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Study on the impact of industrial and commercial capital going to the countryside on non-grain production of cultivated land—based on the provincial panel data of China from 2013 to 2022

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Industrial and commercial capital going to the countryside can effectively alleviate the shortage of funds for agricultural and rural development, which is the key to promote the modernization of agriculture and rural areas. In order to explore the influence of industrial and commercial capital going to the countryside on the non-grain production of cultivated land, based on the panel data of 30 provinces (except Tibet) in China from 2013 to 2022, this paper systematically uses the two-way fixed effect model, the intermediary effect model and the threshold effect model to test the effect, mechanism and threshold effect of industrial and commercial capital going to the countryside on the non-grain production of cultivated land. The results show that: (1) Industrial and commercial capital going to the countryside can effectively restrain the non-grain production of cultivated land. (2) Industrial and commercial capital going to the countryside can restrain non-grain production of cultivated land by accelerating land circulation and improving the level of scientific and technological development. (3) There is a single threshold effect on the inhibition of industrial and commercial capital going to the countryside. When the level of industrial and commercial capital going to the countryside is higher than the threshold value (29.124), the inhibition on non-grain production of cultivated land is weakened. (4) The inhibitory effect of industrial and commercial capital going to the countryside is heterogeneous, which has a greater inhibitory effect on the non-grain production of cultivated land in central China, major grain producing areas, northern region and areas with low marketization. This study enriches the research on the influence of industrial and commercial capital going to the countryside on the production and use of cultivated land, and provides theoretical reference for guiding industrial and commercial capital to invest in agriculture and promoting the sustainable development of agriculture.

KEYWORDS

industrial and commercial capital going to the countryside, non-grain production of cultivated land, mediating effect, threshold effect, heterogeneity analysis

1 Introduction

With the development of world economy, the transformation of agricultural modernization has become the important task of national development. Capital is the key factor to promote the development of agricultural modernization (Rahmatullah and Kuroda, 2016), but the agricultural industry in most developing countries cannot meet the requirements of attracting capital by itself, and it needs the government to promote and introduce social capital such as industry and commerce (Xudoyberdiyevich, 2021). Whether capital investment in agriculture will promote the development of agricultural industry will have an impact on cultivated land security, and then affect national food security. In order to explore this problem, this paper chooses China as the research subject.

As a country with a large population in the world, China's cultivated land resources only account for 7% of the world's total, so it is a top priority to effectively protect cultivated land food production and ensure food security. Due to the urgent need to develop industry in the early days of the founding of the People's Republic of China, the labor force and property mainly flowed to the cities. The development of agriculture and rural areas lacks modern production factors, and agriculture is caught in the dilemma of productivity involution due to the lack of production factors. However, only relying on the accumulated capital of farmers themselves and the agricultural support of the government can not meet the capital demand of modern agricultural development. It is necessary to rely on external forces to introduce capital, technology and other elements. Traditional agriculture can no longer meet the needs of high-quality development of the times, and modern agriculture must be developed. In view of this, China government began to guide a large number of social capital into agriculture. Since 2013, the China Central Government has issued the No.1 Document of the Central Committee for many times to guide industrial and commercial capital to the countryside, promote rural revitalization and develop modern agriculture. Existing studies have shown that capital flowing into rural areas is the key to promote the transformation from resource agriculture to capital agriculture (Zhang and Ma, 2017) and realize agricultural modernization (Xu et al., 2021); Capital flows into rural areas, which promotes the modernization of agriculture and rural areas by integrating land and labor, optimizing resource allocation (Xie and Yu, 2022). However, capital is born with two sides, and there are many practical difficulties while promoting the development of agriculture and rural areas. For example, increasing income inequality in rural areas (Xie and Liang, 2023), manipulating rural resources (Shao et al., 2024), squeezing out grain land, leading to the non-grain production of cultivated land (Zhou and Zhou, 2022), and so on. The phenomenon of non-grain production of cultivated land has affected the grain security in China, and even seriously threatens China's social stability and economic security. Then, whether industrial and commercial capital going to the countryside will affect non-grain production of cultivated land, and how will it affect non-grain production of cultivated land? Studying this problem is of great significance for guiding capital to flow to rural areas and promoting agricultural modernization.

Scholars have not reached a consensus on the relationship between industrial and commercial capital going to the countryside and non-grain production of cultivated land, and there are two different views. One view is that industrial and commercial capital going to the countryside is not conducive to agricultural production, which will aggravate the non-grain production of cultivated land. As early as 2013, Ma Jiujie pointed out that the profit-seeking nature of industrial and commercial capital makes it very sensitive to changes in the market environment, which increases the uncertainty of agricultural management and will have an impact on grain production (Ma, 2013). In 2018, Ding Dong and Yang Yinsheng pointed out that the profit-seeking nature of capital and the low rate of return on grain cultivation have led to the transfer of a large amount of rural capital to non-agricultural and non-grain management, which is not conducive to grain production (Ding and Yang, 2018). Jiang Guanghui and Hu Hao believed that industrial and commercial capital leased agricultural land to rural areas, which promoted the outflow of agricultural land from farmers and affected grain production (Jiang and Hu, 2021). Subsequently, Zhou Hui and Zhou Xin also pointed out that industrial and commercial capital entering rural areas often joins industries with faster capital appreciation, which will occupy grain land and is not conducive to grain production (Zhou and Zhou, 2022). Another view is that the capital of the countryside capital has a positive role in promoting agricultural production and will inhibit non-grain production of cultivated land. Some scholars believe that it is an inevitable trend for industrial and commercial capital to enter agriculture, which can promote the modernization of traditional agriculture (Liu and Xiong, 2015) and solve the problems of insufficient agricultural investment and factor shortage. Capital going to the countryside helps to improve agricultural production efficiency and increase grain output by optimizing the allocation of agricultural production factors, such as promoting farmland circulation and mechanized substitution (Liu et al., 2018). Jiang Guanghui and Hu Hao's research also pointed out that industrial and commercial capital going to the countryside increased the input of mechanical factors, which was conducive to expanding grain production (Jiang and Hu, 2021).

To sum up, scholars have done some research on the contradiction and coordinated development between industrial and commercial capital going to the countryside and cultivated land non-grain production, but the discussion on whether industrial and commercial capital going to the countryside affects and how to affect cultivated land non-grain production needs to be supplemented and expanded.

