(pf'_{N_f} + s\right) - \lambda = 0 \tag{15}$$

$$\frac{\partial \mathscr{L}}{\partial L_f} = U_\pi \cdot pf'_{L_f} - U_L = 0 \tag{16}$$

where U_π and U_L denote the first partial derivative of the utility with respect to π and L, respectively.

Next, a comparative static analysis is conducted. First, the production incentive effect of agricultural subsidies can be identified based on equation (15). If utility remains unchanged through compensatory income adjustments and the subsidy s increases such that equation (15) still holds, then f'_{N_f} must decrease. In the case of $f''_{N_f} < 0$, N_f will increase, thereby reducing abandoned land area D. Second, the income effect of agricultural subsidies can be identified based on equation (16).

[1] https://www.mof.gov.cn/zhengwuxinxi/caijingshidian/zgcjb/202109/t20210916_3753468.htm.

Agricultural subsidies enhance total income π, leading to a reduction in U_π due to diminishing marginal utility. For equation (16) to remain valid, f'_{L_f} needs to increase, and in the case of $f''_{L_f} < 0$, L_f will decrease. Due to the complementary relationship between L_f and N_f, without considering changes in mechanical input, N_f will decrease, which in turn increases the abandoned land area D. In summary, the overall effect of agricultural subsidies on cropland abandonment can be decomposed into a negative production incentive effect and a positive income effect. However, China's growing level of agricultural mechanization development weakens the income effect while strengthening the production incentive effect. Additionally, given the relatively low current income levels of farmers, their preference for leisure is not strong, further weakening the income effect. Therefore, in absolute terms, the production incentive effect outweighs the income effect, resulting in a net negative impact of agricultural subsidies on cropland abandonment. Consequently, we put forward the following hypotheses:

Hypothesis 4-1. The availability of agricultural subsidies mitigates cropland abandonment caused by ACR reduction.

Hypothesis 4-2. The increase in the level of agricultural subsidies curbs ACR reduction-induced cropland abandonment.

Finally, to enhance the clarity of the theoretical logic presented in this study, a theoretical framework diagram (Fig. 1) is included. This diagram effectively illustrates the impact of ACR on cropland abandonment, along with its underlying mediating and moderating mechanisms that have been derived and substantiated in previous sections.

3. Research design

3.1. Data sources

The data employed in this study were sourced from the Chinese Family Database (CFD).[2] The database has been built by conducting field surveys every two years since 2011. The survey was mainly led by Zhejiang University in 2011, 2013, 2015, 2017 and 2019, in conjunction with other universities such as Anhui University, Southwestern University of Finance and Economics, while in 2021, it was jointly conducted by South China Agricultural University and Southwestern University of Finance and Economics. Since information on cropland abandonment is only available from 2013 onwards, we only used data for 2015, 2017, 2019 and 2021.

During the survey, to ensure the national representativeness of the dataset, a stratified, three-stage, proportional population size (PPS) sampling method was employed to collect data from farm households and village directors in 29 provinces in China (excluding Xinjiang and Xizang). Specifically, in the first stage, counties were divided into 10 tiers based on GDP per capita, and counties were randomly selected in tiers. In the second stage, villages were randomly selected at the county level. In the third stage, 20 farm households were randomly selected from each selected village (Zheng, 2024c). The data is nationally representative at multiple levels, including provincial, county, and village (Zheng and Qian, 2022), and is by far one of the most informative large-scale microdatabases on agricultural production variables in China. Based on this database, there have been high-level articles published in Nature and Proceedings of the National Academy of Sciences (PNAS) as well as monographs published in Springer Press (Qian, 2020; Ren et al., 2023; Wu et al., 2018).

To estimate the impact of ACR on cropland abandonment, we conducted a data cleansing process for the empirical purpose of this study. Firstly, households without their own cropland (contracted land, in the Chinese context) were weeded out. Secondly, because older heads of households may have biased responses to the questionnaire, we excluded samples with heads of households over 70 years old. Thirdly, key variables including farm income, off-farm wage income, cropland abandonment, land transfer, agricultural machinery, agricultural subsidies, individual characteristics of household heads, family demographic characteristics and land characteristics were retained. Observations with missing or invalid information pertaining to these variables were deleted. Ultimately, an unbalanced panel dataset spanning four years was obtained, consisting of 24,843 observations for empirical research.

3.2. Empirical strategy

Utilizing panel data, this study employs a high-dimensional fixed-effects model to examine the impact of ACR on cropland abandonment, thereby mitigating potential estimation bias resulting from omitted variables. The model is constructed as follows:

$$Abandonment_{jt} = \alpha_0 + \alpha_1 ACR_{jvt-1} + \beta \boldsymbol{X}_{jt} + \mu_j + \delta_t + \omega_{ct} + \varepsilon_{jt} \quad (17)$$

where j, v, c, and t denote the farm household, village, county, and year, respectively. $Abandonment_{jt}$ is the dependent variable, which is specifically defined as the proportion of abandoned cropland area to total cropland area in year t for farm household j, and takes a value between 0 and 1. According to cobweb theory (Poitras, 2023) and the seasonal and cyclical nature of agricultural production, ACR_{jvt-1} serves as the core independent variable in this study, which is a binary variable defined by comparing the farm income of the household j with the average wage income of other farmers in the same village v last year. When the former exceeds the latter, ACR_{jvt-1} is assigned a value of 0, indicating comparative advantage in agricultural returns; when the former is less than the latter, ACR_{jvt-1} is assigned a value of 1, indicating no comparative advantage in agricultural returns. Note that ACR measurement in this study has three favorable features: (1) the village-level measurement overcomes the issue of self-selection bias to some extent; (2) the core independent variable, as per the CFD questionnaire, occurs before the dependent variable, thus mitigating the occurrence of endogenous problems related to reverse causality; and (3) farm income specifically refers to gross income that is not included in agricultural production costs rather than net income, which can avoid the interference affecting agricultural production costs, such as the agricultural machinery market, land rental market, and agricultural subsidies.

Additionally, $\boldsymbol{X}_{jt}$ represents a series of control variables that may influence farmers' decision to abandon cropland. Based on previous literature and data availability, this study incorporates several control variables including individual characteristics such as the age of the household head and its quadratic term (Deng et al., 2019), education level (Ma and Zhu, 2020), as well as family characteristics like dependency ratio (Zheng, 2024a), health status of family members (Zheng and Qian, 2022), engagement in off-farm work (Xu et al., 2019b; Zheng, 2024b), land size (Deng et al., 2019; Wang et al., 2023), land fragmentation (Deininger et al., 2012; Zheng et al., 2023a), and land certification (Deng et al., 2019; Zheng and Qian, 2022). These control variables are also employed to mitigate potential endogeneity issues arising from omitted variables. Furthermore, the high-dimensional fixed-effects of this model primarily manifest in three dimensions: firstly, individual fixed effects represented by μ_j, which address the issue of omitted variables caused by observable and unobservable factors that remain constant over time; secondly, time fixed effects denoted as δ_t to control for influences on each year that are consistent across individuals, such as macroeconomic fluctuations; thirdly, the interaction effect between county-level fixed effects and time fixed effects indicated by ω_{ct} to account for county-level factors that change over time, such as local land policy and extreme weather. α_0 is the intercept term, α_1 and β are the parameters to be estimated, and ε_{jt} is the random disturbance term.

[2] The data can be accessed from http://ssec.zju.edu.cn/sites/main/template/news.aspx?id=51035.

