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Factors influencing the recessive morphology of farmland use under labor changes based on production input willingness and behavior of farmers

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Abstract: Land use transition occurs through changes in land use morphologies. The decision-making and land use behavior of farmers is the main factor that causes changes in the land use system and subsequent transitions of land use. This study focused on the recessive morphologies of farmland based on the investment in agricultural production inputs by farmers, and established an analytical framework based on induced technological innovation theory and farmers' behavior theory, which followed the pathway of "objective-willingness-behavior." Using survey data for farming households in two counties (Shouguang and Yiyuan) in Shandong province, the main factors influencing farmers' willingness to invest in agricultural production and their differences under the background of labor force changes were comprehensively analyzed with a binary logistic model and ordinary least squares (OLS) regression model. The aim was to provide decision-making guidance for promoting farmland use transition. There were three key results. (1) The scale management objectives of a farmer were limited, with 75% of farmers intending to maintain the current farmland management scale, and planning to retire at an advanced age, although there were regional differences in these phenomena. (2) Farmers' willingness to invest in agricultural production inputs was closely related to agricultural production objectives, farmland use, and agricultural production, whereas the labor structure had no significant effect. Farmers' behavior toward investment in agricultural production inputs was negatively related to their expected retirement age. Changes in the household labor structure were an important factor boosting farmers' investment in agricultural production inputs. (3) It is essential to better understand the cognitive level and structure of farmers, and the characteristics of the labor structure and type of agricultural development could be combined to improve the farmers' cognitive level and willing-

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ness to adopt scale management objectives and generate behavioral responses. Using the dual scale of “land + service” would overcome the structural obstacles faced by farmers, and effectively play the role of providing both policy incentives and regulation.

Keywords: land use transition; recessive morphologies; willingness and behavior; labor change; Shandong province

1 Introduction

Farmland use transition is an important factor in rural transformation and development, and is a critical process in achieving the strategic goal of rural revitalization. With the shock of the COVID-19 pandemic, employment pressure, and changes in the international trade situation, rural revitalization is urgently required to strengthen the income of farmland. However, farmland use is strongly affected by changes in rural labor factors. The mobility of rural production factors and the response of actors in the process of social and economic development brings about changes in the regional spatial structure and land use morphology, which in turn impact on the practice of rural revitalization.

Under this background, the effect of population changes on rural and social structure has become an important part of rural geography research. Labor, land, and capital are the three basic elements of agricultural production (Jansuwan and Zander, 2021), with labor being the most critical and active element (Liu *et al*., 2019). The distribution and use of land, as well as the input and distribution of agricultural capital are all dependent on labor resources. However, with the continuous advances in China’s urbanization process, the occupational differentiation of farmers has intensified, the agricultural working-age population has continued to decrease, and the labor supply has tended to be decline (Li and Sicular, 2013; Long *et al*., 2022). According to the China Statistical Yearbook 2020, from 2001 to 2019, the rural population decreased by 2.0% annually, and the number of employees in primary industry decreased by 3.2% annually. By 2030, 71% of the population is expected to live in urban areas, while the rural labor supply will shrink by 45% between 2010 and 2030. This widespread phenomenon of rural labor out-migration can alleviate livelihood vulnerability, but it will lead to a serious aging trend, an insufficient rural labor supply, and weakening of employee skills (Liang *et al*., 2022). This will inevitably lead to changes in agricultural production and farmland use transition. In recent years, the effect of rural labor structure changes on agricultural production and farmland use caused by non-agricultural employment, urbanization transfer, and aging have attracted increasing attention (Yan *et al*., 2016; Liu, 2018; Li and Li, 2019).

The farmer is the most basic spatial organization unit of economic activitiy in traditional agricultural zones. As the behavior subject and direct decision maker of agricultural production and land use, farming households are an endogenous force supporting rural transformation and rural revitalization. Their behavioral choices have a significant effect on land use transitions and agricultural production. Changes of family labor structure, such as the quantity, age structure, labor ability, and vocational skills, are profoundly changing the rural regional system and agricultural production system. Under the process of urbanization, rural labor is gradually transferred to urban secondary and tertiary industries, and the livelihood strategies of farmers are gradually differentiated, which results in a differentiation of farmland use behavior under different livelihood modes. The imbalance between the transformation of farmland use and labor in traditional agricultural zones is the key problem that restricts rural transformation. Previous studies from both macros-qualitative and micro-quantitative perspectives have shown that property rights, social security, resource endowments (You and Wu, 2010), agricultural production conditions and support policies, and natural disasters all have an effect on the willingness and behavior of agricultural investment. Investment in agricultural production inputs is an important factor in farmland use efficiency, and is also an important dimension of the recessive morphologies of farmland use (Long and Qu, 2018). Previous studies mainly considered the differences in farmers' production input behavior and the factors influencing such behavior. For example, there are differences in farmers' land input behaviors in different regions (e.g., urban suburbs, mountainous areas, and ecologically fragile areas), with the effects of natural disasters (e.g., flood and drought), and under different agricultural support and protection policies (Liu *et al*., 2004; Bryan *et al*., 2009; Song *et al*., 2019). However, there has been little research on farmers' production input willingness and behavior under the background of labor changes. Farmland use morphology from the perspective of rural labor structure is therefore poorly understood. Farmers' willingness to change their agricultural inputs is the result of a rational choice, made according to their own conditions. Farmers' willingness has a basic effect on regional investment in agricultural production inputs, but there is still a lack of systematic analysis of farmers' willingness and behavior as a relatively independent and interconnected entity. In a specific period, the regular pattern of labor development and its role also differs for regions with different land resource conditions, and between economically developed and underdeveloped regions, and therefore the farmland use behavior caused by the labor structure is different. What are the differences in farmers' willingness and behaviors toward investments in agricultural production inputs under the changes in the rural labor structure? What are the factors influencing farmers' willingness and behavior to invest in agricultural production inputs under the background of rural labor structure changes? Based on the survey data of farm households in typical counties in the Huang-Huai-Hai Plain, this paper takes the recessive morphology of farmers' production input as the breakthrough point. Then we construct an analytical framework with reference to the theory of induced technological innovation and the theory of farmers' behavior. We use a binary logistic model and the ordinary least squares (OLS) regression model to explore the factors influencing farmers' willingness to invest in agricultural production and behavior in different landform types. The outcomes will provide guidance for farmland use transition and the coordinated development of the relationship between humans and land. The aim of this study was to analyze the driving mechanism of land use recessive morphologies transition under changes in the labor structure, which will inspire future research and innovation of the research ideas in the field of land use transition, and can also enrich the existing theoretical achievements.

2 Theoretical framework

Land use transition refers to the change of land use morphology within a specific time range during the process of social and economic development, and includes both dominant and recessive morphologies. Dominant morphologies encompass quantity and spatial structural attributes, such as the quantity and spatial patterns of land use types. Recessive morphologies encompass attributes of land quality, property rights, management mode, inputs and outputs (Long *et al*., 2020; 2021). Land use in farming areas is an important factor in agricultural development and land use transition. Farmers, as the micro-behavioral subjects of agricultural production and farmland management, are endogenous forces supporting rural transformation, development, and revitalization. Their behavioral choices have a significant effect on land use transition and agricultural production. The decision-making behavior of farmers results in continuous adjustments to their behavior according to their own needs in a specific social and economic environment (Zang *et al*., 2019). It is a process in which farmers make rational choices in land use arrangements by weighing the cost, benefit, and risk of a specific action. The transition of farmland use at the micro-level is essentially the external manifestation of the farmland morphology under the decision-making behavior of farmers regarding farmland use. The dominant and recessive morphologies of farmland can be promoted by changing the inputs, outputs, management-scale, and planting structure of household farmland.

