Effect of e-commerce popularization on farmland abandonment in rural China: Evidence from a large-scale household survey

Yahui Wang [a,b,c], Aoxi Yang [a], Yuanqing Li [a,b,c], Qingyuan Yang [a,b,c,*]

[a] School of Geographical Sciences, Southwest University, Chongqing 400715, China
[b] New Liberal Arts Laboratory for Sustainable Development of Rural Western China, Chongqing 400715, China
[c] Chongqing Jinfo Mountain Karst Ecosystem National Observation and Research Station, School of Geographical Sciences, Southwest University, Chongqing 400715, China

ABSTRACT

Uncertainty in the food supply continues to increase due to COVID-19 and geopolitical conflicts, and reducing farmland abandonment is an important measure for ensuring food security. In recent years, the Chinese government has promoted e-commerce demonstration projects in rural areas, so we ask does the spread of e-commerce reduce farmland abandonment? This study first constructs a theoretical framework for the effect of e-commerce on farmland abandonment and then quantifies that effect through spatial analysis and econometric models based on 12,732 households in the China Rural Household Panel Survey (CRHPS). The study found that there was a significant spatial aggregation between the popularization of e-commerce and the distribution of abandoned farmland, with a significant negative correlation between these two factors. The popularization of e-commerce has reduced farmland abandonment. The probability and size of farmland abandonment by farmers dropped by 4.1 % and 17.5 % when e-commerce was promoted in a village; the probability and size of farmland abandonment by farmers dropped by 7.8 % and 38.7 % when the rate of the popularization for e-commerce in villages increased by 1 %, respectively. E-commerce can reduce farmland abandonment in rural areas by absorbing returning labour, stimulating the land transfer market and revitalizing rural industry. With the improvement of physical infrastructure such as rural roads, the government should pay attention to the construction of digital villages including e-commerce infrastructure and continue to innovate new ways small farmers to participate in e-commerce, thus helping transform rural spaces and reusing idle land resources.

1. Introduction

The increasing risk of food supply uncertainty in developing countries, which is further exacerbated by the normalization of the global COVID-19 pandemic and geopolitical conflicts, poses a major challenge to ensuring sufficient food supply for the global population (Kaicker et al., 2022; Saâdaoui et al., 2022; Yao et al., 2022). Farmland is crucial for food production, and studying changes in its use is essential for understanding regional and global food security (Liu and Zhou, 2021; Parven et al., 2022). However, farmland abandonment has become a global phenomenon due to rapid socio-economic development (Estel et al., 2015; Terres et al., 2015; Ito et al., 2016; Liang et al., 2020; Hou et al., 2021; Quintas-Soriano et al., 2022), affecting countries such as Europe (Estel et al., 2015; Terres et al., 2015), Japan (Ito et al., 2016), China (Liang et al., 2020; Hou et al., 2021) and the Mediterranean

region (Quintas-Soriano et al., 2022). The extent of abandoned farmland worldwide has reached alarming levels (Estel et al., 2015; Löw et al., 2015; Zhu et al., 2021), hindering efforts to address the global food crisis effectively (Li et al., 2021a; Quintas-Soriano et al., 2022). Therefore, it is urgent to address farmland abandonment comprehensively.

To effectively manage abandoned land, it is necessary to systematically identify the drivers of farmland abandonment. Previous studies have identified various factors contributing to land abandonment (Baumann et al., 2011; Vinogradovs et al., 2018; Wang et al., 2020a), including rural labour shortages (Xu et al., 2019), high agricultural operation costs (Wang et al., 2022), natural disasters (Lee et al., 2021), poor agricultural technology (Movahedi et al., 2021), inferior land quality (He et al., 2020), and wildlife invasion (Sieber et al., 2015; Hua et al., 2016; Yang et al., 2020). The factors influencing farmland abandonment are diverse and complex, exhibiting regional variations

(Movahedi et al., 2021; Wang et al., 2022), and evolve alongside ongoing socio-economic development (Ustaoglu and Collier, 2018; Christian et al., 2018). Despite substantial research efforts, the current understanding of these factors remains insufficient in comprehensively elucidating the phenomenon of farmland abandonment. An interesting phenomenon is that the development of digital villages in rural China, represented by the Internet and e-commerce, has to some extent changed the way rural land is utilized. This observation has the potential to deepen our understanding of the extent of farmland abandonment.

In recent years, the rapid spread of digitalization and informatization in rural areas has led to the emergence of rural e-commerce (Yang, 2022). Supported by robust network communication and logistics systems, rural e-commerce has become a catalyst for comprehensive revitalization of rural areas (Lin et al., 2022). The Chinese government has actively promoted rural e-commerce platforms and demonstrations as part of its efforts for rural rejuvenation (Council of State, 2015; Kwak et al., 2019). Remarkably, the COVID-19 pandemic, while negatively impacting global trade, unexpectedly accelerated the advancement of rural e-commerce in China (Nanda et al., 2021). Traditional offline trading channels for agricultural products faced significant challenges, while e-commerce has bucked this trend and emerged as a new driving force behind nationwide agricultural sales (Kwak et al., 2019; Nanda et al., 2021). According to annual statistics released by the Ministry of Commerce, in 2014, the Chinese government launched the comprehensive demonstration project for e-commerce in rural areas. Since then, rural e-commerce has undergone significant development. Initially, there were 56 counties across 8 provinces participating in the project. However, by 2021, this number had surged to 1672, encompassing all provinces in China, and more than 90 % of these counties were classified as poverty-stricken (Ali Research Institute, 2022). This reflects the widespread adoption and successful promotion of e-commerce in rural areas. Furthermore, the number of rural internet users has reached 284 million, with nearly 16.33 million rural e-commerce and online stores (Ali Research Institute, 2022). Notably, rural online retail sales have been steadily increasing, reaching 4.3 trillion yuan in 2021, which accounted for 29 % of China's total online retail sales. Extensive research has shown that the advent of e-commerce has profoundly impacted the social, economic, and spatial fabric of rural areas (Ndubuisi et al., 2021; Leng, 2022; Tang and Zhu et al., 2020). E-commerce promotes the development of rural industries with unique characteristics, creating new opportunities for improving the supply chain of agricultural products, extending the agricultural industry chain (Peng et al., 2021), enhancing the added value of agricultural products, and accelerating industrial revitalization (Long and Wang, 2018). E-commerce platforms enable smooth flow between urban and rural factors by connecting cities and villages, allowing scattered small farmers to directly connect with the market and achieve seamless integration between production and sales (Li and Qin, 2022). Moreover, e-commerce has expanded sales channels for agricultural products, providing farmers with additional income-boosting opportunities and helping alleviate poverty in rural areas (Li et al., 2021b; Liu et al., 2022; Zhong and Ferrand, 2022; Lechman and Popowska, 2022; Nguyen et al., 2022). It effectively links the achievements of poverty eradication with rural revitalization. In summary, the development of e-commerce continues to inject vitality into rural economic and industrial development (Wang et al., 2020b; Lin et al., 2016; Zhang et al., 2019).

It is worth noting that land is a spatial carrier of socio-economic development, and new industries and business models will generate fresh demand for land use (Long and Tu, 2018; Zhang et al., 2019; Wang et al., 2020b). For instance, the development of rural industries has heightened the demand for industrial and storage land (Tang and Zhu, 2020; Yang, 2018). The emergence of e-commerce has triggered a spatial reconfiguration of rural areas, significantly influencing the structure of land use (Liu et al., 2020; Tan and Chen, 2022). However, limited research has examined the impact of e-commerce on changes in the utilization of rural farmland (Deng et al., 2019; Zou and Mishra,

2022), E-commerce plays a crucial role in driving the industrialization and scaling of agriculture, leading to notable transformations in the agricultural development model. The influence of e-commerce extends to the utilization of rural farmland, primarily manifested in the adjustment of planting structures, the expansion of planting areas, and the transfer of land ownership (Goyal, 2010; Aker and Ksoll, 2016; Donaldson, 2022). Therefore, it is necessary to gain insight into the impact of e-commerce on the use of rural farmland. Specifically, it is crucial to investigate whether e-commerce has improved rural land use and alleviated farmland abandonment in rural China. The current characteristics of farmland abandonment and the development of e-commerce in China provide a unique opportunity to address these questions. This study aims to establish a connection between rural e-commerce development and rural land use change, providing strategic guidance for abandonment management and sustainable food production in other developing countries.

To scientifically explore the relationship between e-commerce and farmland abandonment, several issues need to be addressed. First, there may be endogeneity in the relationship between e-commerce popularization and farmland abandonment, as regions with severe abandonment may prioritize e-commerce adoption. This poses challenges in accurately quantifying the impact of e-commerce on farmland abandonment (Deng et al., 2019). Second, existing studies evaluating the effects of e-commerce have mostly focused on macro and micro levels, making it difficult to measure the impact on individual behaviour at the micro level (Peng et al., 2021). Third, although some studies have quantitatively analysed the impact of e-commerce on micro individuals, they have not revealed the channels and mechanisms through which digital technology affects them, limiting their utility for policymakers (Deng et al., 2019; Zou and Mishra, 2022).

Based on a theoretical framework for the effect of e-commerce on farmland abandonment, this paper utilizes large-scale household survey to explore the quantitative relationship between the above two factors. The contributions of this paper are as follows: A theoretical analytical framework for the effect of e-commerce on land abandonment is constructed under the guidance of agricultural theory. The mechanisms by which e-commerce affects land abandonment are analysed to provide scientific evidence for policy makers. The remainder of this paper is structured as follows: The second part describes the theoretical framework of e-commerce affecting land abandonment. The third part presents the data and methods. The fourth and fifth parts show the results, heterogeneity and mechanism. The sixth and seventh provide discussions and conclusions.