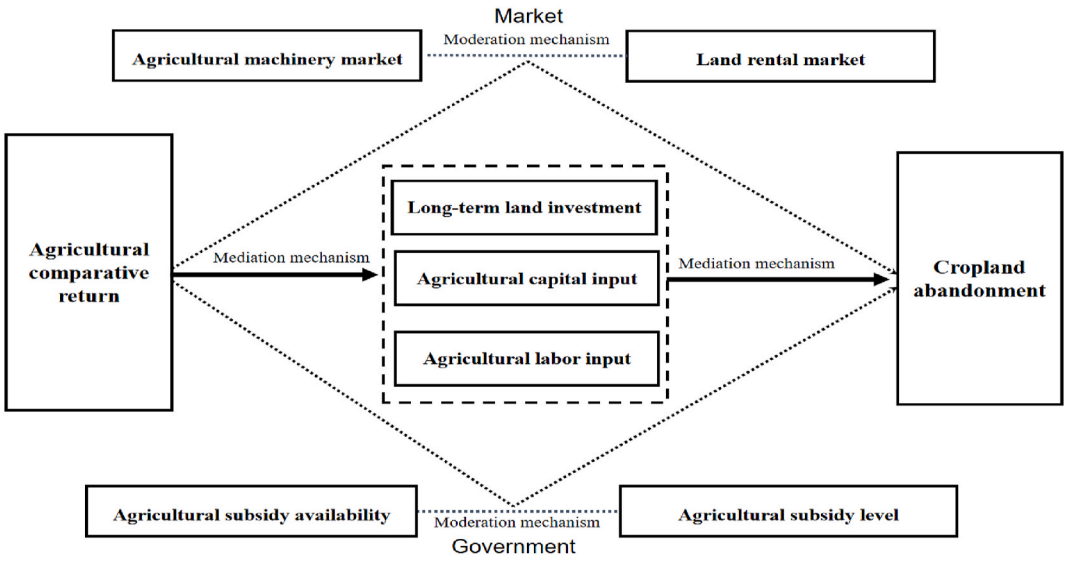

Fig. 1. Analytical framework.

3.3. Sample characteristics and descriptive statistics

Table 1 provides definitions and descriptions of the selected variables. For the dependent variable, the average abandoned cropland per sample farmer accounted for 4.7 % of the total cropland area. Approximately 9.3 % of the sample farmers engaged in cropland abandonment behavior. The descriptive statistics for the core explanatory variable ACR indicate that approximately 54.9 % of the sampled households have lower farm incomes compared to the average wage incomes of other farmers in the same village, suggesting a lack of comparative advantage in agricultural returns.

Next, we proceed to the descriptive statistics of the control variables. The mean age of the household head is approximately 53 years old. Merely 14.1 % of heads of households have completed high school education, indicating a relatively low level of educational attainment. Concerning family demographic characteristics, the average elderly dependency ratio stands at around 0.14, suggesting that there is an average support burden of about 0.14 elderly individuals per labor force, which falls below one person. The average proportion of healthy individuals in the family population amounts to roughly 76.7 %, implying a relatively favorable health status among the sample households. The average proportion of non-farm employment in total household labor is approximately 22.4 %, signifying potential for further non-farm labor transferability. In terms of household land characteristics, the mean per capita cropland area measures about 2.82 mu, revealing a certain disparity compared to the global per capita cropland area (4.8 mu), thereby reflecting the issue of cropland scarcity in China. The average number of cropland plots reaches 5.45, indicating a significant problem of land fragmentation in China. Approximately 67.5 % of farmers reported having obtained land certificates.

3.4. Descriptive statistics on ACR and cropland abandonment

Before estimating the econometric model, we present the correlation between ACR and land abandonment by plotting a grouped bar chart by year (Fig. 2). According to the previous definition, the sample group when $ACR_{jvt-1} = 1$ is named as the more wage income; Conversely, when $ACR_{jvt-1} = 0$, the sample group is named more farm income. It is evident that from 2015 to 2021, there has been a consistent annual increase in the proportion of abandoned cropland areas for sampled households, regardless of comparative advantage in farm income compared to wage income. This underscores the escalating severity of the cropland abandonment issue and emphasizes its significance in our study. Furthermore, in each year, households lacking a comparative advantage in farm income exhibit a higher average proportion of abandoned cropland compared to those with such an advantage. Hence, it can be tentatively inferred that the absence of ACR may contribute to increased cropland abandonment. However, this analysis does not account for other factors and necessitates further rigorous empirical testing to establish causality between ACR and cropland abandonment.

Table 1
Variable definitions and descriptive statistics (N = 24843).

Variables	Definition	Mean	SD	Min	Max
Cropland	Proportion of abandoned cropland area to total cropland area	0.047	0.172	0	1
abandonment	Whether cropland is abandoned (yes = 1, no = 0)	0.093	0.290	0	1
ACR	Whether the household farm income last year was lower than the average wage income of other farmers in the village (yes = 1, no = 0)	0.549	0.498	0	1
Age	Age of household head	53.178	10.877	16	69
Education	Did the head of the household attend high school (yes = 1, no = 0)	0.141	0.348	0	1
Dependency ratio	Dependency ratio of the elderly (0–3)	0.144	0.327	0	3
Family health	Proportion of healthy people in the household (0–1)	0.767	0.311	0	1
Off-farm work	Proportion of off-farm work in the household (0–1)	0.224	0.260	0	1
Land size	Household cropland area per capita (mu)	2.819	6.938	0.001	500
Land fragmentation	Number of cropland plots	5.450	6.058	1	120
Land certification	Whether farmers have obtained a land certificate (yes = 1, no = 0)	0.675	0.468	0	1

Notes: 1 mu = 1/15 ha. Yuan is Chinese currency (1 USD = 7.25 Yuan in 2025).

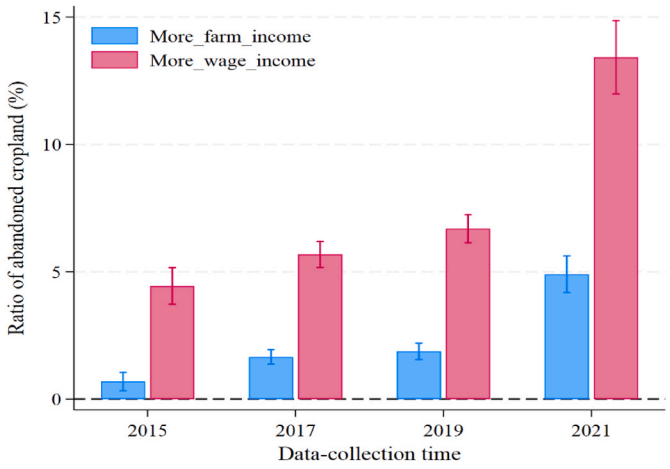

Fig. 2. Correlation between ACR and cropland abandonment.

4. Impact of ACR on cropland abandonment

4.1. Baseline results

The baseline results of the impact of ACR on cropland abandonment, as estimated using the high-dimensional fixed-effects model, are presented in Table 2. The three columns in Table 3 control the household fixed effect, the year fixed effect, as well as the interactive fixed effects of the county and year simultaneously. Column (1) includes only the core explanatory variable ACR, and the results indicate a significant positive impact of ACR on the proportion of abandoned cropland area to total cropland area, with a coefficient of 0.016. This indicates that farmers with lower agricultural return relative to non-agricultural return exhibit a 0.016 increase in the proportion of abandoned cropland area, which accounts for approximately 34 % of the average proportion of abandoned cropland area to total cropland (0.047) observed in the sample households. This is a large impact effect, highlighting the importance of ACR to farmers' cropland use decisions. In columns (2) and (3), the personal characteristics of the head of household and family characteristics are included, respectively. The results demonstrate that ACR still has a significant positive impact on the proportion of abandoned cropland areas, with an almost unchanged coefficient compared to column (1). Consequently, the significant positive impact of ACR on cropland abandonment can be empirically proved, thereby confirming hypothesis 1 posited in our study.

Table 2
The effect of ACR on cropland abandonment.