With the progress made with urbanization and industrialization, the rural farming opportunity costs have risen. Under the dual effects of the urban-pull and rural-push, many young rural laborers have migrated to cities (Taylor *et al*., 1999; Sheng *et al*., 2022). The continuous improvement of the household registration system and the mechanism for the urbanization of the agricultural transfer population has intensified the "scissors gap" between rural population returns and outflows. The selective outflow of many young and middle-aged rural laborers from the rural has led to changes the structure of farm households and decisions about farmland use. Rural labor migration has reduced the number of agricultural workers in rural areas (Gray, 2009; Qian *et al*., 2016; Podhisita, 2017; Caulfield *et al*., 2019). Simultaneously, the aging of the agricultural labor force has also reduced the quality of labor in terms of their health, work capacity, and human capital. As the smallest decision-making unit and the direct decision maker in agricultural production, farmers will adjust agricultural production objectives and land use decisions to adapt to the changes of family labor structure (Xie *et al*., 2017; Zhang *et al*., 2019). This has led to changes in farmland use morphology and promoted the transition of rural farmland use. The action logic of farmers' land use decisions follows the pathway of "objective-willingness-behavior response." According to the theory of planned behavior, as rational individuals, human behavior is a consciously induced action based on internal and external perception, which is directly affected by behavioral willingness. As the main subject of farmland decision-making, farmers' willingness to invest in farmland depends on the comparison between the income obtained and the existing input cost in the input process, which is a reflection of their perceived value. Willingness is the most direct factor affecting behavior (Ajzen, 1991; Matshe and Young, 2004; Salvago *et al*., 2019). The process by which farmers form implementation willingness is also a process in which they commit to actual behavior, which increases the internal cause in the implementation of behavior and assists with the actual implementation. In theory, the willingness intensity of farmers will be reflected in practical actions, i.e., the stronger the willingness of farmers to invest in agricultural production inputs, the higher the possibility of taking practical actions. Farmers' production input behavior is an interactive process of individual objectives, cognition, and behavior. In terms of individual characteristics, farmers will combine retirement age, scale management objectives, and cognition to generate the willingness to invest in agricultural production inputs. In the case of turning will into practice, the farmer will consider internal factors, such as labor quantity and quality, and agricultural production objectives, as well as external factors, such as farmland use and agricultural production, and will then decide whether to invest in agricultural production inputs under the interaction of multiple factors. In the implementation stage of a specific behavior, according to the induced agricultural technology innovation theory and rational economic man theory (Lin, 1991), farmers' agricultural production decisions follow the principle of utility maximization under specific cost constraints. The changes in agricultural labor structure will lead to changes in the relative price of labor factors, inducing substitutions among input factors, and then leading to a change in farmland morphology. Specifically, changes in labor resource endowment lead to changes in factor prices, and therefore farmers, as rational economic men, will inevitably try to replace scarce and expensive factors with abundant and cheap factors through technological innovation. There are two forms of this factor substitution: one is the replacement of traditional labor factors by mechanical devices representing technological progress (Jansuwan and Zander, 2021), and the other is the replacement of land by biotechnology, such as pesticides and fertilizers. Both have a labor substitution effect. In areas with different labor endowments, farmers have different pathways to achieve agricultural economic growth. In the plains, with abundant farmland resources and relatively abundant labor, traditional production factors are gradually replaced by modern agricultural production technologies. Labor-saving machinery is used for improving land productivity and agricultural labor productivity (Dedehouanou *et al*., 2018). In mountainous areas where farmland resources and labor are lacking, the terrain limits the development of agricultural machinery (Luo *et al*., 2019; Tang *et al*., 2021), resulting in a lower potential for mechanical technology to replace labor, but it also increases the input of biotechnology such as pesticides and fertilizers. From the perspective of the labor substitution effect, this study investigated the factors influencing investment in agricultural production inputs, under the background of labor changes in typical agricultural regions based on objective-willingness- behavior (Figure 1).

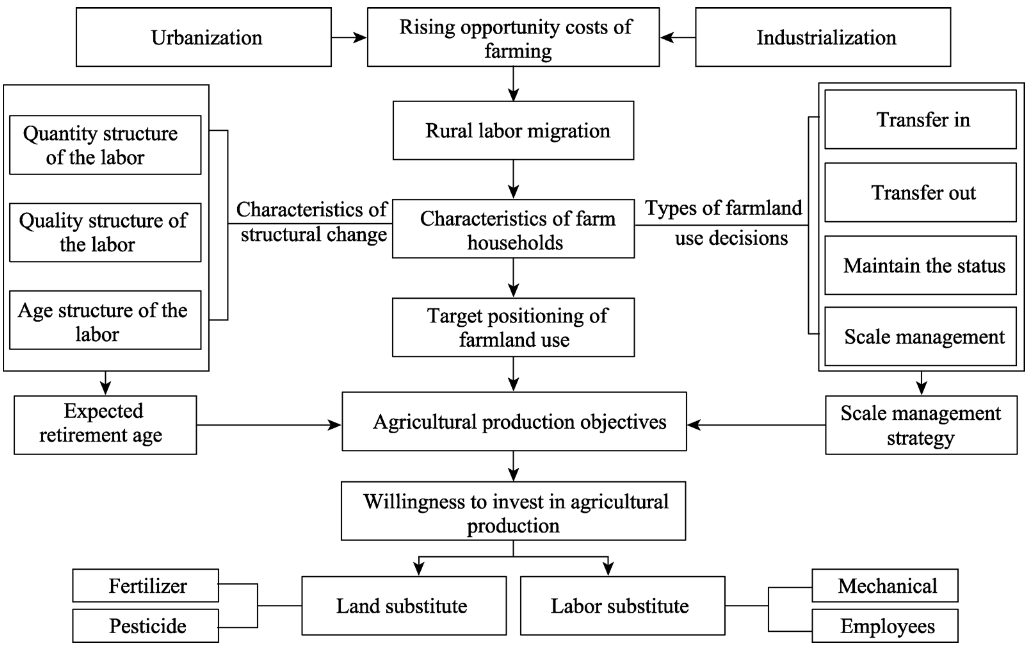

Figure 1 Farmers' objectives and willingness to invest in agricultural production

3 Material and methods

3.1 Study area

Shandong is a large agricultural province in China, with an abundance of farmland resources, high levels of agricultural production, and a large rural population. At the same time, it is also a region with an aging population, a low quality labor force, and large gaps in the level of public services. The limited increase in agricultural and farmers' incomes is an important issue that has restricted the development of regional modern agriculture. Due to their differences in regional topography, economic development levels and agricultural development modes, Shouguang and Yiyuan were selected as plain and mountainous areas respectively to analyze the factors influencing the recessive morphologies of farmland use under the background of labor change. Shouguang, which is located in the northern part of Shandong Peninsula, is the largest vegetable production base and distribution center in China. More than 70% of farmers' per capita disposable income is derived from vegetable production. Shouguang, California (USA), Lansingerland (Netherlands), and Almeria (Spain) are known as "the world's four vegetable regional advantage centers." Shouguang has large scale and diversified vegetable planting, forming a comprehensive vegetable industry cluster. The domestic market is mainly in Wuhan, Guangzhou, Jiangsu, Chengdu, Guiyang, Zhejiang, and other southern regions, while foreign export markets include Japan, South Korea, Russia, the United States, and Venezuela. The total area of plains is 1997.4 km^2. In 2021, the total population of the region was 1,112,800, of which 46.18% were located in rural areas and 487,600 were rural laborers. The farmland area of 981,36.87 ha is mainly distributed in the central and southern parts of Shouguang.

