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Triple-hurdle model analysis of aquaculture farmers' multi-stage willingness to participate in green and healthy aquaculture actions in China: based on ecological cognition and environmental regulation perspectives

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Implementing the action of green and healthy aquaculture is an important measure to ensure the stable and secure supply of crucial agricultural products and promote the green and high-quality development of the fishing industry in China. This article divides the willingness to participate in the green and healthy aquaculture actions (GHAAs) into three stages: whether to participate, mode of participation, and degree of participation based on the dynamic decision-making process of the farmers. Based on micro survey data of aquaculture households in Zhejiang Province, this paper applies the Triple-Hurdle model to analyze the effect of ecological cognition and environmental regulation on multi-stage participation willingness, with a particular emphasis on exploring the differences in participation willingness between two types of green aquaculture methods, traditional and emerging technologies. The results show that ecological cognition has a positive promoting effect on the willingness to participate in actions and the degree of willingness to participate in both types of technological methods, the constrained environmental regulation policies significantly positively affects the degree of willingness to participate in traditional technological methods, and the incentive environmental regulation policies significantly positively affects the willingness to choose emerging technological methods and its degree of willingness to participate. The analysis of the regulatory effect of environmental regulation shows that constrained regulation policies can enhance the willingness of high ecological cognition farmers to participate in actions, while incentive policies are helpful for high ecological cognition farmers' adoption willingness of emerging green production technology. In addition, there are scale and intergenerational differences in the effects of ecological cognition and environmental regulation on farmers' willingness to participate in actions.

KEYWORDS

aquaculture farmers, ecological cognition, environmental regulation, green and healthy aquaculture actions, multi-stage adoption willingness

1. Introduction

Since the reform and opening up, China's aquaculture industry has made leaps and bounds, becoming the world's largest aquaculture country, but the quality and safety of aquatic products and the resources and environmental problems brought about by aquaculture have not been effectively solved. To this end, China's Ministry of Agriculture and Rural Affairs and ten other ministries and commissions jointly issued in 2019 the first guidance document since the founding of the country, endorsed by the State Council, specifically for the aquaculture industry, "Several Opinions on Accelerating the Green Development of the Aquaculture Industry." Since then, on March 30, 2020, the Ministry of Agriculture and Rural Affairs specially issued the "Notice from the General Office of the Ministry of Agriculture and Rural Affairs 'Five Actions' Concerning the Implementation of the Green and Healthy Aquaculture in 2020 "(hereinafter referred to as the "Five Actions"), put forward five action plans including the promotion of ecological and healthy aquaculture mode, the promotion of aquaculture tail water treatment mode, the reduction of aquaculture drug, the replacement of juvenile miscellaneous fish with compound feed and the improvement of the quality of aquaculture seed industry, the greening and upgrading of aquaculture at a national level has thus kicked off. As the "main force" of aquatic production, aquaculture farmers scientifically regulate their production behavior, which is the crux link to realizing the green development of aquaculture from the source. However, in reality, influenced by smallholder consciousness, farmers are often reluctant to change their traditional production models, especially in aquaculture characterized by high input and risk (Han et al., 2007). Therefore, it is of great practical importance to explore the mechanisms influencing the participation in green and healthy aquaculture actions (GHAAs) by aquaculture farmers.

Studies have shown that the green production behavior of aquaculture farmers can be affected by many intrinsic and extrinsic factors. Among them, the internal factors are mainly regarding the resource endowment of the farmers. Resource endowment is a collection of various knowledge, cognitive abilities, and technical reserves that farmers innately possess or acquired accumulation that can be used for production and living, and can be classified into two types: non-physical resource endowment and physical resource endowment (Schreinemachers et al., 2017; Zhao et al., 2022). Studies have shown that individual characteristics such as farmers 'education level and green cognition level, as well as social capital such as social norms and social networks, are the prime non-physical resources that affect farmers 'green production behavior (Chen and Fang, 2011; Joffer et al., 2019). At the same time, the implementation of green production usually requires additional capital, equipment, and human input, while sufficient endowments of physical resources such as labor and capital are also necessary for farmers to choose green production behavior (Jin et al., 2022; Zhu and Deng, 2022). The external factors affecting the green production behavior of farmers are mainly based on various intervention policies formulated by the government. Information asymmetry is considered the fundamental reason why aquaculture farmers do not take the initiative to change their extensive production behavior. Specifically, farmers may be reluctant to implement pro-environmental behavior because they do not understand the hazards of environmental pollution, the benefits of environmental protection, and the use of green production technology (Xie et al., 2021). Reasonable intervention policies can effectively facilitate information transfer and guide pro-environmental behavior to develop in an orderly manner. Some studies have analyzed the effects of restrictive policies such as aquaculture product quality supervision and effluent regulation concerning the pro-environmental aquaculture behavior of aquaculture farmers. Some studies have also evaluated the effect of incentive-based policies such as green production knowledge dissemination, technical training, and government subsidies on the clean environmental behavior of aquaculture farmers (Li and Xu, 2018).