2. Theoretical framework of e-commerce affecting land use decisions

The channels through which e-commerce affects changes in rural land use are complex. With reference to existing theories and empirical studies, we summarize the pathways through which e-commerce affects rural land use changes as follows (Fig. 1). The popularization of e-commerce has redirected the flow of labour migration, thus changing land use decisions. The development of e-commerce has changed the characteristics of rural labour migration (Wang et, al, 2023; Wang & Yi, 2023). On the one hand, e-commerce has promoted the development of logistics and industry, enhanced the ability of districts and counties to absorb the rural labour force, increased the employment rate among rural workers, and, to a certain extent, contributed to the abandonment of farmland by farmers (Yin et, al, 2022; Yin & Choi, 2022). On the other hand, the popularity of e-commerce has increased the probability of self-employment in rural areas, possibly reducing farmland abandonment (Huang et, al, 2021; Huang et, al, 2022). In the past decade, 7023 Taobao villages and 2171 Taobao towns have emerged across the country, providing employment for more than 10 million rural labourers (Ali Research Institute, 2022). Rural e-commerce has reversed the one-way flow of rural labour to cities and absorbed returning labourers.
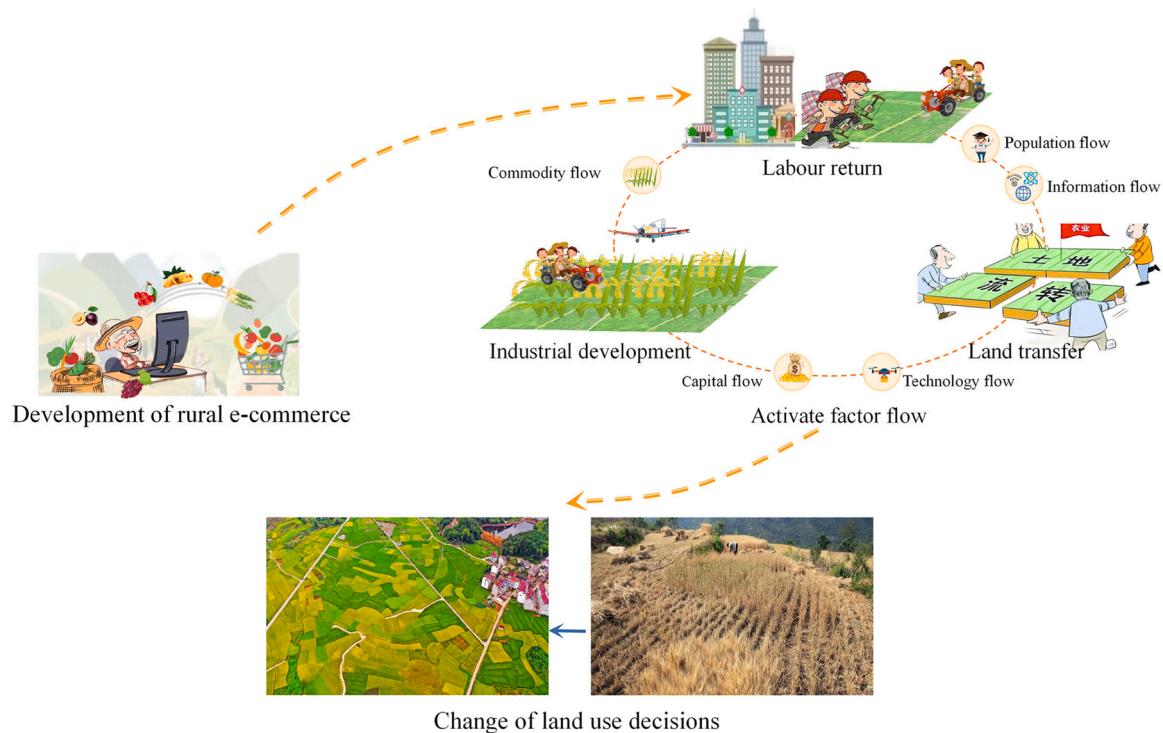
Fig. 1. Mechanism of e-commerce affecting land use in rural areas.

It is evident that e-commerce may change the decision-making process regarding land use by influencing the direction of labour migration.

The popularization of e-commerce has stimulated the land transfer market, thus changing land use decisions (Tan and Chen, 2022). The popularization of e-commerce has led to a return of labour to the countryside, increasing the demand for land resources and the reuse of previously abandoned land through land circulation (Zhang et al., 2019). In Guangxi, Ningxia and Chongqing, for example, driven by live e-commerce broadcasts and poverty alleviation through consumption, rural e-commerce demonstration counties have broadened the marketing of their agricultural products, and the scarcity of land resources has continued to be highlighted, with some regions forming the "company + base + farmers" business model to transfer or reclaim abandoned land, conduct spatial restructuring, and promote the management of abandoned land. Clearly, e-commerce can solve the problem of farmland abandonment by stimulating the land transfer market (Zou and Mishra, 2022).

The popularization of e-commerce has revitalized rural industry, thereby changing land use decisions (Leng and Tong, 2022). E-commerce enterprises improve the quality of agricultural products, lead to the optimization of the product structure and create regional brands through digital technology, thus promoting the upgrading of agricultural industrialization and the intensification, scaling, factorization and full traceability of agricultural production (Jing and Jie, 2021; Zhang et al., 2022). E-commerce enterprises can rely on the natural endowments of different regions to promote foundational special industries in accordance with local conditions and drive the development of a "one village, one product; one town, one industry" perspective through the "internet+" to create a virtuous cycle in the countryside (Long and Wang, 2018). E-commerce has promoted the development of rural industry, improved the value and efficiency of land use, and reduced the probability of farmland abandonment.

In addition, the development of e-commerce is conducive to alleviating the information asymmetry between suppliers and demanders, improving the transparency of information in factor markets, such as the labour and land markets, reducing agricultural costs and increasing agricultural returns, thus reducing land abandonment. Importantly, e-commerce is a new type of production factor that enhances agricultural total factor productivity by linking technologies such as cloud computing and big data with agricultural production, thus shifting agriculture away from small, scattered and disorganized production and helping resolve the problem of land abandonment. Therefore, the relationship between e-commerce and land abandonment is explored to provide a reference for other countries in the world to revitalize their abandoned land. Although this section constructs the theoretical framework for the impact of e-commerce on farmers' land use change, the mechanisms by which e-commerce affects land abandonment by farmers need to be further examined.

3. Materials and methods

3.1. Data

1) National sample survey data of farm households. The data were obtained from the China Rural Household Panel Survey (http://ssec.zju.edu.cn/sites/main/template/news.aspx?id=51036), published by Zhejiang University, as it contains data from the 2017 Household Tracking Survey in rural China, covering 12,732 households from 377 villages in 29 provinces (Fig. 2a). The data are representative at the national, provincial and village levels. The survey includes household and village questionnaires, with the household questionnaire recording detailed information on demographic characteristics, agricultural operations, land abandonment, income and expenditures, and e-commerce applications, while the village questionnaire records detailed information on demographic characteristics, geographical location, public facilities, economic development, social governance and e-commerce popularity. For example, the village questionnaire contains the question "does the village promote e-commerce?". If the answer is yes, it indicates that the village is an e-commerce village; otherwise, it is not an e-commerce village. The data may be subject to artificial statistical bias and need to be cleaned. Observations of households without cultivated land were
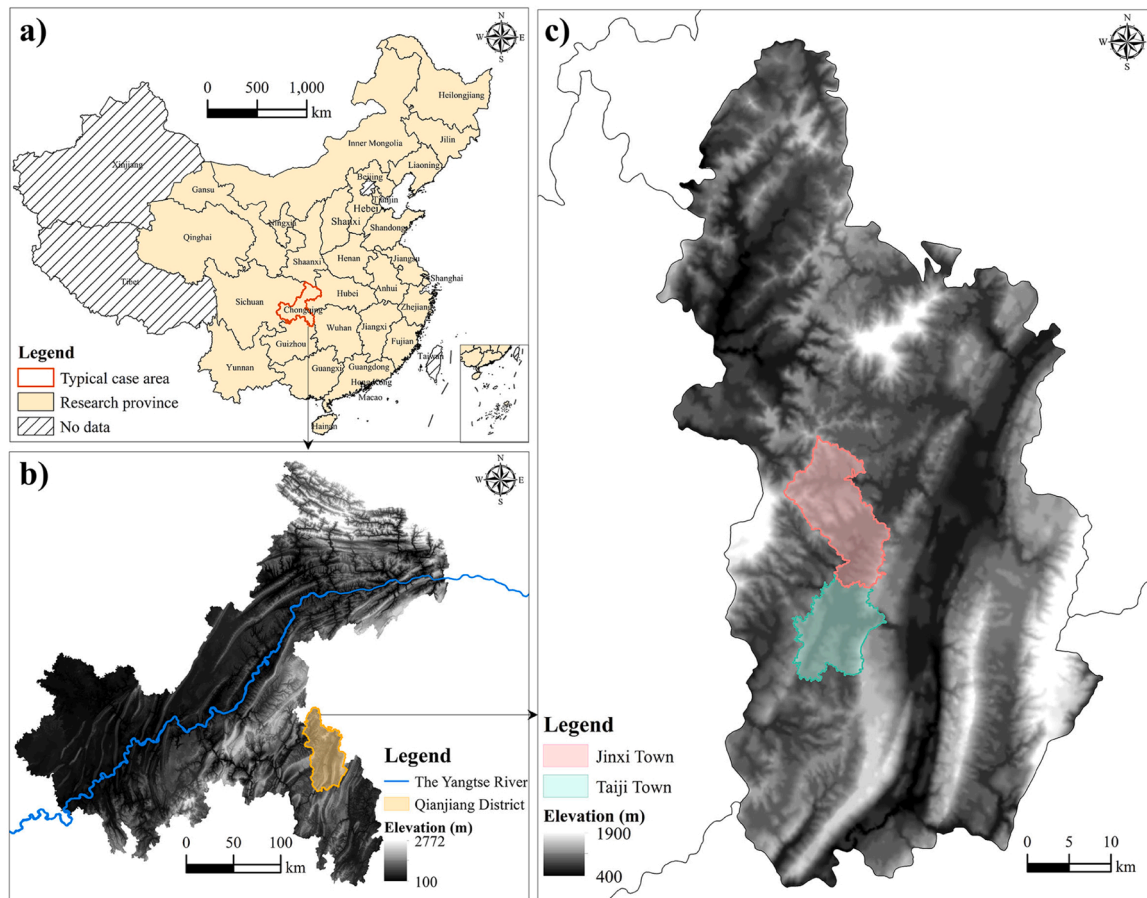
Fig. 2. Spatial distribution of the study areas.

excluded because they did not have information on the basic indicators required for the study. Observations for which the percentage of household agricultural fixed assets or non-agricultural fixed assets was greater than 1 were excluded, and observations without information on important indicators were also excluded. Finally, we obtained 10,450 valid observations of households, spread over 351 villages and distributed across 29 provinces throughout the country.