Yiyuan, located in the center of Shandong province, has a mountainous terrain and is the county with the highest altitude in the province. It is also one of the top 100 fruit producing counties in China and is characterized by the production of agricultural products. In 2021, the county's grain planting area was 9281 ha, with a total output of 349,900 tons. The orchard area in 2021 was 24,135.53 ha, including 10,975.67 ha of apples, 7293.93 ha of peaches, and 1865.8 ha of grapes. The irrigated farmland area was 12,950 ha, the rural population was 46.3619 million, and the rural labor force was 29.9748 million.

3.2 Data sources

The data used in this study were obtained from participatory farmer surveys and departmental interviews in Shouguang and Yiyuan in July 2019. Through a comprehensive analysis of the agricultural development of the two counties, Sunjiaji Street, Jitai Town, Liulu Town, Daotian Town, and Tianliu Town in Shouguang were selected as the study areas in plain counties (Figure 2). These towns were located in central and southern Shouguang, are rich in farmland resources, and have developed green and water-saving agricultural practices. They are nationally designated production bases for agricultural products, such as vegetables, grains, and fruits. In Yiyuan, Dongli Town, Yuezhuang Town, Lishan Street, and Dazhangzhuang Town were selected as the study areas, and were mainly developed as economic forest and fruit planting regions (Table 1). On this basis, taking into account the regional agricultural characteristics, 1–2 typical villages were selected in each town and randomly sampled according to 8% of the household population of the sample villages, and

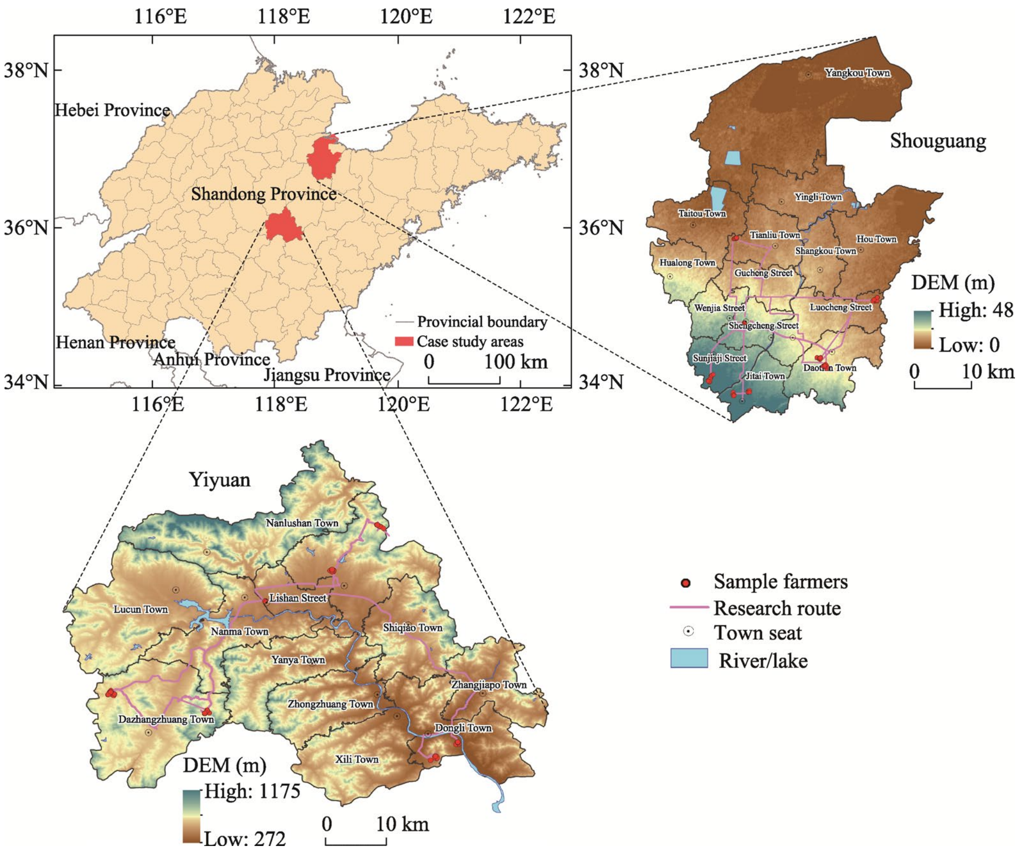

Figure 2 Case area location and sample distribution

Table 1 Details of the sample villages

Town	Investigated villages	Social and economic situation
Sunjiaji Street	Sanyuanzhu village	The birthplace of Chinese winter warm vegetable greenhouses. There are 267 households in the village with 1009 people, a farmland area of 85.67 ha, and more than 530 winter warm vegetable greenhouses. The main corps planted are cucumber, bitter gourd, luffa and other vegetables, as well as cherries.
	Fanyuxin village	Located in southern Shouguang. The main crops planted are cucumber and bitter gourd, 319 households, 1112 people, with a total income of 2.79 million yuan, and the per capita net income of farmers is 39,404 yuan.
Jitai town	Mengjiaguanzhuang village	Located in the northeast of the town, there are 400 households and 1400 people in the village. The main crops planted are red pepper and eggplant.
	Lvjiayi village	Located in the west of the town. The main crop planted is eggplant. There are more than 300 households in the village with approximately 1000 people.
Luocheng Street	Dongzhenguan village	Located in the eastern Shouguang. There are 586 households and 2073 people in the village. The area of farmland is 299.06 ha. The main crop planted is colored peppers. The products have achieved the national "green food" certification.
	Dongdanhe village	The main crops planted are tomato and melon.
Tianliu Town	Cuilingxi village	Located in the south of Daotian Town, with 226 households, 876 people, and 100 ha of farmland. The main crops planted are tomatoes, colored peppers, melon, and other crops.
	Tangjiazhuang village	A total of 165 households in the village with 514 people. The main crop planted is tomato.