Variables	Proportion of abandoned cropland area to total cropland area		
	(1)	(2)	(3)
ACR	0.016***	0.016***	0.016***
	(0.004)	(0.004)	(0.004)
Age		−0.001	−0.001
		(0.002)	(0.002)
Age2		5.01e-06	0.00001
		(0.00002)	(0.00002)
Education		−0.015*	−0.015*
		(0.008)	(0.008)
Dependency ratio			0.019**
			(0.009)
Family health			−0.014*
			(0.008)
Off-farm work			0.026***
			(0.009)
Land size			0.001***
			(0.0002)
Land fragmentation			0.002**
			(0.001)
Land certification			−0.010**
			(0.005)
Household FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
County × Year FE	Yes	Yes	Yes
Mean of dependent variable	0.047	0.047	0.047
Observations	24,843	24,843	24,843
R-squared	0.684	0.684	0.685

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

In terms of control variables, the age of the household head and its quadratic term do not exhibit a significant impact on cropland abandonment, which contradicts the significant nonlinear relationship identified by Zheng et al. (2023a). The education level of the household head is inversely correlated with cropland abandonment, aligning with the findings reported by Ma and Zhu (2020). This can be attributed to improved agricultural management skills associated with higher education, thereby leading to a reduction in cropland abandonment. Older dependency ratios are emerging as a pivotal determinant of cropland abandonment, while the health status of family members plays a crucial role in mitigating cropland abandonment. This finding is consistent with research conducted by Zheng and Qian (2022), which posits that households with poor labor endowments are more likely to abandon cropland. The higher the proportion of off-farm workers, the greater the extent of cropland abandonment, which can be attributed to a decline in farm labor due to the shift to off-farm employment (Xu et al., 2019a; Zheng, 2024b). From the perspective of land characteristics, cropland abandonment increases with the increase in per capita land size, because limited labor may choose to cultivate land of better quality and are more likely to abandon other marginal land in the face of large land sizes. Land fragmentation has a significant positive impact on cropland abandonment, which can be attributed to increased agricultural production costs (Wang et al., 2022; Zheng et al., 2023a). The confirmation of land property rights can effectively mitigate cropland abandonment, primarily due to the policy's reinforcement of farmers' awareness and recognition of property rights, thus fostering a greater sense of value for their cropland.

4.2. Robustness checks

To assess the robustness of the baseline results, a series of rigorous robustness checks are conducted, and the corresponding results are demonstrated in Table 3. One approach to robustness checking is to replace variables. In column (1), the core independent variable ACR is replaced by ACRC. It is defined as whether the household farm income last year was lower than the average wage income of other farmers in the county. The results show that ACRC also has a significantly positive effect on cropland abandonment. Column (2) replaces the dependent variable in baseline regression with a binary variable, denoting whether the cropland is abandoned or not. The results indicate that the positive impact of ACR remains valid. Compared to farmers with a comparative advantage in agricultural returns, those without such an advantage exhibited an increased likelihood of cropland abandonment by 0.015.

The second approach involves replacing the estimation model. Given that a significant proportion of sample households do not exhibit cropland abandonment behavior, the dependent variable is treated as a censored variable (Zheng, 2024a). To obtain an unbiased estimate, we employ a panel Tobit model. As depicted in column (3), the estimated results from the panel Tobit model continue to support the positive impact of ACR on cropland abandonment.

The third approach is to add more control variables. Despite controlling for individual and household characteristics as much as possible in the previous section, it is still difficult to rule out the problem of omitted variables, such as land production conditions and village characteristics. For this reason, we further incorporate the following variables: land market value, per capita income, new agricultural

Table 3
The results of robustness checks.

Variables	Replacing variables		Replacing model	Adding variables	Adjusting sample	
	(1)	(2)	(3)	(4)	(5)	(6)
ACR		0.015**	0.070***	0.015**	0.013***	0.071***
		(0.007)	(0.004)	(0.007)	(0.005)	(0.008)
ACRC	0.011**					
	(0.005)					
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Other variables	–	–	–	Yes	–	–
Household FE	Yes	Yes	–	Yes	Yes	–
Year FE	Yes	Yes	–	Yes	Yes	–
County × Year FE	Yes	Yes	–	Yes	Yes	–
Observations	24,843	24,843	24,843	12,428	20,932	3,911
Log likelihood	–	–	−7717.433	–	–	–
Wald chi2	–	–	−603.07	–	–	–
R-squared	0.685	0.696	–	0.820	0.776	0.045

Notes: ***, **, and * denote significance at the 1 %, 5 %, and 10 % levels, respectively; Robust standard errors and delta-method standard errors are presented in parentheses. In column (4), land market value is defined as logarithm of land market value per mu estimated by the household head; per capita income is defined as per capita disposable annual in the village; new agricultural operators are defined as logarithm of the number of large-scale agricultural operators in the village, including professional operators, family farms, agricultural cooperatives, and farming companies; land water conservancy construction is measured by whether the village has carried out cropland water conservancy construction. Due to space limitations, estimates of other control variables are available from the authors upon request.

operators, and land water conservancy project. Results in column (4) indicate that the positive association between ACR and cropland abandonment remains significant, although some variables in different years are missing, leading to a decline in observations.

The last approach is to adjust the samples. To mitigate the influence of COVID-19, we excluded sampled households in 2021 and focused solely on regression analysis using 2015–2019 samples. The result, presented in column (5), still demonstrates a significant impact of ACR on cropland abandonment. Furthermore, we conducted separate analyses among sampled households in 2021, as depicted in column (6), revealing that even amidst the shock of COVID-19, ACR still exerts a noteworthy positive effect on cropland abandonment.

To sum up, the results of various robustness checks consistently support the reliability and robustness of the baseline results, allowing us to scientifically and accurately assert that lower agricultural return compared to non-agricultural employment income is a significant factor leading to cropland abandonment.

4.3. Endogeneity discussion

As mentioned earlier, this study was designed to minimize potential endogeneity concerns arising from omitted variables, measurement errors, and reverse causality. First, based on data availability, we drew on existing research to include as many relevant control variables as possible, excluding other potential omitted variables. When comparing columns (1)–(3) in Table 2, it is clear that the impact of ACR on cropland abandonment remains significantly positive with robust coefficients, regardless of the inclusion of additional control variables. Second, by redefining the core independent variables, this study mitigated the endogeneity problem caused by measurement errors of the core independent variable. The positive relationship between ACR and cropland abandonment remains robust in the estimated results in column (1) of Table 3. Third, with the benefit of the CFD, reverse causality in this study could be avoided by defining ACR using income variables from the previous year rather than the current year, and at the village/county level rather than the household level.

However, there are also other endogeneity concerns caused by selection bias in this study. In particular, more capable farmers may select better off-farm employment opportunities, and farmers with better land conditions may be more likely to choose farming. In this regard, we employ a Propensity Score Matching (PSM) approach to estimate the impact of ACR on cropland abandonment. Specifically, we utilize three commonly used matching methods, such as one-to-one nearest neighbor (NN) matching, NN matching within caliper, and kernel matching, for estimation. The results in Table 4 indicate that regardless of the matching method used, the average treatment effects (ATT) for ACR remain positive and significant regardless of the matching method used, indicating that our findings are consistent with previous estimates. Therefore, there is no need to worry too much about endogeneity in this study.

4.4. Mechanism analysis

Based on theoretical analysis, we subsequently examined the internal mechanism by which ACR influences cropland abandonment by focusing on changes in input factors of land, capital, and labor. The estimated results are presented in Table 5.

Column (1) exhibits the estimated result of ACR's impact on long-term land investment. We defined a binary variable to characterize the long-term land investment of farmers, assigning a value of 1 when farmers engage in straw or manure return practices, and 0 otherwise. It can be found that compared to farmers with a comparative advantage in agricultural returns, the probability of implementing long-term land investment decreases by 0.026 for farmers without a comparative advantage in agricultural returns. This observed effect accounts for 4.27 % of the proportion of sampled households (0.608) that have implemented long-term investments in land, which can be treated as a relatively obvious effect. The findings demonstrate that a comparative disadvantage in agricultural returns leads to an increase in cropland abandonment due to a reduction in long-term investment in land, which has been proved to help curb cropland abandonment by Ma and Zhu (2020). This is primarily attributed to the lack of cost-effectiveness associated with implementing long-term land investments under conditions of low comparative agricultural returns. Such investments not only require substantial input costs, but also necessitate several years for the beneficial effects of returning straw and manure on land quality to become apparent (Abdulai et al., 2011; Wang et al., 2021; Zheng, 2024c). Therefore, a reduction in long-term land investment produces corresponding reduction in the cost of cropland abandonment, making cropland abandonment easier to occur.