The main contributions of this paper are summarized as follows:

From the perspective of research, this paper focuses on the research on the influence of industrial and commercial capital going to the countryside on non-grain production of cultivated land. Through theoretical analysis and empirical test, it is clear whether and how industrial and commercial capital going to the countryside affects non-grain production of cultivated land, which provides some reference for industrial and commercial capital going to the countryside to invest in agricultural production.

In terms of transmission mechanism, the intermediary role played by land circulation and scientific and technological development level in the influence of industrial and commercial capital going to the countryside on cultivated land non-grain production is summarized and analyzed, which enriches the path mechanism of industrial and commercial capital going to the countryside to participate in agricultural production.

In the research method, considering the reverse causal relationship between industrial and commercial capital going to the countryside and cultivated land non-grain production will cause endogenous

problems and lead to research errors. Therefore, this paper adopts the method of instrumental variables, and selects the development level of digital inclusive finance and agricultural carbon emission level as instrumental variables to alleviate this problem and ensure the accuracy of the research results.

2 Theoretical analysis and research hypothesis

The No. 1 Central Document of China in 2024 puts forward specific goals and requirements for consolidating the agricultural foundation and achieving comprehensive rural revitalization, and proposes to "improve the diversified investment mechanism for rural revitalization" and "encourage social capital to invest in agriculture and rural areas." Industrial and commercial capital going to the countryside has played an important role in improving grain production capacity. First, industrial and commercial capital going to the countryside can improve agricultural infrastructure, improve agricultural production conditions, and provide agricultural productive services (Tu, 2014), thereby improving grain production capacity (Xie and Liu, 2014) and land output rate. Second, industrial and commercial capital to the countryside can bring many advanced production factors such as high-quality talents, market information, new business ideas, and high-quality brands into agriculture, promote agricultural industrialization (Tu, 2014), promote high-quality agricultural development, and help improve grain production capacity. Third, industrial and commercial capital going to the countryside to participate in agricultural production activities, by providing capital subsidies as the starting point, encourage small-scale farmers to participate in technical training, increase their own investment, and improve the comprehensive quality of farmers, which is conducive to cultivating new professional farmers, thereby promoting agricultural production efficiency.

The enhancement of grain production capacity is conducive to promoting the extension of the agricultural industrial chain, promoting the integrated development of primary, secondary, and tertiary industries, and curbing non-grain production on cultivated land. On the one hand, the extension of the agricultural industrial chain can bring about economies of scale and increase agricultural value-added income, thereby attracting production factors into agriculture to promote grain production and curb non-grain production on cultivated land; On the other hand, the integration of the three industries can broaden farmers' income channels and promote the development of new agricultural formats, thereby increasing the demand for grain raw materials, promoting grain production and curbing non-grain production on cultivated land.

> Hypothesis 1: Industrial and commercial capital going to the countryside can improve grain production capacity and inhibit non-grain production of cultivated land.

The Investigation Report on Land Circulation of New Agricultural Management Entity Shows that the decentralized and small-scale land management model can not fully meet the needs of the big market and internationalization, and the speed and degree of land circulation are related to the process of realizing agricultural modernization in China. Industrial and commercial capital going to the countryside has played a positive role in promoting land circulation and promoting the scale and intensification of agricultural production: On the one hand, industrial and commercial capital going to the countryside makes farmers' land property gradually capitalized, which increases farmers' property income and reduces farmers' economic dependence on land (Li et al., 2022), and cultivated land is a scarce resource with large demand and high rent. The economic compensation given by capital has a high substitution effect on the income of operating agricultural land (Xu et al., 2002), which promotes land circulation. On the other hand, due to imperfect policies, most of the contracts signed between capital going to the countryside and farmers are short-term contracts, which can reduce the risk of farmers losing land. Industrial and commercial capital going to the countryside can gain the advantage of large-scale production with the support of the government (Zhao et al., 2021), which is not conducive to the agricultural operation of small farmers and forces farmers to transfer their land.

The increase of land circulation is conducive to promoting the large-scale operation of cultivated land, improving agricultural production efficiency, promoting industrial integration and increasing grain output. The land scale formed by large-scale land transfer will increase the planting area and proportion of grain crops (Yang, 2023). First of all, land transfer is conducive to expanding the scale of agricultural land management (Cai et al., 2008), improving the efficiency of agricultural land allocation, thereby improving agricultural production efficiency (Kawasaki, 2010), which is conducive to increasing grain production. Secondly, the land transfer can promote farmers' participation in industrial integration and development (Yan et al., 2018), which is conducive to agricultural industrial agglomeration and can stimulate the improvement of labor productivity, thus increasing grain production. Finally, land transfer can promote the mechanization and standardization of agricultural production. After land transfer, it is connected into pieces, and mechanized production can reduce costs, increase agricultural output, and improve grain production efficiency, which is beneficial to grain production.

> Hypothesis 2: Industrial and commercial capital going to the countryside can accelerate land circulation, improve agricultural production efficiency and inhibit non-grain production of cultivated land.

Industrial and commercial capital going to the countryside has promoted the gathering of science and technology in agricultural production activities and promoted the improvement of agricultural technology level. On the one hand, the introduction of advanced production equipment and advanced management concepts in the process of industrial and commercial capital going to the countryside can promote the development level of agricultural science and technology and the development of new agricultural formats such as smart agriculture and e-commerce platforms. On the other hand, the factor spillover effect caused by industrial and commercial capital flowing into rural areas has solved the problems of shortage of funds, lack of experience and lack of professional talents in the process of agricultural technology development, and promoted the development level of agricultural science and technology.

The improvement of scientific and technological development level is an important way to promote the modernization of agricultural production mode and reduce the risk of agricultural production. First of

all, industrial and commercial capital invested a lot of capital in agriculture for profit, and at the same time increased investment in agricultural science and technology, which promoted the development level of agricultural science and technology (Cao, 2017), promoted the modernization of agricultural production methods and improved the level of grain production. Secondly, the improvement of scientific development level, especially digital technology, can promote information flow, effectively reduce the transaction cost of agricultural production (Qin et al., 2021), reduce the information barriers, and improve the efficiency of resource allocation, thus promoting the intensification of agricultural industry and benefiting agricultural grain production. Finally, the improvement of scientific development level accelerates the mechanization and standardization of agricultural production, alleviates the labor shortage (Deng et al., 2023), reduces the risk brought by traditional planting industry that may miss the season, avoids manual operation errors, promotes agricultural output and agricultural production efficiency (Guo et al., 2024), which is beneficial to grain production and inhibits non-grain production of cultivated land.