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Town	Village survey	Social and economic situation
Hualong Town	Gaojia village	Located in the southeast of Hualong Town. The main crops planted are pumpkin and radish.
	Lijiazhuang village	Located in the east of Hualong Town. The main crops planted are green beans and lettuce.
Daotian Town	Nanqi village	Located in the southeast of Daotian Town. The main agricultural products include carrots, apples, yam, and broccoli.
Gucheng Street	Wamiao village	Located in the west of Gucheng Street. The main agricultural products include moss, strawberry, green apple, artichoke, and potherb mustard.
Dazhangzhuang Town	Hongxing village	Peanut planting base, while peach, grape, and pear production is also high.
	Fuyu village	The eastern part of the Dazhangzhuang Town belongs to the planting area of yellow tobacco and medicinal materials. The main economic crops are peach, ginseng, peanut and apple.
Yuezhuang Town	Zhujiazhuang village	Located in the southwest of Yiyuan, 1485 people, 487 households, annual labor output of 200 people, 93.33 ha of farmland. The main crops planted are leek, eggplant, apple and other crops.
	Dongbaozhuang village	There are 1108 villagers in 326 households. The per capita income of the villagers is 8700 yuan. The area of basic farmland is 74 ha, which is mainly planted with medicinal materials and peach.
Dongli Town	Xialiugou village	The village has a total of 260 households and 747 people. It has an area of 56 ha of farmland and an additional 58 ha of forest fruit. Apple, peach, and other forest fruit are the leading economic crops.
	Xichangwang village	In the middle and low hilly area, there are 546 households with about 1,600 people, mainly producing orchard fruit products, such as apple, hawthorn and peach, and the Xichangwang white lotus root as a geographical indication product.

then household surveys and face-to-face in-depth interviews were conducted. The content of the questionnaires and interviews mainly included a determination of the basic family situation, the scale of farmland management, planting structure, farmland output and other agricultural production metrics, and farmland use (Table 2). We investigated 18 villages in 10 towns of Shouguang and Yiyuan, and data for a total of 296 farmers was obtained: 186 in Shouguang and 110 in Yiyuan. These data comprehensively reflected the labor structure and farmland use at the household level in the study area.

3.3 Methods

3.3.1 Model selection

Agricultural production inputs are composed of two parts: farmers' agricultural production input objectives and farmers' behavior, and the agricultural production objective is the basis of input willingness and behavior. The three factors are independent but interrelated. First, the influence of farmers' agricultural production objectives on their willingness to invest in agricultural production inputs was analyzed. Then farmers who were willing to change their agricultural production inputs were selected to analyze the effect of labor structure on such changes. In the first stage, the explanatory variable was set as "Willingness to change the agricultural production inputs". Then, parameters were introduced to make a binary logistic estimation for all samples, and the factors influencing farmers' willingness to invest in agricultural production were quantitatively analyzed. The formula was as follows.

Table 2 Variable selection and description

Variable name		Code	Variable description	Max	Min	Mean	Variance
Explained variables							
Willingness to change agricultural inputs		P	1=Yes; 0=No	1	0	0.865	0.342
Agricultural input behavior		Z	Agricultural production input/ten thousand yuan	20	0.100	2.985	3.227
Explanatory variables							
Agricultural production objectives	Planned retirement age	X_1	0=Around 50 years old; 1=60–63 years old; 2=64–67 years old; 3=68–71 years old; 4=72–75 years old; 5=76–79 years old; 6=More than 80 years old; 7=Until incapacitated	7	0	2.973	2.144
	Scale management objectives	X_2	0=Farmland transfer in; 1=Maintain the status; 2=Small part transfer out; 3=Most part transfer out; 4=Abandoned	4	0	1.037	0.756
Labor structure	Quantity	X_3	Proportion of agricultural labor	1	0.125	0.627	0.226
	Quality	X_4	Per capita education years of agricultural labor	15.500	0	6.951	3.575
	Age structure	X_5	Proportion of agricultural labor aged 60 and above	1	0	0.302	0.430
Family characteristics	Householder gender	X_6	0=Male; 1=Female	1	0	0.378	0.486
	Householder education level	X_7	0=Below primary school; 1=Primary school; 2=Junior high school; 3=Senior High School (technical secondary school); 4=College or above	4	0	1.517	1.002
	Proportion of living expenses	X_8	Living expenses/total household expenses	0.962	0.059	0.493	0.177
Farmland use and agricultural production	Farmland area	X_9	Survey data/ha	4.020	0.034	0.372	0.338
	Irrigation type	X_{10}	0=Drip irrigation; 1=Sprinkler irrigation; 2=Flood irrigation; 3=Other	3	0	1.277	1.110
	Soil fertility	X_{11}	0=Good; 1=General; 2=Bad	2	0	1.054	0.227
	Frequency of technical training	X_{12}	0=Never; 1=Sometimes; 2=Often	2	0	0.348	0.537

$$P = \frac{exp\left(\beta_0 + \beta_1 x_1 + \ldots + \beta_k x_k\right)}{1 + exp\left(\beta_0 + \beta_1 x_1 + \ldots + \beta_k x_k\right)} \tag{1}$$

where P is the dependent variable, which is the probability of occurrence of an event relative to the independent variable factor, and the value range is [0, 1]. P=1 means that farmers intend to change agricultural production inputs, while P=0 means that farmers unwilling to change agricultural production inputs. x_k is an independent variable (i = 1, 2,…, k), which is a factor that affects the occurrence of events, including agricultural production objectives (such as planned retirement age, scale management objectives), farmers' own characteristics (such as gender, educational level), farmland use and agricultural production conditions (such as farmland area, type of irrigation, soil fertility, agricultural training). k is the number of independent variables, β_0 is a constant, and β_k is the partial regression coefficient, which reflects the degree of influence of independent variable factor x_k on P.

Seeds, fertilizers, pesticides, machinery, labor, and other capital expenditures are necessary agricultural production inputs. Therefore, using the case of farmers who are willing to change their agricultural production inputs in the first stage, the OLS method was applied to estimate, and determine the factors affecting the investment in agricultural production inputs by farmers in the second stage. The formula was as follows:

$$Z = \beta_0 + \sum \beta_i x_i + \mu \quad (2)$$

where Z is the investment in agricultural production input behavior of farmers (agricultural production capital input); X_i is the explanatory variable (i=1, 2,..., 7), including labor structure (i.e., quantity, quality, age structure), farmers' own characteristics and family expenditure (i.e., gender, education level, proportion of living expenses), and farmland use and agricultural production (i.e., farmland area, type of irrigation, soil fertility, agricultural training). β_0 is a constant, μ is an error term, and β_i represents the coefficient of influence for each influencing factor.

3.3.2 Sample description

As the most basic economic activity subject and decision-making unit in the rural economic organization, farmers are also the most important micro-behavioral subject in rural production activities and farmland management (Zheng *et al.*, 2022). Their subjective agricultural production willingness is affected by factors such as farmland resource endowment and family characteristics, which then affects the management decision-making behavior of the whole family. From Table 3, it can be seen that the sampled farmers had a strong willingness to continue to engage in agricultural production activities. Most (81.4%) of the farmers planned to retire after the age of 60. Although 15.20% of the farmers did not know their retirement age, and confirmed that, they will continue to engage in agricultural production for as long as they can work. The farmland scale management objective of most farmers' households (74.66%) was to maintain the current land management scale. Simultaneously, 256 households were willing to invest in agricultural production, accounting for 86.49% of the total sample. In terms of farmland resource endowment, the farmland management scale of most (72%) households was less than 0.40 ha. Soil fertility in most case (94.60%) was generally good. Drip and flood irrigation was the main type of irrigation, accounting for 38.18% and 39.53% of the total samples, respectively. Based on the theoretical analysis and considering the importance of the family labor structure in investments in agricultural production inputs, there was a focus on the quantity, quality, and age structure of family labor to examine its influence on the willingness and behavior of farmers. It was found that in 48.65% of the surveyed farm households, the share of agricultural labor in the family labor force was less than 50%, indicating that the livelihoods of farmers in the study area were diversified and agricultural production was not the only source of livelihood. The per capita education level of family agricultural labor was mainly primary school (≤6 years) and junior high school (6–9 years), accounting for 41.22% and 40.88% of the total sample, respectively. From the perspective of the age structure of the family labor, the agricultural production in the study area was dominated by young farmers. The proportion of young farmers was 64.19%, and the proportion of elderly farmers was also close to 25%, indicating an aging phenomenon of agricultural labor. The investments in agricultural production inputs by farmers were distributed across all regions, but for 44.26% of the sample households it was mainly concentrated in the range 10,000–30,000 yuan, followed by 30,000–50,000 yuan (20%), while 54 households invested less than 10,000 yuan, accounting for 18.24% of the total sample.

