

## Article

# The Heterogeneous Effects of Multilevel Location on Farmland Abandonment: A Village-Level Case Study in Tai'an City, China

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**Abstract:** As a global phenomenon, farmland abandonment continues to challenge the sustainability of the agri-food supply and rural development. Investigating the heterogeneous effects of multilevel location on farmland abandonment is of great importance to understand the spatial disparity and the mechanism of farmland abandonment, which has significant policy implications for food security and rural revitalization. Taking Tai'an City as a case, this study aims to explore the impact of multilevel location on farmland abandonment at the village level and its spatial heterogeneity. The results show that (1) high accessibility to regional centers and roads, rather than remoteness, leads to a high rate of farmland abandonment; (2) the effect of location varies depending on the level of location. High-level regional centers (city centers and county centers) and roads (national and provincial highways) exert a stronger impact on farmland abandonment than low-level town centers and county highways; (3) the effect of location is topographically heterogeneous due to the influence of terrain on the marginalization of farmland. In the plains, except for county highways, the distance to different levels of regional centers and roads is significantly negatively correlated with farmland abandonment. However, in mountainous areas, only high-level regional centers have significant negative impacts.

**Keywords:** farmland abandonment; multilevel location; heterogeneous effects; village-level data; China



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## 1. Introduction

Enhancing food security has been a hot issue since the 1980s and remains a great challenge in the 21st century [1–3]. According to the “State of Food Security and Nutrition in the World 2021,” 9.9% of the world population was still suffering from hunger and malnutrition in 2020, and the number of people affected by hunger has exhibited an upward trend since 2014 [4]. United Nations organizations and scholars have promoted sustainable agriculture as one of the Sustainable Development Goals to end all forms of malnutrition [2,5]. However, in the context of increasing food demand, farmland abandonment is observed globally, ranging from Europe and North America to recently documented developing countries in Asia and Africa [6–10]. Therefore, fully understanding the underlying factors of farmland abandonment is urgent for promoting agricultural development and achieving zero hunger.

As the most populous country, China's food security status not only affects domestic social stability but also has repercussions on global agri-food prices; thus, it has long received worldwide attention [11,12]. In recent decades, land-use changes and soil erosion brought about by rapid development of industrialization and urbanization have worsened the shortage of agricultural land [13]. At the same time, farmland abandonment has been occurring at an unprecedented rate in rural areas, posing a threat to food security [14–16]. Given the instability of food security and the problem of inefficient use of farmland in rural areas, improving agricultural land use efficiency and increasing agricultural output have become policy priorities. On the one hand, large-scale and mechanized agricultural

production mode is encouraged through farmland transfer and agricultural mechanization to overcome the farmland tenure fragmentation and the low utilization of farmland under the background of the collective ownership of rural land and the household responsibility system with small households as the main body of agricultural land use [17,18]. On the other hand, the rural revitalization strategy, permanent basic farmland policy, and other rural development policies have been proposed to improve the quality and effective use of farmland [19,20]. In this vein, exploring the determinants of farmland abandonment has significant policy implications for agricultural land management and ensuring food security.

Although many studies have investigated the influencing factors of farmland abandonment, some issues have not been sufficiently discussed. Inconsistencies in the mechanisms of location factors have been addressed repeatedly in recent publications [14,21,22]. The traditional view that remoteness leads to a high possibility of farmland abandonment is challenged by new evidence that the distance to markets has a negative impact on abandoning farmland [15,21]. This new finding expands the complexity of mechanisms of farmland abandonment, and its reliability and underlying pathways need further exploration.

In terms of research units, most of the studies are at the household level, focusing on household causal factors, such as migration [7,14], household, and personal characteristics [15]. Studies based on the territorial unit mainly address the impact of parcel-level and regional-level characteristics [23–26]. However, the extent and determinants of farmland abandonment at the village level are poorly understood. The land use practices of rural households are deeply embedded in local villages. First, farmland in the same village generally shares similar geo-physical characteristics. Second, residents in a village tend to have similar farming or working preferences and techniques [27,28]. Third, the unique culture and governance of one village can make its pattern of farmland use different. Village-level studies can make up for the insufficient attention paid to the role of village locality in farmland abandonment in the existing literature. Another advantage of focusing on the village scale is that it helps identify the spatial distribution of abandoned farmland in the urban–rural continuum. The approach not only deepens the understanding of the spatial variations, but also provides policy recommendations for promoting rural development and urban–rural integration.

Regarding study areas, hilly and mountainous regions have received the most attention [8,10,24], but traditional agricultural plains are neglected. The efficiency of farmland use in plains, which is a typical agricultural production area, has an important influence on grain yield. Whether the characteristics and influencing factors of farmland abandonment varies according to different terrains remains to be further studied.

By employing village-level data, this research aims to explore the impact of multilevel location on farmland abandonment and whether this impact has a topographical difference in a traditional Chinese agricultural production area. The results of this study can add evidence to and promote the discussion of the effect of location on farmland abandonment and provide policy recommendations for improving the efficiency of farmland utilization to enhance food security.

## 2. Literature Review

Farmland abandonment generally refers to land that was once cultivated and left to nature or left unmanaged [8,29,30]. A large body of literature has offered valuable insights into the mechanisms of farmland abandonment. Many of these studies point out that land marginalization is the fundamental cause of this decline in agricultural practices, which results from a combination of socio-economic, political, and geo-physical factors [31–34]. Neo-classical economics believes that in a market economy, land resources are often used in the most profitable way [35]. When the profit generated by farmland is equal to or less than its cost or opportunity cost, rational farmers are highly likely to give up farming their land [36].

Social and economic changes are believed to be major drivers of farmland abandonment [9,37]. Farmland abandonment often occurs along with urbanization and rural depopulation [38–40]. The classic dual sector model and the Todaro model have explained large-scale rural out-migration due to more profitable non-agricultural employment in cities [41,42]. These models have revealed the pathway of rural land abandonment caused by population decline. Much empirical evidence shows positive correlations between rural out-migration and farmland abandonment [8,14,38]. The development of local non-agriculture industries also makes farming less profitable and less attractive because of higher salaries of secondary and tertiary jobs. Farmers in such areas tend to move out from the agricultural sector or become part-time farmers, thus increasing the likelihood of discarding farmland [8,24,43].