> Hypothesis 3: Industrial and commercial capital going to the countryside can reduce the risk of agricultural production and inhibit the non-grain production of cultivated land by improving the level of scientific and technological development.

Due to the differences in agricultural production mode and the popularity of industrial and commercial capital going to the countryside in China, especially in economic development level, grain production capacity, geographical location and marketization degree, the impact of industrial and commercial capital going to the countryside on non-grain production of cultivated land may be heterogeneous in different regions. First of all, the difference of economic development level will lead to the difference of infrastructure and services in different regions, and then affect the level of industrial and commercial capital going to the countryside. In areas with high economic development, the original facilities and services are relatively perfect, so the impact of industrial and commercial capital going to the countryside should be small, on the contrary, it will have a greater impact on the non-grain production of cultivated land in areas with low economic development; Secondly, for regions with different grain production capacity, the main grain producing areas are important areas bearing the grain production in China, so the supervision of this area is strict, and the industrial and commercial capital going to the countryside has a great influence on the non-grain cultivation of cultivated land in the main grain producing areas; Thirdly, geographical location will determine the quality of cultivated land. There are many plains in the northern region, and industrial and commercial capital going to the countryside is conducive to greatly promoting the connection of cultivated land in the plain region, thus promoting large-scale production. Therefore, industrial and commercial capital going to the countryside has a greater impact on cultivated land in the northern region; finally, the level of marketization will affect the level of industrial and commercial capital going to the countryside. For areas with higher marketization level, the factors of production flow faster and the demand for capital is less, so industrial and commercial capital has less influence on it. On the contrary, areas with lower marketization level have greater demand for capital and industrial and commercial capital has greater influence on it.

> Hypothesis 4: The impact of industrial and commercial capital going to the countryside on non-grain production of cultivated land is heterogeneous in areas with different economic development levels, different grain production capacity, different geographical locations and different marketization levels.

The mechanism diagram of the influence of industrial and commercial capital going to the countryside on non-grain production of cultivated land is shown in Figure 1.

3 Materials and methods

3.1 Data sources

This study takes the panel data of 30 provinces (regions) in China (except Tibet) as the research object. Considering that the China

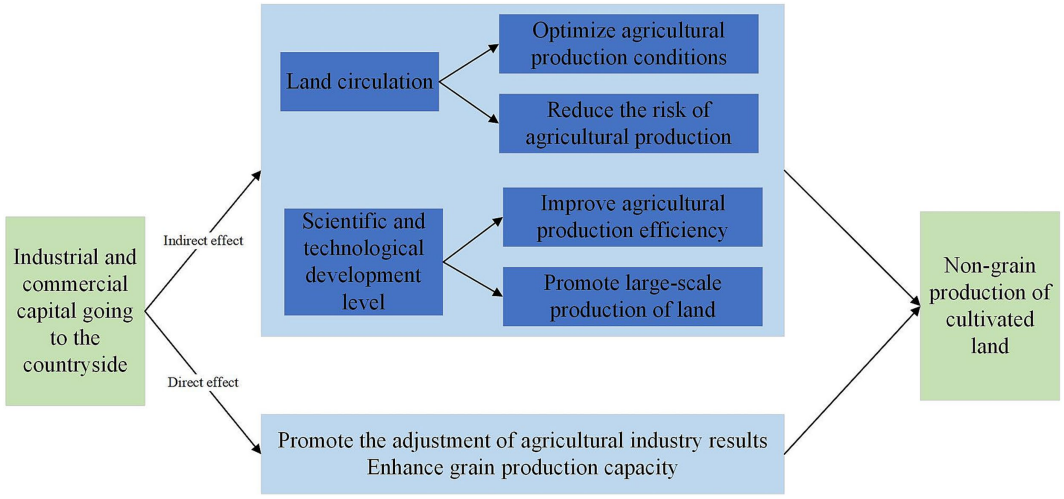

FIGURE 1
Mechanism diagram of industrial and commercial capital going to the countryside.

Central Government officially issued the policy document on industrial and commercial capital going to the countryside in 2013, this paper selects 2013–2022 as the sample interval, and constructs the provincial-level balanced panel data as the total sample. The source of the selected indicators is explained as follows: (1) The non-grain production level of cultivated land is measured by the proportion of grain planting area to the total crop planting area. The corresponding index data mainly comes from China Rural Statistical Yearbook. (2) The level of industrial and commercial capital going to the countryside is measured by the data of agricultural enterprises, which comes from the China Agricultural Research Database (CCAD) of Carter Enterprise Research of Zhejiang University. (3) The indicators of intermediate variables and control variables mainly come from China Statistical Yearbook, China Rural Statistical Yearbook and the website of National Bureau of Statistics. For individual missing data, this paper uses linear interpolation to fill in to ensure data integrity.

3.2 Variable selection

(1) Explanatory variable: The explanatory variable of this study is the non-grain production level of cultivated land. Non-grain production of cultivated land refers to the use of cultivated land to produce crops other than grain crops (except rice, wheat, potatoes, soybeans and corn). Referring to the research of Wang et al. (2023), this paper selects the non-grain planting structure to measure the non-grain production level of cultivated land, that is, the proportion of non-grain crop planting area to the total crop planting area is symbolized as Dec. The specific calculation formula is as follows:

$$R_A = \left(1 - \frac{N}{T}\right) * 100\% \quad (1)$$

In Equation 1, N represents the area of grain crops, T represents the total sown area of crops, and R_A represents the level of non-grain production of cultivated land.

(2) Key explanatory variable: The key explanatory variable of this paper is the industrial and commercial capital going to the countryside. Industrial and commercial capital going to the countryside in this paper refers to the participation of industrial and commercial capital outside the countryside in agricultural and rural production activities. According to the research of Huang et al. (2023) and Jia et al. (2024), this paper uses the number of agricultural-related enterprises to represent the level of industrial and commercial capital going to the countryside, symbolized as Cap. The main business income of large-scale agricultural processing enterprises is used as an alternative indicator of the key explanatory variable, with the symbol Proc.

(3) Mediating variables: The intermediate variables of this study are land circulation level and scientific and technological development level. Scientific and technological development is conducive to promoting the reform of agricultural production mode, land transfer can accelerate agricultural large-scale production, and both intermediary variables affect agricultural production. This study uses technology market transaction volume and land transfer area to represent scientific and technological development level and land transfer indicators, with symbols Tech and Tran, respectively.