Table 3 The overall characteristics of interviewed farmers

Questions	Options	Number of households	Proportion (%)
Planned retirement age	<60	10	3.378
	60–71	187	63.176
	72–79	50	16.892
	⩾80	4	1.351
	Until incapacitated	45	15.203
Scale management objectives	Farmland transfer in	46	15.541
	Farmland transfer out	24	8.108
	Maintain the status	221	74.662
	Abandoned	5	1.689
Whether to change agricultural inputs	Yes	256	86.486
	No	40	13.514
Farmland management scale (ha)	⩽0.134	52	17.568
	(0.134–0.402]	163	55.068
	(0.402–0.67]	56	18.919
	>0.67	25	8.446
Soil fertility	Good	0	0.000
	General	280	94.595
	Bad	16	5.405

Questions	Options	Number of households	Proportion (%)
Irrigation type	Drip irrigation	113	38.176
	Sprinkler irrigation	27	9.122
	Flood irrigation	117	39.527
	Other	39	13.176
Proportion of agricultural labor	⩽0.5	144	48.649
	(0.5–1)	90	30.405
	1	62	20.946
Agricultural labor per capita years of education	⩽6	122	41.216
	(6–9]	121	40.878
	(9–12]	50	16.892
	>12	3	1.014
Proportion of agricultural labor aged 60 and above	0	190	64.189
	(0–1)	33	11.149
	1	73	24.662
Agricultural production input/ten thousand yuan	<1	54	18.243
	[1–3)	131	44.257
	[3–5)	58	19.595
	⩾5	53	17.905

Note: The proportion of the elderly agricultural labor aged 60 and above = number of agricultural labor aged 60 and above/total agricultural labor, 0 is a non-elderly farming family (the labor engaged in agricultural production is all middle-aged or young people under 60), (0, 1) is a mixed family (the family agricultural labor includes both young and middle-aged or older people), 1 is a purely elderly farming family (the family agricultural labor is the elderly over 60 years old).

4 Results

4.1 Agricultural production objectives and their regional differences

Based on its topography, the study area was divided into a plain area (Shouguang) and mountainous area (Yiyuan), and the regional differences in farmers' agricultural production objectives were analyzed. The results of a statistical analysis showed that there was a difference in agricultural production objectives between farmers in the plain and mountainous areas. Generally, the expected retirement age of farmers in mountainous areas was later than that in the plains (Figure 3). Nearly 5% of farmers in the plains plan ended their involvement in agricultural production activities at the age of 50 to help their descendants take care of grandchildren, while the proportion of such farmers in the mountainous areas was less than 1%. Because the agricultural development of Shouguang is mainly based on the greenhouse production of vegetables and has formed an industrial chain, farming incomes are significantly higher than in Yiyuan, where economic activity is mainly based on fruit production. Because of their long-term engagement in agricultural production in a high temperature and high humidity environment, greater damage to health, and susceptibility to chronic rheumatic diseases, nearly 61% of the sampled farmers in the plain area planned to retire at the ages of 60–67, while the proportion of such farmers in the mountainous area was only 35%. This also shows that the agricultural production objectives of farmers were closely related to the type of regional agricultural development. Additionally, 21.82% of farmers in mountainous areas planned to engage in agricultural production activities, while only 11.29% of farmers in plain areas choose this option. This may be because the level of economic development in the mountainous areas was lower than in the plains. The income from agricultural production and migrant workers were the main sources of livelihood for rural households in the mountainous areas.

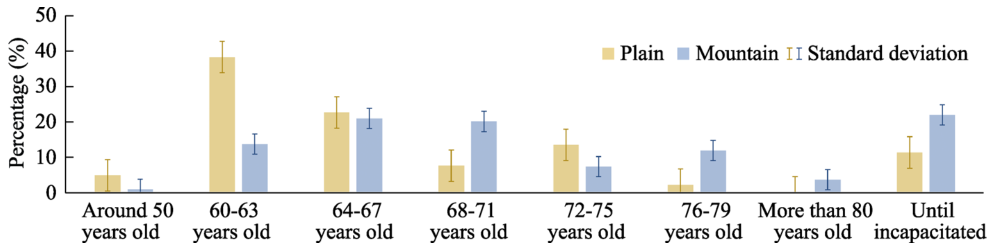

Figure 3 Planned retirement age of farmers

The comparison of farmland management scale between the two counties found that most of the farmers in the plains (69.89%) and mountainous (82.73%) areas intended to maintain the current scale of farmland management (Figure 4). Simultaneously, because the scale management of farmland by plain farmers in Shouguang was more intense, 19.89% were willing to transfer in more farmland, while less than 9% of farmers opted to transfer in farmland in mountainous areas. This was because the terrain in the plain area was flat, and the farmland was mostly concentrated and contiguous, which was convenient for large-scale management, while large-scale management in mountainous areas was difficult to achieve. Additionally, although farmers in mountainous areas were more dependent on farmland than in the plains, the distribution of farmland parcels was scattered and the distance between parcels was large. These conditions were not conducive to effective scale management, and farmers were therefore less willing to transfer in farmland than in plain areas. Only 7.27% of farmers were willing to transfer out farmland, and large-scale management was difficult to achieve. It was further found that farmers' agricultural production objectives were related to agricultural development types and topographical conditions.