The above studies have examined the factors influencing aquaculture farmers' green production behavior from different perspectives, but there is still some room for expansion. In terms of research content, previous studies on green production behavior in aquaculture have focused on traditional green technology (TGT) models such as pesticide reduction and reduction of aquaculture density, while little attention has been paid to emerging green technology (EGT) methods such as feed substitution and aquaculture tailwater management. Currently, the connotation and requirements of green and healthy aquaculture have undergone significant changes. It not only demands the assurance of the quality and safety of aquatic products but also emphasizes the environmental friendliness and resource conservation in the aquaculture process (Tang et al., 2014). To this end, in 2020, China's Ministry of Agriculture and Rural Affairs proposed the "Five Actions," which include not only TGT methods such as reducing the use of drugs and controlling aquaculture capacity but also incorporate EGT methods such as feed substitution and aquaculture wastewater treatment. The replacement of juvenile miscellaneous fish with compound feed (feed substitution) is significant to alleviate the decline of offshore fishery resources (Lei, 2010; Liu and Peng, 2021), and the implementation of aquaculture tailwater treatment can improve the environmental quality of surrounding waters (Zhang and Ma, 2020). In reality, farmers often have little incentive to respond to such green production models with positive resource and environmental externalities (Hukom et al., 2020). In these regards, this paper examines the willingness of farmers to adopt traditional and emerging green production technology concerning the "Five Actions" program promulgated and implemented by the Ministry of Agriculture and Rural Affairs, to make up for the lack of existing research. Simultaneously, constrained by knowledge structure and information asymmetry, it is more difficult for farmers to form accurate cognitive perception and evaluation regarding novel green production technologies, which in turn affects their willingness to adopt. Therefore, it is necessary to build upon the new concepts and policies of modern green and healthy aquaculture to explore the differences in farmers' willingness to choose between traditional and emerging green technologies, and dig into the underlying influencing factors. This will provide references for identifying the key actions for promoting green and healthy aquaculture and enhancing the efficiency of technology promotion.

Based on the current background of China's GHAAs, this paper uses micro-survey data of aquaculture farmers in Zhejiang Province, China, and analyzes the impact of ecological cognition and environmental regulation on the willingness of aquaculture farmers to participate in GHAAs using the Triple-Hurdle model. The paper focuses on exploring the differences in willingness to participate in traditional and emerging green technologies and further discusses the regulatory role of the environmental regulation. The possible marginal contributions of this paper include three aspects. Firstly, unlike most previous studies that simply divide the willingness to participate in green production into a binary variable of "yes or no," this paper divides the decision-making process of aquaculture farmers' participation in green and healthy aquaculture into three dynamic decision-making stages of "whether to participate," "mode of participation" and "degree of participation," which more realistically reflects the decision-making process of aquaculture farmers and improves the reliability and reference value of the conclusions. Secondly, based on the GHAAs plan, this paper examines the differences in the willingness of aquaculture farmers to choose traditional and emerging green production technologies, making up for the research gap on emerging green production technologies such as feed substitution and aquaculture wastewater treatment, and providing strong references for current policy promotion and practice. Finally, this paper incorporates two categories of factors, ecological cognition and environmental regulation, into the analysis framework of green production intention, revealing the common mechanism of interaction between intrinsic and extrinsic factors. This further enriches and develops the research on the influencing factors of green production intention.

2. Theoretical analysis

2.1. The influence of ecological cognition and environmental regulation on participation willingness in GHAAs

Whether farmers participate in green and healthy aquaculture can be viewed as a decision-making problem for farmers to choose new technologies with significant positive externalities. As rational economic agents, farmers' choice of new production technology is a decision made by comparing the costs and benefits of the old and new technology to maximize profit (Yu et al., 2017). With the propagation and implementation of the green development concept, some scholars point out that farmers have ecological as well as economic rationality and can obtain public utility from agricultural non-economic functions (Yan et al., 2017). Farmers usually become concerned about ecological issues after their subsistence needs are met and incorporate eco-efficiency goals into their behavioral decisions (Hukom et al., 2020). Conducting green and healthy farming is conducive to food security and eco-environmental protection, and can satisfy farmers' demands for social and environmental benefits and other public interests, thus increasing their public utility. Therefore, farmers' participation willingness in GHAAs depends on maximizing their total utility after the sum of economic and ecological benefits.

According to the theory of planned action, cognition is the basis of behavior, and personal cognition determines preferences, which then influence final behavioral decisions (Cooke and Sheeran, 2004). Ecological cognition is an individual's basic understanding of the ecological environment and mastery of relevant ecological knowledge and technology, which can reflect individual ecological values, environmental perception ability, and the level of green production technology reserves (Zhang et al., 2019). Traditional farming practices can lead to eutrophication and drug contamination of the water body, which affects farmers' profits (Bbxa et al., 2021). When farmers can perceive the harm that traditional farming models may cause to aquatic product quality and the watershed environment, they are inclined to adopt green production technology driven by economic and ecological rationality (Li et al., 2020). In addition, the more knowledgeable farmers are about green production and technology, the more they can realize the importance of green farming and discover the possible economic and ecological benefits of traditional farming models, thus being more inclined to participate in green production (Obubuafo et al., 2008). Based on these, the following hypothesis is proposed:

> Hypothesis *H1*: Ecological cognition had a significant positive effect on farmers' participation willingness in GHAAs.

Farmers' production decisions are aimed at maximizing individual utility, but in practice, they are also constrained by external policies. Farmed tailwater treatment has typical positive environmental externalities and may face an imbalance between marginal private benefits and marginal social benefits. The implementation of green production usually involves additional capital and labor inputs, resulting in lower marginal private returns, but the marginal social benefits from green products may be higher. At this point, the government must internalize the externality problem by setting constraints and incentives to correct the marginal private costs or benefits and maximize the social benefits (Li et al., 2019). The restrictive environmental regulation policy is mainly based on pollution monitoring and penalties. Under the restrictive policy scenario, the probability of government penalties for excessive drug use and tailwater pollution by farmers increases, and the cost of not implementing green farming increases for farmers, who are driven by economic rationality to comply with regulatory objectives and choose to participate in green production (Kim et al., 2010). Incentive environmental regulation policies are mainly focused on green production subsidies. Financial subsidies can reduce the acquisition costs of farmers to participate in green production and increase their private benefits, thus promoting the implementation of green production by farmers (Chen and Mu, 2022). Based on these, the following hypothesis is proposed:

> Hypothesis *H2*: Restrictive and incentive environmental regulation policies have a significant positive effect on farmers' participation willingness in GHAAs.

