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Livelihood Capital, Ecological Cognition, and Farmers' Green Production Behavior

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Abstract: Green development of agriculture is inevitable to meet the objective demand of rural ecological environment protection and high-quality agricultural development. Livelihood capital is the basic condition for farmers to carry out the activities of production and management, while ecological cognition is the direct motivation for their behaviors. Based on field research data from 436 farm households in 4 counties of Langao, Fuping, Mian, and Yaozhou in Shaanxi Province, China, the study conducted the double-hurdle model (DHM) to empirically analyze the effects of livelihood capital and ecological cognition on farmer's decision on green production and the degree of green production. The results show that (1) farmers' livelihood capital is the basic condition that significantly affects farmers' green production. Specifically, human capital and social capital have a positive contribution to farmers' green production decision and degree of green production; natural capital and financial capital do not have a significant effect on green production decision, but have a significant positive effect on the degree of green production behavior; physical capital, as farmers' stock capital, does not have a significant effect on green production behavior. (2) Ecological cognition plays a positive moderating role in farmers' decisions on green production, but as a subjective cognition, its contribution to the degree of green production is not significant. This paper explores the relationship between livelihood capital, ecological cognition, and farmers' green production behavior, and provides suggestions for improving farmers' participation in green production.

Keywords: livelihood capital; ecological cognition; green production behavior

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1. Introduction

Green production is an important element in promoting sustainable agricultural development, ensuring consumer food safety, and protecting the rural ecological environment [1,2]. For a long time, the crude growth model of depending on increasing resource factor inputs has promoted the high growth of the agricultural economy, which also aggravated the deterioration of the rural ecological environment and the pollution of agricultural surface sources [3,4]. This has directly affected the living conditions of rural residents and the quality and safety of agricultural products, which is not conducive to rural environmental protection and agricultural transformation and upgrading. In recent years, the Chinese government has attached great importance to the green development of agriculture, requiring agricultural development to be oriented to green production. A series of policies and measures have been issued to achieve the goal of agricultural modernization, which includes resource saving, environmental friendliness, and product safety. In addition, other actions to control the application of chemical fertilizers and pesticides have achieved certain results. From 2015 to 2019, the total amount of fertilizer application for agricultural use in China gradually decreased from 2.055 million tons to 1.7996 million tons, and the amount of pesticide use decreased from 60.2 million tons to 46.4 million tons from 2014 to 2019 (as shown in Figure 1). The government has put forward new requirements for agricultural production by strengthening the prevention and control of

agricultural surface source pollution and carrying out agricultural green development operations. Transforming agricultural development and promoting green agricultural production has become an important path for rural ecological environmental protection and management [5]. As the decision maker from a micro perspective and the participant in agricultural production activities [6], farmers conduct green production affected by several factors. It is of great importance to explore the influencing factors and decision-making mechanisms of their green production behaviors in order to guide farmers to participate in green production and then promote rural ecological environmental protection and achieve sustainable agricultural development.

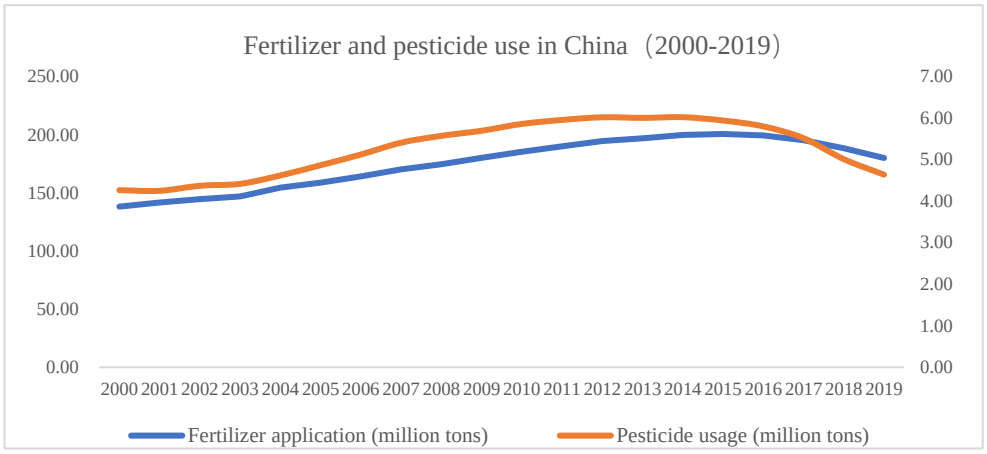

Figure 1. Changes in total fertilizer and pesticide application in China (2000–2019).

Scholars at home and abroad have conducted a lot of research on the influencing factors of farmers' green production behavior at the theoretical and empirical levels. The dual identity of farmers as "economic man" and "social man" makes their production behavior more rational [7]. From the perspective of objective conditions of agricultural production, here are important reasons that restrict farmers from participating in green production: farmers' labor status, economic capacity, geographic location, social environment, and other livelihood capital stock, and their ability to combine livelihood capital stock [8]. Among them, human capital such as farmers' age, education level, psychological cognition, and social capital are nonphysical resources that farmers can use [9–11], such as younger and highly educated agricultural producers being more inclined to adopt green production [12,13]; physical resources such as land size and physical capital, as well as financial assets, also play an important role in farmers' behavioral choices [14], and studies have shown that labor size and household income are also key factors influencing green agricultural production behavior [15]. According to the rational economic man hypothesis, an individual will make a rational decision based on the consideration of their own endowment status and economic interests. Therefore, when farmers make green production decisions, they consider both the incremental income brought by green production and the adoption cost of green technology [16,17]. However, in empirical studies, some scholars find that the influence of livelihood capital on different farmers' participation in green production varies widely. For example, farmers with more human, financial, and social capital tend to choose a diverse portfolio of livelihood strategies [18–20] and pay less attention to green agriculture, while farmers with more physical and natural capital are more dependent on rural and agricultural production and more inclined to obtain long-term benefits through green production [21,22]. Moreover, farmers' green production behavior does not fully accord with the rational decision-making paradigm [23,24]. Some studies show that farmers may still engage in green production even though the costs are higher than the benefits. Thus, it seems that the analysis of green production behavior under neoclassical economics, which starts from the premise of rational farmers, can hardly fit with the realistic logic of green