Geo-physical conditions are repeatedly scrutinized by existing literature. Land quality, represented by a single or a combination of slope, fragmentation, soil quality, and irrigation facilities, has a significant impact on marginalization [44]. Steep or fragmented farmland is generally unsuitable for mechanization and intensification, which requires more cost and is thus prone to idleness [24,26]. Similarly, farmland with poor soil quality or poor irrigation facilities is more likely to be abandoned because it either requires more input or produces less output [8,10].

Political or institutional factors exert profound influence on farmland utilization. Agricultural subsidies are able to increase the profit of farmland output, giving farmers an incentive to maintain and keep farming land. For example, subsidies supported by Common Agricultural Policy and the Less Favored Areas payment scheme in Europe are slowing down farmland abandonment rates [23]. The termination of agricultural subsidies in the 1990s is believed to be the dominant reason of agricultural land abandonment in post-Soviet European Russia [45]. Land system reform plays a critical role in farmland abandonment in Eastern Europe, as the shift in land ownership to a private system leads to a high mismatch of farmland ownership and farming preferences [33].

The location of farmland, often measured by the distance to markets or roads, also plays an important role in farmland abandonment. However, there is no consensus in the academic circle on the mechanism of the location effect, and two competing hypotheses have sparked heated discussions [14,21,22]. The traditional view is that remoteness leads to a high rate of farmland abandonment. On the one hand, remote areas are often seen as areas deprived of farming and transporting infrastructures, resulting in low agriculture competitiveness [10,34]. On the other hand, in mountainous or hilly regions, remoteness is related to a higher degree of steepness, fragmentation, and poor soil quality of farmland, which are not conducive to agricultural modernization [46,47].

However, a negative correlation between remoteness and farmland abandonment has been observed in recent studies [15,21]. For example, a study from Swiss mountains shows that the frequency of land abandonment decreases with increasing distance from the road [31]. A similar result is found in a Chinese case, which indicates a significant and negative relationship between cropland abandonment and distance to towns [15]. Scholars argue that accessibility to the market or the road can promote out-migration and off-farm employment and thus increase the occurrence of farmland abandonment [14,48]. Furthermore, accessibility can play a different role in areas with different geographical characteristics [47,48]. Evidence from Northeast Spain demonstrates that in the Pyrenean region, which is a mountainous area, remoteness is one of the main determinants of farmland abandonment, whereas in the Central Ebro Basin, land abandonment increased as distance to provincial capitals and roads decreased in the recent period [48]. A post-socialist case study also proves that road accessibility only affects cropland abandonment in hilly and mountainous regions [47].

Although the role of location in the abandonment of farmland has been involved in a certain amount of literature, the direction, extent, and spatial heterogeneity of the location effect are rarely discussed in detail. First, limited findings support the negative relationship between remoteness and farmland abandonment. Does this phenomenon only exist in a

few particular areas? More evidence is needed to discuss the effect of location on farmland abandonment and its mechanisms.

Second, little information is provided about the differences in the impact of multilevel markets or roads on farmland abandonment. Scholars use different indicators to represent location factors, such as construction zone, county town, and town [10,15,24]. This variation may be another reason for the contrasting relationship between location and abandonment. Exploring the influence of different levels of accessibility is helpful in understanding the underlying mechanisms.

Third, the pathway of the effect of location on farmland abandonment is not sufficiently discussed in China, where the contradiction between the shortage of high-quality farmland and the large demand for food is particularly prominent. As a typical developing country, China's dramatic restructuring of vast rural areas under urbanization and industrialization has attracted worldwide attention. The high opportunity costs of farmers because of market proximity and the bio-physical disadvantages caused by remoteness are the two main contradictory explanations of the location effects in the existing studies mentioned above. Which reason has a stronger explanatory power in the context of urbanizing China? Moreover, unlike capitalist societies, China has adopted collective ownership system of rural land, and the transaction of agricultural land is strictly banned. Does the land management system also play an important role? These questions need to be discussed.

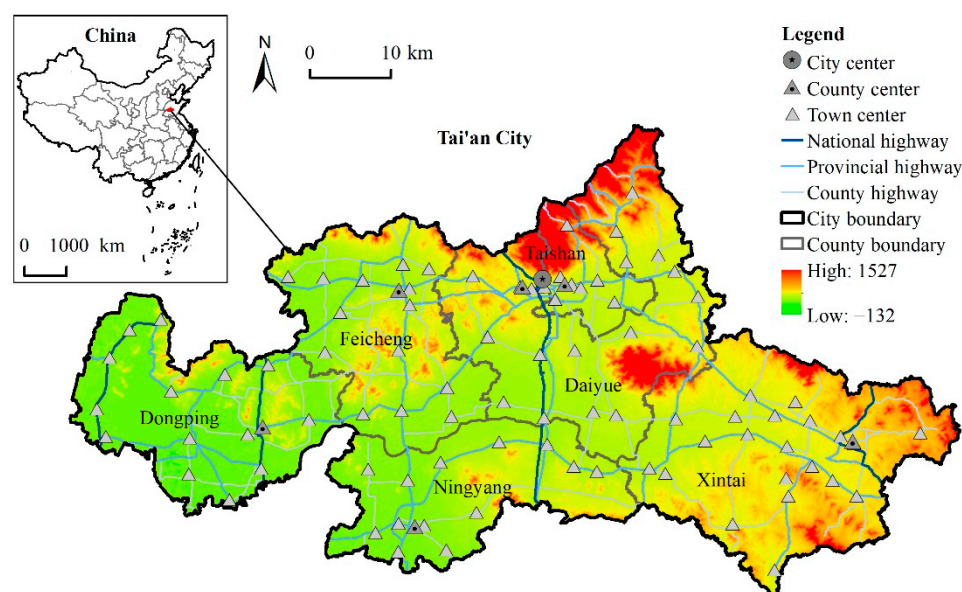
Finally, whether the influence of distance is heterogeneous in different geographical areas remains to be further investigated. Compared to mountainous regions, the land quality and the conditions for agricultural modernization in plains are superior. The infrastructure deprivation and bio-physical disadvantages caused by remoteness is generally more prominent in mountainous regions. Therefore, pathways of the role of accessibility in farmland abandonment may be different in plain and mountainous regions.