Aquatic products pollution and environmental pollution caused by traditional farming models are typical negative externality problems, in the reality that responsibility is hard to identify and define, even if farmers recognize the hazards of traditional farming models, under the "free ride" motive usually still do not choose to take the initiative to participate in green production. Therefore, it is necessary to strengthen the ecological cognition of farmers through environmental regulation policies such as subsidies, supervision, and penalties to internalize externalities and promote their transformation from green cognition to green behavior. According to situational cognitive theory, different contexts may have an impact on the relationship between farmers' cognition and behavior (Guo and Zhao, 2014). Policy and institutional contexts are vital external contexts faced by farmers. It has been shown that providing both incentive and restrictive environmental regulations positively moderate the relationship between farmers' ecological cognition and green production behavior (Huang et al., 2020; Luo et al., 2022). In the environmental regulation context, farmers with a high level of ecological cognition are more willing to put their green cognition into practice under certain constraints and incentives to obtain the maximum individual utility. Based on these, the following hypothesis is proposed:

> Hypothesis *H3*: Restrictive and incentive environmental regulation policies can enhance the effect of ecological cognition on farmers' participation willingness in GHAAs.

2.2. The dynamic decision-making process of participation willingness in the GHAAs

According to the theory of behavioral stage change, behavioral decision-making is not a static event, but a dynamic multi-stage process (Prochaska and Diclemente, 1983). The complete green production decision process contains multiple stages from whether to decide to participate to decide the degree of participation (Dimara and Skuras, 2003; Doss, 2010; Chen et al., 2020). For green aquaculture, the first stage is for farmers to decide if they would like to participate in green and healthy aquaculture. Farmers usually have a high reliance on long-established aquaculture experience in the production and operation process (Figure 1). However, under traditional aquaculture models, high aquaculture densities, excessive medication, and tailwater discharge may cause pest and disease problems, affecting the yield and quality of aquatic products, as well as damaging the surrounding ecological environment. In this context, driven by economic and ecological rationality, farmers will decide whether to change their traditional aquaculture practices and adopt green production technology based on maximizing their utility. For farmers who are willing to participate, the second stage requires them to decide on the specific technical mode to adopt for green farming, including two methods: TGT and EGT. Furthermore, in the third stage, for those farmers who choose to adopt a specific green technology, it is necessary to further consider to what extent they are willing to apply these green technologies. This can be measured by investigating the cost that farmers are willing to invest in adopting green technology.

3. Methods and materials

3.1. Methods

According to the previous theoretical analysis section, the aquaculture farmers decisions related to green production technology adoption could be seen to be a dynamic stage process: whether to participate, mode of participation, and degree of participation. To explore the three-stage participation willingness and the associated influencing factors, a Triple-Hurdle model was employed for the empirical analysis. The Triple-Hurdle model can be used to analyze three-stage farmer behavior decisions and address all possible conditionally uncorrelated errors (Burke et al., 2015; Yang et al., 2020). The complete triple-hurdle model is expressed as:

$$y_1 = x_1(EV, CV) \tag{1}$$

$$y_2 = x_2(EV, CV) \tag{2}$$

$$y_3 = x_3(EV, CV) \tag{3}$$

$$y_4 = x_4(EV, CV) \tag{4}$$

In Eqs. (1)–(4), y1 is the binary variable of aquaculture farmers' willingness to participate in GHAAs, y2 is a binary variable of farmers' willingness to choose green technology mode (including TGT and EGT), y3 and y4 are the degree of willingness to adopt TGT and the degree of willingness to adopt EGT, respectively. x1, x2, x3, x4 are sets of explanatory variables, where EV is the core explanatory variable and CV is the control variable. Finally, the integration of the formulas

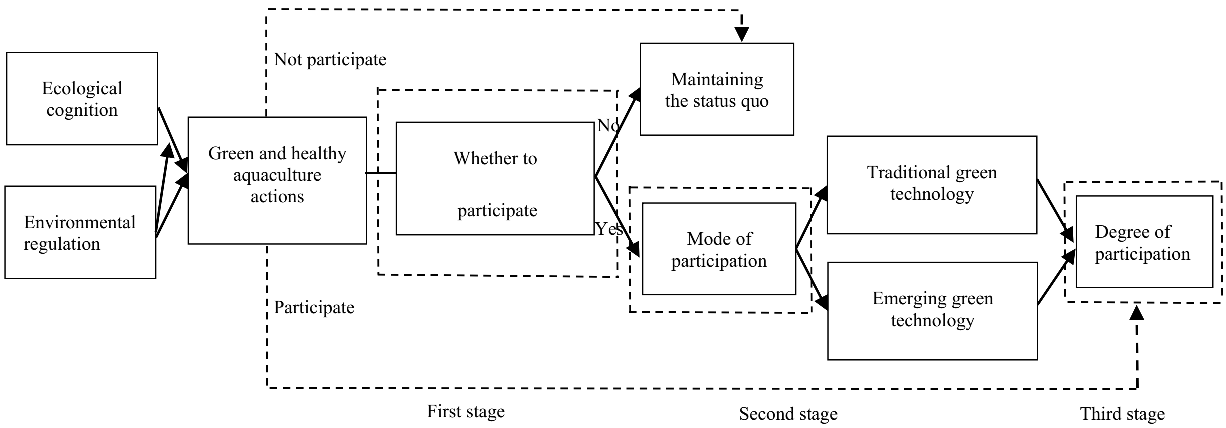

FIGURE 1
Theoretical framework.