production behavior. This leads to the question of whether livelihood capital can promote green production behavior of farmers.

With the development of psychology, scholars have attempted to analyze the "limited rationality" of farmers from the viewpoints of psychology and economics. Under the framework of neoclassical economics, they argue that the limits of farmers' rational decisions are due to cognitive differences and incomplete information [25,26]. For farmers, the degree of access to green production information affects the level of green cognition [27], forming ecological cognitive differences among farmers, which further constrains the limits of farmers' green production decisions. This means that farmers with higher green cognition tend to adopt green production behaviors [28]. Empirical studies also show that an increase in farmers' cognition about green production can lead farmers to recognize the economic, social, and ecological benefits of green production, and thus take the initiative to learn and acquire technologies and information about green production, which means that they are more likely to reduce the use of pesticides and fertilizers, and to protect the agricultural environment [29]. In addition, scholars have combined cognition with social interaction and environmental regulation [30,31] to analyze the joint influence of them on green production behavior, and these studies all affirm the positive role of cognition in promoting farmers' participation in green production.

The above studies have laid a solid foundation for the selected topic of this paper, and also proved that this topic deserves further investigation. (1) Recent studies only explore the influence of livelihood capital on farmers' production behavior from individual dimensions or directly by questionnaire indicators, ignoring the analysis of the relationship between the overall level of livelihood capital and green production behavior; (2) Most recent studies separate livelihood capital and ecological cognition to discuss their influence on farmers' production behavior, without considering the mechanism of their interaction on green production behavior. From this point of view, this paper incorporates livelihood capital, ecological cognition, and green production behavior into a unified analytical framework, and uses the double-hurdle model to analyze the influence of livelihood capital on farmers' green production behavior. Based on micro-survey data of 436 farmers in 4 counties, this study further explores the role of ecological cognition in the influence of livelihood capital on farmers' green production behavior, in order to analyze the decision-making mechanism of farmers' behavior in depth and formulate targeted policy measures. The aim of this paper is to analyze the decision-making mechanism of farmers' behavior, and formulate targeted policy measures to guide farmers' participation in green production, so as to provide a theoretical basis and reference for solving rural ecological environment problems and achieving high-quality agricultural development.

2. Theoretical Analysis and Model Construction

2.1. Theoretical Analysis

Livelihood capital is the sum of all resources possessed by an individual or household and used to sustain livelihoods, including individual capabilities and actions, as well as physical and social resources needed for household livelihoods. According to the sustainable livelihoods analysis framework proposed by the UK Department for International Development (DFID), the livelihoods capital of farm households can be divided into natural, human, physical, social, and financial capital [32]. The five components interact and constrain each other to cover the productive livelihood situation of farm households more comprehensively. Many scholars have measured the sustainable livelihood capacity of farm households, especially the poor, from the five dimensions of livelihood capital and verified that livelihood capital has significant effects on farm households' livelihood strategies and production behaviors [33]. Nowadays, when green agriculture and the quality of agricultural products are of great concern, whether and to what extent to participate in green production are undoubtedly important livelihood decisions that farmers must face.

Among the five subdivision dimensions of livelihood capital, natural capital is the natural resource owned by farmers, which is usually measured by the area of land owned

by farmers. Due to the existence of economies of scale, farmers with larger acreages can reduce the cost of green production and obtain higher output; therefore, farmers with larger acreages are more willing to participate in green production [34]. Human capital is the overall labor force status of farm households, including average age, number of laborers, physical health, and skills possessed, which is usually characterized by age or educational attainment. The more labor available to be invested in agricultural production, the more likely it is that the production chain will be finely tuned to provide labor security for green production [35]. Physical capital is the facilities, instruments, and tools held by farm households to sustain their productive lives, such as housing, household appliances, and agricultural machinery. The richer the physical capital is, the more efficient and productive the farmer is, and the greater the output is. Under this condition, the likelihood of adopting green production will be higher. Social capital is the association between individuals and organizations or other individuals, which is expressed in various social resources that farmers have, such as relationships with other farmers, social prestige, and social participation [36]. Social capital accelerates the diffusion of market information and new technologies through learning acquisition mechanisms, which help farmers change their production attitudes and reduce communication costs to reach cooperation quickly. Financial capital is the sum of disposable financial assets acquired by farm households through various channels, such as annual income, savings, accessible loans, and bailouts. With richer financial capital, the stronger the payment capacity and risk resistance of farmers, the more likely they are to adopt green production, as they have the objective conditions and risk-coping ability to engage in green production. In addition, compared to traditional farming methods, green production methods, such as organic fertilizer substitution, green pest control, and plant protection drone application technologies, are more costly and uncertain in terms of returns, and are more dependent on farmers' livelihood capital [37–39].