The estimate in Column (2) illustrates the impact of ACR on agricultural capital input, which is estimated using logarithm. The results show that the input of agricultural capital by farmers with comparative agricultural returns increased by 1.88 times more than that of farmers without comparative agricultural returns. This implies that ACR may enhance cropland abandonment by diminishing agricultural capital

Table 4
The results of PSM estimates.

PSM methods	Cropland abandonment		ATT	S.E.	T-value	Common support	
	Treat	Control				Treat	Control
Nearest neighbor matching (n = 1)	0.068	0.020	0.048***	0.003	18.85	11,199	13,625
NN matching with caliper (n = 4, r = 0.05)	0.068	0.020	0.048***	0.002	20.60	11,199	13,625
Kernel matching (bandwidth = 0.03)	0.068	0.021	0.047***	0.002	21.19	11,199	13,625

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

Table 5
The result of mechanism analysis.

Variables	Dependent variable		
	(1) Long-term land investment	(2) Agricultural capital input	(3) Agricultural labor input
ACR	−0.026***	−1.880***	−0.074***
	(0.009)	(0.072)	(0.006)
Control variables	Yes	Yes	Yes
Household FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
County × Year FE	Yes	Yes	Yes
Observations	23,204	24,843	24,843
R-squared	0.847	0.839	0.853

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

input. This phenomenon arises primarily from rational farmers' tendency to allocate their capital solely to high-yield projects (Huang and Shi, 2021). Consequently, the reduction in capital input for agricultural production corresponds to a decrease in cropland allocation, ultimately leading to an increase in cropland abandonment (Chen et al., 2025; Deininger et al., 2012).

The third column demonstrates the estimated impact of ACR on agricultural labor input, which is depicted as the proportion of agricultural labor to the total household population. The results indicate that farmers without comparative agricultural returns experience a reduction of approximately 7.4 percentage points in the proportion of agricultural labor to the total household population compared to those with comparative agricultural returns. This accounts for about 18.97 % of the mean proportion of agricultural labor in the total household population (0.39) in the sampled households. The findings provide evidence that ACR increases cropland abandonment by diminishing agricultural labor input primarily due to the allure of high-yield off-farm livelihood activities (Xu et al., 2019a; Zheng, 2024b), resulting in an out-transfer of labor and subsequent suspension of land management due to workforce shortage and eventual cropland abandonment.

To conclude, we provide empirical evidence that ACR leads to cropland abandonment primarily through the reduction of long-term land investment, agricultural capital input, and agricultural labor input. The hypotheses 2-1,2-2,2-3 proposed by the aforementioned theory have been validated.

4.5. Further discussion

4.5.1. Moderating effect of factor market development

Based on the analysis in the previous section, it is of great significance to further explore how to alleviate the problem of cropland abandonment caused by low ACR. We first examine from a market perspective whether the development of factor markets in agricultural production can suppress cropland abandonment due to low ACR, and the results are shown in Table 6.

The estimates in columns (1) to (3) reveal the moderating effect of agricultural machinery market development. Using a subsample regression method, columns (1) and (2) examine the impact of ACR on cropland abandonment in villages with and without agricultural machinery markets, respectively. It is found that ACR has a significant positive effect on cropland abandonment in both cases, but the estimated coefficient for ACR is smaller in villages with agricultural machinery markets (0.013) compared to those without (0.060). To further identify the significance of this difference, we next include an interaction term between ACR and the village agricultural machinery market variable (assigned as 1 for villages with agricultural machinery markets and 0 for those without) in the regression model, as shown in column (3). The interaction term is statistically significant at a 5 % level and has an estimated coefficient of −0.042. This indicates that compared to villages without agricultural machinery markets, villages with such markets can mitigate the promotion effect of low comparative returns on cropland abandonment by approximately 0.042. The main reason for this is that agricultural machinery replaces labor at a much lower cost, alleviating the labor shortage in agricultural production (Ma et al., 2022). This confirms Hypothesis 3-1. The development of agricultural

Table 6
The results of moderating effect of factor market development.

Variables	Proportion of abandoned cropland area to total cropland area					
	Moderating effect of agricultural machinery market			Moderating effect of land rental market		
	(1)	(2)	(3)	(4)	(5)	(6)
ACR	0.013***	0.060**	0.056***	0.008	0.028*	0.030***
	(0.005)	(0.028)	(0.021)	(0.005)	(0.016)	(0.010)
ACR × Agricultural machinery market			−0.042**			
			(0.021)			
ACR × Land rental market						−0.018*
						(0.010)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Household FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
County × Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	20,412	1,847	22,259	19,294	5,549	24,843
R-squared	0.702	0.814	0.692	0.739	0.832	0.685

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

machinery markets effectively mitigates cropland abandonment caused by low comparative returns in agriculture.

The estimates in columns (4) and (5) represent the moderating effects of land rental market. Similarly, we initially employ a subsample regression method to examine the impact of ACR on cropland abandonment in villages with and without land rental markets, as depicted in columns (4) and (5). It can be observed that in the presence of a land rental market, ACR does not exert a significant effect on cropland abandonment. Conversely, in villages without a land rental market, ACR exhibits a significantly positive effect on cropland abandonment, with an estimated coefficient larger than that under a land rental market. In column (6), we introduce an interaction term between ACR and variables related to the land rental market (where villages with land rental markets are assigned 1; otherwise, 0) to further investigate their disparities. This disparity is examined by the statistically significant negative coefficient (−0.018) at the 10 % significance level for the interaction term. One possible explanation is that the development of land rental markets can not only provide opportunities for the reuse of idle cropland, but also allow farmers to earn a share of rental income (Ito et al., 2016; Zheng et al., 2025). This makes it unnecessary for farmers to abandon their croplands. Hypothesis 3-2 is verified, and the development of land rental markets (Zhang et al., 2014), effectively mitigates instances of low ACR-induced abandoned croplands.

4.5.2. Moderating effect of government subsidies

Subsequently, we investigate from a government perspective whether agricultural subsidies provided by the government to farmers can mitigate cropland abandonment resulting from low ACR. To delve deeper into the moderating role of government agricultural subsidies, this study conducts a comprehensive analysis from two perspectives: the availability and level of agricultural subsidies.

Columns (1) to (3) in Table 7 present estimates of how the availability of agricultural subsidies moderates the impact of ACR on cropland abandonment. The results indicate that, regardless of whether agricultural subsidies are available or not, low comparative returns have a significant and positive effect on cropland abandonment. However, under conditions where agricultural subsidies exist, the positive impact of ACR (0.009) is smaller than without any agricultural subsidy (0.048). To test whether this difference is significant, we considered the interaction term between ACR and agricultural subsidy availability. Column (3) shows that this interaction term is not significant, indicating that the moderating effect of agricultural subsidy availability has not been effectively utilized. Hypothesis 4-1 is falsified. This may be due to the fact that under China's latest agricultural subsidy policy (Fan et al., 2023), most farmers actually engaged in agricultural production can receive agricultural subsidies.

Columns (4) to (6) provide estimates of how the level of agricultural subsidies moderate the impact of ACR on cropland abandonment. To facilitate group comparisons, we redefined the continuous variable representing the level of agricultural subsidies as a binary variable. A value of 1 is assigned if the subsidy level exceeds the average subsidy level of other households in the same village; otherwise, a value of 0 is assigned. Results from grouped regression disclose that when a farmer household receives a higher agricultural subsidy per mu than others in the same village, the positive impact of ACR on cropland abandonment (0.006) is insignificant and lower compared to scenarios where a farmer receives significantly less agricultural subsidy than others in the same village (0.032). Moreover, this difference has also been proven to be statistically significant by column (6), confirming Hypothesis 4-2 and indicating that agricultural subsidy level is effective in suppressing the promotion of cropland abandonment caused by low agricultural returns. To sum up, it is not enough to address the availability of subsidies for farmers in order to reduce the impact of cropland abandonment caused by low ACR. Full consideration should be given to the level of subsidies, allowing farmers to receive higher subsidies than the average level of other farmers in the same village, thereby maximizing the moderating effect of agricultural subsidies.