established the triple-hurdle model likelihood function for each aquaculture farmer i:

$$f\left(y|\alpha,,,,,\beta,,,,,\delta_1,,,,,\delta_2,,,,,\sigma_1,,,,,\sigma_2\right)=\left[1-\Phi\left(\alpha x_1\right)\right]^{1[y_i=0]}\times\left[\Phi\left(\alpha x_1\right)\left\{\begin{array}{l}\left[\dfrac{\Phi\left(\beta x_2\right)\phi\left(\dfrac{\ln y_3-\delta_1 x_3}{\delta_1}\right)}{\sigma_1 y_3}\right]^{1[y_2=0]}\\\left[\dfrac{\Phi\left(\beta x_2\right)\phi\left(\dfrac{\ln y_4-\delta_2 x_4}{\delta_2}\right)}{\sigma_2 y_4}\right]^{1[y_2=1]}\end{array}\right\}\right]^{1[y_i=1]} \quad (5)$$

In Eq. (5), $\Phi(\cdot)$ is the cumulative density function of the standard normal distribution, α is the parameter of the first decision stage explanatory variable x1, β is the parameter of the second decision stage explanatory variable x2, δ1 and δ2 are the parameters of the two variance explanatory variables x3 and x4 in the third decision stage, and σ1 and σ2 denote the standard deviation of the corresponding truncated normal distribution. $1[\cdot]$ is an indicator function. If the expression given in brackets is true, the value is 1 and 0 otherwise. To address the sample selection bias, the inverse Mills ratio (IMR) was constructed using the results of the previous regression stage, respectively, and the IMR was added to the latter model for regression as a control variable along with other explanatory variables to obtain the estimated parameter W of the IMR. If W is not significant then the model is not subject to sample selection bias, otherwise IMR needs to be used as a control variable to correct for the sample selection problem. In addition, to ensure the identifiability of the model estimates, the previous stage equations need to contain at least one exclusive restrictive variable that does not appear in the latter equations.

3.2. Data source

The data in this paper are from a field study conducted by the research team from July to November 2021 in Zhejiang Province, China, among aquaculture farmers. Aquaculture includes pond aquaculture, net cage aquaculture, factory aquaculture, raft aquaculture and other modes, and the technical and economic characteristics of different aquaculture modes vary greatly. In this study, only pond aquaculture farmers were selected as respondents. According to the China Fisheries Statistical Yearbook, the proportion of pond aquaculture production in China accounted for about 48.84% of the total aquaculture production in 2019. Moreover, Pond aquaculture is also the hardest hit by excessive drug use and environmental pollution. Therefore, it is representative and relevant to use pond aquaculture farmers as the study object.

Zhejiang is one of the major provinces of pond aquaculture in China, with the second-highest production of marine pond aquaculture and the seventh-highest production of freshwater pond aquaculture in the country, according to the China Fisheries Statistical Yearbook. Zhejiang has consistently served as a leading demonstration area for implementing central policies. Following the requirements put forth by the central government and the Ministry of Agriculture and Rural Affairs to promote green development in aquaculture, Zhejiang took the initiative to formulate an action plan for green development in aquaculture and subsequently promoted the adoption of green and healthy aquaculture practices throughout the province. Considering the research purpose and research maneuverability, four major aquaculture production regions in Zhejiang Province, Ningbo, Hangzhou, Huzhou, and Taizhou, were chosen as the survey regions (Figure 2). On this basis, non-probability sampling methods were used to further determine the districts and villages for sample collection. Based on the geographical information map of the distribution of farmed water resources in Zhejiang Province (Chen, 2017), the districts and counties with relatively large pond aquaculture areas and production were identified among the above four regions, and six districts and counties were finally identified, namely Xiangshan and Ninghai counties in Ningbo, Qiantang and Xiaoshan districts in Hangzhou, Deqing County in Huzhou, and Sanmen County in Taizhou. A total of 410 questionnaires were distributed in the formal survey, and 370 valid questionnaires were obtained after eliminating invalid ones.

3.3. Variable selection

Dependent variable. The dependent variable in this paper is the willingness of farmers to participate in GHAAs. The decision-making process of aquaculture farmers' green technology adoption contains three stages, thus three dependent variables were set in this paper. The specific meanings and assigned values of the dependent variables are shown in Table 1. The willingness to participate or not to participate in the first decision stage was a dichotomous variable. During the survey, the four main green production technology models were first explained to the farmers, and then they were asked whether they were willing to participate in actions. In the second stage, farmers who were willing to participate actions were asked whether they would prefer to adopt TGT methods or EGT methods. Low-density aquaculture and drug reduction are green technology modes that have been promoted for a long time before the introduction of the "Five Actions," and these two types of technologies are defined as TGT methods in this study. The feed substitution and tailwater treatment are the key green technologies to be promoted by the government after the formulation of the "Five Actions" in 2020, and these two types of technologies are defined as emerging green technologies in this study. In the third stage, farmers who chose different technological methods were asked how much they were willing to invest in the chosen green technology.