This study aims to explore the heterogeneous effects of multilevel location on farmland abandonment in China using village-level data. Specifically, the impact of distance to different levels of markets and roads is first investigated. Furthermore, the influence of multilevel location on farmland abandonment in different terrains is examined. On these bases, the mechanisms of the location effect are discussed.

### 3. Materials and Methods

#### 3.1. Study Area

This study takes Tai'an City as the case (Figure 1). The city is located in the middle of Shandong province, which is a traditional agricultural area in the North China Plain. It has a total area of 7762 square kilometers and is 66.8 km away from Jinan, the capital of Shandong Province. Various types of landforms are found in Tai'an City. Mountains account for 41.1% of the total area, hills account for 18.3%, and plains account for 40.6%. Tai'an contains more than 3000 village-level units nested in 6 county-level regions, including 2 districts (Taishan District, Daiyue District), 2 county-level cities (Xintai City, Feicheng City), and 2 counties (Ningyang County, Dongping County). In 2020, the permanent population of Tai'an City was 5.47 million, of which the urban population accounts for 64%. The urbanization rate has increased by nearly 14 percentage points in the past 10 years, indicating a significant restructuring of urban–rural structure. Despite rapid industrialization in recent decades, agriculture still plays an important position in its economy. Among the GDP of CNY 276.65 billion in 2020, the agriculture industry accounts for 10.8%, which is higher than the national level (7.7%). The main grain crops for this area are wheat and maize (usually planted in rotation per year), and the main cash crop is vegetables. In general, the diversity of topography, the significant role of agriculture, and the restructuring of the urban–rural relationship mean that the farmland types and utilization ways are manifold in Tai'an City. These conditions make the city a proper case for exploring the impact of location on farmland abandonment.



**Figure 1.** The study area.

### 3.2. Data

Six sets of data are used in this research, namely, farmland abandonment data, geographical data, socio-economic data, geo-physical characteristics of farmland, policy, and data of village types (Table 1). Farmland abandonment data come from the third national land survey in China. It is an official survey that started in 2017, and the preliminary data came out in 2019. It contains information about 12 land use types, including the plot area of each type and whether a farmland plot is abandoned. This survey is valuable as the accurate data of farmland abandonment are difficult to obtain. There are two main sources of data currently used in this topic. The first source is the sampling survey of rural households where the farmland use of rural households is inquired. However, data from household level surveys are unsuitable to manifest the characteristics of territorial units. The other method to acquire territorial farmland abandonment data is through remote sensing image interpretation techniques. However, the accuracy of identification is not high, especially in hilly and mountainous areas [23]. The third national land survey used in this study recorded the use of each land plot, and these land plots can be aggregated into the village level, which can accurately reflect the real situation of farmland abandonment in villages.

**Table 1.** Datasets of the study.

Dataset	Indicator	Source
Farmland abandonment	Farmland abandonment	The third national land survey
Geographical characteristics	Different levels of location and altitude	Remote-sensing images and digital elevation models
Socio-economic characteristics	Off-farm development, out-migration, farmland resources, agricultural mechanization, and farmland transfer	Village report
Geo-physical characteristics of farmland	Farmland quality, fragmentation, and slope	Updated evaluation of cultivated land quality grade
Policy	Policy incentives	Historical and cultural towns and villages in Shandong province and the first batch of rural revitalization demonstration villages in Shandong Province
Village types	/	National urban and rural division code for statistics

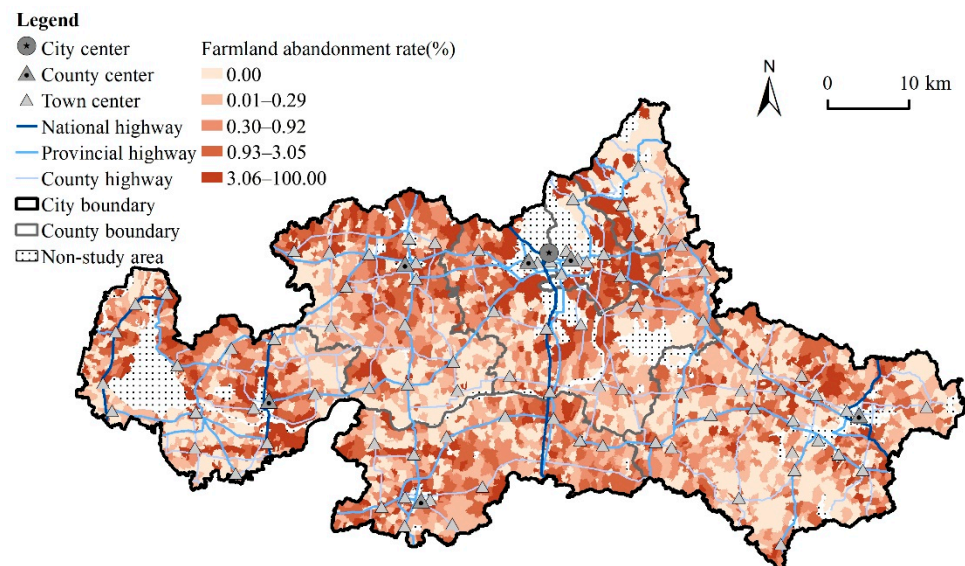
Multilevel location and mean altitude of each village come from remote-sensing images and digital elevation models. Villages' socio-economic characteristics are obtained from the village report (2015), which consists of information about labor force, off-farm



development, farmland resources, agricultural mechanization, and farmland transfer. The geo-physical information of farmland is taken from the updated evaluation of cultivated land quality grade (2019). The data related to the policy come from the historical and cultural towns and villages in Shandong Province, and the first batch of rural revitalization demonstration villages in Shandong Province announced before the end of 2019. According to the national urban and rural division code for statistics, the position of village-level units on the urban–rural continuum of Tai’an City can be divided into five types, namely, the main urban area, the urban–rural integration area, the town area, the town–rural integration area, and the village. Given that this study focuses on the use of farmland in rural areas, units in main urban areas and units without farmland are excluded. A small number of mismatched units (20 units) due to the multitude of data sources are also excluded, leaving 3421 village-level units for analysis.