5. Heterogeneous effects of ACR on cropland abandonment

The previous section demonstrated a positive correlation between ACR and cropland abandonment. However, given the significant variations in regional development levels, functional positioning, and terrain across China, further investigation is required to establish the validity of this relationship. Therefore, in this section, this study aims to analyze the heterogeneity effects of ACR on cropland abandonment from three dimensions: geographical regional heterogeneity, heterogeneity in the functional positioning of grain production, and terrain heterogeneity.

5.1. Heterogeneity of different geographical regions

Considering the ascending level of economic development in China from west to east, along with the disparity among the northeastern, eastern, central, and western regions, a sub-sample was selected from each region, strictly adhering to the classification criteria set by the National Bureau of Statistics of China.[3] Carrying out regressions among the four sub-samples respectively enables us to unveil geographical heterogeneity in how ACR influences cropland abandonment.

The estimated coefficient results of ACR are shown in Fig. 3, which reveals that ACR has a significant positive impact on cropland abandonment in the central and western regions. However, there is no significant effect of ACR on cropland abandonment in the northeastern and central regions. One possible reason is that the eastern region has the most developed economy with abundant off-farm employment opportunities and high wages (Han et al., 2021; Zheng and Qian, 2022), resulting in much higher non-agricultural returns compared to agricultural returns. This implies relatively lower ACR, resulting in a larger marginal effect of ACR on cropland abandonment. The western region, being economically underdeveloped, exhibits lower levels of agricultural development and consequently lower ACR, hence showing a significant impact of ACR on cropland abandonment as well. In contrast, there may not be a substantial difference between off-farm employment and agricultural production income in the northeastern and central regions due to their primary agricultural activities (Xu et al., 2019a); therefore, whether or not there is a low ACR does not significantly affect farmers' decision to abandon their cropland. Moreover, in the northeastern and central regions, favorable land conditions have facilitated the development of both the agricultural machinery market and the land rental market (Duan et al., 2022; Niu et al., 2025). Simultaneously, agricultural subsidy policy in the northeastern and central regions is relatively well established (Fan et al., 2023). These factors collectively contribute to mitigating the impact of low ACR on land abandonment.

5.2. Heterogeneity of different grain areas

The previously insignificant effect of ACR on cropland abandonment in the northeastern and central regions may also be related to the fact that many major grain provinces are located in these two regions. In rural China, the policy of major grain areas is a fundamental measure to ensure food security (Zheng and Qian, 2022). This can potentially result in heterogeneity between major and non-major grain areas. Therefore, we categorize our samples into two sub-groups: those from major grain areas and those from non-major grain areas based on each province's positioning in terms of their contribution to grain production function.[4] Subsequently, grouped regression will be conducted for these two sub-samples.

[3] http://www.stats.gov.cn/zt_18555/zthd/sjtjr/dejtjkfr/tjkp/202302/t20230216_1909741.htm#:~:text = %.

[4] https://news.cctv.com/2022/12/22/ARTI6EJkerwO4t3oUaHw6GUE221222.shtml.

Table 7
The results of moderating effect of agricultural subsidy from government.

Variables	Proportion of abandoned cropland area to total cropland area					
	Moderating effect of agricultural subsidy availability			Moderating effect of agricultural subsidy level		
	(1)	(2)	(3)	(4)	(5)	(6)
ACR	0.009*	0.048***	0.024***	0.006	0.032***	0.022***
	(0.005)	(0.014)	(0.007)	(0.009)	(0.009)	(0.006)
ACR × agricultural subsidy availability			−0.012			
			(0.008)			
ACR × agricultural subsidy level						−0.013*
						(0.007)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Household FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
County × Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	15,398	9,445	24,843	12,855	11,988	24,843
R-squared	0.803	0.827	0.685	0.834	0.827	0.685

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

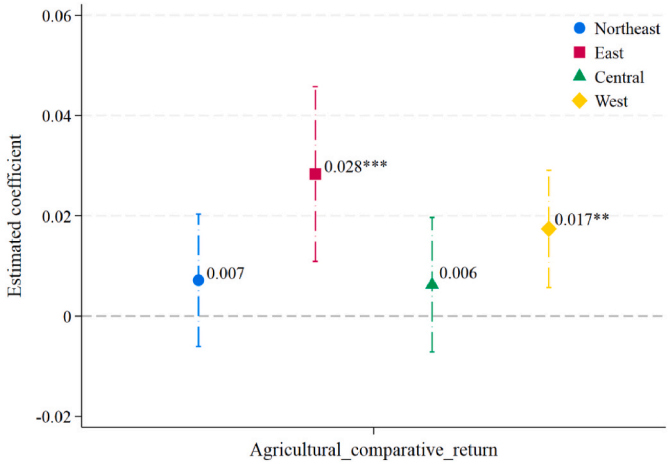

Fig. 3. ACR and cropland abandonment: Regional heterogeneity.

Fig. 4 illustrates the estimated coefficients of ACR on cropland abandonment in the two sub-groups. It is evident that ACR does not exert a significant impact on cropland abandonment among farmers in major grain areas. Conversely, in non-major grain areas, ACR demonstrates a significantly positive effect on cropland abandonment, with an estimated coefficient higher than that of the whole sample. This can be attributed to two aspects: firstly, compared to non-major grain areas, major grain areas benefit from a range of supportive policies implemented by the government such as pricing mechanisms, insurance coverage, subsidies and other measures (Ye et al., 2023; Zhang et al., 2021). These initiatives can compensate for lower ACR and enhance farmers' motivation to cultivate crops (Fan et al., 2023) while mitigating the issue of cropland abandonment due to low agricultural returns. The government offers substantial subsidies to farmers in major grain regions, and Section 4.4.2 has fully demonstrated the moderating effect of agricultural subsidies on mitigating the impact of ACR on cropland abandonment; secondly, unlike non-major grain areas, major grain areas are subject to relevant government restrictive policies, including strict prohibitions on abandoning cropland (Zheng and Qian, 2022). For example, the penalty criteria for abandoning cropland are implemented more strictly in major grain areas: no subsidies if cropland is abandoned for one year; and land use rights will be taken back if cropland is abandoned for more than two years. Consequently, farmers in major grain areas are less likely to abandon their croplands due to low agricultural returns.

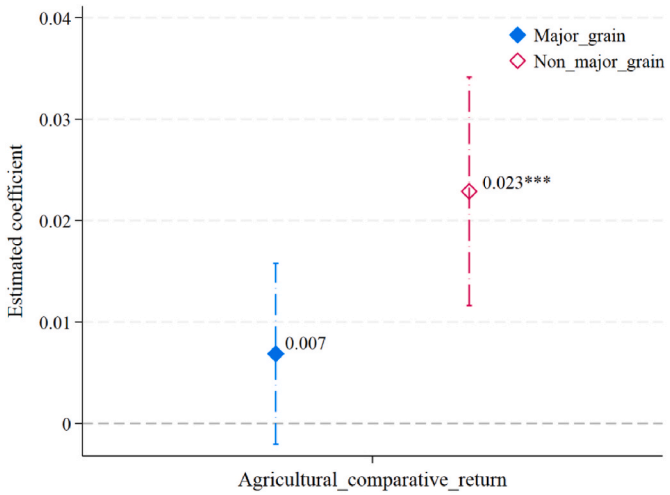

Fig. 4. ACR and cropland abandonment: Major grain area heterogeneity.

5.3. Heterogeneity of different terrain zones

The land use behavior of farmers may vary due to differences in terrain, as the terrain determines the difficulty of land production, with plains being more favorable for cultivation compared to mountains (Xu et al., 2019b). Therefore, based on the terrain information of the sample households, we divided them into two groups: those with plain-type land and those with mountain-type land, estimating separately the impact of ACR on cropland abandonment within each group to explain this heterogeneity.