Core explanatory variables. The core explanatory variables of this study are ecological cognition and environmental regulation. With reference to existing studies, ecological cognition can be divided into two variables: pollution perception and benefit perception. The questionnaire was designed to assess the pollution perception through the question "Do you agree that traditional aquaculture methods cause ecological pollution and contamination of aquatic products." The benefit perception was assessed by the question "Do you agree that green production technology can improve the

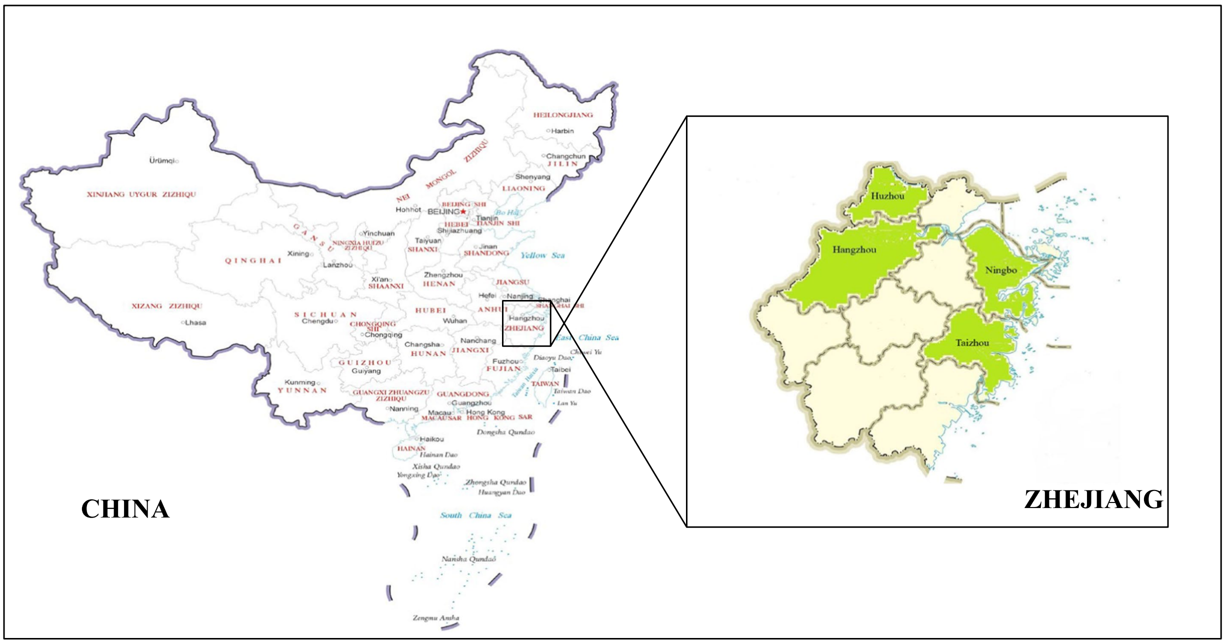

FIGURE 2
Map of Zhejiang Province showing the study area.

TABLE 1 Variable definition, assignment and descriptive statistics.

Variable name		Variable meaning and assignment	Mean value	Standard deviation
Willingness to participate in GHAAs	Whether to participate	Willing to participate in actions = 1; Unwilling to participate in actions = 0	0.722	0.448
	Mode of participation willingness	Prefer to adopt EGT = 1; Prefer to adopt TGT = 0	0.403	0.490
	Degree of participation	Logarithmic value of willingness to invest in the adoption of green technologies (CNY/hm^2 year)	10.902	0.670
Ecological cognition		Mean values of pollution perception and benefit perception scores	2.312	0.830
Environmental regulation	Restrictive environmental regulation policies	Policy strength: Very low = 1; Low = 2; Moderate = 3; High = 4; Very high = 5	3.582	0.627
	Incentive environmental regulation policies	Policy strength: Very low = 1; Low = 2; Moderate = 3; High = 4; Very high = 5	2.382	0.625
Individual characteristics	Age	Actual age / years	50.032	7.489
	Gender	Female = 0; Male = 1	0.773	0.419
	Education level	Elementary school and below = 1; Middle school = 2; High school = 3; College and above = 4	1.635	0.657
	Aquaculture experience	Years engaged in aquaculture / years	9.544	3.638
Household characteristics	Number of household laborers	Number of laborers in the household / person	2.478	0.816
	Annual household income	Total annual household income level / 10,000 CNY	16.659	11.931
	Aquaculture scale	Actual area of ponds operated by aquaculture households/hm^2	2.713	2.173
Social organization	Cooperatives	Not joined = 0; Joined = 1	0.295	0.456
	Village cadres	No one in the family is a village cadre = 0; Someone in the family is a village cadre = 1	0.111	0.314
Regional characteristics	Demonstration district (county)	Yes = 1; No = 0	0.568	0.495
Exclusive restrictive variables	Disease and pollution losses	Very small loss = 1; Small loss = 2; Medium loss = 3; Large loss = 4; Very large loss = 5	3.097	0.931
	Technology training experience	Yes = 1; No = 0	0.273	0.445

ecological environment and the quality of aquatic products." Both variables were measured using the Likert 5-point measure. Both variables were measured using the Likert 5-point scale. Then, the average of two variables, pollution perception and benefit perception, was taken as the score of ecological cognition variable. Environmental regulation is divided into two categories: restrictive environmental regulation policies and incentive environmental regulation policies. Drawing on existing studies, farmers' subjective perceptions of environmental regulation policies were used to assess policy intensity, i.e., to obtain farmers' evaluations of the strength of penalties for aquaculture pollution behavior and the strength of subsidies for green production.