(2) Interview data of farm households in typical case areas. To intuitively understand the impact of e-commerce on farmland abandonment, we interviewed the subjects in typical e-commerce demonstration areas. The interview areas were chosen from Taiji town and Jinxi town in the Qianjiang district of Chongqing (Fig. 2b). In the heart of the Wuling Mountains, the Qianjiang district is a combination of old revolutionary areas, ethnic minority areas, remote mountainous areas and key poverty alleviation areas and is dominated by hilly and mountainous terrain, where crops such as rice, rape and citrus are grown and farmland abandonment is serious. In 2016, the Qianjiang district included a comprehensive rural e-commerce demonstration county, and both Taiji township and Jinxi township are highly representative of mature e-commerce development (Fig. 2c). The interviews were conducted in August 2021, and the main interviewees were village cadres and rural households. The interviews provided information on the development of e-commerce, demographic characteristics, farmland abandonment, geographical location, and socioeconomic development.

3.2. Methods

3.2.1. Logit model

In quantitatively evaluating the effect of e-commerce on farmland abandonment, the dependent variable, whether the farmer has abandoned his or her farmland, is a nonlinear, binary discrete variable that does not obey a normal distribution and does not satisfy the conditions for estimating a linear regression, so we need to build a binary choice model. The logit model is a binary discrete choice model that assumes that the random error term follows a logistic distribution (Poirier, 1994). This model can be used to model behavioural choices based on the principle of utility maximization. The qualitative variable Y_{vi} is introduced because there are two scenarios within this study: farmers abandon their farmland or farmers do not abandon their farmland. When a farmer abandons his or her farmland, $Y_{vi} = 1$; otherwise, $Y_{vi} = 0$. The logit model is constructed as follows:

$$p(Y_{vi} = 1 | X_{vi}, \beta_i) = \alpha_0 + \beta_1 E\_commerce_v + \beta_2 X1_{vi} + \beta_3 X2_{vi} + \beta_4 X3_{vi} + \varepsilon_{vi}$$

(1)

where Y_{vi} indicates whether the farmers in village v have abandoned their farmland. When farmers have abandoned their farmland, $Y_{vi} = 1$; otherwise, it is 0. $E\_commerce_v$ indicates whether village v is an e-commerce village; if e-commerce has been popularized, $E\_commerce_v = 1$; otherwise, it is 0. $X1_{vi}$, $X2_{vi}$ and $X3_{vi}$, which are a series of factors affecting the incidence of farmland abandonment. These factors include the characteristics of the head of household, of the family and of the village, ε_{vi} is the error term, while β_1, β_2 and β_3 are the parameters to be estimated.

3.2.2. Tobit model

When quantifying the effect of the popularization of e-commerce on the scale of farmland abandonment, the dependent variable is the area of abandoned farmland, which is nonnegative and left-censored at zero (Koc and Sahin, 2018). Therefore, model estimation bias can be effectively avoided by using the Tobit model for the regression analysis of this restricted dependent variable. The Tobit model is constructed as follows:

$$AF_{vi} = \delta_0 + \gamma_1 E\_commerce_v + \gamma_2 X1_{vi} + \gamma_3 X2_{vi} + \gamma_4 X3_{vi} + \theta_{vi} \qquad (2)$$

where AF_{vi} is the area of farmland abandoned by household i in village v, and $X1_{vi}$, $X2_{vi}$ and $X3_{vi}$ are a series of factors that affect the scale of farmland abandonment by farmers. They include the head of household, family and village characteristics. θ_{vi} is the error term; γ_1-γ_4 are the parameters to be estimated. Table 1 presents the definitions and basic statistical descriptions of the variables. The results show that 18 % of farmers have abandoned some farmland, with an average of 0.016 ha of farmland having been abandoned. Meanwhile, 36 % of the villages have popularized e-commerce, 17.91 % of the farmers have used e-commerce, and the average duration of e-commerce popularization is 2.58 years.

3.3. Endogeneity test

The selection of comprehensive e-commerce demonstration counties is strictly exogenous from the farmers' perspective, and it is not influenced by farmers' micro-behaviour. Therefore, it can be regarded as being as good as random. However, at the village level, the popularization of e-commerce may not be random, meaning that villages that are highly socioeconomically developed or that have experienced severe farmland abandonment may be more likely to be selected as pilot areas (Wang et al., 2018). Therefore, if there is such endogeneity in the econometric models described above, then the coefficient for the impact of the popularization of e-commerce on farmland abandonment is biased. It is very important to determine whether the popularity of e-commerce at the village level is affected by village-level factors. The model is set as follows:

$$E\_commerce_v = \alpha_v + \beta_v X_v + \varepsilon_v \qquad (3)$$

where $E\_commerce_v$ indicates whether e-commerce is popular in village v. If it is popular, then $E\_commerce_v = 1$; otherwise, $E\_commerce_v = 0$. X_v is a series of village characteristics, ε_v is an error term, and β_v is the parameter to be estimated. In this paper, logit and probit models are used to estimate the robustness of the results.

Table 2 presents the empirical results for the determinants of the village-level popularization of e-commerce. The results show that the estimation results from the logit and probit models are highly consistent, and show that the coefficients on all village-level factors are almost insignificant; that is, the village-level factors have no effect on the village-level popularization of e-commerce. We can safely say that whether e-commerce has been popularized in a village is not affected by the characteristics of the village, so the popularization of e-commerce can be regarded quasi-natural experiment at the village level; therefore, the endogeneity problem can be ignored.

4. Results

4.1. Spatial patterns of e-commerce popularization

Fig. 3 presents the provincial-level e-commerce popularization rate, calculated as the percentage of villages adopting e-commerce in the province, and the results show that the popularization rate of e-commerce reached 36 % at the national level. Although there is a great deal of variation among the provinces, spatial clustering is evident. The popularization rate of e-commerce is generally high in the eastern coastal areas of China, with the rates in Hebei, Shandong and Jiangsu exceeding 60 %. In contrast, the popularization rate is generally lower in

Table 1
Definitions and descriptive statistics of variables.

Variables	Definitions	Mean	S. D	N
Dependent variables				
Farmland abandonment	Has the farmer abandoned farmland; Yes= 1, no= 0	0.18	0.34	10,450
Area of abandoned farmland	Area of farmland abandoned by the family, ha	0.016	0.12	10,450
Key independent variables				
E-commerce popularization	Has the village popularized e-commerce? Yes= 1, no= 0	0.36	0.48	351
Rate of the popularization for e-commerce	Ratio of households in the village using e-commerce, %	17.91	22.12	351
Duration of e-commerce popularization	Duration of e-commerce popularization in the village, years	2.58	4.16	10,450
Household characteristics (N = 10450)				
Total farmland area	Total area of land farmed by the family, ha	0.54	1.14	10,450
Number of plots	Total number of family plots	5.12	5.78	10,450
Area of each plot	Area of each plot, ha	0.15	0.55	10,450
Total income of family	Total household income, yuan	52,000	75,000	10,450
Value of productive agricultural assets	Value of productive agricultural assets held by the family, yuan	651.21	8000	10,450
Value of agricultural machinery assets	Value of agricultural machinery assets held by the family, yuan	3839	86,000	10,450
Age of the householder	Age of the householder, years	56.53	12.66	10,450
Educational level of the householder	Illiterate= 1, primary school= 2, middle school= 3, high school= 4, junior college= 5, university= 6	2.61	1.16	10,450
Marital status of the householder	Unmarried= 1, married= 2, cohabitating= 3, separated= 4, divorced= 5	2.33	1.16	10,450
Village characteristics (N = 351)				
Rate of labour outmigration	Percentage of migrant workers in the total population, %	40.91	21.11	351
Rate of labour repatriation	Percentage of returning workers in the total population, %	7.12	44.21	351
Total farmland area in the village	Total farmland area in the village, ha	272	332.87	351
Total area of abandoned land of the village	Total area of abandoned farmland in the village, ha	9.65	22.11	351
Percentage of transferred farmland	Percentage of farmland that has been transferred, %	12.91	24.32	351
Rent per unit of farmland area	Level of rent per unit of farmland area in the village, yuan	514.56	384.24	351
Per capita disposable income	Per capita disposable income in the village, yuan	7370	3296	351

Table 1 (*continued*)

Variables	Definitions	Mean	S. D	N
Land confirmation	Has complete land confirmation in village; yes= 1, no= 0	0.44	0.50	351
Numbers of roads to the nearest county	Numbers of roads to the nearest county	2.30	0.65	351
Poverty alleviation county	Yes= 1, no= 0	0.12	0.32	351
Old-age care security system	Urban—rural old-age care security system; Yes= 1, no= 0	0.35	0.48	351
Has non-agricultural specialty industry	Yes= 1, no= 0	0.21	0.41	351
Value of non-agricultural industry output	Value of the output of non-agricultural industries, 10^4 yuan	17.00	1000	351

Table 2
Determinants of the popularization for e-commerce in a village.