(4) Control variables: Referring to the research of Gao and Du (2022), this study controlled the variables of rural characteristics, market characteristics, and government characteristics. The three rural characteristic variables include energy and power level (*Dies*), urbanization level (*Urba*), agricultural product price level (*Price*), farmers' income level (*Inco*), and farmers' education level (*Educ*). Market characteristic variable and government characteristic variable are replaced by economic development level (*Agdp*) and financial expenditure level (*Fina*) respectively. Descriptive statistics of each variable are shown in Table 1.

3.3 Model setting

(1) Benchmark regression model.

Referring to the research of Tang and Chen (2022), this paper uses a double fixed effect model to test the impact of industrial and

TABLE 1 Descriptive statistics.

Variables	Observations	Average value	Standard error	Minimum value	Maximum value
Dec	300	34.474	15.143	2.9246	64.4875
Cap	300	92.189	69.806	3.2810	445.2470
Dies	300	0.172	0.185	0.0192	1.0442
Inco	300	1.436	0.597	0.5108	3.5717
Educ	300	0.047	0.027	0.0138	0.1999
Agdp	300	6.256	3.105	2.1952	19.0206
Fina	300	0.260	0.110	0.1050	0.7534
Urba	300	61.387	11.385	37.8855	89.5344
Price	300	103.102	5.930	86.4000	123.300
Mtran	300	16.473	14.425	0.2711	68.9731
Tech	300	0.654	1.135	0.001	7.9475

commercial capital going to the countryside on non-grain production of cultivated land. The specific function model is shown in Equation 2.

$$Dec_{i,t} = \partial + \beta_1 Cap_{i,\ t} + \sum \varphi_i Control_{i,t} + \gamma_t + v_i + \varepsilon_{i,t} \quad (2)$$

In Equation 2, i and t represent region and year respectively, *Dec* represents the level of non-grain production of cultivated land, *Cap* represents the level of industrial and commercial capital going to the countryside, *Control* represents a combination of control variables, including energy and power level (*Dies*), farmers' income level (*Inco*), farmers' education level (*Educ*), economic development level (*Agdp*), fiscal expenditure level (*Fina*), urbanization level (*Urba*), and agricultural product price level (*Price*), r_t is the year fixed effect, v_i is the province fixed effect, and ε is the random error term.

(2) Mediating effect model

This paper refers to Wen and Ye's (2014) mediation effect theory and test method, constructs a mediation effect test model, conducts empirical tests on the two mediating variables of land transfer level and scientific and technological development level, and explores the transmission mechanism of industrial and commercial capital going to the countryside on non-grain production of cultivated land. The specific function model is shown in Equation 3.

$$\begin{cases} Dec_{i,t} = \partial_0 + \beta_1 Cap_{i,t} + \sum \eta_i Control_{i,t} + \gamma_t + v_i + \varepsilon_{i,t} \\ Mtran_{i,t} \ / \ Tech_{i,t} = w_0 + \mu_1 Cap_{i,t} + \sum \vartheta_i Control_{i,t} + \gamma_t + v_i + \varepsilon_{i,t} \\ Dec_{i,t} = \theta_0 + \lambda_1 Cap_{i,t} + \tau_2 Mtran_{i,t} \ / \ Tech_{i,t} + \sum \phi_i Control_{i,t} + \gamma_t + v_i + \varepsilon_{i,t} \end{cases} \quad (3)$$

In Equation 3, the coefficient β_1 represents the total impact of industrial and commercial capital going to the countryside on non-grain production of cultivated land; the coefficient μ_1 represents the impact of industrial and commercial capital going to the countryside on the level of land transfer/level of scientific and technological development; and λ_1 represents the direct impact of industrial and commercial capital going to the countryside on non-grain production of cultivated land after controlling the mediating variables of land transfer level/level of scientific and technological development.

(3) Threshold regression model

In order to further explore whether there is a threshold effect of the impact of industrial and commercial capital going to the countryside on non-grain production of cultivated land, this paper draws lessons from the research of Wang (2015) and constructs a threshold regression model of the impact of industrial and commercial capital going to the countryside on non-grain production of cultivated land. The specific function model is shown in Equation 4.

$$\begin{aligned} Dec_{i,t} = {} & \partial_3 + \sum \varphi_i Control_{i,t} + \beta_3 Cap_{i,t} I\left(q_{i,t} \le o\right) \\ & + \beta_4 Cap_{i,t} I\left(q_{i,t} > o\right) + \gamma_t + v_i + \varepsilon_{i,t} \end{aligned} \quad (4)$$

In Equation 4, *Dec* represents the non-grain production level of cultivated land, *Control* is the combination of control variables, *Cap* is the threshold variable of the level of industrial and commercial capital going to the countryside, o is the threshold value, I is indicator function, if $q_{i,t} \le o$ is true, the function value is 1, otherwise it is 0, and other variables have the same meaning as Equation 2.

4 Results

4.1 Benchmark regression results

First, based on the results of the LM test, F test, and Huasman test, it was preliminarily determined that the fixed effect model would be used for regression analysis. Secondly, after adding time fixed effects and individual fixed effects to the regression in turn, it was found that both the time fixed effects and individual fixed effects of the sample were significant, which determined that this paper used a double fixed effects model. Finally, the benchmark regression model was tested on the total sample, and the results are shown in Table 2.

From the columns (1) to (3) in Table 2, it can be seen that with more and more fixed effects, the estimation coefficient value of industrial and commercial capital going to the countryside is getting larger and larger, which shows that the non-grain production of cultivated land is greatly affected by time and region, so it is verified that it is more reasonable to use the double fixed model. After introducing fixed year effect and fixed province effect in turn, the estimation coefficient of industrial and commercial capital going to the countryside is always significantly negative at the level of 1%, indicating that industrial and commercial capital going to the countryside can significantly inhibit the non-grain production of cultivated land, and the research hypothesis 1 has been verified. Specifically, for every one percentage point increase in the level of

TABLE 2 Benchmark regression model test.