Estimated results, as shown in Fig. 5, indicate that ACR has a significant positive impact on cropland abandonment among both plain and mountain type farmers. However, the estimation coefficient of ACR is higher among farmers with mountain-type land. This disparity stems from three factors: First, mountain terrain inherently increases farming costs due to steep slopes that prevent mechanization and require more labor (Hong et al., 2024). Second, small, scattered plots in the mountains face market disadvantages. They are more difficult to rent out or consolidate, reducing profitability compared to large contiguous plains (Zheng et al., 2023a). Third, ecological limits on mountain slopes (e.g., soil erosion risks) restrict yield improvements, making farmers more likely to abandon cropland (Deng et al., 2019). Additionally, mountain areas often lack infrastructure (e.g., irrigation) to buffer climate shocks, worsening the effect of ACR on cropland abandonment (Deng et al., 2019). Once abandoned, mountain land faces higher ecological recovery costs (e.g., reversing erosion), creating a "lock-in" effect where recultivation becomes impractical, unlike reversible abandonment patterns in

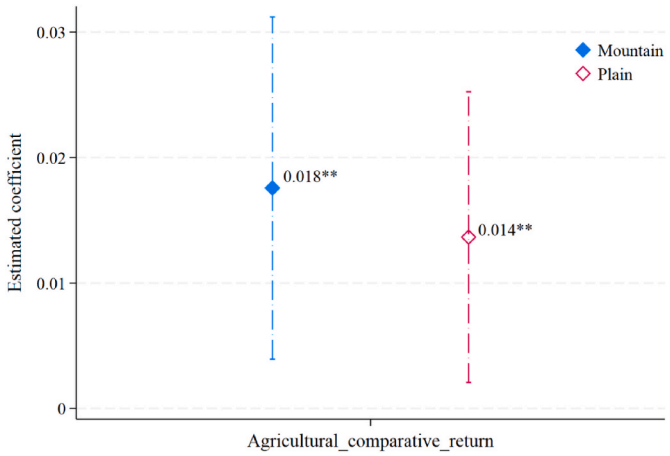

Fig. 5. NAOE and cropland abandonment: Terrain heterogeneity.

plains.

6. Conclusions and discussion

6.1. Conclusions

In the ongoing rural-urban transformation, the opportunity cost of farming has gradually increased, resulting in a widening gap between agricultural income and non-agricultural wage income. Consequently, these low ACRs have contributed to a substantial outflow of rural production factors to urban areas, potentially posing serious challenges to global food security and sustainable agricultural development. Against this background, this study employs the 2015–2021 CFD and panel high-dimensional fixed-effects models to examine the impact of ACR on cropland abandonment.

Our empirical results show that ACR significantly aggravated farmers' cropland abandonment behavior, increasing the ratio of abandoned cropland areas by 1.6 %. This significant and positive correlation between ACR and cropland abandonment was still established after various robustness checks, including substitution of dependent variable, core independent variable, model, and samples. The mechanism analysis suggests that the decline in long-term land investment, input of agricultural capital and input of agricultural labor was an important channel for farmers to abandon cropland due to low ACR. However, the agricultural machinery market and the land rental market could reduce the negative impact of ACR on land use to some extent, while current agricultural subsidies have little effect. Heterogeneity analysis further reveals that the effects of ACR on cropland abandonment vary significantly across geographical regions, grain areas, and terrain zones. Specifically, regarding different geographical regions, ACR mainly increased cropland abandonment in eastern and western China. With regard to different grain areas, ACR increased cropland abandonment in non-major grain areas, but had no effect on major grain areas. For different terrain zones, the effect of ACR on cropland abandonment in mountainous areas was slightly higher than that in plains.

6.2. Policy implications

Reducing cropland abandonment, strengthening land quantity protection and promoting sustainable land use are important choices for food security and sustainable agricultural development. In this sense, the above findings of our study have important reference value for policymakers in developing countries.

Firstly, we must give priority to agriculture and rural areas, encourage the return of rural production factors to urban and rural areas, and block the mechanism of ACR that triggers cropland abandonment. In rural-urban transformation, urban expansion and rural decay are common practical problems in most developing counties. Appropriate government intervention is therefore needed to guide the flow of land, capital and labor to rural areas, thus creating opportunities for the sustainable use of cropland.

Secondly, there is also an urgent need to jointly promote the construction of agricultural machinery markets and land rental markets in rural communities. On the one hand, replacing labor with machinery can effectively compensate for the shortage of agricultural labor due to rural-urban migration, thereby reducing cropland abandonment. On the other hand, by enhancing the market for rural land rentals, developing countries can benefit from transferring cropland from inefficient to efficient producers through land marketization, thereby preventing idle and unnecessary waste of valuable land resources.

Finally, substantial intensification of the reform of agricultural subsidies is an essential element in enhancing ACR and reducing cropland abandonment. Developing countries can improve their agricultural support and protection mechanisms, increase farmers' access to and income from agricultural subsidies, and thus stimulate their enthusiasm for agricultural pursuits. Fifth, developing counties should pay attention to the heterogeneity of different regions and promote the effective management of abandoned cropland according to local conditions. For example, for developed regions, there is a need to establish a feedback mechanism for secondary and tertiary industries to feed agriculture and cities to support rural areas; for less developed regions and non-major grain areas, it is essential to increase support for agricultural subsidies.

6.3. Research deficiencies and prospects

Cropland abandonment represents a complex socio-economic challenge with a multidimensional research landscape around the world. Numerous studies have pointed out that cropland abandonment is the result of a combination of factors (Xu et al., 2019a; Zavalloni et al., 2021; Ojha et al., 2022), of which low ACR is considered the most important driving factor (Zhang et al., 2019). Unlike prior studies that mostly mention ACR indirectly (Ma and Zhu, 2020; Guo et al., 2023), or quantify non-economic factors of cropland abandonment (Deininger et al., 2012; Deng et al., 2019), this study directly explores the impacts and mechanisms of ACR on cropland abandonment by constructing ACR measurement indicators. This not only provides an indicator reference for ACR-related quantitative research, but also makes up for the lack of attention to key economic factors in the existing literature on cropland abandonment. However, due to data limitations and divergent research foci, the following aspects still warrant further investigation.

First and foremost, as pivotal policy instruments to influence farmers' production input decisions, the direct impact of agricultural subsidies and credit constraint relaxation on cropland abandonment cannot be ignored. While this research has illuminated the moderating effect of agricultural subsidies on the relationship between ACR and cropland abandonment, future studies could directly examine how these subsidies affect cropland abandonment behavior through income effects or substitution effects. Simultaneously, exploring the causal relationship between credit constraint relaxation and cropland abandonment, alongside strategies to deepen financial and credit system reforms for abandonment reduction, would provide valuable insights into policy formulation.

Moreover, under improved data accessibility conditions, future studies could delve into post-2021 cropland abandonment problems and governance strategies. This emphasis arises from the Chinese government's implementation of a series of policy initiatives since 2021, most notably the Guiding Opinions on the Coordinated Utilization of Abandoned Cropland to Promote Agricultural Production Development, which highlights a heightened policy focus on this issue compared to previous periods.

Lastly, while substantial efforts have been invested to mitigate potential endogeneity issues at their source, this study cannot guarantee

the full elimination of such concerns. As such, future research is encouraged to identify appropriate instrumental variables that enable robust causal identification of the relationship between ACR and cropland abandonment, thereby advancing theoretical understanding and policy relevance. In addition, a more nuanced discussion of the various sources of endogeneity would be valuable. For example, the construction of new ACR measures and the re-estimation of their impact on cropland abandonment.

CRediT authorship contribution statement

Linyi Zheng: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Songqing Jin:** Writing – review & editing, Project administration, Methodology, Conceptualization. **Liufang Su:** Writing – original draft, Methodology, Formal analysis, Conceptualization.

Disclosure statement

No potential conflict of interest was reported by the authors.