Control variables. The following control variables are selected. First, individual characteristics variables, including age, gender, education level, and aquaculture experience. Second, household characteristics variables, including the number of household laborers, annual household income, and aquaculture scale. Third, social organization variables, including cooperatives and village cadres. The fourth is a regional variable, measured by whether the sample location is a national-level fishery health aquaculture demonstration district (county). In 2013, the Ministry of Agriculture and Rural Affairs decided to organize the establishment of national-level fishery health aquaculture demonstration district (county). The aim was to expand the scale of the demonstration of healthy aquaculture practices and ensure the quality and safety of aquaculture products. According to the list published by the Ministry of Agriculture, among the six sample areas selected for this study, Xiangshan County, Deqing County and Sanmen County belong to the national-level fishery health aquaculture demonstration district (counties), while the other three districts and counties do not. Fifth is the exclusive restrictive variable. Aquaculture diseases and environmental pollution can reduce farmers' profitability and lead to farmers' willingness to shift their original production methods and increase their willingness to adopt green production technologies, but they do not directly influence farmers' willingness to choose different green production technology model (traditional green production technology or emerging green production technology). Therefore, disease and pollution losses were used as an exclusive restrictive variable in the second stage decision equation. In the questionnaire, we designed the question "How much revenue is lost due to aquaculture diseases and environmental pollution in daily production and business activities "to measure this exclusive restrictive variable. Farmers have limited knowledge of green production technologies, especially emerging technologies such as compound feed use and aquaculture tailwater treatment. Relevant technical training experiences can help farmers better understand and master emerging green production technologies, which in turn may influence their willingness to choose the technical model, but have no direct effect on the adoption degree willingness. Therefore, drawing on existing research (Yang et al., 2020), we used technology training experience as an exclusive restrictive variable in the third stage of the decision equation. The value of the technology training experience variable was measured by the question "whether or not you have participated in training on emerging green production technologies such as compound feed use and aquaculture tailwater treatment."

The definitions and descriptive statistics of each variable are shown in Table 1.

4. Results

4.1. Analysis of the effects of ecological cognition and environmental regulations on participation willingness in GHAAs

To exclude possible covariance problems between variables, the variance inflation factor method was used to test for multiple covariances in all independent variables. The results show that the maximum variance inflation factor VIF is 1.81, which is much smaller than 10, so there is no multicollinearity problem in the model. Based on the triple-hurdle model, Stata software was used to estimate the data. First, two regression models were established by introducing two core explanatory variables, ecological cognition, and environmental regulation, respectively. Then, the third regression model was established by introducing ecological cognition and environmental regulation simultaneously. The coefficients and significance of the variables in the three models were found to be consistent, which means that the model estimation results were relatively robust. Table 2 shows the estimation results of introducing both ecological cognition and environmental regulation variables, and the subsequent analysis is based on these results. The results of the first-stage probit model estimation showed that the disease and pollution losses variable was significant at the 5% statistical level and thus was appropriate as an exclusive restrictive variable. Further, to test the existence of sample selection bias, the IMR obtained from the first-stage probit regression was brought into the second-stage regression model as a control variable. The results showed that the regression coefficient of IMR was 0.558 with $p > |z| = 0.385$, which did not pass the significance test, indicating that there was no sample selectivity bias and no correction was required.

Ecological cognition had a positive effect on farmers' willingness to participate or not to participate in the first stage and on their willingness to choose modes in the second stage, and had a significant positive effect on the degree of participation in EGT methods in the third stage, while it did not have a significant effect on the degree of participation in TGT methods. When farmers can accurately perceive that traditional aquaculture practices may cause environmental pollution and affect the quality of aquatic products, they will be willing to change their traditional production methods. In addition, farmers' perceptions of the potential benefits of green technology also contribute to the willingness of farmers to adopt it. The higher the level of ecological cognition, the more farmers tend to choose EGT and are also willing to invest more money in it. The possible reason is that the higher the level of ecological cognition, the higher the demand of farmers for public benefits such as ecological protection, and thus the higher the preference for emerging technological methods with typical positive resource-environmental externalities such as compound feed use and aquaculture tailwater treatment. The above results verified hypothesis *H1*.

Among the environmental regulation variables, restrictive policies had a significant positive effect on the willingness to participate or not to participate in the first stage and the degree of participation of TGT methods in the third stage. Increased environmental regulation and pollution penalties by the government mean higher costs for farmers for illegal drug use and tailwater discharge, which will increase farmers' willingness to adopt green technology. Restrictive policies significantly increased the willingness of farmers to adopt TGT

TABLE 2 Estimated results of the impact of ecological cognition and environmental regulation on participation willingness in GHAAs.

Variable	First stage (whether to participate)	Second stage (mode of participation)	Third stage (degree of participation)	
			TGT	EGT
Core explanatory variables				
Ecological cognition	0.236* (0.133)	0.432*** (0.120)	−0.011 (0.062)	0.093* (0.055)
Restrictive environmental regulation policies	0.907*** (0.130)	0.035 (0.130)	0.358*** (0.062)	0.072 (0.069)
Incentive environmental regulation policies	0.785*** (0.151)	0.413*** (0.156)	0.074 (0.076)	0.376*** (0.087)
Control variables				
Age	0.018 (0.014)	−0.017 (0.012)	−0.013** (0.006)	0.005 (0.007)
Gender	0.633*** (0.232)	0.271 (0.279)	−0.035 (0.112)	−0.388** (0.163)
Education level	−0.038 (0.166)	0.029 (0.146)	−0.06 (0.063)	−0.09 (0.101)
Aquaculture experience	0.159 (0.149)	−0.165 (0.119)	−0.028 (0.059)	0.016 (0.066)
Number of household laborers	−0.522*** (0.131)	0.410*** (0.136)	−0.017 (0.074)	0.02 (0.075)
Annual household income	−0.005 (0.007)	−0.01 (0.008)	−0.001 (0.003)	0.006 (0.005)
Aquaculture scale	0.018 (0.335)	0.131 (0.311)	0.182 (0.164)	0.027 (0.146)
Cooperatives	−0.119 (0.239)	−0.145 (0.218)	0.942 (0.101)	0.559*** (0.126)
Village cadres	0.429 (0.335)	−0.874*** (0.322)	0.135 (0.120)	0.208 (0.205)
Demonstration district (county)	0.477** (0.219)	0.340* (0.197)	0.084 (0.093)	0.148 (0.118)
Exclusive restrictive variables				
Disease and pollution losses	0.258** (0.120)			
Technology training experience		0.701*** (0.263)		
Constant	−5.814*** (0.972)	−2.727*** (0.967)	3.632*** (0.467)	2.804*** (0.544)
Log-likelihood	−116.971	−150.247	−101.357	−86.858
LR chi2	203.70***	67.99***	45.48***	51.71***
Observations	370	267	144	123