Variables	(1)	(2)	(3)
	Dec	*Dec*	*Dec*
Cap	−0.014***	−0.015***	−0.016***
	(0.00462)	(0.00479)	(0.00494)
Dies	8.817***	8.191***	7.116**
	(2.856)	(2.901)	(3.038)
Inco	−5.694***	−9.179***	−9.271***
	(1.424)	(2.081)	(2.647)
Educ	39.62***	36.75***	35.35***
	(12.36)	(12.93)	(12.88)
Agdp	1.380***	1.430***	1.406***
	(0.278)	(0.287)	(0.289)
Fina	9.682**	12.61**	12.96**
	(4.889)	(5.480)	(5.611)
Urba	0.250***	0.045	0.048
	(0.0615)	(0.109)	(0.156)
Price	0.019	−0.021	−0.022
	(0.0190)	(0.0284)	(0.0281)
Constant	12.13***	30.44***	35.39**
	(4.416)	(8.312)	(17.43)
Year		Yes	Yes
Province			Yes
Observations	300	300	300

*** means 1% significance level, ** means 5% significance level, * means 10% significance level.

industrial and commercial capital going to the countryside, the level of non-grain production of cultivated land will be reduced by about 1.6%. The reason may be that the factors of production brought by industrial and commercial capital going to the countryside can effectively improve the level of agricultural production, increase grain output and curb non-grain production of cultivated land. Accordingly, the relevant departments of China Central government should speed up the improvement of relevant policies on industrial and commercial capital going to the countryside, and actively encourage and guide social capital to go to the countryside in an orderly manner.

From the results in column (3) of Table 2, it can be seen that most of the control variables have a significant impact on the non-grain production of cultivated land. The specific results are as follows: the level of energy power has a positive impact on the non-grain production of cultivated land at the level of 5% significance, with a coefficient of 7.116, indicating that the improvement of energy power level makes the non-grain production level of cultivated land rise. The possible reason is that the development of electricity and energy makes it convenient to engage in agricultural activities, and farmers are more inclined to produce economic crops with high economic value, which leads to the decline of grain production and the increase of non-grain levels. Farmers' income level has a significant negative impact on non-grain production of cultivated land, with a coefficient of −9.271, indicating that the increase of farmers' income can significantly reduce non-grain production of cultivated land. The possible reason is that the opportunity of long-term investment in agricultural production increases with the increase of income, and improving agricultural production mode is conducive to increasing grain production and reducing the level of non-grain production in cultivated land. The education level of farmers has a significant positive impact on the non-grain production of cultivated land, with a coefficient of 35.35, indicating that the non-grain production level of cultivated land has also improved significantly with the improvement of farmers' education level. The possible reason is that with the development of society, farmers' educational level and cultural level have improved significantly, and their ability to accept new things has also improved significantly. High-quality farmers are more willing to develop in cities, thus changing their identity from farmers to citizens, resulting in a decrease in agricultural labor input, which is not conducive to grain production. The level of economic development has a significant positive impact on the non-grain production of cultivated land, with a coefficient of 1.406, indicating that the non-grain production level of cultivated land will increase with the development of social economy. The possible reason is that with the economic development, more and more farmers give up agricultural production with little economic benefit and engage in other industrial production activities; with the economic development, industrial expansion is increasing, rural land is occupied, agricultural production is threatened, and grain output is reduced. The level of fiscal expenditure has a positive impact on the non-grain production of cultivated land at a significant level of 5%, with a coefficient of 12.96, indicating that with the increase of fiscal expenditure, the non-grain production level of cultivated land will also increase. The possible reason is that with the increase of financial expenditure, the subsidies to agriculture will also increase, which leads to the phenomenon that some capital going to the countryside to rent farmland to obtain agricultural subsidies, which hinders normal agricultural production activities and is not conducive to grain production.

4.2 Endogeneity and robustness test

4.2.1 Endogeneity test

There may be two endogenous problems in the study of the influence of industrial and commercial capital going to the countryside on non-grain production of cultivated land. One is the problem of missing variables. Although the factors that affect industrial and commercial capital going to the countryside and non-grain production of cultivated land are included in the econometric model as much as possible, there are inevitably missing variables, which lead to the correlation between the missing variables and disturbance terms, thus generating endogenous problems. The second is the two-way causal problem. Industrial and commercial capital going to the countryside and non-grain production of cultivated land will interact with each other, resulting in a two-way causal problem. Based on this, in order to alleviate the possible endogenous problems, on the one hand, considering that the development level of digital inclusive finance (*Incl*) is closely related to industrial and commercial capital going to the countryside and non-grain production of cultivated land, the conditions that instrumental variables are related to endogenous explanatory variables and have nothing to do with random disturbance terms are met; On the other hand, agricultural carbon emissions (*Carb*) can reflect agricultural production activities from the side, which is related to industrial and commercial capital going to the countryside and has nothing to do with random disturbance. Therefore, the development level of digital inclusive finance and agricultural carbon emissions are selected as instrumental variables, and the two-stage least square method is used for regression analysis. The regression results are shown in Table 3.

According to the regression results in Table 3, the estimation coefficients of digital inclusive finance development level and agricultural carbon emissions in the first-stage regression results are significantly positive, and both of them have passed the test of unidentifiable and weak instrumental variables, which shows that the instrumental variables selected in this study are reasonable; The estimation coefficients of the level of industrial and commercial capital going to the countryside in the two-stage regression results are −0.138 and −0.303, respectively, which are significant at the level of 1%, indicating that the conclusion that industrial and commercial capital going to the countryside can significantly inhibit the non-grain production of cultivated land after dealing with endogenous problems through instrumental variables is still valid.

4.2.2 Robustness test

In order to ensure the reliability of the empirical results, this paper adopts the replacement of core explanatory variables and econometric models to test the robustness, and the results are shown in Table 4.

Referring to the research of Shao et al. (2024), this paper makes an empirical analysis by replacing the level of industrial and commercial capital going to the countryside with *Cap*, the main business income of large grain processing enterprises, and the results are shown in column (2) of Table 4. After replacing the core explanatory variables, the estimation coefficient of industrial and commercial capital going to the countryside is significantly negative,

TABLE 3 Endogenous test.

Variables	(1)		(2)	
	One-stage regression	Two-stage regression	One-stage regression	Two-stage regression
	Cap	*Dec*	*Cap*	*Dec*
Cap		−0.138***		−0.303***
		(−3.14)		(−2.88)
Incl	14.988***			
	(6.63)			
Carb			0.071***	
			(3.73)	
Control variable	Yes	Yes	Yes	Yes
Constant	237.226***	74.008***	200.622***	124.275***
	(4.33)	(3.60)	(3.19)	(3.19)
Unidentifiable test (LM statistics)	39.331***		13.706***	
Weak instrumental variable test (Cragg-Donald Wald F statistic)	43.907(16.380)		13.931(8.96)	
Observations	300	300	300	300
R^2		0.121		−0.760

*** means 1% significance level, ** means 5% significance level, * means 10% significance level.

TABLE 4 Robustness test.