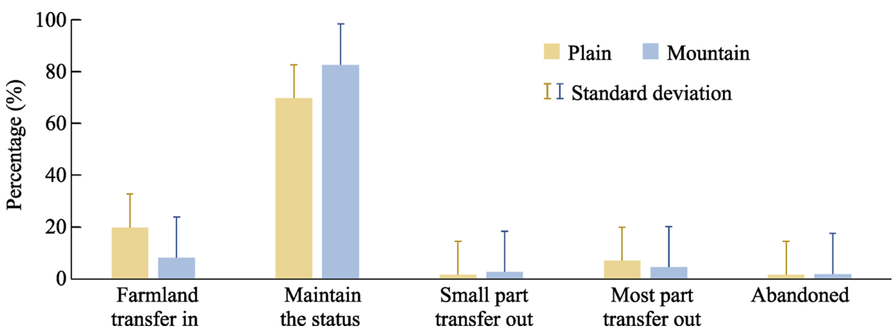

Figure 4 Farmer scale management objectives

4.2 Factors influencing the willingness to invest in agricultural production input

Stata 15.0 was used to conduct a logistic model operation to analyze the factors influencing the willingness to invest in agricultural production. In the selection of independent variables, the influence of internal and external factors on farmers' willingness to invest was the main considerations. The internal factors mainly included the farmers' agricultural production objectives, labor structure, and family characteristics, and the external factors included farmland use and agricultural production. The model Prob>chi2 value was 0.000, indicating that the overall estimated effect of the model was good. The questionnaire survey of farmers showed that 83.33% and 90.91% of the sampled farmers in the plains and mountainous areas were willing to invest in agricultural production inputs. By comparing and analyzing the influencing factors in Table 4, it was found that agricultural production objectives, family characteristics, farmland use, and agricultural production had a significant positive effect on farmers' willingness to invest in agriculture. Farmland area and type of irrigation were the factors with the greatest influence and both passed the significance test. The second most important factors were the planned retirement age of farmers and the objectives of scale management. The independent variable of labor structure failed the 10% test and was less significant. From the perspective of farmers' land use and agricultural production, this indicates that farmers were more likely to invest in agricultural production input to further obtain large-scale benefits or marginal benefits based on their current understanding of the management area. At the same time, the larger the farmland area of a household, the more technology and capital it needs to invest in household agricultural production. However, when the farmland area exceeds the threshold, i.e., when it reaches the maximum scale of family management, the input of farmers to farmland will decrease, which will change the willingness of farmers to invest in agricultural production. As the basic conditions of agricultural production, the type of irrigation and soil fertility were significantly positively correlated with the willingness to invest in agricultural production, which was significant at the 1% and 10% levels, respectively. The worse the irrigation conditions and soil fertility were, the stronger the farmers' willingness to invest in agricultural production inputs. They will attempt to improve agricultural irrigation conditions through water-saving irrigation measures, and increase the application of chemical fertilizers and pesticides to change soil physicochemical properties and enhance soil fertility. Additionally, the frequency of participationin technical training also significantly affects their willingness to invest in agriculture. The higher the frequency of farmers participating in agricultural technology training, the greater the probability that their willingness to invest in agricultural production will change.

Household agricultural production objectives have a significant impact on whether to change invest in agricultural production inputs. Specifically, the planned retirement age and the scale management objectives were significantly positively correlated at the 5% significance level. The later the planned retirement age, the less willing farmers were to adopt scale management, and the greater the probability of farmers changing their willingness to invest in agriculture. The later farmers planned to retire from agricultural production, the stronger their expected future labor force constraints. Therefore they were more inclined to maintain or even reduce the scale of operation, and were also more willing to invest in agricultural production inputs to achieve factor substitution. From the analysis results for different regions, it was apparent that the factors influencing farmers in mountainous areas and plains shared commonalities, but they also had certain differences. The willingness of farmers in the plains to invest in agricultural production was mainly affected by the scale management objectives, while farmers' scale management objectives and planned retirement age were more important for farmers in mountainous areas. The effect of farmers' scale management objectives on the willingness to invest in agriculture in the plain area was greater than the effect of a farmers' planned retirement age. Most farmers (74.19%) confirmed that they would change invest in agricultural production inputs to maintain the current farmland management scale. This may be because the agricultural production mode of vegetable greenhouse planting in the plain area required large amounts of manpower and capital investment in greenhouse construction, maintenance, and vegetable planting management. Farmers were more inclined to maintain the current scale of farmland management. The agricultural crops in Yiyuan were dominated by fruit, for which the crop growth cycle is long, the investment effect is slow, and the willingness of farmers to operate on a large scale is conservative. At the same time, because farmers in mountainous areas were more dependent on agriculture than in the plains and were expected to retire at a later age, 84% of the sampled farmers indicated that they would change their willingness to invest in agriculture to maintain the existing farmland management scale.

Table 4 The regression model of farmers' willingness to invest in agriculture

Explanatory variables		Code	Odds Ratio	S.E	Z-statistic	Significance level
Agricultural production objectives	Planned retirement age	X_1	1.241	0.128	2.100	0.035
	Scale management objectives	X_2	2.246	0.761	2.390	0.017
Labor structure	Quantity	X_3	0.541	0.487	–0.680	0.495
	Quality	X_4	0.886	0.384	–0.280	0.781
	Age structure	X_5	2.266	1.389	1.330	0.182
Family characteristics	Householder gender	X_6	0.588	0.251	–1.250	0.213
	Householder education level	X_7	1.595	0.575	1.290	0.195
	Proportion of living expenses	X_8	0.078	0.095	–2.100	0.036
Farmland use and agricultural production	Farmland area	X_9	0.891	0.036	–2.860	0.004
	Irrigation type	X_{10}	1.762	0.383	2.600	0.009
	Soil fertility	X_{11}	0.179	0.169	–1.820	0.069
	Frequency of technical training	X_{12}	0.509	0.168	–2.050	0.041
	Constants		28.782	55.479	1.740	0.081
	Log likelihood		–93.556			
	Pseudo R^2		0.202			
	Samples		296			

4.3 Factors influencing farmers' behavior in investing in agricultural production input

It is critical to the development of agriculture to clarify which factors affect farmers' behavior in investing in agricultural production inputs. The analysis of input willingness cannot reflect the influence of other factors on farmers' specific behavior in investing in agricultural production inputs. For example, the loss of rural labor due to the urbanization process has impacted the quantity, quality, and age structure of labor. Farmers' personal characteristics and social and economic conditions also affect their input behaviors. Therefore, on the basis of the above analysis, to further analyze the influence of labor structure and other factors on farmers' response behavior, farmers who were willing to change their invest in agricultural production inputs were taken as the dependent variable to establish an OLS regression model of farmers' behavior measures. To gradually determine the effect of labor structure factors, three models were established according to different indicators of labor structure factors, and the influence of labor structure on the response behavior of farmers' agricultural production capital investment was analyzed. Model 1 focused on evaluating the effect of labor structure from the perspective of labor quantity. The per capita education level of the agricultural labor was introduced as an independent variable to construct model 2, which was mainly used to clarify the effect of labor quality on farmers' production input response behavior. On the basis of models 1 and 2, model 3 was constructed to further explore the explanatory power of labor age structure on farmers' input in agricultural production (Table 5).

Table 5 Regression model of farmers' behavior in investing in agricultural production inputs

Explanatory variables			Model 1		Model 2		Model 3	
			Coefficient	t	Coefficient	t	Coefficient	t
Agricultural production objectives	Planned retirement age	X_1	–0.142	–2.030**	–0.152	–2.170**	–0.146	–2.100**
	Scale management objectives	X_2	–0.237	–1.180	–0.297	–1.470	–0.174	–0.860
Labor structure	Quantity	X_3	–1.227	–1.830*	—	—	—	—
	Quality	X_4	—	—	0.198	0.610	—	—
	Age structure	X_5	—	—	—	—	–0.908	–2.520***
Family characteristics	Householder gender	X_6	0.212	0.660	0.234	0.720	0.267	0.840
	Householder education level	X_7	0.262	1.600*	0.165	0.640	0.213	1.300
	Proportion of living expenses	X_8	–7.411	–8.600***	–7.289	–8.430***	–7.316	–8.570***
Farmland use and agricultural production	Farmland area	X_9	0.315	7.110***	0.317	7.110***	0.297	6.660***
	Irrigation type	X_{10}	–0.560	–3.790***	–0.601	–4.100***	–0.540	–3.680***
	Soil fertility	X_{11}	0.568	0.840	0.481	0.710	0.472	0.700
	Frequency of technical training	X_{12}	–0.450	–1.570	–0.477	–1.650*	–0.464	–1.630
	Constants		7.055	5.240***	6.458	4.920***	6.621	5.090***
	R^2		0.517		0.511		0.523	
	F		26.22		25.61		26.83	
	Samples		256		256		256	

Note: *, **, *** represent significant at the confidence level of 0.1, 0.05 and 0.01, respectively.