### 3.3. Variable

The dependent variable in this study is the village’s farmland abandonment rate. It is calculated by dividing the abandoned farmland plot area by the total farmland plot area of each village. The probability of village’s farmland abandonment is not selected as the dependent variable because using it to reflect the real situation of the village’s farmland abandonment is problematic. The calculation of village-level farmland abandonment is based on each farmland plot. As long as one piece of plot is discarded, the possibility of farmland abandonment of the village is 100%, neglecting the fact that most of the farmland plots are in use. Figure 2 shows the spatial distribution of farmland abandonment rate. The surrounding area of the city center is a high-value concentration area of farmland abandonment rate. The area around the county center and the national highway also has a high farmland abandonment rate.



**Figure 2.** The spatial distribution of farmland abandonment rate.

Two types of location variables at different levels are used as explanatory variables. The distance to regional centers (or markets) and that to main roads are the two most commonly used location variables in existing literature [8]. The distance to regional centers reflects the accessibility of the off-farm labor market on the one hand, which influences the labor opportunity cost of agriculture [15]. On the other hand, areas adjacent to regional centers generally have better farming conditions than remote ones, including infrastructure and land quality, especially in hilly and mountainous areas [34,47]. Adjacency will thus affect the input cost of farming. Distance to three levels of regional centers are explored, namely, city level, county level, and town level. The higher the level of the regional center,

the more developed the economy and the more prosperous the labor market. In China, the government is often located in densely populated areas, which are also regarded as regional market centers. Therefore, the distance to different levels of regional centers is measured by Euclidian distance from the geometric center of the village to the location of three levels of governments.

Similarly, the distance to main roads reflects the convenience to regional centers on the one hand and the transportation costs of farm products on the other hand [14,24]. Main roads are also divided into three levels: national highway, provincial highway, and county highway. National highways are roads connecting provincial capitals and important economic centers across the country; provincial highways connect centers within the province; county roads connect the county center and towns in the county. The higher the level of the road, the better the accessibility to higher-level centers. The distance to roads is measured through the nearest Euclidian distance from the geometric center of the village to the three levels of roads.

The control variables consist of three categories: socio-economic variables, geo-physical characteristics of farmland, and policies. Although the analysis is based on the village unit, the first two types of variables used are also key factors affecting farmland abandonment at the household level in the existing literature. The data of these variables are aggregated at the village level, making up for the weakness that territorial-based studies ignore the agency of actors.

Off-farm employment, out-migration, farmland resources, agricultural mechanization, and farmland transfer represent socio-economic characteristic of villages. High non-agricultural employment rate and large-scale out-migration often lead to the insufficient input of labor force in farming, which may cause a high tendency to abandon farmland [8,14]. More farmland resources and higher degree of agricultural mechanization generally result in higher agricultural productivity and profits, which tend to prevent farmland from being discarded [49]. The transfer of farmland is an important alternative farmland management option and is actually a reallocation of farmland resources. Idle or low-yield farmland that is fragmented is aggregated and reused through farmland transfer. In this way, the possibility of farmland abandonment is decreased [50]. The off-farm employment rate is calculated by the ratio of non-agricultural employment population to the total population. Out-migration is measured by the proportion of non-labor force to the total population. In contemporary China, rural–urban migrants are mainly driven by economic interests and are mainly composed of people who have the ability to work [51–53]. Villages with large-scale out-migration usually show a high proportion of children and elderly people [54]. Therefore, the proportion of non-labor population can reflect the rural out-migration to a certain extent. Farmland resources refer to the per capita farmland area of rural residents of each village. Mechanization in agriculture is measured by the amount of diesel oil used in agriculture. Farmland transfer refers to the proportion of households with farmland transferred to the total number of households.

Variables related to geo-physical characteristics of farmland include farmland flatness, quality, and integrity. These variables are related to the productivity of farmland. Farmland that is flat, high-quality, and integrated tends to have higher yield and profits and thus has low probability of being discarded [8]. Flatness is calculated by the ratio of the area of farmland patches of 2 degrees and below to the total area. Farmland quality is measured on the basis of the data set of updated evaluation of cultivated land quality grade. According to the data, the farmland plot quality is the result of a comprehensive evaluation of a series of indicators related to productivity, soil quality, and infrastructure. It is presented in the form of 15 grades, on which basis 4 types are further divided, namely, excellent grade, high grade, medium grade, and low grade. The proportion of the area of excellent and high-grade farmland plots to the total area of farmland is used as the indicator of the village's farmland quality. Farmland integrity is calculated by the average area of farmland plots. The smaller the average area of the plot, the greater the fragmentation of the farmland.

The policy-related variable used in this study is whether the village is an officially recognized historical and cultural village or a rural revitalization demonstration village. These villages can receive policy incentives to develop their economy, society, and environment. Incentives for agricultural development and environmental protection may lead to low farmland abandonment.

Table 2 summarizes the statistics of variables. Statistics of these variables in plain regions and mountainous regions are also listed and compared by using a *t*-test. The farmland abandonment rate is significantly lower in plains than in mountainous regions. Villages in plains have significantly better proximity to the city center, town center, and provincial highway, but the distance to the nearest county center is shorter in mountainous areas. The distance from villages to the national and county highways do not differ significantly between the two regions. Off-farm employment rate is higher in hilly areas, but the out-migration in this region is significantly lower. Compared to mountainous regions, the mechanization, transfer rate, flatness, quality, and integrity of farmland in the lowland are significantly higher. No significant difference was observed between the two regions in terms of farmland resources and the number of villages that benefited from the policy.

### 3.4. Methods

Farmland abandonment is not a random phenomenon. The extent of farmland abandonment can only be observed in villages that have abandoned farmland, which is influenced by geo-physical environment, socio-economic factors, and policies. According to our data, 40% of villages have no arable land discarded. The sample selection bias problem thus arises when estimating the net effect of location on farmland abandonment rates. The observation of farmland abandonment in a village can be understood as aggregated results of local households' land use behaviors. Therefore, the village-level analysis in this study draws on the perspective of household decision making and regards farmland abandonment as a two-stage process. The first stage can be understood as whether the village has abandoned farmland, and the second stage can be seen as the extent of abandoned farmland. Heckman two-stage model is employed here to solve this problem. In the first stage, the Probit model is used to predict the probability of farmland abandonment on the basis of all observed values. In addition, the inverse Mills ratio (IMR) of each observation value is calculated in the meantime. In the second stage, using samples of villages with abandoned farmland, the OLS regression model is employed to examine the determinants of farmland abandonment rate. The IMR is added as a control variable to obtain a consistent estimator. In the estimation of the regression model, if the IMR is not equal to zero and is significant, it indicates the existence of a "self-selection" problem and using the Heckman two-stage model is appropriate. The Heckman two-stage model is expressed in the following equation:

the first stage:

$$P_i = \alpha_0 + \alpha_1 M_i + \alpha_2 X_i + \mu_i \quad (1)$$

the second stage:

$$Y_i = \beta_0 + \beta_1 M_i + \beta_2 X_i + \beta_3 \lambda_i + \varepsilon_i \quad (2)$$

where  $P_i$  represents the probability of farmland abandonment of village  $i$ ;  $M_i$  represents the explanatory variables;  $X_i$  is a series of control variables;  $Y_i$  represents the farmland abandonment rate of village  $i$ ;  $\lambda_i$  represents the IMR calculated from the probability model;  $\alpha$  and  $\beta$  are parameters of the Probit model and the OLS regression model, respectively;  $\mu_i$  and  $\varepsilon_i$  represent the error term of the probability model and the OLS regression model, respectively, which both obey a normal distribution.



**Table 2.** Summary statistics of variables.

Variable	Description	All Regions (N = 3421)		Plain Regions (N = 2871)		Mountainous Regions (N = 550)	
		Mean	S. D.	Mean	S. D.	Mean	S. D.
Dependent variables							
Farmland abandonment rate	The percentage of abandoned farmland area to the total farmland area (%)	2.80	10.51	2.64	9.82	3.61 **	13.56
Explanatory variables							
Dist_UC	Distance to the city government (km)	47.61	21.50	46.51	20.96	53.36 ***	23.34
Dist_CC	Distance to the nearest county-level government (km)	18.27	9.13	18.57	9.21	16.67 ***	8.53
Dist_TC	Distance to the nearest town-level government (km)	4.06	1.95	3.82	1.81	5.33 ***	2.18
Dist_NH	Distance to the nearest national highway (km)	14.48	8.66	14.52	8.52	14.25	9.33
Dist_PH	Distance to the nearest provincial highway (km)	3.37	2.94	2.94	2.40	5.61 ***	4.22
Dist_CH	Distance to the nearest county highway (km)	2.82	2.74	2.85	2.87	2.65	1.85
Control variables							
Off-farm employment	The proportion of off-farm employment to the total population	0.70	0.19	0.68	0.18	0.80 ***	0.19
Out-migration	The proportion of non-labor population to the total population	0.38	0.11	0.39	0.11	0.37 ***	0.10
Farmland resource	Per capita farmland area (m <sup>2</sup> /person)	951.22	682.03	957.59	670.11	917.95	740.93
Mechanization	The amount of diesel oil (liters)	14,744.88	37,254.93	15,943.66	40,071.67	8487.24 ***	14,320.37
Transfer	The proportion of households with farmland transferred to the total households	0.23	0.27	0.23	0.27	0.20 ***	0.26
Flatness	The proportion of the area of farmland with slopes less than or equal to 2 degrees to the total farmland area	0.59	0.41	0.68	0.38	0.13 ***	0.19
Quality	The proportion of the area of high-quality farmland to the total farmland area	0.87	0.26	0.90	0.24	0.75 ***	0.31
Integrity	Average area of farmland plot (m <sup>2</sup> )	27,280.03	19,710.41	29,121.61	20,269.69	17,667.00 ***	12,727.99
Policy	Whether it is a historical and cultural village or a demonstration village for rural revitalization	0.02	0.13	0.02	0.12	0.02	0.13

Note: Referring to the standard topographic map of China and existing research, villages below 200 m are identified as plain regions, and those above 200 m are identified as mountainous regions [22,55]. Asterisks indicate that the mean values of the variables in the plain regions and the mountainous regions are significantly different. \*\* and \*\*\* indicate significance at 0.05 and 0.01 levels, respectively.

The models were fitted using the STATA program version 14.0 (StataCorp LP., College Station, TX, USA). Variables were processed before modelling. First, explanatory variables were transformed to the logarithmic form. Second, independent variables were standardized. Finally, multicollinearity was detected. The result shows that the variance inflation factor (VIF) is less than 2, indicating the absence of multicollinearity.

#### 4. Results

##### 4.1. The General Impact of Location on Farmland Abandonment

Table 3 shows the modeling results of location effect on farmland abandonment. Model 1 and Model 2 only examine the impact of location variables, which serve as benchmark models. Control variables are added to Model 3 and Model 4 on the basis of Model 1 and

Model 2. Model 2 and Model 4 are second-stage models in which IMR (Lambda) calculated from first-stage Probit models is added. Lambda is significant in both Model 2 and Model 4, indicating the existence of the sample selection bias problem. Thus, the Heckman two-stage model is properly used.

**Table 3.** Modeling results of farmland abandonment.

Variable	Model 1		Model 2		Model 3		Model 4	
	Coeff.	S.E.	Coeff.	S.E.	Coeff.	S.E.	Coeff.	S.E.
Dist_UC	−0.10 ***	0.03	−27.56 ***	1.78	−0.06 **	0.03	−5.51 ***	0.39
Dist_CC	−0.16 ***	0.03	−39.09 ***	2.78	−0.15 ***	0.03	−4.60 ***	0.63
Dist_TC	−0.02	0.02	−5.91 ***	0.51	−0.09 ***	0.03	−1.57 ***	0.44
Dist_NH	−0.06 **	0.02	−14.99 ***	1.08	−0.09 ***	0.03	−2.09 ***	0.41
Dist_PH	−0.04 *	0.02	−10.32 ***	0.80	−0.09 ***	0.03	−1.59 ***	0.43
Dist_CH	−0.02	0.02	−3.73 ***	0.43	−0.03	0.02	0.11	0.29
Off-farm employment					0.08 ***	0.02	0.89 **	0.42
Out-migration					0.06 ***	0.02	1.05 ***	0.34
Farmland resource					0.17 ***	0.03	−0.33	0.65
Mechanization					0.15 ***	0.03	1.02 **	0.40
Transfer					−0.01	0.02	−0.73 ***	0.27
Flatness					−0.16 ***	0.03	−3.31 ***	0.69
Quality					0.03	0.03	−1.22 ***	0.30
Integrity					−0.10 ***	0.03	−2.58 ***	0.51
Policy					0.08 ***	0.02	1.46 ***	0.34
Lambda			419.64 ***	31.94			30.72 ***	7.03
Constant	0.28 ***	0.02	−262.72 ***	20.35	0.29 ***	0.02	−14.68 ***	4.50
N		3421		2045		3421		2045
Prob > $\chi^2$ / Prob > F		0.00		0.00		0.00		0.00
Pseudo R <sup>2</sup> / R <sup>2</sup>		0.02		0.22		0.05		0.23