Variables	Logit	Probit
Log (Rate of labour outmigration)	0.463	0.281
	(0.30)	(0.36)
Log (Rate of labour repatriation)	5.769	3.132
	(1.59)	(1.91)
Log (Rate of abandoned land of the village)	–0.118	–0.126
	(–0.16)	(–0.31)
Log (Percentage of transferred farmland)	–0.302	–0.158
	(–0.91)	(–0.92)
Log (Rent per unit of farmland area)	0.215*	0.119*
	(1.67)	(1.67)
Log (Total farmland area in the village)	0.105	0.074
	(0.54)	(0.71)
Log (Per capita disposable income)	0.464	0.248
	(1.64)	(1.63)
Log (Value of non-agricultural industry output)	0.053	0.028
	(1.14)	(1.15)
Numbers of roads to the nearest county	0.179	0.099
	(0.76)	(0.85)
Land confirmation	–0.244	–0.127
	(–0.33)	(–0.35)
Has non-agricultural specialty industry	–1.105	–0.573
	(–1.63)	(–1.65)
Poverty alleviation county	0.011	0.013
	(0.02)	(0.06)
Old-age care security system	–0.775	-0.409
	(–1.35)	(–1.48)
Constant	–4.226	39.69
	(–1.26)	(–1.34)
Regional dummies	Yes	Yes
Wald chi2	38.29	39.69
Pseudo R^2	0.121	0.121
Number of samples	351	351

Notes: * denotes coefficients significance at the 10 % level, T values are in parentheses. In this study, there are 126 and 225 villages with and without e-commerce popularization, respectively. Rent per unit of farmland area are deflated with price indices. All model simulations were performed using STATA.15.

central and western China, with the rates in Jiangxi, Hunan, Hubei, Shaanxi, Gansu and Qinghai less than 20 %.

4.2. Spatial patterns of farmland abandonment

Fig. 4 presents the rate of farmers who abandoned their farmland. Fig. 4a shows the rate of farmers who abandoned their farmland, and the overall rate across China is 18.19 %, with obvious spatial agglomeration characteristics. The rate is generally high in the south, with those in Guangdong and Chongqing even exceeding 20 %, while the rate is generally low in the north, with those in Henan, Shandong, Hebei, Jiangsu, Liaoning, Inner Mongolia and Gansu being less than 10 %. Fig. 4b shows the rate of abandoned farmland area and the overall rate across China is 9.54 %, and this rate exhibits clear spatial clustering characteristics, with generally higher rates in central and western China, including Chongqing, Hubei and Gansu, where the rate exceeds 10 %, and lower rates (less than 5 %) in the eastern coast, in the northeast and in the southeast.

Comparing Figs. 3 and 4 reveals a notable inverse correlation between e-commerce and farmland abandonment. The provinces with higher e-commerce popularization rates have lower rates of farmers who abandoned farmland and abandoned farmland area, forming a negative correlation. Statistical analysis confirms this association (Fig. 5), reinforcing the negative correlation between e-commerce and farmland abandonment. Based on these findings, this paper hypothesizes that e-commerce may mitigate farmland abandonment, and we will verify this causal relationship by employing econometric models.

4.3. Effect of e-commerce popularization on farmland abandonment

Table 3 presents the empirical results for the effect of e-commerce on farmland abandonment by farmers. Model 1 incorporates e-commerce and the householder-, household- and village-level characteristics, and Model 2 incorporates regional dummy variables into Model 1 to increase the robustness of the results. The coefficient on village-level e-commerce popularization is significant at the 1 % level with a coefficient of –0.386 and a marginal effect of –0.041, indicating that when e-commerce is promoted within a village, the percentage of farmers who abandon their farmland decreases by 4.1 %. Similarly, Model 3 incorporated the popularization rate of e-commerce in the village and the householder-, household- and village-level characteristics, while Model 4 incorporated regional dummy variables into Model 3, giving more robust results. The coefficient on the popularization rate of e-commerce in the village was significantly negative at the 5 % level, with a coefficient of –0.779 and a marginal effect of –0.078, meaning that when the popularization rate of e-commerce in a village increases by one percentage point, the percentage of farmers who abandon their farmland decreased by 7.8 %. The e-commerce popularization significantly reduces the probability of farmers abandoning farmland; that is, when e-commerce is popularized in a village, the probability of farmers abandoning their farmland decreases by 4.1 %, and when the popularization rate of e-commerce in a village increases by one percentage point, the probability of farmers abandoning their farmland decreases by 7.8 %.

Table 4 presents the results for the effect of e-commerce on the abandoned farmland area based on the Tobit model. Model 5 and Model 7 are baseline regressions that do not incorporate regional dummy variables, while Model 6 and Model 8 provide robust estimation results. Model 6 shows that the coefficient on village-level e-commerce popularization is –0.178, and this is significantly negative at the 5 % level, meaning that when e-commerce is popularized in a village, the area of farmland abandoned by farmers decreases by 17.8 %. The coefficient on the popularization rate of e-commerce in the village is –0.387, and this is significantly negative at the 5 % level, indicating that when the popularization rate of e-commerce in a village increases by one percentage point, the area of farmland abandoned by farmers decreases by 38.7 %. The results for the other control variables are generally consistent with the results in Table 3 and are not repeated here due to space constraints.

5. Heterogeneity and mechanism

5.1. Heterogeneity of e-commerce affecting farmland abandonment

There are differences in the timing of the implementation of e-commerce in different regions, and the underlying theory implies that
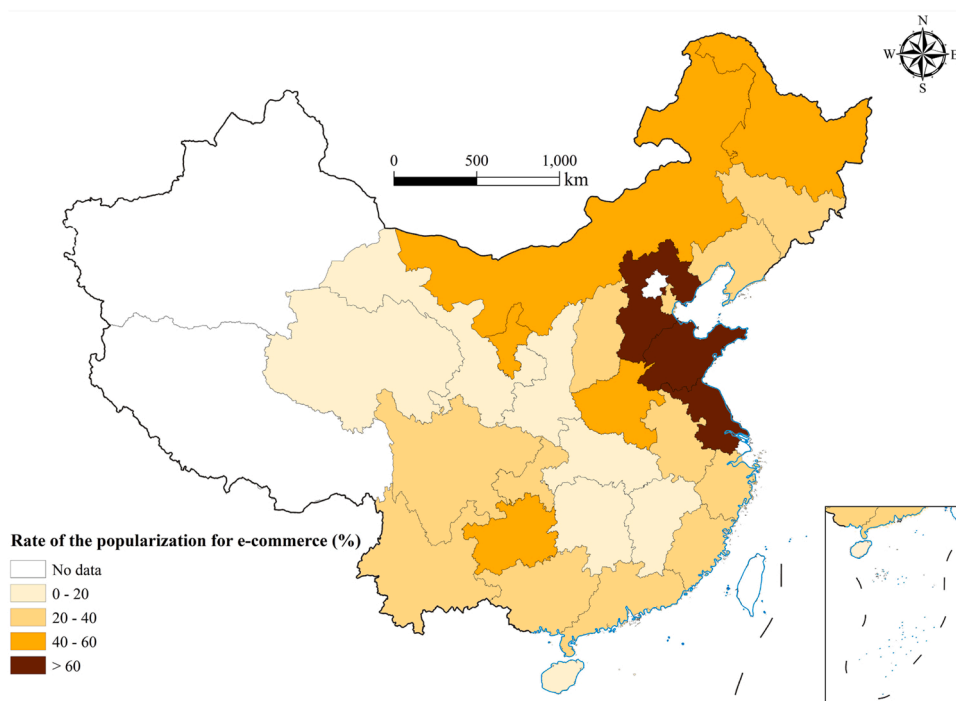
Fig. 3. Spatial patterns in rate of the popularization for e-commerce at the provincial level.
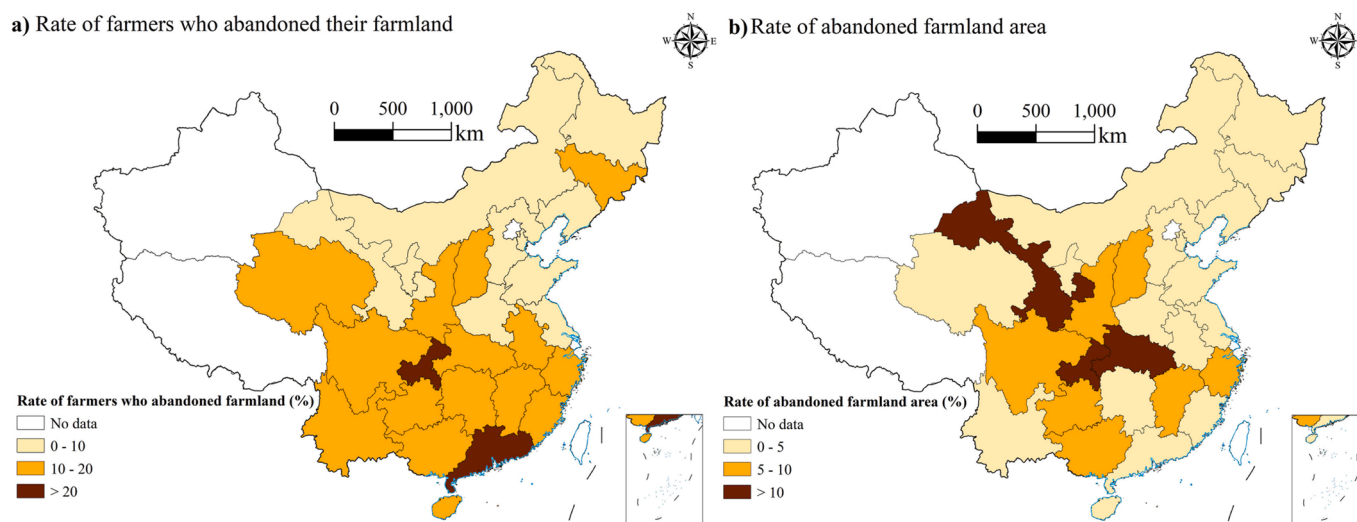

Fig. 4. Spatial patterns in farmland abandonment at the provincial level.

the impact of e-commerce popularization on farmland abandonment by farmers will vary with the duration of the popularization. Therefore, the sample is divided into two groups according to the duration of e-commerce popularization, that is, less than 5 years and at least 5 years, and a heterogeneity analysis is conducted. Table 5 presents the effect of e-commerce on farmland abandonment by farmers under different popularization durations. The probability and size of farmers abandoning their farmland decrease by 2.5 % and 13.9 % when e-commerce has been popularized in the village for less than 5 years, while the probability and size of farmers abandoning their farmland decrease by 5.6 % and 19.7 % when e-commerce has been popularized for more than 5 years. Table 6 indicates that the probability and size of farmland abandonment decrease by 4.2 % and 32 % for each one percentage point increase in the popularity of e-commerce in the village when e-commerce has been popularized for less than 5 years, while both decrease by

11.2 % and 41.4 % accordingly when the popularization of e-commerce has occurred for more than 5 years. It can be said that the longer the duration of e-commerce popularization, the more e-commerce helps reduce farmland abandonment.