The regression analysis showed that all three models passed the test and achieved good results for complex economic and social issues. Most of the variable symbols were consistent with theoretical expectations, and the significance level was greater more than 90%. The variance inflation factor (VIF) was less than 10, the mean VIF was less than 1, and a collinear diagnosis was passed. The main factors affecting the behavior of farmers willing to invest in agricultural production inputs were family agricultural production objectives (planned retirement age, scale management objectives), labor structure (the number of laborers and their age structure), family characteristics (householder education level, the proportion of living expenses), and farmland use and agricultural production (area of farmland, frequency of technical training, type of irrigation).

(1) From the perspective of internal factors that affected farmers' response behaviors, farmers' behavior in investing in agricultural production inputs were closely related to family agricultural production objectives and the labor structure. The later farmers planned to retire, the less willing they were to operate on a large scale, and the lower their capital investment in agricultural production. This was because in the process of agricultural production, farmers face practical problems, i.e., as they grow older, their physiological functions decline and they do not have the energy and ability to engage in agricultural production (Rogers *et al*., 2013; Fried and Tauer, 2016). Their source of income gradually changes from farming to support by children. Farmers become less dependent on agricultural production, and land becomes a spiritual sustenance. With increasing age, farmers will therefore gradually reduce their investment in agriculture. However, because of the "fairness" mentality of farmers, the stronger their willingness to adopt scale management, the more farmland they will transfer in. In this situation, if they decide to increase their capital investment, they will try their best to cover all farmland. Otherwise, increased inputs will not cover all farmland. Therefore, the stronger the willingness of farmers to operate on a large scale, the greater their investment in agriculture. If farmers choose to transfer out farmland or even abandon it, the investment in agriculture will be reduced. For individual farmers, changes in household labor structure are an important factor that promotes changes in household agricultural production input behavior. Models 1 and 3 showed that household agricultural production inputs were inversely proportional to the number of household laborers and their age structure, and the relationships were significant at the 10% and 1% levels, respectively. This was because labor is a factor in agricultural production, and changes in the quantity and age structure of agricultural labor resources will induce the substitution of input factors. The smaller the quantity of agricultural labor in the household, the higher the dependence on machinery and technology in the agricultural production process, and the higher the employment of labor during busy farming seasons, and therefore more expenses are incurred. At the same time, the aging of household labor will force farmers to reduce the investment in agricultural production. For mixed-age farming families, the family agricultural labor includes both young, middle-aged, and old people, and their livelihoods are sustained from various sources. Agricultural production is no longer the only source of livelihood. This dependence on agriculture for this type of farming family has decreased, and therefore their capital investment in agricultural production has also decreased. For elderly farming families, the family agricultural labor is 60 years old and above, and agricultural production provides their cultural identity (O'Leary and Tuan, 1975). For the vast majority of elderly farmers, farming has become a habit. The cost of farming is increasing while the income source of elderly farmers remains limited. For these farmers, the investment in agricultural production is minimal. Additionally, family characteristics are also an important factor affecting agricultural production inputs, but there was no obvious correlation with personal characteristics such as the

gender and education level of the householder, while there was a significant negative relationship with family living expenses. Family living expenditure had a squeezing effect on agricultural expenditure. The greater the family living expenditure, the less the farmers invested in agriculture. Regardless of the changes in the quantity, quality, or age structure of the household labor, the effect of family living expenses on investments in agricultural production inputs did not differ much.

(2) Among the external factors, farmland area and irrigation conditions had a significant influence on farmers' behavior in investing in agricultural production inputs. According to Model 1, 2, and 3, the farmland area of households was positively correlated with investments in agricultural production inputs, which was significant at the 1% level. For individual farmers, with an increase in the farmland management area, seeds, chemical fertilizers, pesticides, machinery, employment, and other agricultural material costs would increase. At the same time, according to the induced technological innovation theory, with a reduction in the quantity and quality of family agricultural labor and the aging of the labor force, farmers will seek technology, machinery, and other factors to replace labor, thus increasing their investment in agriculture. Additionally, the type of irrigation was also a significant factor influencing farmers' behavior in investing in agricultural production input, with the degree of influence second only to that of family living expenses. With the changes in the household labor structure, the coefficient of influence for the type of irrigation on farmers' input behavior was greater than 0.5. The more water-saving irrigation measures are adopted by farmers, the higher the investment in agriculture is, which is also related to the investment in irrigation equipment itself. The early investment cost of water-saving irrigation measures, such as drip irrigation and sprinkler irrigation was high, while the investment in flood irrigation was almost zero. We also found that the agricultural production mode of vegetable greenhouses in Shouguang was large-scale planting. The land parcels were concentrated and contiguous, mainly using drip irrigation and sprinkler irrigation, while in Yiyuan flood irrigation was the main approach.

5 Discussion

(1) The decision-making behavior of farmers' farmland use is a process in which farmers continuously adjust their agricultural production objectives, willingness, and decision-making behavior according to their own needs and actual conditions in a specific social and economic environment. The differences in farmers' pursuit of farmland production and value capacity leads to differences in their mode of farmland use, degree of use, and agricultural production input intensity (Liu *et al*., 2012). The differences and changes in the farmland use objectives, willingness, and behaviors of farmers are the basis for studies of farmland use transition. The behavioral preferences of farmers had the predominant impact on their investments in agricultural production inputs, which is one of the reasons for the regional differences in the transformation of farmland use. As the micro-subject of farmland use, farmers' willingness and behavioral preference for farmland use dominates the whole process of farmland use. Using the binary logistic model and OLS to analyze the mechanism of farmers' willingness and behavior to invest in agricultural production, we found that agricultural production objectives, family characteristics, farmland use, and the agricultural production situation of farmers' internal and external factors had significant effects on their

willingness and behavior toward investing in agricultural production inputs. This conclusion was consistent with that of Ren *et al*. (2018; 2020). In addition to the above factors, the behavior toward investing in agricultural production inputs was also closely related to the characteristics of labor structure, such as the quantity, quality, and age structure of household labor, among which the influence of the labor quantity on farmers' investments in agricultural production inputs was significantly greater than that of the labor structure. To adapt to the changes of family labor conditions, farmers will adjust the agricultural production capital input of machinery, chemical fertilizers, pesticides and hired labor to maximize the agricultural production benefits. The input willingness preferences and differences among farmers in different topographies also affect their behavior toward investing in agricultural production. These findings enable the micro-mechanisms and obstacles to rural industrial revitalization to be identified, so achieving the goal of optimizing the structure of farmland use and factor inputs. At the same time, farmland use transition at the farmer scale is undoubtedly an important part of rural industrial revitalization, especially in traditional agricultural areas where high-yield, efficient, green, and sustainable agriculture is an important foundation of rural industrial revitalization. Under the background of multiple factors such as labor changes, the impact of COVID-19, and the complex and changeable international trade situation. It is of great significance to study the internal mechanism of farmland use transition at the farming household scale to stabilize agricultural production, ensure food security, and promote rural revitalization.