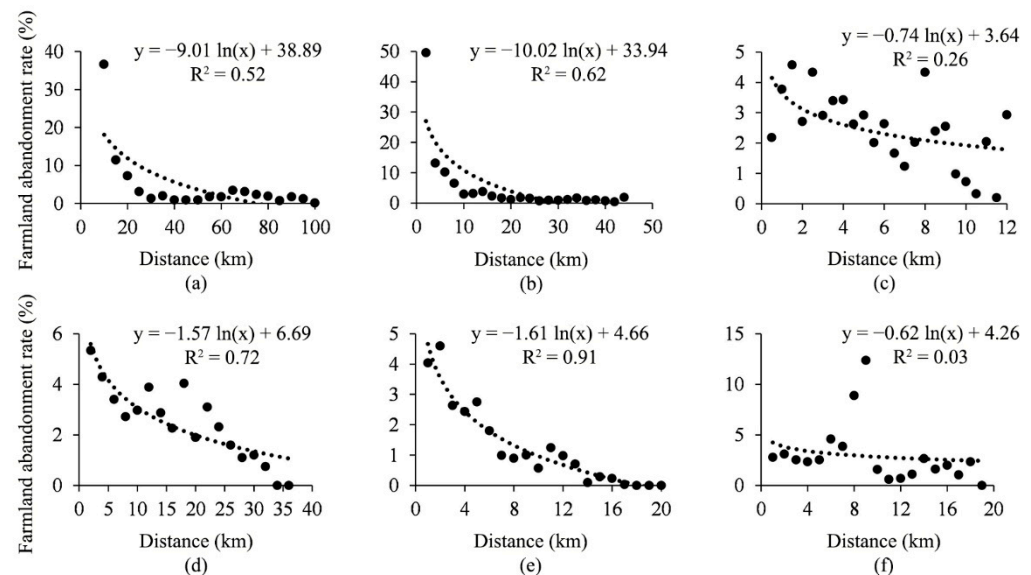
Note: \*, \*\*, and \*\*\* indicate significance at 0.1, 0.05, and 0.01 levels, respectively.

As displayed in Model 2, The farmland abandonment rate is significantly negatively correlated with distance to all levels of regional centers and roads. After adding control variables, the results of the location effect exhibit a similar pattern, except that the association between farmland abandonment rate and distance to the county highway becomes nonsignificant (Model 4). The findings indicate that farmland abandonment tends to occur in places adjacent to markets and roads, and farmland abandonment rate decay with distance. This may result from the attraction of off-farm employment and the impact of land use transition. On the one hand, regional centers always act as a reservoir of off-farm employment opportunities. However, the accessibility to such opportunities is geographically uneven. The obstacles and costs to obtaining off-farm employment in regional centers decrease as distance increases [56]. Thus, compared to remote areas, suburban rural residents generally have higher possibility to work off-farm in the nearby market. In this vein, the agricultural labor force input is lower in areas adjacent to regional centers, leading to higher rate of farmland abandonment. On the other hand, continuous rapid urbanizing progress involves transferring a huge amount of rural farmland to construction land, and such land use transition is more prone to occur in places near urbanized areas [57]. When the availability of farmland is not expected to be long-term and stable, which means the profit from farming is highly uncertain, rural households will reduce and even stop investing in farmland. Therefore, farmland closer to urban centers is more likely to become idle.

The impact of the proximity of different levels of markets and roads on farmland abandonment rate has varying degrees. As Model 4 shows, the absolute values of the coefficients of the distance to the city center and the county center are close, but far greater than that of the distance to the town center. Similarly, the distance to the national highway and that to the provincial highway have close absolute values of the coefficients, but the impact of the distance to the county highway is even nonsignificant. The greater impact of the accessibility of high-level markets and roads on farmland abandonment implies that in the current stage of rapid urbanization in Tai'an City, the city center and the county center play a dominant role in the regional development of urbanization and

non-agricultural labor market [58]. Therefore, they have far-reaching influence on the transition of agriculture and livelihoods in vast rural areas. However, this impact of the town center is limited.

The relationship between multilevel location and farmland abandonment rate is further examined. We first established multiple equidistant buffer zones on the basis of regional centers and roads at each level. Then, the mean value of farmland abandonment rate of villages within each buffer zone was calculated. On this basis, the relationship between the distance and the mean value of the farmland abandonment rate was fitted (Figure 3). The decline in the farmland abandonment rate slows down as the distance to the regional centers and roads increases, which is particularly obvious in the relationships between farmland abandonment rate and the distance to the city center and the county center. The villages' average farmland abandonment rate within 10 km from the city center is close to 40%, but it drops to below 10% when the distance is beyond 20 km. Similarly, the average farmland abandonment rate within 5 km from the nearest county center is about 50%, but it also decreased to less than 10% after 5 km.