	(1) Benchmark model	(2) Replace the core explanatory variables	(3) Unconditional panel quantile model	
			25%	95%
Variables	Explained variable: *Dec*			
Cap	−0.016***		−0.080**	−0.113***
	(0.00494)		(0.0375)	(0.0416)
Proc		−0.005***		
		(0.00164)		
Control variable	Yes	Yes	Yes	Yes
Constant	30.77***	36.51***	−14.02	−77.40
	(11.23)	(10.82)	(27.39)	(84.80)
Year	Yes	Yes	Yes	Yes
Province	Yes	Yes	Yes	Yes
Observations	300	300	300	300
R^2	0.388	0.383	0.914	0.776

*** means 1% significance level, ** means 5% significance level, * means 10% significance level.

which is consistent with the estimation coefficient of industrial and commercial capital going to the countryside in the benchmark regression model, indicating that industrial and commercial capital going to the countryside will significantly inhibit the non-grain production of cultivated land.

Quantile regression econometric model can estimate the regression coefficients of the explained variables under different quantiles, and it is not easily affected by extreme values, so the regression results have a robust advantage. Unconditional quantile regression does not depend on the choice of control variables, and the estimation results are more accurate. Because the data used in this study is provincial panel data, the year effect and provincial effect must be controlled, so this study uses the unconditional quantile fixed effect model proposed by Borgen (2016) to test the robustness, and the results are shown in column (3) and column (4) of Table 4. It can be seen that the estimation coefficients of industrial and commercial capital's level of going to the countryside are negative at 25 and 95%, and both of them have passed the significance test, which is consistent with the test results of the benchmark regression model, indicating that the research results are robust.

4.3 Analysis of intermediation effects

Based on the previous theoretical analysis and empirical test, it can be concluded that industrial and commercial capital going to the countryside will significantly inhibit the non-grain production of cultivated land, while land is the basic element of agricultural production, and science and technology is an important driving force to promote agricultural efficiency, so there may be a transmission mechanism of "industrial and commercial capital going to the countryside—land circulation/scientific and technological development level—non-grain production of cultivated land." Based on the test method of intermediary effect, this study conducted a step-by-step test on two intermediary variables, land circulation and the level of scientific and technological development, and the regression results are shown in Table 5.

From the columns (1) and (4) of Table 4, it can be seen that industrial and commercial capital going to the countryside has a significant negative impact on the non-grain production of cultivated land. On this basis, the intermediary effect between land circulation and the level of scientific and technological development is further tested. From columns (2) and (3) of Table 4, the regression coefficient of industrial and commercial capital going to the countryside to land circulation is positive and significant, which means that industrial and commercial capital going to the countryside will accelerate land circulation. After introducing the intermediary variable of land circulation, the estimation coefficient of industrial and commercial capital going to the countryside is not significant, so it can be judged that industrial and commercial capital going to the countryside has a complete intermediary effect on the non-grain production of cultivated land through land circulation, and has formed the "industrial and commercial capital going to the countryside-(promoting) land circulation-(reducing) non-grain production of cultivated land." From the columns (5) and (6) of Table 4, it can be seen that industrial and commercial capital going to the countryside can significantly improve the level of scientific and technological development. After the introduction of intermediary variable, the estimation coefficient of the impact of industrial and commercial capital going to the countryside on cultivated land non-grain production is still significantly negative at the level of 1%, indicating that the level of scientific and technological development plays a partial intermediary role in the process of industrial and commercial capital going to the countryside affecting cultivated land non-grain production, forming a negative transmission path of "industrial and commercial capital going to the countryside-(improving) the level of scientific and technological development-(reducing) cultivated land non-grain production," and the research hypothesis 3 has been verified. Referring to the research method of He et al. (2019), the Sobel method and Bootstrap method are used to further verify the two intermediate variables: land circulation and the level of scientific and technological development. The Sobel test requires strict sample data, and the Bootstrap method can overcome the shortcomings of stepwise regression method. From Table 4, the results of stepwise regression passed the Sobel test and Bootstrap test, which further verified the establishment of the transmission mechanism of land transfer and scientific and technological development level.

4.4 Threshold effect regression analysis

In order to further explore the relationship between industrial and commercial capital going to the countryside and non-grain production of cultivated land, this paper selects industrial and commercial capital going to the countryside as the threshold variable for research. Through Bootstrap self-help method, 1,000 samples were randomly selected for single-threshold and double-threshold tests. From the test

TABLE 5 Intermediary effect test.

Variables	Land circulation			Scientific and technological level		
	(1)	(2)	(3)	(4)	(5)	(6)
	Dec	*Mtran*	*Dec*	*Dec*	*Tech*	*Dec*
Cap	−0.016***	5.654***	−0.006	−0.016***	0.008***	−0.023***
	(0.00494)	(0.633)	(0.00554)	(0.00494)	(0.0009)	(0.0054)
Mtran			−0.002***			
			(0.000480)			
Tech						1.069***
						(0.3308)
Constant	30.77***	3,461**	36.75***	30.77***	−0.685	31.50***
	(11.23)	(1,437)	(11.10)	(11.23)	(2.095)	(11.028)
Sobel test (*p-value*)	0.0008(The land transfer mechanism is effective)			0.0026(The scientific and technological level mechanism is effective)		
Ind_eff test(p-val)	0.006 (Indirect effect established)			0.002 (Indirect effect established)		
Year	Yes			Yes		
Province	Yes			Yes		
Observations	300	300	300	300	300	300
R^2	0.388	0.635	0.418	0.388	0.750	0.412

*** means 1% significance level, ** means 5% significance level, * means 10% significance level.

TABLE 6 Threshold effect test.

Threshold variable	Threshold number	*F* value	*p* value	BS times	Critical value		
					1%	5%	10%
The level of capital going to the countryside	Single threshold	24.99*	0.077	1,000	38.819	28.360	23.207
	Double threshold	8.14	0.637	1,000	39.912	25.211	20.497

*** means 1% significance level, ** means 5% significance level, * means 10% significance level.

results in Table 6, it can be seen that the *F* value of the single-threshold capital going to the countryside index is 24.99, which is significant at the level of 10%, and it has passed the single-threshold test; Secondly, the double-threshold test shows that the F value of the index of industrial and commercial capital going to the countryside is 8.14, but it does not pass the significance test, indicating that there is no double threshold. Therefore, this study judges that there is a single threshold effect of industrial and commercial capital going to the countryside. Further, the estimated threshold values of industrial and commercial capital going to the countryside index is tested. As shown in Table 7, the threshold value of industrial and commercial capital going to the countryside index is 29.124.