Ecological cognition is the awareness of farmers about the rural habitat environment and belongs to the psychological characteristics of individual farmers. In this paper, ecological cognition is reflected in the extent to which farmers attach importance to the current agricultural environmental pollution situation, the extent to which they understand agricultural science knowledge and environmental protection policies, and the extent to which they recognize the value of green agricultural production. According to behavioral economics theory, an individual's perception of things directly or indirectly affects their preference and willingness to choose. Scholars generally agree that ecological cognition is the psychological basis and logical starting point of farmers' behavioral decisions [40], and that correct ecological cognition is the prerequisite for farmers' environmental protection behavior, and its level is directly related to the behavioral decisions and behavioral level of participation in green production [41]. When farmers recognize the necessity of improving the ecological environment and the importance of green production, they will consider the impact of ecological changes on the long-term benefits of agricultural production and rural living environment while pursuing economic benefits through agricultural production, and the higher their willingness and degree of participation in green production will be; that is, ecological cognition positively moderates the influence of livelihood capital on farmers' green production behavior.

Based on the above analysis, the theoretical research framework of this paper is constructed as shown in Figure 2.

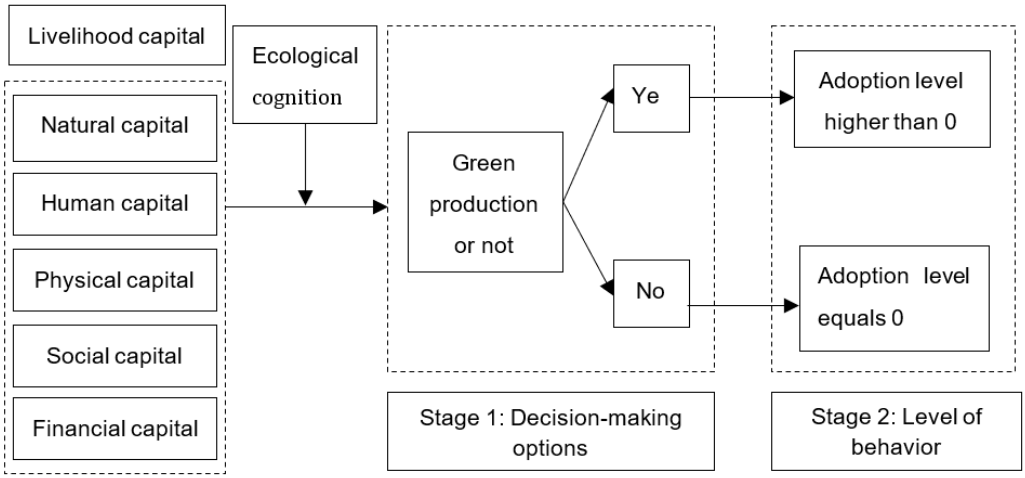

Figure 2. Theoretical framework of livelihood capital influencing green production behavior of farm households.

2.2. Model Construction

According to theoretical analysis, the green production behavior of farmers can be divided into two stages: the first stage is the decision of whether farmers adopt green production behavior, which takes the value of 1 if farmers adopt green production behavior and 0 if they do not. The second stage is the degree of green production by farmers who choose green production, which is expressed by the number of items in which farmers adopt green production behavior. The second stage is the degree of green production by farmers who choose green production, which is expressed by the number of items for which farmers adopt green production behavior. To avoid model estimation bias due to errors in the participation decision equation being carried into the adoption degree equation, the double-hurdle model (DHM) was selected for the econometric analysis, drawing on the study by Newman et al. (2003) [42]. In this model, also known as the generalized Tobit model, the decision choice equation and the degree choice equation can have different estimated coefficients, which is suitable for analyzing the factors that influence two different decision stages with sequential order in the economic behavior of individuals. The double-hurdle model is constructed as follows:

Firstly, the model of farmers' behavioral decision on green production is constructed:

$$\begin{aligned} D_i^* &= \alpha X_{1i} + \mu_i \quad \mu_i \sim N(0,1) \\ D_i &= \begin{cases} 1, & D_i^* > 0 \\ 0, & D_i^* < 0 \end{cases} \quad i = 1,2,\ldots n \end{aligned} \tag{1}$$

If the farmer adopts green production behavior ($D_i = 1$), then enter the green production behavior degree selection model.

$$G_i^* = \beta X_{2i} + \delta_i \quad \delta_i \sim N\left(0, \sigma^2\right) \tag{2}$$

Combining Equations (1) and (2), the double-hurdle model is obtained as follows.

$$\begin{cases} G_i = G_i^*, & D_i^* > 0, \ D_i = 1 \\ G_i = 0, & D_i^* \le 0 \end{cases} \tag{3}$$

In Equations (1)–(3), X_{1i} and X_{2i} are independent variables; α and β are regression coefficients, n is the sample size, and μ_i and δ_i are error terms. In Equation (1), D_i^* indicates the indicator variable of green production decision of farmers, $D_i^* > 0$, $D_i = 1$ indicates that farmers are engaged in green production, and $D_i^* \le 0$, $D_i = 0$ indicates that farmers

are not engaged in green production. (2) G_i^* is the indicator variable of green production degree, where $D_i^* > 0$ and $D_i = 1$, $G_i = G_i^*$.