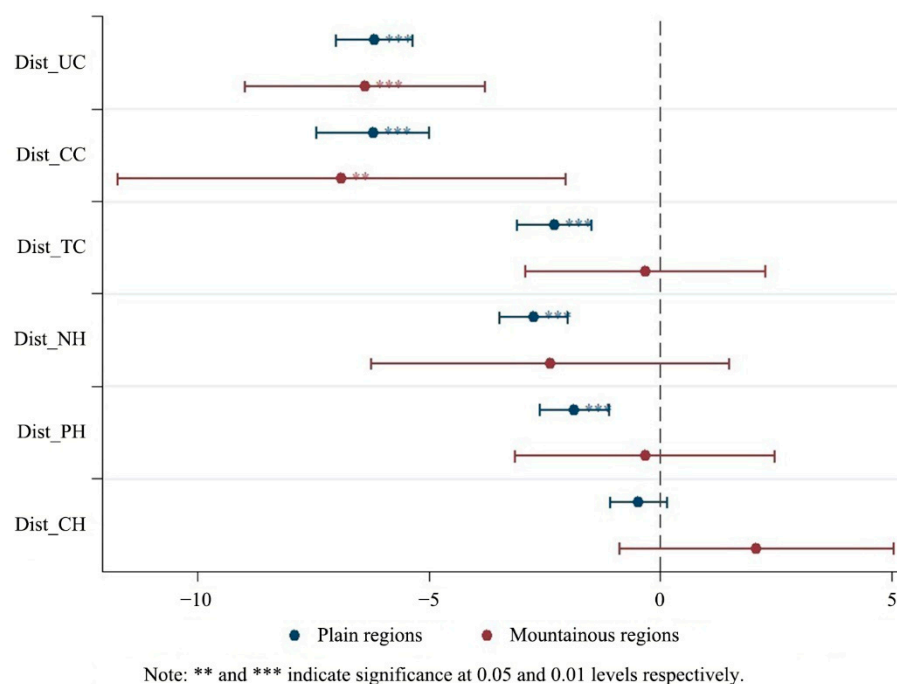
**Figure 3.** Relationships between farmland abandonment rate and distance to regional centers and roads of different levels. (a) The relationship between farmland abandonment rate and distance to the city center; (b) The relationship between farmland abandonment rate and distance to the nearest county center; (c) The relationship between farmland abandonment rate and distance to the nearest town center; (d) The relationship between farmland abandonment rate and distance to national highway; (e) The relationship between farmland abandonment rate and distance to provincial highway; (f) The relationship between farmland abandonment rate and distance to county highway.

The effects of most of the control variables confirmed the main conclusions achieved in household-level studies, except for a few contrary to expectation. Local off-farm employment rate and out-migration rate are positively associated with farmland abandonment as expected. The per capita farmland area has no significant correlation with the farmland abandonment rate. This result may be due to the complexity of the impact pathways. On the one hand, households with more farmland tend to be better promoted and better equipped in agricultural activities to gain profits, which prevents them from discarding lands. On the other hand, cultivation cost generally increases with the increase in per capita farmland area. Therefore, farmland of a larger size is more difficult to be continuously used when the investment in agriculture decreases for the reasons of out-migration or turning to off-farm jobs [31]. The effect of agricultural mechanization is significantly positive, which is contrary to our expectation. This finding may be due to the fact that the use of agricultural machinery tends to favor continuous and concentrated farmland. However, the farmland

of households in China is generally multi-block and geographically fragmented. Farmland parcels in marginal areas are not effectively used and are thus easily discarded [47]. The positive impact of agriculture mechanization is also found in a case study in Ukraine [21]. The transfer rate, quality, flatness, and integrity of farmland have significant negative correlations with farmland abandonment as expected. Villages that receive policy honors have higher rates of farmland abandonment. This may be because historical and cultural villages and rural revitalization demonstration villages are inclined to promote the development of non-agricultural industries to make economic growth prominent.

#### 4.2. The Impact of Location on Farmland Abandonment in Different Terrain

Figure 4 exhibits the modeling results of farmland abandonment in plains and mountainous areas. Given that multilevel location is the main explanatory variable of our concern, the results of control variables are omitted. The impact of location on farmland abandonment is different in plains and in mountainous areas. In plains, the distance to different levels of markets and roads affect farmland abandonment in a similar way to the general pattern aforementioned. However, the location effect is different in mountainous areas. Among all location variables, only the distance to the city center and the county center have significant negative association with the rate of farmland abandonment. The nonsignificant impact of the town center implies that the town-level center in mountainous regions play a weaker role in industrialization and population agglomeration than in plains. In mountainous areas, inconvenient transportation and loose settlement structures of villages pose difficulty for the town center to attract capital and population [59]. Thus, the extent of industrialization and population concentration of the town center is low, and rural households are more dependent on agriculture.



**Figure 4.** Coefficients of multilevel location in plains and mountainous regions.

The nonsignificant association between road accessibility and farmland abandonment in mountainous areas may be related to the positive impact of road adjacency on agricultural production and sales. Rough and sparse roads in mountainous villages often make it difficult to transport agricultural production materials and agricultural products, which increase the cost of cultivation and raise the probability of abandoning farmland [24,60]. Therefore, the farther the distance from main roads, the higher the abandonment rate of

farmland. The role of agricultural restrictions is comparable to that of market attraction mentioned above, making the effect of the main roads nonsignificant.

#### 4.3. Robustness Test

The distance from villages to the regional centers are measured using Euclidean distance. However, this measurement does not reflect the actual accessibility of regional centers, especially in places with large water areas or mountainous areas. To measure the accessibility more accurately, we use the shortest road distance from villages to regional centers as a substitute. It is calculated using ArcGIS software (Esri, Redlands, CA, USA) on the basis of road network data. Table 4 shows the results of the robustness test. The first two models use all samples, the middle two models use samples from the plains, and the last two models use samples from mountainous areas. The impact of location variables does not change with the change of measurements, indicating that the influence of explanatory variables on farmland abandonment is robust.

**Table 4.** Robustness test of the effect of multilevel location on farmland abandonment.

Variable	Model 1	Model 2	Model 3	Model 4	Model 6	Model 7
	Coeff. (S.E.)	Coeff. (S.E.)	Coeff. (S.E.)	Coeff. (S.E.)	Coeff. (S.E.)	Coeff. (S.E.)
Dist_UC	−0.05 ** (0.02)	−4.52 *** (0.34)	−0.05 * (0.03)	−4.72 *** (0.34)	−0.06 (0.08)	−6.27 *** (1.40)
Dist_CC	−0.15 *** (0.03)	−4.30 *** (0.64)	−0.17 *** (0.03)	−5.58 *** (0.62)	−0.12 (0.11)	−6.10 ** (2.49)
Dist_TC	−0.06 ** (0.02)	−1.06 *** (0.38)	−0.06** (0.03)	−1.51 *** (0.36)	0.01 (0.07)	1.40 (1.25)
Dist_NH	−0.08 *** (0.03)	−2.03 *** (0.42)	−0.08*** (0.03)	−2.55 *** (0.38)	−0.08 (0.11)	−2.34 (1.85)
Dist_PH	−0.09 *** (0.03)	−1.47 *** (0.43)	−0.07** (0.03)	−1.32 *** (0.37)	0.02 (0.08)	−0.91 (1.37)
Dist_CH	−0.02 (0.02)	0.29 (0.29)	−0.04 (0.03)	−0.07 (0.31)	0.06 (0.06)	1.83 (1.43)
Control variables	YES	YES	YES	YES	YES	YES
Lambda		31.46 *** (7.16)		40.38 *** (6.75)		83.14 *** (25.80)
Constant	0.27 *** (0.02)	−15.79 *** (4.64)	0.36 *** (0.03)	−20.06 *** (4.08)	0.20 (0.17)	−50.04 *** (18.13)
N	3421	2045	2871	1737	550	308
Prob>chi2/Prob>F	0.00	0.00	0.00	0.00	0.00	0.00
Pseudo R <sup>2</sup> /R <sup>2</sup>	0.05	0.22	0.07	0.24	0.07	0.22