***, **, *Significant at the 1, 5, and 10% level. Standard errors in parentheses.

methods. The possible reason is that, before the Ministry of Agriculture promoted the "Five Actions" for green and healthy aquaculture, the long-term environmental regulation policy for aquaculture was mainly focused on the control of aquaculture capacity and regulation of drug use, which led to more pressure on farmers not to participate in TGT methods.

Incentive policies have a significant positive effect on the willingness to participate in the first stage, the willingness to choose the methods in the second stage and the willingness to invest in the extent of emerging green technologies in the third stage. The participation in GHAAs usually requires additional capital and manpower investment, which increases production and operating costs. Green production policy subsidies can directly relieve farmers' capital investment pressure, compensate for the external costs of adopting green technology, enhance the level of returns, and thus increase farmers' willingness to adopt it. The estimation results of the second and third stages indicated that the higher the farmers' perception of the incentive policy, the more inclined they were to choose to adopt the EGT and also to invest more money in the EGT. The possible reason is that, compared with the TGT method involving changes in aquaculture density and drug use habits, the adoption of EGT methods such as compound feed substitution and tailwater treatment does not involve changes in production habits, but mainly generates additional costs for the purchase of feed and facilities. Therefore, when farmers perceive that the subsidy policy can compensate for the adoption cost and improve the net income, they will be more willing to choose and invest more money to adopt the EGT. Hypothesis *H2* was verified.

4.2. Analysis of the interaction effect between ecological cognition and environmental regulation

According to situational cognitive theory, external contexts, especially policy contexts, may have an impact on the relationship between farmers' cognition and behavioral intentions (Guo and Zhao, 2014). For farmers with a high level of ecological awareness, the imposition of some environmental regulation policies can effectively stimulate their willingness to green production. To this end, this paper further explored the effect of the interaction between ecological cognition and environmental regulation on farmers' participation willingness in GHAAs. The interaction terms of ecological cognition with restrictive and incentive policies were introduced for regression analysis. The results are shown in Table 3.

The farmers' willingness in the first participation decision stage was significantly and positively influenced by the interaction term of ecological cognition and restrictive environmental regulation policies.

TABLE 3 Impact of the interaction between ecological cognition and environmental regulation on participation willingness in GHAAs.

Variable	First stage (whether to participate)	Second stage (mode of participation)	Third stage (degree of participation)	
			TGT	EGT
Ecological cognition	0.255* (0.140)	0.356** (0.120)	−0.007 (0.072)	0.034 (0.068)
Restrictive environmental regulation policies	1.161*** (0.169)	0.041 (0.130)	0.349*** (0.068)	0.090 (0.068)
Incentive environmental regulation policies	0.927*** (0.172)	0.394** (0.156)	0.082 (0.081)	0.306*** (0.089)
Ecological cognition × Restrictive environmental regulation policies	0.619*** (0.233)	0.104 (0.156)	−0.033 (0.087)	−0.028 (0.073)
Ecological cognition × Incentive environmental regulation policies	0.218 (0.217)	0.171 (0.193)	−0.021 (0.104)	0.246** (0.099)
Other variables	Control	Control	Control	Control
Log-likelihood	−112.034	−149.588	−101.270	−83.845
LR chi2	213.58***	69.31***	45.65***	57.74***
Observations	370	267	144	123

***, **, *Significant at the 1, 5, and 10% level. Standard errors in parentheses.

For farmers with a high level of ecological cognition, improving the strength of environmental supervision, pollution penalties, and other restrictive policies can help guide them to participate in actions. Farmers with a high level of ecological awareness, i.e., ecological-social rationality, are familiar with the hazards of aquaculture pollution and the benefits of green production, and restrictive policies can further stimulate the endogenous motivation of farmers to green production. The interaction term between ecological cognition and incentive policies had a significant impact on the degree of participation in EGT methods in the third stage. Government subsidies for green production can compensate farmers for the acquisition costs when implementing emerging green technologies such as compound feed use and tailwater treatment, improve expected returns, and solve the problem of farmers with high ecological cognition reducing green production inputs due to cost–benefit considerations. Hypothesis *H3* was verified.

4.3. Heterogeneity analysis

Previous studies have shown that differences in production scale and age of farmers may affect their ecological cognition and policy perceptions, which in turn affect their willingness to adopt green production technologies (Li et al., 2020; Chen and Mu, 2022). Referring to the “Criteria for the Identification of Other Producers of Agricultural Products of a Certain Scale” issued by the Zhejiang Provincial Department of Agriculture, farmers operating aquaculture with an area of 2 hm2 and above were classified as large-scale farmers, and those below 2 hm2 were classified as small-scale farmers. The division of generational differences was referred to existing studies (Duan et al., 2022), which categorized farmers born in 1975 and before as older generation farmers and those born after 1975 as new generation farmers.