3. Data Sources and Variable Descriptions

3.1. Data Sources

The data of this study come from the field research of "small farmers embedded in agricultural value chain" conducted by the research team in March 2022 in four counties, namely Fuping, Yaozhou, Mian, and Langao in Shaanxi Province (Figure 3), which are all dominated by grain cultivation, with wheat, corn, and rice as the main crops. The survey area is rich in geography and landscape, agricultural production is frequent and diverse, and farmers' production and life are closely linked to the geographic environment. Therefore, the region was selected for the survey with a certain degree of typicality and representativeness. The survey adopted a combination of stratified sampling and random sampling. Firstly, according to the level of regional economic development, grain cultivation area, total production, and output value, 2–3 sample townships were firstly selected from each sample county, 3–4 sample villages were selected from each township, and 10–12 farming households randomly selected in each sample village as survey subjects. In order to ensure the authenticity and validity of the questionnaire, the survey was conducted in the form of one-on-one interviews between the researchers and the farmers, which mainly included the basic information about the farmers' families, the agricultural production and operation status, the basic situation of organic fertilizer application, the awareness of ecological environmental protection, and the implementation of green production behavior. A total of 460 questionnaires were distributed, and after excluding some poor-quality questionnaires with missing data, outliers, and inconsistent answers, 436 valid questionnaires were obtained, with an effective rate of 94.78%. The characteristics of the sample farm households match the rural socioeconomic conditions and corresponding statistics in Shaanxi Province and are more representative.

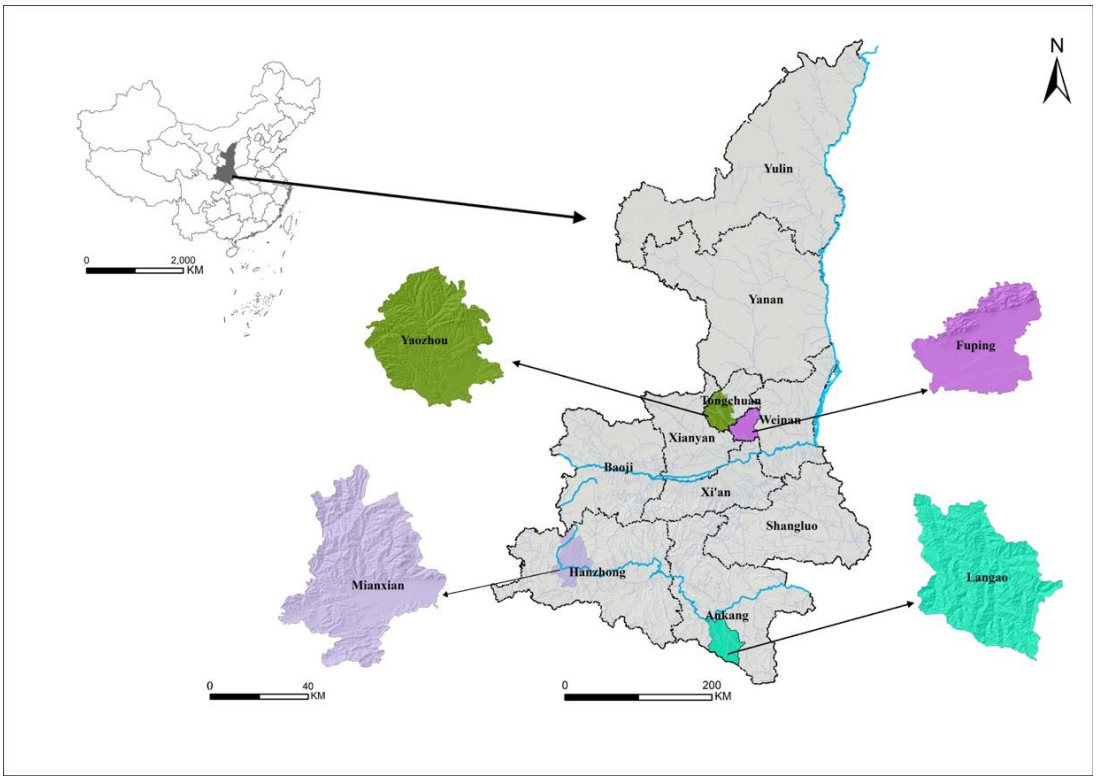

Figure 3. Location map of the sample counties.

3.2. Variable Description and Statistics

3.2.1. Explained Variable: Green Production of Farmers (G)

According to the "one control, two reduction, three basic" pollution prevention goal of the Ministry of Agriculture, the questionnaire designed five options to measure farmers' green production behaviors: pesticide reduction, organic fertilizer application, straw return, mulch recycling, and water conservation irrigation, and the survey asked farmers whether they implemented the above green production behaviors. In the survey, farmers were asked whether they had implemented the above green production behaviors, and the options included "did" and "did not", and were assigned the values of 1 and 0. Based on the method of Cai (2016) [43], the sum of the scores of the five behaviors was used as the score of farmers' green production behavior implementation.

3.2.2. Explanatory Variable: Farmers' Livelihood Capital (LC)

The DFID sustainable livelihoods framework classifies livelihood capital into five dimensions: natural capital, financial capital, physical capital, human capital, and social capital. In order to comprehensively reflect the livelihood level of farm households, this paper draws on the studies of scholars such as Li et al. (2017) [44] and Quandt et al. (2019) [45] on the construction of livelihood capital indicator system, from natural capital (nc), human capital (hc), physical capital (mc), financial capital (fc), and social. A total of 15 subdimensions of natural capital (nc), human capital (hc), physical capital (mc), financial capital (fc), and social capital (sc) were used to measure the livelihood capital of farmers (see Table 1).