Note: \*, \*\*, and \*\*\* indicate significance at 0.1, 0.05, and 0.01 levels, respectively.

## 5. Discussion

In response to the discussion on the two competing hypotheses of the effect of location on farmland abandonment, the results of this study indicate that the attraction of urban markets, rather than the constraints of cultivation in remote areas, plays a leading role. It should be pointed out that this study is not intended to verify which hypothesis is right or wrong under any circumstances, but to be a starting point to discuss the possibility that different pathways take place in different contexts. Our findings are deeply rooted in local socio-economic, geographical, cultural, and institutional conditions.

First, the higher explanatory power of urban market attractiveness on the location effect is closely related to the stage of rapid urbanization. In this stage, urbanization is characterized by centralization of population and capital in advantageous areas, leading to significant spatial heterogeneity in the flow and agglomeration of elements along urban–rural gradients. From the perspective of distance to urbanized areas, suburban villages are usually much better than remote villages in terms of non-agricultural economic development level, access to information, and opportunities for off-farm employment [56]. Therefore, rural households in remote areas are relatively dependent on agriculture, which leads to the low rate of farmland abandonment. From the perspective of the level of markets, the city center and the county center are the main containers of urbanization



and off-farm employment opportunities, whereas the town center is underdeveloped and mainly plays the role of providing public and commercial services for rural households [61]. This reason explains why the impact of high-level markets and roads is stronger.

Second, the gently undulating terrain and the attachment to agriculture nurtured based on it contribute to low farmland abandonment rate in remote villages. In areas with gentle topographic relief, the constraints of agriculture are not prominent in the vast majority of villages. Moreover, the culture that values agriculture formed for a long time under such geographical conditions have led to a high attachment to agriculture for rural households. In addition, farmers in mountainous or remote villages are more vulnerable to the deprivation of education, information, and skills, making it costly to transform their livelihoods. Therefore, in mountainous or remote villages, farmers may choose to give up their farmland only when the benefits of off-farm employment or out-migration far outweigh those of agricultural activities.

Finally, the results are embedded in the Chinese land system, where the ownership of rural farmland belongs to the village collective. On the one hand, the collectively owned rural farmland is not allowed to be traded personally. Therefore, even if the price of farmland near urbanized areas is high, rural households cannot benefit from selling it. On the other hand, non-agricultural uses of farmland are strictly limited, especially those classified as permanent basic farmland. In this vein, under the premise that labor opportunity costs are high and the trade and non-agricultural uses of farmland are restricted, suburban households are inclined to reduce or cease agriculture input, leading to the high rate of abandonment. This logic may explain why the results of this study are contrary to research done in some capitalist societies. Farmland in capitalist countries is privately owned, and changes in its use and ownership can be determined by individuals. According to the theory of land rent, land prices increase as land becomes closer to the market [62]. Therefore, as much literature has documented, farmland closer to the urbanized markets will be used more intensively for high profits and is less likely to be left idled [23,47].

This study has following three limitations. First, the number of villages located in high mountains is not large enough. Most mountainous villages are in low mountains and hills, with only a few villages having an average altitude of more than 500 m. The sample is insufficient to examine whether the impact of multilevel location on farmland abandonment in villages in high mountains is significantly different from that in villages in plains. In addition, due to the cross-sectional data, the changes in the effect of location in different urbanization stages cannot be further explored. Lastly, the correlations between location and farmland abandonment are examined through econometric models. However, the underlying mechanism has not been quantitatively tested, which needs further investigation.

## 6. Conclusions and Policy Implication

This study takes Tai'an City as a case to explore the effect of multilevel location on village-level farmland abandonment rate and its differences in plains and mountainous areas. We found that (1) the higher the proximity to regional centers and roads, the higher the abandonment rate of farmland. This finding means that in the two competing hypotheses, accessibility to regional centers and roads, rather than remoteness, leads to a high rate of farmland abandonment. (2) The impact strength of different levels of location on farmland abandonment varies. High-level regional centers (city centers and county centers) and roads (national and provincial highways) have a stronger impact on farmland abandonment compared with low-level town center and county highway. The average farmland abandonment rate is much higher in the areas adjacent to high-level regional centers and roads than that in areas near the town center and the county highway. (3) The effect of location is different between plains and mountainous areas, as rugged terrain can exacerbate the adverse effects of remoteness on agricultural production in terms of agricultural facilities and the quality of farmland. In the plains, except for the county highway, the distances to regional centers and roads at different levels are significantly

negatively correlated with the farmland abandonment rate. In mountainous areas, only high-level regional centers have significant negative impacts.

On the basis of the results of this study, three policy suggestions are put forward to alleviate farmland abandonment and improve the function of farmland. First, according to the finding that suburban villages have higher farmland abandonment rate, we propose to develop multifunctional use of suburban farmland to increase profits. Facing the new demand of dietary consumption and rural tourism of urban residents, suburban villages should be encouraged to develop urban agriculture and pastoral complexes by virtue of their proximity. Second, in order to prevent rural households from reducing agricultural input due to the misunderstanding that their farmland will be expropriated, it is recommended to publicize plans of permanent basic farmland, ecological conservation redline, and urban development boundaries promptly. Rural residents can thus make rational decisions on the use of farmland when they know whether their farmland will officially change to urban land in the near future. Finally, our research finds that the transfer of farmland can help reduce the abandonment rate. Therefore, promoting the transfer of farmland by improving the farmland transfer system is proposed.

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