5.2. Mechanism of e-commerce reducing farmland abandonment

To validate the theoretical framework presented in Fig. 1, we conducted an in-depth analysis using comprehensive farm household survey data to explore the underlying mechanisms through which e-commerce influences farmland abandonment. We meticulously considered facets encompassing the rural labour market, the land transfer market and industrial development, and this approach will enable us to draw more general conclusions regarding the impact of e-commerce on rural areas. Table 7 presents the effect of e-commerce on rural labour migration.
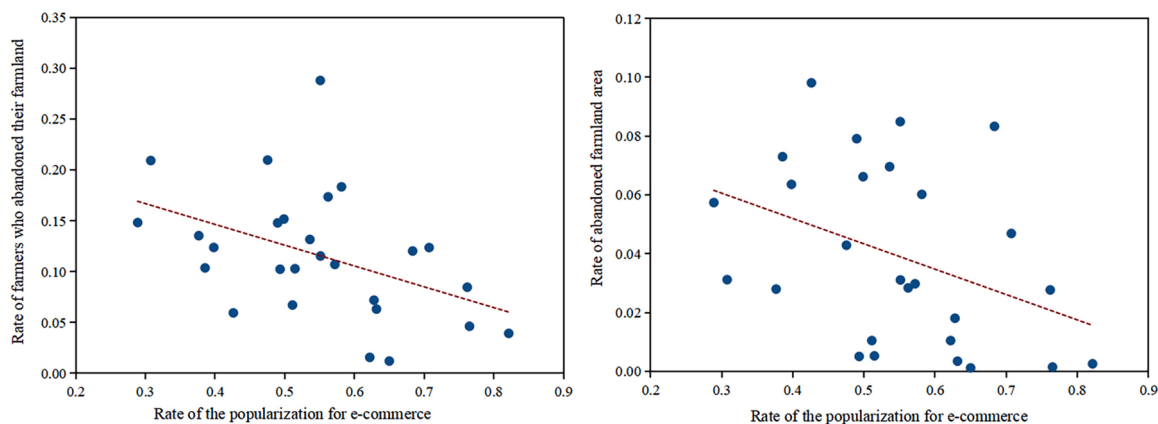
Fig. 5. Relationship between the rate of the popularization for e-commerce and the rate of farmland abandonment at the provincial level.

Model 9 and 10 show that the popularity of e-commerce significantly reduces the probability of rural workers migrating out. Models 11 and 12 show that increases in the e-commerce popularization rate can significantly increase the probability of workers returning to the village. In other words, the e-commerce popularization reduces the attractiveness of cities and increases the attractiveness of rural areas. According to the National Bureau of Statistics, the number of migrant workers across the country was 285.6 million in 2020, a decrease of 1.8 % compared to the same period during the previous year; i.e., more than 5 million people returned to the countryside from cities. The number of rural labourers returning to the countryside is expected to increase in the future, driven by the construction of digital rural villages and the comprehensive revitalization of agriculture. Table 8 show that the e-commerce popularization can significantly improve the rate of land transfer and stimulate the rural land rental market. Similarly, a different study found that the development of rural land transfer markets can significantly reduce the abandonment of farmland in mountainous areas (Shao et al., 2015), and this is consistent with the empirical analysis of this paper. Table 9 show that e-commerce increases the value added of non-agricultural industries in villages.

Combining the above analysis, we found that e-commerce development has fostered the growth of rural industries, created local job opportunities, and provided a platform for entrepreneurial endeavours among farmers (Fig. 6). Consequently, it has encouraged farmers working in urban areas to return to their rural roots and has helped retain the existing labour force within villages. This abundance of rural labour has reduced the amount of abandoned farmland caused by labour shortages. Concurrently, the industrialization of agriculture has further driven the expansion and mechanization of agricultural production, and then, stimulating the land transfer market and revitalizing abandoned farmland.

5.3. Typical case on e-commerce reducing farmland abandonment

To corroborate the conclusions obtained from the econometric model analysis, we chose Qianjiang District in Chongqing as a typical case study area for further field research. Qianjiang District was designated as a comprehensive demonstration county for rural e-commerce in 2016. Previously, there was a serious problem of farmland abandonment in the area, with more than 70 % of the farmers in Taiji Town and Jinxi Town in the district abandoning their farmland, and the area of farmland abandoned amounted to 200 ha. The case area vigorously developed mulberry sericulture industry and promoted the integration of e-commerce and industry, creating a set of mulberries, sericulture, silk reeling, silk weaving in one of the whole industry chains of silk. The agricultural industry shifted from a single farming to diversified agricultural industry. A total of 6267 ha of mulberry gardens was established, covering 24 towns and streets, the whole industrial chain of perennial

employment of more than 15,000 people. The development of rural industries in the villages has provided more job opportunities and entrepreneurial prospects for the local residents, attracting rural labour back to the countryside. Farmers' income has become diversified. Besides earning wages from working in rural enterprises, farmers also lease out their land, generating rental income. In Qianjiang District, 10,156 households participate in land transfer, with an area of about 4666 ha, and each household generates an annual income of up to 1536 yuan from land transfer. Therefore, the per capita annual income of farmers increased from 4000 yuan in 2015 to 14000 yuan in 2021. In addition, the government has transformed abandoned land into suitable areas for sericulture, gradually revitalizing the abandoned land. Currently, more than 200 ha of abandoned land has been reclaimed for cultivation. Table 10 specifically presents the development of e-commerce in the case area, the characteristics of farmland abandonment, the solutions to farmland abandonment and the effects of their implementation.

6. Discussions

6.1. Challenges of e-commerce development in rural areas

In recent years, e-commerce and agricultural development have continued to integrate in rural China, evolving from the initial networking of sales to digitization of transportation and production, enhancing the precision of the agricultural supply chain. In addition, e-commerce serves as a channel connecting small-scale farmers to broader markets, facilitating a seamless link between production and marketing, and it plays a leading role in the overall promotion of digital rural development. Thus, e-commerce has now become an important means for developing countries to extend digital benefits to rural areas and the agricultural sector. However, the development of e-commerce in rural China is still in its infancy and faces a variety challenges, in particular, the logistics and distribution system are obviously lagging behind, and cold storage and preservation technology is backward. In rural areas, the main participants in e-commerce are local farmers who lack basic online marketing skills and knowledge. Meanwhile, the development of e-commerce lacks a strong branding strategy, and there is a serious homogenization of e-commerce among villages, which weakens the attractiveness of agricultural products. As a result, e-commerce in rural China has not yet formed a substantial and large-scale branding influence, and its effect on the transformation of rural land use and spatial restructuring is still not yet fully realized.

6.2. Potential for e-commerce reducing farmland abandonment

E-commerce promotes the spatial reconfiguration of factors such as labour, land, capital and technology in rural areas, which has a positive impact on alleviating the problem of farmland abandonment. According

Table 3

Effect of e-commerce popularization on farmers' abandonment decisions.

Variables	Model 1	Model 2	Model 3	Model 4
E-commerce popularization	−0.381** [−0.039] (−2.28)	−0.386** [−0.041] (−2.23)		
Rate of the popularization for e-commerce			−0.870*** [−0.087] (−2.73)	−0.779** [−0.078] (−2.29)
Area of each plot	−0.102*** (−6.09)	−0.024* (−1.69)	−0.100*** (−6.00)	−0.024* (−1.69)
Log (Total income of family)	0.003 (0.17)	−0.009 (−0.50)	0.003 (0.21)	−0.008 (−0.45)
Log (Value of productive agricultural assets)	−0.020 (−1.25)	−0.022 (−1.06)	−0.023 (−1.38)	−0.023 (−1.08)
Log (Value of agricultural machinery assets)	−0.109*** (−10.31)	−0.124*** (−9.12)	−0.109*** (−10.36)	−0.124*** (−9.14)
Age of the householder	−0.087*** (−6.17)	−0.090*** (−3.68)	−0.087*** (−6.15)	−0.090*** (−3.68)
Age of the householder^2	0.001*** (6.62)	0.001*** (4.25)	0.001*** (6.60)	0.001 (4.24)
Log (Rate of labour outmigration)	1.723*** (6.12)	0.993*** (3.26)	1.591*** (5.57)	0.882*** (2.87)
Log (Percentage of transferred farmland)	−0.771*** (−3.94)	−0.676*** (−3.32)	−0.755*** (−3.88)	−0.662*** (−3.31)
Log (Rent per unit of farmland area)	−0.162*** (−4.81)	−0.171*** (−4.71)	−0.148*** (−4.34)	−0.159*** (−4.36)
Land confirmation	0.004 (0.03)	−0.039 (−0.30)	−0.072 (−0.72)	−0.127 (−1.15)
Regional dummies	No	Yes	No	Yes
Constant	1.537*** (3.04)	0.856 (1.25)	1.432*** (2.82)	0.764 (1.11)
LR chi2	449.08	485.97	451.65	486.46
Pseudo R²	0.0548	0.0946	0.055	0.095
AUC	0.679	0.783	0.681	0.782
Numbers of samples	10,232	6719	10,232	6719

Note: T values are in parentheses. ***, **, and * indicate significance at the 1 %, 5 %, and 10 % levels, respectively, and the marginal effects are reported in brackets. In Models 1–4, variables such as the marital status and education level of the head, the number of plots held by the family, the number of roads to the nearest district and county, and the specialty industries within the village were included. The magnitudes and significance of the coefficients on the variables in the model did not change significantly, so the estimates for the above variables were not included in the table for simplicity. These notes also apply to the tables below.

to a nationally representative sample survey, more than 20 % of Chinese farmers abandoned their farmland in 2020, resulting in 1/10 of the cultivated land being abandoned, with an area of abandonment of about 1.34×10^7 ha (Wang et al., 2023). Unfortunately, this trend of abandonment continues to escalate. Our studies indicate that the popularization of e-commerce in rural areas will reduce the number of farm households who abandoned their farmland by 4.1 % and the area of abandoned land by 17.5 %. It can be assumed that if e-commerce is popularized, the size of farm households who abandoned their farmland will decrease to 16.69 %, and the area of abandoned farmland will decrease by 2.35×10^6 ha. According to the national grain yield of 5621 kg/ha and the per capita grain consumption of 400 kg, the size of abandoned farmland reduced by the popularization of e-commerce can produce 1.32×10^7 tons of grain, which is enough to maintain the annual consumption of 3.3×10^7 people.