Table 1. Weighting measures of farmers' livelihood capital evaluation indicators.

	Weighting	Indicator	Meaning and Assignment	Nature	Mean	S.D	w_i
Natural Capital	0.1246	Land area	Household's existing land area (mu)	Positive	12.4934	9.2640	0.0337
		Terrain	Mountainous = 1; Hilly = 2; Plain = 3	Positive	1.4513	0.4998	0.0500
		Degree of fragmentation	Number of plots cultivated by the farming household	Negative	5.9727	2.5271	0.0529
Human Capital	0.1905	Years of farming	Years of farming by the household head (years)	Negative	19.8849	14.0348	0.0750
		Number of laborers	Resident working population of the farming household (persons)	Positive	4.3363	1.4368	0.0270
		Literacy level	Years of education of the household head (years)	Positive	5.5133	1.6190	0.0091
Physical Capital	0.1987	Agricultural machinery	Does the farming household own farm machinery? Yes = 1; No = 0	Positive	0.0973	0.2977	0.0721
		Household appliances	Does the farming household have a computer, TV, and open wireless network? Computer × 1 + TV × 1 + wireless network × 1	Positive	1.8407	0.7934	0.0384
		Housing	Does the farming household purchase a commercial house? Yes = 1; No = 0	Positive	0.3274	0.4714	0.0727
Financial Capital	0.2653	Agricultural income	Household income from agriculture in 2020 (million yuan)	Positive	2.2599	2.1233	0.1036
		Nonfarm income	Household's nonfarm income obtained in 2020 (RMB 10,000)	Negative	0.4344	0.8485	0.0672
		Bank financing	Household's borrowing from bank in 2020 (RMB 10,000)	Positive	9.2487	17.8757	0.0957
Social Capital	0.2209	Outworking experience	Household head's time spent working outside the home in the last three years (months)	Positive	5.6372	3.1756	0.0897
		Whether to join a cooperative	Yes = 1; No = 0	Positive	0.2212	0.4169	0.0887
		Whether there are cadres in the family	Yes = 1; No = 0	Positive	0.1150	0.3205	0.1242

The scientific determination of the weights of each indicator plays a crucial role in the accurate measurement of farmers' livelihood capital. To ensure that the weights can objectively reflect the importance of the corresponding indicators in the constructed indicator system, the entropy weighting method of the objective weighting method is used to calculate the weights. The weights of 15 indicators and five subdimensions of livelihood capital were obtained. Among the subdimensions, financial capital and social capital have the highest weights, followed by physical capital and human capital, and natural capital has the lowest weight. The specific calculation process is as follows:

First, the data are normalized,

$$x'_{ij} = \frac{x_{ij} - \min(x_{1j}, x_{2j}, \ldots, x_{nj})}{\max(x_{1j}, x_{2j}, \ldots, x_{nj}) - \min(x_{1j}, x_{2j}, \ldots, x_{nj})} \quad (4)$$

where i = 1, 2, . . . , n; j = 1, 2, . . . , m.

Then, the share of farmer i in this indicator under indicator j (p_{ij}) is calculated:

$$p_{ij} = \frac{x'_{ij}}{\sum_{i=1}^{n} x_{ij}} \quad (5)$$

Next, the information entropy of each index is calculated (e_i):

$$e_i = -\frac{1}{\ln m} \sum_{j=1}^{m} \left(j \times \ln p_{ij} \right) \quad (6)$$

Then, the information redundancy of each index (d_i) can be found:

$$d_i = 1 - e_i \quad (7)$$

Finally, the weights of each indicator are calculated (w_i):

$$w_i = \frac{d_i}{\sum_{i=1}^{n} d_i} \quad (8)$$

From this, the level of farm household livelihood capital is calculated (LC_{ij}):

$$LC_{ij} = \sum_{1}^{m} w_i x'_{ij} \quad (9)$$

3.2.3. Moderating Variable: Ecological Cognition (EC)

Three questions were set in the questionnaire: "Is it important to protect the rural ecological environment", "Do you know the policy of rural ecological protection", and "Should green production be carried out at this stage". If the answer of the farmer is "Yes", it is assigned a value of 1, otherwise 0. The sum of the scores of the three questions is the ecological awareness level of the farmers.

3.2.4. Control Variables

In order to further control the interference of farmers' personal characteristics, household characteristics, and regional differences on the results and improve the accuracy of the model estimation, the age of the household head, the government subsidy received by the household in the previous year, and four regional variables were selected as control variables.

4. Descriptive Statistical Analysis of Variables

As shown in Table 2, the sample farmers used two green production behaviors on average, and the analysis of the questionnaire data showed that the green production behaviors adopted were mainly focused on straw return, followed by water-saving irrigation, and

were not enthusiastic about pesticide reduction and organic fertilizer application due to the fear of pests and yield reduction. Among the livelihood capital, the mean value of financial capital was the highest, followed by social capital, physical capital, and human capital, and the lowest was natural capital. The mean value of livelihood capital was 0.2485, and the overall level of livelihood capital was low and varied widely among farmers. The mean value of ecological cognition was 2.5575, i.e., farm households generally considered rural environmental protection and green agricultural production practices to be very important, but their knowledge of ecological protection policies was relatively weak. The mean value of technical training was 0.7522, indicating that most farmers had participated in technical training. The mean value of government subsidies obtained by the sample farmers was RMB 0.219 million, but the dispersion was high. The sample farmers were more evenly distributed in the four counties.