(2) The factors influencing on farmers' scale management willingness and behavior are not a single pathway, but rather there are complex linkages and interactive relationships. 1) There was a correlation between the planned retirement age of farmers and the age structure of the labor force. Labor is the basic element of agricultural production. As the urbanization process has intensified, the rise of non-agricultural wages and the rising opportunity cost of farming has contributed to the migration of rural labor, which has changed the supply structure of rural labor. The continuous improvement of the citizenization mechanism for the migrant agricultural population has intensified the "scissors gap" between the return of the rural population and the continued population outflow, and the rural population structure has developed new characteristics. The agricultural labor structure also presents challenges to agricultural and rural modernization, and rural revitalization. In this context, the later retirement age of farmers will increase the aging trend of the agricultural labor structure, especially in mountainous areas with low levels of economic development. This leads to a decline in human capital and insufficient endogenous power for rural revitalization, which will inevitably hinder the implementation of the rural revitalization strategy. 2) There were also correlations between the family labor structure, farmland resources (farmland area), and scale management objectives. This was consistent with the results of Zhao and Zhang (2019) and Lyu *et al*. (2020) who concluded that the resource endowment characteristics of farming households will have a certain impact on the willingness to adopt scale management. Previous studies have shown that the trend for rural labor to adopt non-agricultural work and the aging of the population structure have increased the trend of farmland marginalization in mountainous areas. Farm households with few farmland resources, poor farmland quality, insufficient household funds, or a small household labor force, and a large household consumption population will prefer non-agricultural production. Transoprt links are often in-

convenient and farmland located long distances from roads and with steep slopes has been abandoned. Farmers or new agricultural operating subjects with fewer family farmland resources but sufficient family funds and agricultural labor will increase their income by expanding their farmland management scale. The farmland management scale and agricultural production objectives have significant effects on farmers' agricultural production investment, which is consistent with Xu *et al*. (2022). 3) There was a further correlation between the type of irrigation and soil fertility, which affected investments in agricultural production inputs. Farmers in Shouguang are mainly dependent on groundwater for agricultural irrigation. With the rapid development of the social economy and facility agriculture, water consumption has increased dramatically. As a result, the underground water levels have dropped sharply. Farm land faces the threat of salinization, resulting in a decline in soil fertility and farmers often need to improve soil fertility through the application of organic or biological fertilizers, which increases the cost of agricultural production.

(3) For farmers, the willingness and behavior to invest in agricultural production inputs are the result of rational selections according to their own conditions. Farmers' scale management objectives and planned retirement age have a fundamental impact on their willingness to invest in agricultural production inputs. The later the retirement age of farmers and the smaller the target of scale management, the more likely that farmland marginalization and abandonment will occur. Sustainable agricultural development cannot be separated from the support and guarantee of agricultural production inputs. Agricultural production inputs have become the core factor in modern agricultural growth under market economy conditions. Agricultural production investment, especially agricultural funds, can substitute for other agricultural production factors. Agricultural investment in chemical fertilizers, pesticides, agricultural membranes, and other mobile funds can increase land productivity and agricultural outputs. It can alleviate the scarcity of natural resources such as land, and can then have a certain substitution effect on agricultural production. Agricultural fixed funds such as machinery, equipment, and transportation tools can save labor time, reduce labor intensity, and improve agricultural labor productivity, and can ultimately replace agricultural labor.

(4) The transition of farmland use is an effective for farmers to increase their income. Combined with the above results, to improve the enthusiasm of farmers for farmland investment and therefore to increase their income, we should not only consider the farmers' resource endowment, but also the influence of internal factors on farmers' willingness to invest in farming. To achieve this, a number of actions are proposed. 1) We should better understand farmers' cognitive levels and structure, as well as their willingness and potential needs.These factors should then be combined with the characteristics of the local labor structure and types of agricultural development to improve farmers' cognitive level and scale management willingness to bring about a behavioral response. This would effectively play the incentive and regulatory role of policies supporting and benefiting agriculture. 2) Due to the large differences in individual characteristics and resource endowments of farmers, as well as the structural obstacles, such as an insufficient labor force, many farmers still have no willingness for large-scale management. Therefore, "land + service" should be taken as the target when guiding the transfer of farmland, to strengthen the agricultural socialized service system for farmers. Developing cooperative, order-oriented, trustee-oriented, and

other service modes, to promote the scale of agricultural production and services, drive agricultural production inputs and remedy structural obstacles, will improve the efficiency of farmland use and economic benefits, therefore increasing farmers' income. 3) The problems of low human capital, poor structure, and the obvious regional differences of agricultural labor need to be addressed. It is necessary to build agricultural organizations and new agricultural management systems, which will be suitable for the structure of agricultural labor and will cultivate new agricultural management practices, such as family farms and farmer cooperatives. By taking measures to promote standardized production and the mechanization of agriculture, the organization of agricultural production can be improved. Simultaneously, differentiated regulatory measures should be issued for the different regions and various agricultural operating entities, and adaptive encouragement policies should be formulated according to the agricultural production conditions and limiting factors in various regions, to overcome the obstacles. 4) Additionally, according to the theory of agricultural production factor substitution, the improvement of agricultural technology and mechanization can reduce the time and intensity of agricultural labor per unit of farmland. Therefore, under the background of changes in the rural population structure and agricultural labor structure, the development of agriculture still needs technology inputs. First, it is necessary to promote the transfer of mechanized production from food crops to cash crops in the plain area, and to extend mechanized production from cultivation to management during picking, harvesting, and other mechanized processes. Second, agricultural mechanization in hilly and mountainous areas should be improved, the application of agricultural mechanization should be promoted, and the mechanization development gap between hilly and plain areas should be reduced.

6 Conclusions

Based on both induced agricultural technology innovation theory and rational economic man theory, this study considered the pathway of objective-willingness-behavior, and from the perspective of the recessive morphology of farmland use conducted a theoretical analysis of the mechanisms influencing farmers' willingness and behavior to invest in agricultural production inputs. Based on data from 296 farming household surveys in Shouguang and Yiyuan, empirical evidence was gathered using the binary logistic estimation method, the OLS model, and the comparative analysis method. There were three main conclusions.

(1) The agricultural production objectives of farmers in the plains and mountainous areas had both commonalities and differences. Farmers in the plains and mountainous areas did not have a strong target for the scale management of farmland, and most farmers tended to maintain the current scale of farmland management, accounting for 69.89% and 82.73% respectively. The expected retirement age of farmers in the mountainous areas was later than that in the plains.

(2) The willingness to invest in agricultural production inputs was mainly affected by agricultural production objectives, family characteristics, farmland use, and agricultural production. The type of irrigation and farmland management area were the external factors that had the greatest impact and their influence passed the significance test. Soil fertility status and the frequency of participating in technical training also had significant but small effects. Among the internal factors, the planned retirement age and scale management objectives

both affected farmers' willingness to invest in agricultural production inputs at the significance level of 5%.

(3) The behavior of farmers toward investing in agricultural production was related to family agricultural production objectives, labor structure, family characteristics, farmland use, and agricultural production, with all factors passing the significance test. The later the farmers plan to retire, the less willingness there was to operate on a large scale, and the less capital they invested in agricultural production. For individual farmers, the number of family laborers, the age structure of laborers, and family living expenses were significantly negatively correlated with farmers' agricultural capital investment, but were not significantly related to personal characteristics, such as the gender and education level of the householder. In terms of farmland use and agricultural production conditions, the effect of the type of irrigation on the investment in agricultural production inputs was greater than that of the family farmland area, and it passed the significance test.

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