Table 4

Effect of e-commerce popularization on the abandoned farmland area.

Variables	Model 5	Model 6	Model 7	Model 8
E-commerce popularization	−0.152* [−0.152] (−1.85)	−0.178** [−0.178] (−2.23)		
Rate of the popularization for e-commerce			−0.247* [−0.247] (−1.67)	−0.387** [−0.387] (−2.43)
Area of each plot	0.007*** (3.24)	0.017*** (4.93)	0.007*** (3.25)	0.017*** (4.92)
Log (Total income of family)	−0.003 (−0.28)	−0.007 (−0.61)	−0.002 (−0.27)	−0.007 (−0.59)
Log (Value of productive agricultural assets)	0.015 (1.54)	0.010 (0.85)	0.014 (1.46)	0.010 (0.83)
Log (Value of agricultural machinery assets)	−0.008 (−1.47)	−0.009 (−1.40)	−0.008 (−1.51)	−0.009 (−1.45)
Age of the householder	−0.017* (−1.67)	−0.011 (−0.82)	−0.017* (−1.67)	−0.011 (−0.83)
Age of the householder^2	0.0002** (2.13)	0.0002 (1.36)	0.0002** (2.13)	0.0002 (1.37)
Log (Rate of labour outmigration)	0.436** (2.53)	0.348* (1.84)	0.385** (2.20)	0.278 (1.45)
Log (Percentage of transferred farmland)	−0.080* (−1.67)	−0.101** (−2.02)	−0.083* (−1.74)	−0.102** (−2.04)
Log (Rent per unit of farmland area)	−0.067*** (−2.77)	−0.059** (−2.28)	−0.062** (−2.53)	−0.052** (−1.99)
Land confirmation	0.036 (0.51)	−0.007 (−0.10)	−0.015 (−0.27)	−0.056 (−0.89)
Regional dummies	No	Yes	No	Yes
Constant	0.948*** (2.74)	0.730* (1.68)	0.923*** (2.66)	0.684 (1.51)
LR chi2	0.0056	0.0189	0.0055	0.0191
Numbers of samples	10,232	6766	10,232	6766

Note: T values are in parentheses. ***, **, and * indicate significance at the 1 %, 5 %, and 10 % levels, respectively.

Table 5

Effect of e-commerce on farmland abandonment under different durations.

Variables	Farmland abandonment (yes=1, no=0)		Area of abandoned farmland	
	Time<5 years	Time>=5 years	Time<5 years	Time>=5 years
E-commerce popularization	−0.236* [−0.025] (−1.74)	−0.338** [−0.056] (−2.12)	−0.139* [−0.139] (−1.76)	−0.197* [−0.197] (−1.92)
Other variables	Yes	Yes	Yes	Yes
Regional dummies	Yes	Yes	Yes	Yes
Constant	1.967*** (3.34)	0.964* (1.70)	1.039** (2.42)	0.821* (1.91)
Pseudo R²	0.0461	0.0479	0.0049	0.0043
Numbers of samples	8669	8007	8669	8007

Notes: T values are in parentheses. ***, **, * indicate significance at the 1 %, 5 %, and 10 % levels, respectively. Both the control variables and the regional dummy variables are included in the model, but the results for the control variables are not presented in the table due to space limitations.

Table 6

Effect of e-commerce popularization rate on land abandonment under different durations.

Variables	Farmland abandonment (yes=1, no=0)			Area of abandoned farmland	
	Time< 5 years	Time> =5 years		Time< 5 years	Time> =5 years
Rate of the popularization for e-commerce	−0.404***[−0.042]	-0.676*[−0.112]		−0.320*[−0.320]	−0.414*[−0.414]
	(−2.70)	(−1.75)		(−1.73)	(−1.67)
Other variables	Yes	Yes		Yes	Yes
Regional dummies	Yes	Yes		Yes	Yes
Constant	1.039**	0.821*		0.886**	0.535*
	(2.42)	(1.91)		(2.32)	(1.78)
Pseudo R^2	0.0049	0.0043		0.0203	0.024
Numbers of samples	8669	8007		5203	4541

Notes: T values are in parentheses. ***, **, * indicate significance at the 1 %, 5 %, and 10 % levels, respectively.

Table 7

Effect of e-commerce on rural labour migration.

Variables	Rate of labour force outmigration		Rate of labour force repatriation	
	Model 9	Model 10	Model 11	Model 12
E-commerce popularization	−0.001		0.024***	
	(−0.10)		(3.64)	
Rate of the popularization for e-commerce		−0.133***		0.159***
		(−13.41)		(12.86)
Other variables	Yes	Yes	Yes	Yes
Regional dummies	Yes	Yes	Yes	Yes
Constant	0.278	0.289	0.289	0.278
Adj R^2	0.226	0.257	0.342	0.364
Number of samples	4395	4395	4378	4378

Notes: T values are in parentheses. ***, **, * indicate significance at the 1 %, 5 %, and 10 % levels, respectively.

Table 8

Effect of e-commerce on the rural land transfer.

Variables	Model 13	Model 14
E-commerce popularization	0.057***	
	(3.11)	
Rate of the popularization for e-commerce		0.092**
		(2.38)
Other variables	Yes	Yes
Regional dummies	Yes	Yes
Constant	−0.284***	−0.287***
	(−2.80)	(−2.83)
Adj R^2	0.125	0.124
Number of samples	6766	6766

Notes: T values are in parentheses. ***, **, * indicate significance at the 1 %, 5 %, and 10 % levels, respectively.

Table 9

Effect of e-commerce on rural industry development.

Variables	Has non-agricultural specialty industry		Value of non-agricultural industry output	
	Model 15	Model 16	Model 17	Model 18
E-commerce popularization	1.230***		2.388***	
	(12.62)		(11.28)	
Rate of the popularization for e-commerce		3.094***		7.435***
		(15.52)		(16.73)
Other variables	Yes	Yes	Yes	Yes
Regional dummies	Yes	Yes	Yes	Yes
Constant	−4.087***	−4.244***	−1.221	−1.175
	(−6.67)	(−6.85)	(−1.02)	(−0.99)
Pseudo R2/Adj R2	0.294	0.304	0.262	0.278
Number of samples	6819	6819	6948	6948

Notes: T values are in parentheses. ***, **, * indicate significance at the 1 %, 5 %, and 10 % levels, respectively.

farmland abandonment.

To ensure the sustainable development of rural e-commerce, the government should implement a comprehensive array of strategic measures. These include enhancing the logistics and distribution system, investing in cold chain infrastructure to preserve and safeguard original products, and prioritizing the encouragement of agricultural production and supply centers. An integral facet involves incentivizing tech-savvy young talents to return to their rural roots, with the government offering comprehensive training programs designed to equip farmers with essential digital skills and nurture a skilled rural digital workforce. It is paramount to capitalize on the distinctive attributes of locally sourced products, thereby fostering the creation of premium agricultural brands. Concurrently, there is an imperative to prioritize the development of digital infrastructure and improve rural network communication conditions. The utilization of cutting-edge technologies, including 5 G, cloud computing, the Internet of Things, and blockchain, will expedite the establishment of a robust digital network system. Finally, expediting the creation of an e-commerce ecosystem tailored to the specific needs of small-scale farmers and consistently innovating strategies to usher more farmers into the era of the digital economy should remain a focal point of these endeavours.

7. Conclusion and implications

E-commerce popularization and farmland abandonment exhibit a significant negative spatial relationship; that is, the percentage of farmers who abandon farmland and the rate of abandoned farmland area are relatively low in provinces with a high e-commerce popularization rate and vice versa. E-commerce can significantly reduce the probability and scale of farmers abandoning farmland. When e-commerce was popularized in villages, the probability and scale of farmland abandonment by farmers decreased by 4.1 % and 17.5 %, respectively, and when the popularization rate of e-commerce in villages increased by one percentage point, the probability and scale of farmland abandonment by farmers decreased by 7.8 % and 38.7 %, respectively. E-commerce has reconfigured the rural population, rural land and rural industry by absorbing returning labour, stimulating the land transfer market, and revitalizing rural industries, thus changing the ways that rural land is used and, to a certain extent, solving the problem of