Table 2. Descriptive statistics of variables.

Variable Type	Variable Name	Variable Description	Mean	S.D
Explained Variable	Green Production Participation in Decision Making	Whether to participate in any of the green production links Participation = 1; No participation = 0	0.8761	0.3309
	Degree of Green Production Participation	The scores of the 5 green agricultural production behaviors are summed	2.1907	1.1809
Explanatory Variables	Livelihood Capital	Calculated by Equations (4)–(9)	0.2485	0.1962
	Natural Capital	Calculated by Equations (4)–(9)	0.0292	0.0174
	Human Capital	Equations (4)–(9) is calculated	0.0656	0.0322
	Physical Capital	Equations (4)–(9) calculated	0.0899	0.0385
	Financial Capital	Equations (4)–(9) is calculated	0.1874	0.0609
	Social Capital	Equations (4)–(9) is calculated	0.1463	0.0433
Moderating Variables	Ecological Cognition	Total score of farmers' awareness of ecological protection, environmental policies, and green production	2.5575	0.8339
Control variables	Age of Household Head	Actual age of household head in the survey year	50.4667	36.5459
	Government Subsidies	Amount of various transfer payments obtained by farm households in the previous year (RMB 10,000)	0.2190	0.2050
	Technical Training	Did you participate in agricultural technology training in the last three years? Yes = 1; No = 0	0.7522	0.4337
	Fuping County	The location of the sample household is Fuping County	0.2018	0.4018
	Yaozhou County	The sample household is located in Yaozhou County	0.2752	0.4471
	Langao County	The location of the sample household is Langao County	0.2752	0.4471
	Mianxian County	The location of the sample farmer is Mianxian County	0.2294	0.4209

5. Regression Results and Analysis

5.1. Impact of Livelihood Capital on Green Production Behavior of Farm Households

On the basis of the aforementioned subdivision of livelihood capital, the impact of five subdivisions of livelihood capital: natural capital, human capital, physical capital, financial capital, and social capital on the decision and degree of green production behavior was analyzed, and the double-hurdle model of farmers' green production behavior was estimated by using the software of Stata15.

The regression results in Table 3 show that human capital and social capital positively influence farmers' green production behavior decisions, among which the regression coefficient of human capital is 22.2263 and the influence of social capital on farmers' green production decisions is smaller than that of human capital, both of which pass the signif-

icance test at the 5% level. Although the coefficients of natural capital, financial capital, and physical capital were positive, they did not pass the significance test, indicating that these three dimensions did not have a significant impact on farmers' green production behavior decisions. The effects of the dimensions of livelihood capital on farmers' green agricultural participation differed from the previous analysis, except for human capital and social capital, which positively affected farmers' green agricultural participation, and the regression coefficients of natural capital and financial capital were 7.5485 and 1.6445, respectively, and passed the significance test. This indicates that after farmers made the decision to participate in green agriculture, their participation degree is influenced by the scale of cultivation, geographical conditions, and disposable income. One possible explanation for the effect of physical capital on farmers' green production not passing the test is that physical capital belongs to farmers' stock capital and green production, as a new concept and thing, is not significantly influenced by farmers' stock capital.

Table 3. Estimation results of double-hurdle model for livelihood capital influencing green production behavior of farm households.

	Behavioral Decision Making	Regression Standard Error	Degree of Behavior	Regression Standard Error
Natural Capital	2.3850	6.35346	7.5485 **	3.4194
Human Capital	22.2263 **	10.4441	10.8468 ***	4.0022
Physical Capital	0.6372	0.1141	3.5120	2.6783
Financial Capital	3.3715	2.6159	1.6445 ***	0.5119
Social Capital	5.1595 **	2.6245	4.2280 **	1.7621
Control	Y	Y	Y	Y
Con	−1.5872	1.1122	1.5835 ***	0.2487
n		436		
Log-likelihood value		−136.5498		
Wald chi-squared value		256.99 **		

Note: **, and *** indicate significance at the 5%, and 1% levels, respectively, and the numbers in parentheses are the standard errors of the coefficients.

5.2. Moderating Effect of Ecological Cognition on Livelihood Capital on Green Production Behavior of Farmers

According to the aforementioned theoretical analysis, ecological cognition not only plays a direct role in farmers' green production behavior, but also plays a moderating role in the influence of livelihood capital on farmers' green production. Therefore, the interaction terms of ecological cognition and livelihood capital were introduced into the baseline regression model to analyze the role of ecological cognition in farmers' green production behavior, and the empirical results are shown in Table 4.

Table 4. Co-influence of livelihood capital and ecological cognition on green production behavior of farm households.

Variable	Model 1		Model 2	
	Behavioral Decision Making	Degree of Behavior	Behavioral Decision Making	Degree of Behavior
Livelihood capital	6.6265 ** (2.8423)	2.3223 *** (0.3759)	2.3957 ** (1.2625)	3.143 ** (1.4395)
Ecological cognition	0.9563 *** (0.2177)	0.7163 *** (0.1062)	0.47245 ** (0.2182)	0.7956 *** (0.1780)
Cross-multiplication term			2.6797 ** (2.1801)	0.3172 (0.6144)
Control	Y	Y	Y	Y
Con	−2.7694 *** (0.8303)	0.2732 (0.3056)	−1.3272 (1.1122)	0.1699 (0.4160)
Log-likelihood value	−120.6003		−135.476	
Wald χ^2	133.46 **		152.43 **	

Note: **, and *** indicate significance at the 5% and 1% levels, respectively, and the numbers in parentheses are the standard errors of the coefficients.