Introducing industrial and commercial capital to the countryside as a threshold variable into the benchmark regression model, the results are shown in Table 8. When the level of industrial and commercial capital going to the countryside is lower than 29.124, the level of industrial and commercial capital going to the countryside has a negative impact on the non-grain production of cultivated land at a 1% significance level. Specifically, the level of industrial and commercial capital going to the countryside increases by 1, and the level of non-grain production of cultivated land decreases by 12.04%; When the level of industrial and commercial capital going to the countryside is higher than 29.124, the level of capital going to the countryside has a negative impact on the non-grain production of cultivated land at a significant level of 1%. Specifically, the level of industrial and commercial capital going to the countryside increases by 1 and level of non-grain production of cultivated land decreases by 1.4%. Therefore, with the improvement of the level of industrial and commercial capital going to the countryside, the inhibitory effect on non-grain production of cultivated land will be greatly reduced. Therefore, it is necessary to continuously strengthen the supervision and guidance of capital to prevent the profit-seeking nature of capital from adversely affecting grain production.

TABLE 7 Threshold estimates.

Threshold variables	Threshold estimate	95% Confidence interval
λ_1	29.124	[28.315, 30.075]

TABLE 8 Regression of threshold panel model.

Variables	*Dec*	Standard error	*T* value
Dies	6.356**	2.806	2.27
Inco	−5.378***	1.364	−3.94
Educ	36.767***	11.707	3.14
Agdp	1.084***	0.272	3.99
Fina	3.995	4.896	0.82
Urba	0.298***	0.060	4.95
Price	0.013	0.018	0.71
Cap≦29.124	−0.1204***	0.022	−5.38
Cap > 29.124	−0.014***	0.005	−3.12
Constant	13.569***	3.699	3.67
Observations	300		
R^2	0.413		

*** means 1% significance level, ** means 5% significance level, * means 10% significance level.

4.5 Further analysis results

Considering China's vast territory, different regions have different economic development levels due to differences in resource endowments and government system implementation. Therefore, the impact of industrial and commercial capital going to the countryside on non-grain production of cultivated land in regions with different economic development levels may be different. Therefore, according to the regional division standards of the National Bureau of Statistics, and referring to the research of Wang et al. (2022) and Ren and Cheng (2024), this study divides the total sample into three regions: eastern, central, and western. The impact of industrial and commercial capital going to the countryside on non-grain production of cultivated land in the eastern, central, and western regions is examined, respectively. The results are shown in column (1) of Table 9. The results show that the inhibitory effect of industrial and commercial capital going to the countryside on non-grain production of cultivated land in the central region is the strongest, followed by the western region, and finally the eastern region. The reason why the impact on the eastern region is small and the effect is not obvious may be that the eastern coastal region has a developed economy, complete infrastructure, high agricultural production level, and sufficient original capital, so the impact of industrial and commercial capital going to the countryside on agricultural production is small. The central and western regions are relatively remote in geographical location, relatively backward in economic development, and lack modern elements in agricultural development. The capital and technology brought by industrial and commercial capital going to the countryside will significantly affect agricultural production activities and help promote grain production. Therefore, the central and western regions show a significant inhibitory effect.

Considering the fragmentation of agricultural resources in China, the impact of industrial and commercial capital going to the countryside on non-grain production of cultivated land in areas with different grain production capabilities may be different. Based on the above analysis, referring to the research of Meng et al. (2024) and Zhang and Li (2024), the total sample was divided into main grain-producing areas and non-main grain-producing areas, and the impact of industrial and commercial capital going to the countryside in areas with different

TABLE 9 Heterogeneity test of economic development level and grain production capacity.

Variables	(1)			(2)	
	Dec				
	Eastern Region	Central Region	Western Region	Major grain-producing areas	Non-major grain-producing areas
Cap	−0.005	−0.033**	−0.020*	−0.019***	−0.016
	(0.00573)	(0.0129)	(0.0101)	(0.00601)	(0.0101)
Constant	71.72***	−49.24	−19.39	−0.763	22.23
	(14.95)	(42.10)	(15.16)	(18.17)	(14.50)
Control variable	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes	Yes
Province	Yes	Yes	Yes	Yes	Yes
Observations	130	60	110	130	170
R^2	0.599	0.538	0.719	0.247	0.608

*** means 1% significance level, ** means 5% significance level, * means 10% significance level.

TABLE 10 Heterogeneity test regression of geographical location and marketization environment.

Variables	(1)		(2)	
	Dec			
	Northern region	Southern region	Market-oriented high-level areas	Market-oriented low-level areas
Cap	−0.030***	−0.019**	0.005	−0.031***
	(0.00701)	(0.00810)	(0.00845)	(0.00808)
Constant	−54.89**	61.13***	40.14***	1.697
	(21.57)	(13.09)	(15.03)	(23.26)
Control variable	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes
Province	Yes	Yes	Yes	Yes
Observations	140	160	169	131
R^2	0.541	0.403	0.461	0.418

*** means 1% significance level, ** means 5% significance level, * means 10% significance level.

grain production capabilities on non-grain production of cultivated land was examined, and the results are shown in column (2) of Table 9. The results show that for the main grain-producing areas, the estimated coefficient of industrial and commercial capital going to the countryside is −0.019, which passes the significance test at the 1% level. For non-main grain-producing areas, the estimated coefficient is −0.0164, but does not pass the significance test. The main grain-producing areas bear most of China's grain production and transportation, and the government strictly supervises the capital going to the countryside in this area, so the industrial and commercial capital to the countryside can effectively improve the level of grain production. The level of agricultural production capacity in non-main grain-producing areas is relatively low. Capital tends to invest in areas with high profits, so it will have little impact on non-major grain-producing areas.