CRediT authorship contribution statement

Wang Yahui: Writing – review & editing, Software, Funding acquisition, Data curation, Conceptualization. **Li Yuanqing:** Methodology, Investigation, Conceptualization. **Yang Aoxi:** Writing – original draft, Validation, Methodology, Data curation. **Yang Qingyuan:** Writing – review & editing, Validation, Funding acquisition.
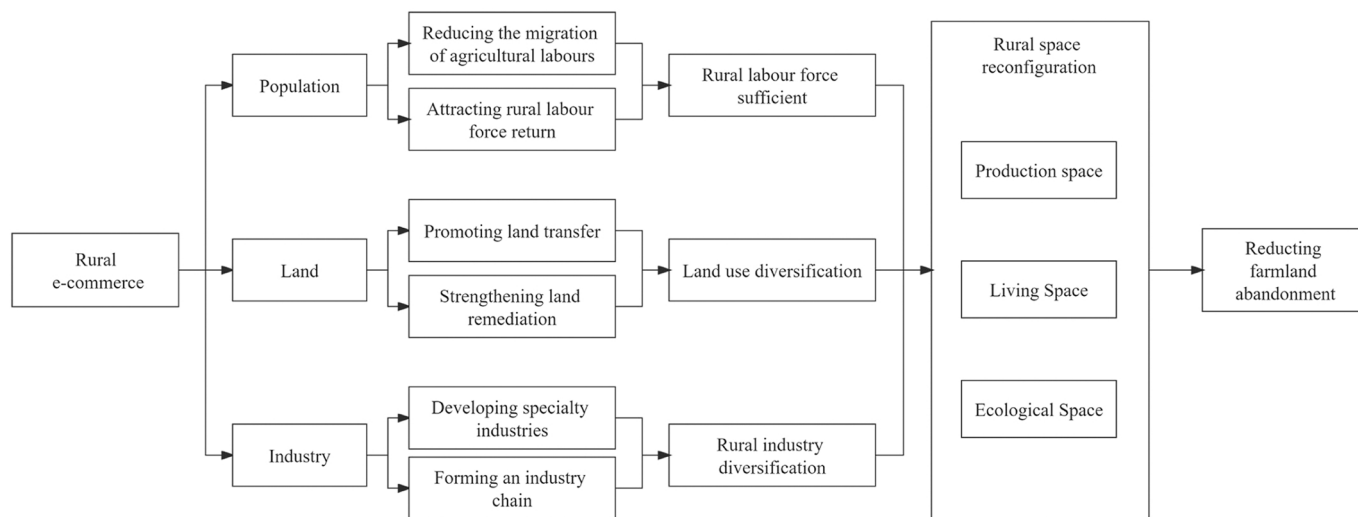
Fig. 6. Mechanism of e-commerce reducing farmland abandonment.

Table 10
Typical case on abandoned land management by e-commerce development.

Topics	Details
Development of e-commerce	The government is vigorously developing mountain-specific agriculture with special features, developing rural e-commerce, and promoting agricultural industries on a large scale
Problems	The case area is a deeply impoverished township, dominated by hilly and mountainous terrain, with poor soil that does not retain water or fertilizer well. With the increase in non-agricultural wages and large-scale rural worker migration, agricultural costs are high and returns are low due to the small and miscellaneous nature of farming and the dilapidated infrastructure, thus, a large amount of farmland has been abandoned.
Solutions	Relying on the comprehensive demonstration of e-commerce in rural areas, the village has built a model that combines the party branch, leading enterprises, cooperatives, and farmers, in which the farmers' land is invested in by cooperatives, and the farmers can work for the cooperatives. Since 2016, the government has gradually converted the abandoned land into sericulture land. To improve infrastructure, farmers have taken advantage of the high survival rate of mulberry trees and the ability of their root systems to block rock crevices and maintain soil and water, gradually revitalizing the abandoned land and enabling the development of three agriculture industries: mulberries, mushrooms, and chicken.
Effectiveness	Since 2016, dozens of agricultural cooperatives have been established, with nearly 400 ha of land discounted into shares, forming a model of scale, digitalization and maximization of benefits in the sericulture industry. The villagers' income has shifted from a single source, labour or traditional farming, to multiple sources through labour and dividends, with annual per capita income rising from 4,000 yuan in 2015–14,000 yuan in 2021. Currently, more than 200 ha of abandoned land has been reclaimed for farmland.

Declaration of Competing Interest

None.

Data Availability

The authors do not have permission to share data.

References

Aker, J., Ksoll, C., 2016. Can mobile phones improve agricultural outcomes? Evidence from a randomized experiment in Niger. Food Policy 60, 44–51. https://doi.org/10.1016/j.foodpol.2015.03.006.

Ali Research Institute, 2022. Digital Business to Promote Agriculture: High-quality Development of Agricultural Products e-Commerce from Ali's Platform. Ali Research Institute,, Beijing.

Baumann, M., Kuemmerle, T., Elbakidze, M., Ozdogan, M., Radeloff, V., Keuler, N., Prishchepov, A., Kruhlov, I., Hostert, P., 2011. Patterns and drivers of post-socialist farmland abandonment in Western Ukraine. Land Use Policy 28 (3), 552–562. https://doi.org/10.1016/j.landusepol.2010.11.003.

Christian, L., Max, S., Alexander, V., Prishchepov, Stephan, E., Tobias, K., 2018. Spatial variation in determinants of agricultural land abandonment in Europe. Sci. Total Environ. 644, 95–111. https://doi.org/10.1016/j.scitotenv.2018.06.326.

Council of State, 2015. Guidance on Accelerating the Development of Rural E-Commerce. from http://www.gov.cn/zhengce/content/2015–11/09/content_10279.htm.

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. https://doi.org/10.1016/j.landusepol.2019.104243.

Donaldson, D.A., 2022. Digital from farm to fork: infrastructures of quality and control in food supply chains. J. Rural Stud. 91, 228–235. https://doi.org/10.1016/j.jrurstud.2021.10.004.

Estel, S., Kuemmerle, T., Alcántara, C., Levers, C., Prishchepov, A., Hostert, P., 2015. Mapping farmland abandonment and recultivation across Europe using MODIS NDVI time series. Remote Sens. Environ. 163, 312–325. https://doi.org/10.1016/j.rse.2015.03.028.

Goyal, A., 2010. Information, direct access to farmers, and rural market performance in central India. Am. Econ. J. -Appl. Econ. 2 (3), 22–45. https://doi.org/10.1257/app.2.3.22.

He, Y., Xie, H., Peng, C., 2020. Analyzing the behavioural mechanism of farmland abandonment in the hilly mountainous areas in China from the perspective of farming household diversity. Land Use Policy 99, 104826. https://doi.org/10.1016/j.landusepol.2020.104826.

Hou, D., Meng, F., Prishchepov, A.V., 2021. How is urbanization shaping agricultural land-use? Unraveling the nexus between farmland abandonment and urbanization in China. Landsc. Urban Plan. 214, 104170 https://doi.org/10.1016/j.landurbplan.2021.104170.

Hua, X., Yan, J., Li, H., He, W., Li, X., 2016. Wildlife damage and cultivated land abandonment: findings from the mountainous areas of Chongqing, China. Crop Prot. 84, 141–149. https://doi.org/10.1016/j.cropro.2016.03.005.

Huang, L., Huang, Y., Huang, R.Y., Xie, G.J., Cai, W.W., 2022. Factors influencing returning migrants' entrepreneurship intentions for rural E-commerce: an empirical investigation in China. Sustainability 14 (6), 3682. https://doi.org/10.3390/su14063682.

Huang, L.J., Xie, G.J., Huang, R.Y., Li, Gg.K., Cai, W.W., Apostolidis, C., 2021. Electronic commerce for sustainable rural development: exploring the factors influencing BoPs' entrepreneurial intention, 10604-10604 Sustainability 13 (19). https://doi.org/10.3390/su131910604.

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. https://doi.org/10.1016/j.landusepol.2016.06.020.

Jing, W., Jie, T., 2021. Research on the influence of E-commerce on the adjustment of rural industrial structure under the background of "internet plus" using intuitionistic fuzzy sets. J. Intell. Fuzzy Syst. 40 (4), 8207–8215. https://doi.org/10.3233/JIFS-189643.

Kaicker, N., Gupta, A., Gaiha, R., 2022. Covid-19 pandemic and food security in India: can authorities alleviate the disproportionate burden on the disadvantaged. J. Policy Model. 44 (5), 963–980. https://doi.org/10.1016/j.jpolmod.2022.08.001.

Koc, S., Sahin, M., 2018. Tobit model and an application. Ksu Tarim Ve Doga Dergisi-ksu. J. Agric. Nat. 21 (1), 73–80.

Kwak, J., Zhang, Y., Yu, J., 2019. Legitimacy building and e-commerce platform development in China: the experience of Alibaba. Technol. Forecast. Soc. Change 139, 115–124. https://doi.org/10.1016/j.techfore.2018.06.038.

Lechman, E., Popowska, M., 2022. Harnessing digital technologies for poverty reduction. Evidence for low-income and lower-middle income countries. Telecommun. Policy 46 (6), 102313. https://doi.org/10.1016/j.telpol.2022.102313.

Lee, J., Oh, Y.-G., Yoo, S.-H., Suh, K., 2021. Vulnerability assessment of rural aging community for abandoned farmlands in South Korea. Land Use Policy 108, 105544. https://doi.org/10.1016/j.landusepol.2021.105544.

Leng, X., 2022. Digital revolution and rural family income: evidence from China. J. Rural Stud. 94, 336–343. https://doi.org/10.1016/j.jrurstud.2022.07.004.

Leng, X.C., Tong, G.J., 2022. The digital economy empowers the sustainable development of china's agriculture-related industries, 10967-10967 Sustainability 14 (17). https://doi.org/10.3390/su141710967.

Li, G.Q., Qin, J.H., 2022. Income effect of rural E-commerce: empirical evidence from Taobao villages in China. J. Rural Stud. 96, 129–140. https://doi.org/10.1016/j.jrurstud.2022.10.019.

Li, X.K., Guo, H.D., Jin, S.Q., Ma, W.L., Zwng, Y.W., 2021b. Do farmers gain internet dividends from E-commerce adoption? Evidence from China. Food Policy 101, 102024. https://doi.org/10.1016/j.foodpol.2021.102024.

Li, Y., Ma, W., Jiang, G., Li, G., Zhou, D., 2021a. The degree of cultivated land abandonment and its influence on grain yield in main grain producing areas of China. J. Nat. Resour. 36 (6), 1439–1454.

Liang, X., Li, Y., Zhou, Y., 2020. Study on the abandonment of sloping farmland in Fengjie County, Three Gorges Reservoir Area, a mountainous area in China. Land Use Policy 97, 104760. https://doi.org/10.1016/j.landusepol.2020.104760.

Lin, G., Xie, X.R., LV, Z.Y., 2016. Taobao practices, everyday life and emerging hybrid rurality in contemporary China. J. Rural Stud. 47, 514–523.