Model 1 is the regression result of adding ecological cognition to the baseline model, and its regression coefficients are significantly positive in the first and second stages. This indicates that the level of ecological cognition of farmers can significantly promote farmers' behavioral decision of green production, and enhance the degree of green production of farmers. Model 2 adds the interaction term of ecological cognition and livelihood capital, and the coefficient of the interaction term in the first stage regression is 2.6797 and passes the test at a 5% significance level, indicating that ecological cognition plays a positive moderating role in livelihood capital influencing farmers' green production decision, i.e., the higher the level of farmers' ecological cognition, the more farmers are willing to choose green production under a certain level of livelihood capital. On the one hand, the higher the level of ecological cognition of farmers, the more important ecological environmental protection is to farmers. In this case, farmers can actively search for information about green production, and be motivated to further improve their human and social capital through learning and communication; on the other hand, the higher the level of ecological cognition, the more farmers are informed of environmental protection policies and green production technologies, and farmers' willingness to engage in green production increases. On the other hand, the higher the level of ecological awareness, the more farmers are informed of environmental protection policies and green production technologies, and the more willing they are to produce green.

In the two-stage regression, the coefficient of the interaction term between livelihood capital and ecological cognition has a positive effect on the participation of farmers in green production, but it does not pass the significance test, i.e., the positive moderating effect of ecological cognition on livelihood capital on the degree of green production of farmers is not significant. The possible reason lies in the confliction between the large costs and risks of green production and the ecological cognition of farmers, which measures the subjective willingness and awareness of green production among farmers. However, the degree of green production adoption is mainly limited by a series of objective factors such as economic ability and technical means. Therefore, the moderating effect of farmers' ecological cognition is not significant on the degree of green production influenced by livelihood capital.

5.3. Endogeneity Test

Considering that livelihood capital and green production behavior may be causally related, the endogeneity test is conducted using the instrumental variable method. Referring to the research of Peng and Chen (2022) [46], "the distance between farmers and farmers' markets" (referred to as "market distance") is selected as a tool variable. The closer the farmer's distance to the market, the easier it is to obtain information about ecological cognition and green production, which satisfies the basic requirement that instrumental variables are related to endogenous variables. Meanwhile, there is no direct correlation between farmers' distance to farmers' markets on their participation in green production, and the variable can be considered as an exogenous variable.

The specific test steps are as follows: first, OLS regression is conducted with the social capital composite index as the explanatory variable and the instrumental variable "distance between farmers and the village committee" as the explanatory variable to obtain the fitted values of the endogenous variables. The F-value is 11.857 at the first stage, which is significant at the 1% statistical level and greater than the critical value of 10, indicating that there is no weak instrumental variable problem. Second, the fitted values were included in the two-column model regression as explanatory variables, and Table 5 gives the comparative results of the baseline regression and the second-stage model estimation of the two-column model. Compared with the results of the baseline regression, the effects of livelihood capital on farmers' behavioral decisions and behavioral level of participation in green production are significantly positive after considering the endogeneity issue, but the coefficients are reduced, indicating that the effects of livelihood capital on green production behavior would be overestimated if the endogeneity issue is not considered.

Table 5. Endogeneity test.

Variables	Baseline Regression		Instrumental Variables Approach	
	Behavioral Decision Making	Degree of Behavior	Behavioral Decision Making	Degree of Behavior
Livelihood capital	3.3749 **	2.2241 ***	2.0714 **	2.0057 **
	(1.7215)	(0.3366)	(1.0432)	(1.0008)
Control	Y	Y	Y	Y
Con	0.27413	1.2382	0.8638	1.8844
	(0.3555)	(0.1270)	(0.2326)	(0.1057)
Wald χ^2	118.12 **		106.61 **	
First stage model F-value	11.857 ***			

Note: **, and *** indicate significance at the 5%, and 1% levels, respectively, and the numbers in parentheses are the standard errors of the coefficients.

5.4. Robustness Test

To test the robustness of the results, the Heckman two-step regression method is used in this paper. In order to avoid the problem of multicollinearity, it is necessary to introduce at least one variable that is relevant to farmers' green production behavior decision but not to their degree of green production. In this study, "whether or not to participate in agricultural technology training" is selected as the identifying variable. The regression results are shown in Table 6, Model 3, Model 4, and Model 5, which include livelihood capital, ecological cognition, and the interaction term of the two, respectively. The results show that "whether or not to participate in agricultural technology training" passed the significance test at the 5% level, indicating that this identifying variable is suitable for the analysis of the sample selection model. The inverse Mills ratio coefficients were not significant, indicating that there was no sample selection bias. The effect of livelihood capital on green production behavior was significant in both the behavioral decision regression and the behavioral degree regression. The interaction term of livelihood capital and ecological cognition had a significantly positive effect on the decision of green production behavior, but the effect on the degree of behavior was not significant, which was basically consistent with the results of DHM regression.

Table 6. Robustness test.