Considering that the northern and southern regions of China have a large span, and there are certain differences in living customs and concepts, which may have different effects on industrial and commercial capital going to the countryside and non-grain production of cultivated land, this study divides the total sample into northern and southern regions according to the traditional north–south dividing line (Qinling-Huaihe line) and with reference to Yang et al. (2024) and Jiang et al. (2024), and investigates the effects of industrial and commercial capital going to the countryside on non-grain production of cultivated land in different geographical locations. The results are shown in column (1) of Table 10. It can be seen that industrial and commercial capital going to the countryside has a significant inhibitory effect on the non-grain production of cultivated land in both northern and southern regions, but the inhibitory effect in the northern region is better. The possible reason is that the northern region has a superior geographical location and many plains, and industrial and commercial capital going to the countryside to facilitate agricultural production, with low cost, which is conducive to increasing grain production and has the strongest inhibitory effect on non-grain production of cultivated land.

Considering the different degree of marketization in different regions of China, it will affect the effect of industrial and commercial capital going to the countryside on the non-grain production of cultivated land. Based on the above analysis and referring to the research of Xing and Liu (2024) and Fan et al. (2011), the total sample

is divided into high-level areas and low-level areas, and the influence of industrial and commercial capital going to the countryside in different market-oriented areas on cultivated land non-grain production is investigated. The specific results are shown in column (2) of Table 10. The influence of available industrial and commercial capital to the countryside on cultivated land non-grain production in areas with high degree of marketization is not significant. The possible reason is that the high degree of marketization reflects the relatively good economic environment and the free flow of production factors, and the resource allocation in this area is more effective, and capital has little influence on it. Industrial and commercial capital going to the countryside has a significant inhibitory effect on non-grain production in areas with low marketization level. The possible reason is that the degree of marketization is low and the factors needed for agricultural production cannot be allocated in time. However, industrial and commercial capital going to the countryside can effectively alleviate the shortage of agricultural production funds, thus improving agricultural production level, benefiting grain production and restraining non-grain production of cultivated land.

Finally, the impact of industrial and commercial capital going to the countryside on non-grain production of cultivated land is significantly heterogeneous. Judging from the heterogeneity of economic development level, industrial and commercial capital going to the countryside has the strongest inhibitory effect on non-grain production of cultivated land in the central region, followed by the western region and finally the eastern region; Judging from the heterogeneity of grain production capacity, industrial and commercial capital going to the countryside has a significant impact on the non-grain production of cultivated land in the main grain producing areas, but has a poor effect on the non-grain producing areas. From the perspective of geographical heterogeneity, industrial and commercial capital going to the countryside has a significant inhibitory effect on the non-grain production of cultivated land in both northern and southern regions in China, but the inhibitory effect in the northern region is better; Judging from the heterogeneity of market-oriented environment, industrial and commercial capital going to the countryside has a significant inhibitory effect on non-grain production of cultivated land in low-level market-oriented areas, but has no significant impact on high-level market-oriented areas.

5 Conclusion and policy implications

5.1 Main conclusions

Ensuring the safety of cultivated land is the basis of realizing grain security, agricultural modernization is an important way to realize grain security, and grain security is a major event related to the national economy, people's livelihood and social security of all countries in the world. The development of modern agriculture needs a lot of capital investment, and the industrial and commercial capital going to the countryside is the key to the development of modern agriculture. In order to study the influence of industrial and commercial capital going to the countryside on cultivated land non-grain production, this paper takes the balanced panel data of 30 provinces in China (except Tibet) from 2013 to 2022 as the total sample, and analyzes the influence and mechanism of industrial and commercial capital going to the countryside on cultivated land non-grain production by using the two-way fixed effect model. The main conclusions are as follows:

First, industrial and commercial capital going to the countryside has a significant negative impact on non-grain production of cultivated land, which shows that industrial and commercial capital going to the countryside can effectively curb non-grain production of cultivated land. After controlling the endogenous problems, replacing the core explanatory variables and replacing the robustness test of the econometric model, this conclusion still holds.

Secondly, industrial and commercial capital going to the countryside to inhibit the non-grain production of cultivated land by promoting land circulation and improving the level of scientific and technological development, forming a path mechanism of "industrial and commercial capital going to the countryside-(promoting) land circulation/(improving) the level of scientific and technological development-(reducing) non-grain production of cultivated land"; The threshold test shows that when the level of industrial and commercial capital going to the countryside is higher than the threshold (29.124), the inhibitory effect on non-grain production of cultivated land will be significantly reduced.

5.2 Policy implications

This study puts forward the following policy suggestions to ensure grain security, implement farmland protection and encourage capital to go to the countryside: First, improve the policy of industrial and commercial capital going to the countryside, guide industrial and commercial capital to invest in the countryside through tax incentives, fund subsidies and other measures, and strengthen supervision to prevent non-grain production of cultivated land. Secondly, establish a linkage mechanism between the government and industrial and commercial capital, increase investment in agricultural infrastructure, and form an investment-driven effect. Thirdly, optimize agricultural insurance policies, reduce agricultural production risks and attract industrial and commercial capital investment. In addition, strengthen land circulation and technology promotion, improve agricultural production efficiency and promote industrial structure upgrading. Finally, considering regional differences, formulate differentiated policies and coordinate development in various regions, especially in the central and western regions and major grain-producing areas, so as to achieve balanced development of agricultural modernization throughout the country.

5.3 Research limitations and future research directions

Future research can be conducted in three different ways. First, micro-farmer survey data can be used for in-depth analysis. This study uses balanced panel data from 30 provinces (except Tibet) from 2013 to 2022, which may not be able to fully and thoroughly study the specific impact of industrial and commercial capital going to the countryside on non-grain production of cultivated land at the micro-farmer level. Secondly, the level of non-grain production of cultivated land can be measured from multiple aspects such as output structure, planting income, and planting scale. This study only uses planting structure to measure the level of non-grain production of cultivated

land, which cannot fully reflect the actual situation of non-grain production of cultivated land. Future research can consider combining indicators of these dimensions to obtain more accurate evaluation indicators of the level of non-grain production of cultivated land. Finally, long-term follow-up research can be conducted in the future to observe the long-term trend and impact of industrial and commercial capital going to the countryside on non-grain production of cultivated land, and provide more accurate reference for the formulation of relevant policy recommendations.

Data availability statement

Publicly available datasets were analyzed in this study. This data can be found at: https://www.stats.gov.cn/zs/tjwh/tjkw/tjzl/202302/t20230215_1907997.html.

Author contributions

HY: Investigation, Supervision, Writing – original draft, Writing – review & editing. FW: Data curation, Methodology, Software, Visualization, Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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