Lin, Y.C., Yang, R., Yang, F., 2022. Developmental transformation and modern goverance framework of Taobao village towards rural revitalization. J. Nat. Sci. Hunan Norm. 45, 34–45.

Liu, M., Zhang, Q., Gao, S., Huang, J., 2020. The spatial aggregation of rural e-commerce in China: An empirical investigation into Taobao Villages. J. Rural Stud. 80, 403–417. https://doi.org/10.1016/j.jrurstud.2020.10.016.

Liu, M., Shi, P.F., Wang, J.X., Wang, H.M., Huang, J.K., 2022. Do farmers get a greater return from selling their agricultural products through e-commerce. Rev. Dev. Econ. 1–28. https://doi.org/10.1111/rode.12968.

Liu, Y., Zhou, Y., 2021. Reflections on China's food security and land use policy under rapid urbanization. Land Use Policy 109, 105699. https://doi.org/10.1016/j.landusepol.2021.105699.

Long, F.Y., Wang, C., 2018. Poverty alleviation through rural e-commerce mode of "One Village, One Product and One Shop": a case from Suqian, Jiangsu Province, 012031-012031 IOP Conf. Ser.: Earth Environ. Sci. 185. https://doi.org/10.1088/1755-1315/185/1/012031.

Long, H.L., Tu, S.S., 2018. Land use transition and rural vitalization. China Land. Science 32 (07), 1–6.

Löw, F., Fliemann, E., Abdullaev, I., Conrad, C., Lamers, J.P.A., 2015. Mapping abandoned agricultural land in Kyzyl-Orda, Kazakhstan using satellite remote sensing. Appl. Geogr. 62, 377–390. https://doi.org/10.1016/j.apgeog.2015.05.009.

Movahedi, R., Jawanmardi, S., Azadi, H., Goli, I., Viira, A.-H., Witlox, F., 2021. Why do farmers abandon agricultural lands? The case of Western Iran. Land Use Policy 108, 105588. https://doi.org/10.1016/j.landusepol.2021.105588.

Nanda, A., Xu, Y., Zhang, F., 2021. How would the COVID-19 pandemic reshape retail real estate and high streets through acceleration of E-commerce and digitalization. J. Urban Manag. 10 (2), 110–124. https://doi.org/10.1016/j.jum.2021.04.001.

Ndubuisi, G., Otioma, C., Tetteh, G.K., 2021. Digital infrastructure and employment in services: Evidence from Sub-Saharan African countries. Telecommun. Policy 45 (8), 102153. https://doi.org/10.1016/j.telpol.2021.102153.

Nguyen, T.T., Nguyen, T.-T., Grote, U., 2022. Internet use, natural resource extraction and poverty reduction in rural Thailand. Ecol. Econ. 196, 107417 https://doi.org/10.1016/j.ecolecon.2022.107417.

Parven, A., Pal, I., Witayangkurn, A., Pramanik, M., Nagai, M., Miyazaki, H., Wuthisakkaroon, C., 2022. Impacts of disaster and land-use change on food security and adaptation: evidence from the delta community in Bangladesh. Int. J. Disaster Risk Reduct. 78, 103119 https://doi.org/10.1016/j.ijdrr.2022.103119.

Peng, C., Ma, B., Zhang, C., 2021. Poverty alleviation through e-commerce: village involvement and demonstration policies in rural China. J. Integr. Agric. 20 (4), 998–1011. https://doi.org/10.1016/S2095-3119(20)63422-0.

Poirier, D., 1994. Jeffreys prior for Logit-models. J. Econ. 63 (2), 327–339. https://doi.org/10.1016/0304-4076(93)01556-2.

Quintas-Soriano, C., Buerkert, A., Plieninger, T., 2022. Effects of land abandonment on nature contributions to people and good quality of life components in the Mediterranean region: a review. Land Use Policy 116, 106053. https://doi.org/10.1016/j.landusepol.2022.106053.

Saâdaoui, F., Ben Jabeur, S., Goodell, J.W., 2022. Causality of geopolitical risk on food prices: considering the Russo–Ukrainian conflict. Financ. Res. Lett. 49, 103103 https://doi.org/10.1016/j.frl.2022.103103.

Shao, J.A., Zhang, S., Li, X., 2015. The role of rural farmland transfer in preventing farmland abandonment in the mountainous areas. Acta Geogr. Sin. 70 (4), 636–649.

Sieber, A., Uvarov, N.V., Baskin, L.M., Radeloff, V.C., Bateman, B.L., Pankov, A.B., Kuemmerle, T., 2015. Post-Soviet land-use change effects on large mammals' habitat in European Russia. Biol. Conserv. 191, 567–576. https://doi.org/10.1016/j.biocon.2015.07.041.

Tan, L., Chen, L., 2022. The driving mechanism and path analysis of the coupling development of rural special reconstruction and land use transformation. J. Nat. Resour. 37, 1829–1847.

Tang, W.C., Zhu, J., 2020. Informality and rural industry: rethinking the impacts of E-commerce on rural development in China. J. Rural Stud. 75, 20–29. https://doi.org/10.1016/j.jrurstud.2020.02.010.

Terres, J.-M., Scacchiafichi, L.N., Wania, A., Ambar, M., Anguiano, E., Buckwell, A., Coppola, A., Gocht, A., Källström, H.N., Pointereau, P., Strijker, D., Visek, L., Vranken, L., Zobena, A., 2015. Farmland abandonment in Europe: identification of drivers and indicators, and development of a composite indicator of risk. Land Use Policy 49, 20–34. https://doi.org/10.1016/j.landusepol.2015.06.009.

Ustaoglu, E., Collier, M.J., 2018. Farmland abandonment in Europe: an overview of drivers, consequences, and assessment of the sustainability implications. Sci. Total Environ. 26, 396–416. https://doi.org/10.1139/er-2018-0001.

Vinogradovs, I., Nikodemus, O., Elferts, D., Brūmelis, G., 2018. Assessment of site-specific drivers of farmland abandonment in mosaic-type landscapes: a case study in Vidzeme, Latvia. Agric., Ecosyst. Environ. 253, 113–121. https://doi.org/10.1016/j.agee.2017.10.016.

Wang, C.C., Miao, J.T., Phelps, N.A., Zhang, J., 2020b. E-commerce and the transformation of the rural: the Taobao village phenomenon in Zhejiang Province, China. J. Rural Stud. 81, 159–169. https://doi.org/10.1016/j.jrurstud.2020.10.017.

Wang, C., 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. https://doi.org/10.1016/j.jrurstud.2022.03.013.

Wang, X.M., Yi, F.M., 2023. The effect of rural e-commerce development on return migration intentions: evidence from the China migrants dynamic survey. Appl. Econ. Lett. https://doi.org/10.1080/13504851.2023.2211323.

Wang, Y., Li, X., Li, W., Tan, M., 2018. Land titling program and farmland rental market participation in China: evidence from pilot provinces. Land Use Policy 74, 281–290. https://doi.org/10.1016/j.landusepol.2017.07.030.

Wang, Y., Li, X., Xin, L., Tan, M., 2020a. Farmland marginalization and its drivers in mountainous areas of China. Sci. Total Environ. 719, 135132 https://doi.org/10.1016/j.scitotenv.2019.135132.

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 https://doi.org/10.1016/j.clepro.2023.137772.

Xu, D., Deng, X., Guo, S., Liu, S., 2019. Labour migration and farmland abandonment in rural China: empirical results and policy implications. J. Environ. Manag. 232, 738–750. https://doi.org/10.1016/j.jenvman.2018.11.136.

Yang, H., Lupi, F., Zhang, J., Liu, J., 2020. Hidden cost of conservation: a demonstration using losses from human-wildlife conflicts under a payments for ecosystem services program. Ecol. Econ. 169, 106462 https://doi.org/10.1016/j.ecolecon.2019.106462.

Yang, R., 2018. Spacial differentiation and mechanisms of typical rural areas in the suburbs of a meyropolis: a case study Beicun village, Baiyun City, Guangzhou. Acta Geogr. Sin. 74, 1622–1636.

Yang, R., 2022. Space reconstruction process and internal driving mechanisms of Taobao villages in metropolitan fringe areas: a case study of Lirendong village in Guangzhou, China. J. Geogr. Sci. 32, 2599–2623.

Yao, H., Zang, C., Zuo, X., Xian, Y., Lu, Y., Huang, Y., Li, X., 2022. Tradeoff analysis of the pork supply and food security under the influence of African swine fever and the COVID-19 outbreak in China. Geogr. Sustain. 3 (1), 32–43. https://doi.org/10.1016/j.geosus.2022.01.005.

Yin, Z.H., Choi, C.H., 2022. Does e-commerce narrow the urban-rural income gap? Evidence from Chinese provinces. Internet Res. 32, 1427–1452.

Zhang, Y., Long, H., Ma, L., Tu, S., Li, Y., Ge, D., 2022. Analysis of rural economic restructuring driven by e-commerce based on the space of flows: the case of Xiaying village in central China. J. Rural Stud. 93, 196–209. https://doi.org/10.1016/j.jrurstud.2018.12.001.

Zhang, Y.N., Long, H.L., Tu, S.S., Li, Y.R., Ma, L., Ge, D.Z., 2019. A multidimensional analysis of rural restructuring driven by E-commerce: a case of Xiaying Village in Central China. Sci. Geogr. Sin. 2019 (39), 947–956.

Zhong, X.M., Ferrand, C., 2022. Construction of agricultural products of e-commerce ecological network system under the background of "Internet Plus". Wirel. Commun. Mob. Comput. 2022. https://doi.org/10.1155/2022/8121193.

Zhu, X., Hu, R., Zhang, C., Shi, G., 2021. Does Internet use improve technical efficiency? Evidence from apple production in China. Technol. Forecast. Soc. Change 166, 120662. https://doi.org/10.1016/j.techfore.2021.120662.

Zou, B., Mishra, A.K., 2022. How internet use affects the farmland rental market: an empirical study from rural China. Comput. Electron. Agric. 198, 107075 https://doi.org/10.1016/j.compag.2022.107075.