Variable	Model 3		Model 4		Model 5	
	Behavioral Decision Making	Degree of Behavior	Behavioral Decision Making	Degree of Behavior	Behavioral Decision Making	Degree of Behavior
Livelihood capital	3.4647 **	0.8995 **	3.173 **	2.0180 ***	3.0101 **	1.8372 *
	(1.7415)	(0.3019)	(1.4395)	(0.4916)	(1.2316)	(1.0554)
Ecological cognition			0.7999 ***	0.4710 **	0.5088 *	0.4097 **
			(0.2380)	(0.2238)	(0.2857)	(0.2072)
Cross-multiplication term					2.8903 **	0.0305
					(1.3324)	(0.0791)
Technical training	0.0882 **		0.4832 *		0.5599 **	
	(0.0361)		(0.2752)		(0.2363)	
Control	Y	Y	Y	Y	Y	Y
Con	0.5212	3.2425 **	1.9801 *	1.5872	1.0995	1.3565
	(0.4051)	(1.5288)	(1.1840)	(1.1122)	(0.9974)	(1.2328)
N	436	366	436	366	436	366
λ	3.014		0.8718		1.095	
	(4.7243)		(0.6337)		(0.7305)	

Note: *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively, and the numbers in parentheses are the standard errors of the coefficients.

5.5. Discussion

We used the DHM to analyze the factors influencing farmers' green production behavior. The results indicate that, as hypothesized, livelihood capital is the basis for farmers' participation in green production, and farmers with higher human and social capital are more likely to make green production decisions and to produce more greenly. This result is consistent with the findings of Wang et al. (2021) using regression models in the southwest [47]. However, the effects of financial, natural, and physical capital on green production behavior decisions were not significant, which is inconsistent with the findings of Wang et al. (2020) in Hubei Province [48]. The latter argued that among livelihood capital, financial capital, natural capital, and physical capital had a significant effect on whether farmers applied organic fertilizer; this difference implies that organic fertilizer application, a green production behavior, is more influenced by financial and geographical conditions. The reason for this is that the cost of organic fertilizer is higher than that of common fertilizer, and land area, topography, and mechanization have a greater impact on fertilizer application efficiency, so farmers pay more attention to financial capital, natural capital, and physical capital when making organic fertilizer adoption decisions.

We also found that ecological cognition enhanced the positive influence of livelihood capital on farmers' green production behavior decisions, which is consistent with the study and theory of Xie et al. (2021) [49]. However, the moderating role of ecological cognition in the extent to which livelihood capital affects farmers' green production behavior was not significant. A possible explanation for our findings is that after farmers make green production decisions, their participation in green agriculture is mainly constrained by objective factors, such as capital, technology, and geographical conditions of farming, and the effect of ecological cognition on the degree of participation is not significant. In fact, the aforementioned regression results on the second stage of farmers' green production behavior indicate that natural capital and financial capital have a significant effect on the degree of green production.

6. Conclusions and Implications

The widespread concern of the Chinese government and society about the rural ecological environment and the quality of agricultural products requires us to better understand the influencing factors of farmers' participation in green production in order to increase their motivation to participate in green production and achieve rural environmental improvement and value-added agricultural products. We propose a literature-based conceptual model to assess the influence of livelihood capital and its subdivisional dimensions on the behavioral decisions and the degree of green production behavior of farm households, while the influence of these objective factors on farm households' behavioral decisions is moderated by farm households' psychological cognition. To investigate the causal relationship between livelihood capital, ecological cognition, and green production behavior, a double-hurdle model was applied to a cross-sectional dataset including 436 surveyed households in 4 counties in Shaanxi Province, China. The following are the main findings of this study, as well as its policy implications and limitations.

This study has some theoretical contributions that provide theoretical insights useful for understanding farm household participation in green production. While most qualitative studies have used the combined value of livelihood capital to analyze its impact on farmers' behavioral decisions [8,11], this study focuses on analyzing its impact on green production behavior in terms of the subdivision dimension of livelihood capital. In addition, our study enriches the theory and evidence of the green production behavior framework by classifying green production behavior into behavioral decisions and degrees of behavior.

Our findings also suggest that farmers' perceptions of environmental protection and green agriculture enhance the positive impact of livelihood capital on green production behavior. Thus, increasing the importance farmers place on rural ecology may significantly increase the likelihood of farmers adopting green production. Local governments should

give priority to improving farmers' ecological cognition, such as establishing an incentive mechanism for green production, strengthening publicity and guidance on ecological environmental protection and green agricultural technologies, making farmers effectively aware of the hazards of ecological degradation and the value of green agriculture, enhancing farmers' role identity and sense of responsibility to participate in green production, and promoting a social atmosphere in rural areas that values the ecological environment.

Another important insight from our study is that broadening the channels for farmers to learn green agricultural technologies can improve their human and social capital, as well as enhance their ecological awareness, which is an important initiative to promote their green production behavior. Through a combination of "online" and "offline" diversified green agricultural field guidance and technical training, we can improve rural residents' access to green agricultural technologies and promote their participation in green agricultural production.

Overall, our findings emphasize the importance of livelihood capital and ecological awareness for farmers' participation in green agriculture. Despite the findings and implications of this study, it also has several limitations. On the one hand, the sample data were cross-sectional and could only measure farmers' livelihood capital, cognition, and behavior in a certain period, i.e., the findings reflected static relationships among variables and could not reflect dynamic changes in farmers' production behavior; follow-up investigations of farmers' green production behavior could try to use time-series data. On the other hand, limited to the research data, the impact of livelihood capital and ecological cognition on the performance of green production behavior was not further analyzed, which is both a shortcoming and a direction for future research.

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