Declaration of competing interest

This manuscript has not been published or presented elsewhere and is not under consideration by another journal. We have read and understood your journal's policies, and we believe that neither the manuscript nor the study violates any of these. We declare that we have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

The authors acknowledge the support of the Major Special Project of Philosophy and Social Science Foundation of the Ministry of Education of China (Grant No. 2024JZDZ064), the Youth Humanities and Social Sciences Foundation of the Ministry of Education of China (Grant No. 23YJC790203), the Zhejiang Humanities and Social Sciences Foundation (Grant No. 24YJRC01ZD-1YB, ZKZD2024001), the Zhejiang Provincial Department of Education Foundation (Grant No. Y202351967), and the Fundamental Research Funds for the Central Universities (Grant No. S20250025).

Appendix. Complementary derivation processes of theoretical analysis

A.

$$\underset{N_f,L_f,K_f}{Max}\ \pi = pf\left(N_f, L_f, K_f\right) - uK_f + rN_r + wL_n + T\left(N_f\right)$$

$$s.t.\quad N_f + N_r \le \bar{N} \quad L_f + L_n \le \bar{L}$$

To take the constraints condition into the objective function:

$$\underset{N_f,L_f,K_f}{Max}\ \pi = pf\left(N_f, L_f, K_f\right) - uK_f + r\left(\bar{N} - N_f\right) + w\left(\bar{L} - L_f\right) + T\left(N_f\right)$$

Based on the above equation, taking the first order derivative with respect to L_f, N_f and K_f respectively yields:

$$\frac{\partial \pi}{\partial N_f} = pf'_{N_f} - r + \frac{\partial T\left(N_f\right)}{\partial N_f} = 0$$

$$\frac{\partial \pi}{\partial L_f} = pf'_{L_f} - w = 0 \quad \frac{\partial \pi}{\partial K_f} = pf'_{K_f} - u = 0$$

B.

$$pf'_{N_f} = r - \frac{\partial T\left(N_f\right)}{\partial N_f}$$

where r and $\frac{\partial T\left(N_f\right)}{\partial N_f}$ is exogenous parameter. Take the total differential of the above equation as follows:

$$f'_{N_f}dp + pf''_{N_f}dN_f = 0$$

$$\Rightarrow \quad \frac{dN_f}{dp} = -\frac{f'_{N_f}}{pf''_{N_f}} > 0$$

C.

$$\frac{\partial \pi}{\partial K_f} = pf'_{K_f} - u = 0 \quad \Rightarrow \quad pf'_{K_f} = u$$

Take the total differential of the above equation as follows:

$$pf''_{K_f}dK_f = du$$

$$\Rightarrow \quad \frac{dK_f}{du} = \frac{1}{pf''_{K_f}} < 0$$

D.

$$f(N_f, L_f, K_f) = A^{1-\partial}\left(N_f^{\alpha} L_f^{\beta} K_f^{\gamma}\right)^{\partial}$$

$$\Rightarrow \quad f'_{N_f} = A^{1-\partial}\alpha\partial N_f^{\alpha\partial-1} L_f^{\beta\partial} K_f^{\gamma\partial}$$

By substituting the aforementioned formula into $pf'_{N_f} = r - \frac{\partial T(N_f)}{\partial N_f}$, we can get:

$$pA^{1-\partial}\alpha\partial N_f^{\alpha\partial-1} L_f^{\beta\partial} K_f^{\gamma\partial} = r - \frac{\partial T(N_f)}{\partial N_f}$$

E.

$$pA^{1-\partial}\alpha\partial N_f^{\alpha\partial-1} L_f^{\beta\partial} K_f^{\gamma\partial} = r - \frac{\partial T(N_f)}{\partial N_f}$$

Under the condition of holding other factors constant, take the total differential of the above equation with respect to as follows:

$$pA^{1-\partial}\alpha\partial(\alpha\partial-1)N_f^{\alpha\partial-2} L_f^{\beta\partial} K_f^{\gamma\partial} dN_f + pA^{1-\partial}\alpha\partial N_f^{\alpha\partial-1}\gamma\partial L_f^{\beta\partial} K_f^{\gamma\partial-1} dK_f = 0$$

$$\Rightarrow \frac{dN_f}{dK_f} = -\frac{pA^{1-\partial}\alpha\partial N_f^{\alpha\partial-1}\gamma\partial L_f^{\beta\partial} K_f^{\gamma\partial}}{pA^{1-\partial}\alpha\partial(\alpha\partial-1)N_f^{\alpha\partial-2} L_f^{\beta\partial} K_f^{\gamma\partial}} = -\frac{\gamma\partial N_f K_f}{(\alpha\partial-1)} > 0$$

F.

$$\frac{\partial\pi}{\partial L_f} = pf'_{L_f} - w = 0 \quad \Rightarrow \quad pf'_{L_f} = w$$

Take the total differential of the above equation as follows:

$$pf''_{L_f} dL_f = dw$$

$$\Rightarrow \quad \frac{dL_f}{dw} = \frac{1}{pf''_{L_f}} < 0$$

Data availability

The authors do not have permission to share data.

References

Abdulai, A., Owusu, V., Goetz, R., 2011. Land tenure differences and investment in land improvement measures: theoretical and empirical analyses. J. Dev. Econ. 96, 66–78.

Adamopoulos, T., Restuccia, D., 2014. The size distribution of farms and international productivity differences. Am. Econ. Rev. 104, 1667–1697.

Andrianarimanana, M.H., Yongjian, P., Rabezanahary Tanteliniaina, M.F., 2023. Assessment of the importance of climate, land, and soil on the global supply for agricultural products and global food security: evidence from Madagascar. Food Policy 115, 102403.

Berry, R.A., Cline, W.R., 1980. Agrarian structure and productivity in developing countries. Land Econ. 56, 495–502.

Binswanger, H.P., Deininger, K., Feder, G., 1995. Chapter 42 power, distortions, revolt and reform in agricultural land relations. In: Handbook of Development Economics. Elsevier, pp. 2659–2772.

Blair, D., Shackleton, C.M., Mograbi, P.J., 2018. Cropland abandonment in South African smallholder communal lands: land cover change (1950-2010) and farmer perceptions of contributing factors. Land-Basel 7.

Chari, A., Liu, E.M., Wang, S.-Y., Wang, Y., 2021. Property rights, land misallocation, and agricultural efficiency in China. Rev. Econ. Stud. 88, 1831–1862.

Chen, M., Han, Q., Zhang, C., Chen, J., 2025. Valuing the effect of capital goes to countryside on cropland abandonment: evidence from rural China. Habitat Int. 156, 103299.

Cui, Y., 2023. Mechanization's impact on agricultural total factor productivity. Agric. Econ. 69, 446–457.

Deininger, K., Savastano, S., Carletto, C., 2012. Land fragmentation, cropland abandonment, and land market operation in Albania. World Dev. 40, 2108–2122.

Deng, X., Xu, D., Zeng, M., Qi, Y., 2019. Does internet use help reduce rural cropland abandonment? Evidence from China. Land Use Policy 89, 104243.

Duan, J.K., Ren, C.N., Wang, S.T., Zhang, X.M., Reis, S., Xu, J.M., Gu, B.J., 2022. Consolidation of agricultural land can contribute to agricultural sustainability in China (Dec, 10.1038/s43016-021-00415-5, 2021). Nat. Food 3, 179-179.

Fan, P., Mishra, A.K., Feng, S., Su, M., Hirsch, S., 2023. The impact of China's new agricultural subsidy policy on grain crop acreage. Food Policy 118, 102472.

Feder, G., Just, R.E., Zilberman, D., 1985. Adoption of agricultural innovations in developing countries: a survey. Econ. Dev. Cult. Change 33, 255–298.

Guo, A., Yue, W., Yang, J., Xue, B., Xiao, W., Li, M., He, T., Zhang, M., Jin, X., Zhou, Q., 2023. Cropland abandonment in China: patterns, drivers, and implications for food security. J. Clean. Prod. 418, 138154.

Han, W., Wei, Y., Cai, J., Yu, Y., Chen, F., 2021. Rural nonfarm sector and rural residents' income research in China. An empirical study on the township and village enterprises after ownership reform (2000-2013). J. Rural Stud. 82, 161–175.

Hong, C., Prishchepov, A.V., Bavorova, M., 2024. Cropland abandonment in mountainous China: patterns and determinants at multiple scales and policy implications. Land Use Policy 145, 107292.

Huang, J., Shi, P., 2021. Regional rural and structural transformations and farmer's income in the past four decades in China. China Agric. Econ. Rev. 13, 278–301.

Inada, K.-I., 1963. On a two-sector model of economic growth: comments and a generalization. Rev. Econ. Stud. 30, 119–127.

Ito, J., Nishikori, M., Toyoshi, M., Feuer, H.N., 2016. The contribution of land exchange institutions and markets in countering farmland abandonment in Japan. Land Use Policy 57, 582–593.

Johnson, N.L., Ruttan, V.W., 1994. Why are farms so small? World Dev. 22, 691–706.

Kuemmerle, T., Olofsson, P., Chaskovskyy, O., Baumann, M., Ostapowicz, K., Woodcock, C.E., Houghton, R.A., Hostert, P., Keeton, W.S., Radeloff, V.C., 2011. Post-Soviet farmland abandonment, forest recovery, and carbon sequestration in Western Ukraine. Glob. Change Biol. 17, 1335–1349.

Lewis, W.A., 1954. Economic development with unlimited supplies of labour. Manch. Sch. 22, 139–191.

Li, X., Ito, J., 2021. An empirical study of land rental development in rural Gansu, China: the role of agricultural cooperatives and transaction costs. Land Use Policy 109, 105621.

Ma, W., Zhu, Z., 2020. A note: reducing cropland abandonment in China – do agricultural cooperatives play a role? J. Agric. Econ. 71, 929–935.

Ma, W., Zhu, Z., Zhou, X., 2022. Agricultural mechanization and cropland abandonment in rural China. Appl. Econ. Lett. 29, 526–533.

Niu, W., Luo, L., Shi, Y., Chai, C., Wang, H., Tian, Q., Jin, Y., Kong, X., Yu, Q., Ren, L., Zhang, B., 2025. Impacts of "One Household One Plot" and "One Village Group One Plot" fragmentation consolidation models on cultivated land use transition from perspective of human-land system. Habitat Int. 156, 103252.
Ojha, R.B., Atreya, K., Kristiansen, P., Devkota, D., Wilson, B., 2022. A systematic review and gap analysis of drivers, impacts, and restoration options for abandoned croplands in Nepal. Land Use Policy 120, 106237.
Poitras, G., 2023. Cobweb theory, market stability, and price expectations. J. Hist. Econ. Thought JHET 45, 137–161.
Qian, W., 2020. The Economy of Chinese Rural Households. Springer.
Ren, C., Zhou, X., Wang, C., Guo, Y., Diao, Y., Shen, S., Reis, S., Li, W., Xu, J., Gu, B., 2023. Ageing threatens sustainability of smallholder farming in China. Nature 616, 96–103.
Sazama, G.W., Davis, H., 1973. Land taxation and land reform. Econ. Dev. Cult. Change 21, 642–654.
Stehfest, E., van Zeist, W.-J., Valin, H., Havlik, P., Popp, A., Kyle, P., Tabeau, A., Mason-D'Croz, D., Hasegawa, T., Bodirsky, B.L., Calvin, K., Doelman, J.C., Fujimori, S., Humpenöder, F., Lotze-Campen, H., van Meijl, H., Wiebe, K., 2019. Key determinants of global land-use projections. Nat. Commun. 10, 2166.
Takeshima, H., Hatzenbuehler, P.L., Edeh, H.O., 2020. Effects of agricultural mechanization on economies of scope in crop production in Nigeria. Agric. Syst. 177, 102691.
Tang, L., Ma, X., Zhou, Y., Shi, X., Ma, J., 2019. Social relations, public interventions and land rent deviation: evidence from Jiangsu Province in China. Land Use Policy 86, 406–420.
Wang, J., Cao, Y., Fang, X., Li, G., Cao, Y., 2022. Does land tenure fragmentation aggravate farmland abandonment? Evidence from big survey data in rural China. J. Rural Stud. 91, 126–135.
Wang, Y., Wu, P., Mei, F., Ling, Y., Qiao, Y., Liu, C., Leghari, S.J., Guan, X., Wang, T., 2021. Does continuous straw returning keep China farmland soil organic carbon continued increase? A meta-analysis. J. Environ. Manag. 288, 112391.
Wang, Y., Yang, A., Yang, Q., 2023. The extent, drivers and production loss of farmland abandonment in China: evidence from a spatiotemporal analysis of farm households survey. J. Clean. Prod. 414, 137772.
Wu, Y., Xi, X., Tang, X., Luo, D., Gu, B., Lam, S.K., Vitousek, P.M., Chen, D., 2018. Policy distortions, farm size, and the overuse of agricultural chemicals in China. In: Proceedings of the National Academy of Sciences, vol.115, pp. 7010–7015.
Xu, D., Deng, X., Guo, S., Liu, S., 2019a. Labor migration and farmland abandonment in rural China: empirical results and policy implications. J. Environ. Manag. 232, 738–750.
Xu, D., Deng, X., Huang, K., Liu, Y., Yong, Z., Liu, S., 2019b. Relationships between labor migration and cropland abandonment in rural China from the perspective of village types. Land Use Policy 88, 104164.
Ye, D., Zhen, S., Wang, W., Liu, Y., 2023. Spatial double dividend from China's main grain-producing areas policy: total factor productivity and the net carbon effect. Humanit. Soc. Sci. Commun. 10, 459.
Zavalloni, M., D'Alberto, R., Raggi, M., Viaggi, D., 2021. Farmland abandonment, public goods and the CAP in a marginal area of Italy. Land Use Policy 107, 104365.
Zhang, D., Wang, H., Lou, S., 2021. Research on grain production efficiency in China's main grain-producing areas from the perspective of grain subsidy. Environ. Technol. Innovat. 22, 101530.
Zhang, X., Hu, L., Yu, X., 2023. Farmland leasing, misallocation reduction, and agricultural total factor productivity: insights from rice production in China. Food Policy 119, 102518.
Zhang, X., Zhao, C., Dong, J., Ge, Q., 2019. Spatio-temporal pattern of cropland abandonment in China from 1992 to 2017: a meta-analysis. Acta Geogr. Sin. 74, 411–420.
Zhang, Y., Li, X., Song, W., 2014. Determinants of cropland abandonment at the parcel, household and village levels in mountain areas of China: a multi-level analysis. Land Use Policy 41, 186–192.
Zheng, L., 2024a. Big hands holding small hands: the role of new agricultural operating entities in farmland abandonment. Food Policy 123, 102605.
Zheng, L., 2024b. Does off-farm work induce farmland abandonment? Evidence from China. China Agric. Econ. Rev. 16, 664–682.
Zheng, L., 2024c. Those with constant property rights have perseverance: china's land tenure reform promotes environment-friendly farming practices. Humanit. Soc. Sci. Commun. 11, 763.
Zheng, L., Li, L., Jin, S., 2025. Opening the village door: china's agricultural e-commerce facilitates the transformation of land rental markets. Agric. Econ., e70010
Zheng, L., Qian, W., 2022. The impact of land certification on cropland abandonment: evidence from rural China. China Agric. Econ. Rev. 14, 509–526.
Zheng, L., Su, L., Jin, S., 2023a. Reducing land fragmentation to curb cropland abandonment: evidence from rural China. Canadian Journal of Agricultural Economics/Revue canadienne d'agroeconomie 71, 355–373.
Zheng, Q., Ha, T., Prishchepov, A.V., Zeng, Y., Yin, H., Koh, L.P., 2023b. The neglected role of abandoned cropland in supporting both food security and climate change mitigation. Nat. Commun. 14, 6083.