Scale heterogeneity. The estimation results in Table 4 show that ecological cognition had a significant effect on the willingness to participate in actions in the first stage for large-scale farmers, while the effect was not significant for small-scale farmers. Large-scale farmers are more likely to achieve economies of scale and lower implementation costs when adopting green production technologies, while small-scale farmers may still be reluctant to adopt green production technologies due to cost–benefit considerations, even if they have a high level of ecological cognition. This research result is consistent with the findings of studies focused on green production behaviors among small-scale aquaculture farmers (Phong et al., 2021). In terms of environmental regulation, restrictive policies had a significant positive effect on the participate in EGT methods in the third stage of large-scale farmers, while the effect on small-scale farmers was not significant. The impact of incentive policies on the willingness of large-scale farmers to participate in actions was only reflected in the first stage, while the impact on small-scale farmers was felt throughout the three decision-making stages.

Intergenerational heterogeneity. The estimated results in Table 5 show that ecological cognition had a significant positive effect on the willingness to choose green technology methods in the second stage for both generations of farmers, and a non-significant effect on the willingness in the other stages. In terms of environmental regulation, the impact of restrictive policies on the willingness of farmers to participate in actions was consistent between the two generations, while the impact of incentive policies on the willingness of farmers in the second and third participation decision stages differed significantly between the two generations. Specifically, the incentive policies were able to significantly increase the willingness of the new generation of farmers to adopt TGT, while the effect on the older generation of farmers was not significant. This conclusion is consistent with the research findings of Pannell and Claassen (2020) and Guo et al. (2022). Incentive policies had a significant positive effect on the willingness of the older generation of farmers to adopt emerging green production technology, while the effect on the willingness of the new generation of farmers to adopt emerging green production technology was not significant.

4.4. Robustness tests

Robustness tests were conducted by constructing new variables to replace the original core explanatory variables and smoothing

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TABLE 4 Scale differences in the impact of ecological cognition and environmental regulation on participation willingness in GHAAs.

Variable	Large-scale farmers				Small-scale farmers			
	First stage (whether to participate)	Second stage (mode of participation)	Third stage (degree of participation)		First stage (whether to participate)	Second stage (mode of participation)	Third stage (degree of participation)	
			TGT	EGT			TGT	EGT
Ecological cognition	0.601** (0.251)	0.234* (0.167)	−0.346 (0.088)	0.172** (0.070)	0.504 (0.317)	0.861*** (0.299)	0.043 (0.110)	0.262* (0.142)
Restrictive environmental regulation policies	1.041*** (0.187)	0.158 (0.169)	0.450*** (0.090)	0.143* (0.076)	0.971*** (0.268)	−0.233 (0.238)	0.281*** (0.070)	−0.002 (0.101)
Incentive environmental regulation policies	0.929*** (0.229)	0.203 (0.215)	−0.107 (0.117)	0.115 (0.099)	1.110*** (0.298)	0.687** (0.268)	0.274*** (0.083)	0.774*** (0.119)
Other variables	Control				Control			
Log-likelihood	−62.637	−89.358	−59.447	−36.970	−39.379	−51.899	−23.950	−26.398
LR chi2	112.35***	32.60***	37.99***	25.11**	120.55***	53.36***	38.92***	58.49***
Observations	207	153	82	71	163	114	62	52

***, **, *Significant at the 1, 5, and 10% level. Standard errors in parentheses.

TABLE 5 Intergeneration differences in the impact of ecological cognition and environmental regulation on participation willingness in GHAAs.

Variable	New generation farmers				Older generation farmers			
	First stage (whether to participate)	Second stage (mode of participation)	Third stage (degree of participation)		First stage (whether to participate)	Second stage (mode of participation)	Third stage (degree of participation)	
			TGT	EGT			TGT	EGT
Ecological cognition	0.144 (0.268)	0.410* (0.246)	0.043 (0.091)	0.136 (0.099)	0.263 (0.174)	0.592*** (0.173)	−0.013 (0.077)	0.048 (0.070)
Restrictive environmental regulation policies	0.940*** (0.240)	0.094 (0.276)	0.301*** (0.095)	−0.034 (0.175)	0.986*** (0.172)	0.270 (0.222)	0.378*** (0.080)	0.100 (0.076)
Incentive environmental regulation policies	0.928*** (0.267)	0.264 (0.312)	0.394** (0.145)	0.101 (0.126)	0.709*** (0.206)	0.578** (0.246)	0.019 (0.088)	0.559*** (0.110)
Other variables	Control				Control			
Log-likelihood	−40.351	−47.185	−21.495	−28.350	−68.837	−92.025	−66.762	−49.988
LR chi2	85.95***	33.17***	37.66***	14.22	132.05***	56.03***	32.03***	51.84***
Observations	134	92	46	46	236	175	98	77

***, **, *Significant at the 1, 5, and 10% level. Standard errors in parentheses.

the sample singularities. First, the measure of restrictive environmental regulation policies was replaced from "the strength of penalties for aquaculture pollution behavior "to "the strength of aquaculture environmental monitoring," and the measure of incentive environmental regulation policies was replaced from "the strength of subsidies for green production "to "the support intensity of policy-based aquaculture insurance," and then the regression was repeated, and the results are shown in Table 6. Comparison with Table 2 shows that the direction and significance of the effects of the core explanatory variables of ecological cognition and environmental regulation in the three decision stages are basically the same, indicating that the estimation results are robust.

Respondents' evaluation of ecological cognition and environmental regulation in micro surveys may be influenced by subjective factors, resulting in underestimation or overestimation of data values, and thus generating sample singularities. In view of this, with reference to existing studies (Zhang et al., 2020; Fei et al., 2022), the maximum and minimum singular values of the observed values of the core explanatory variables were smoothed using the winsorized method and then regressed to further verify the robustness of the results, and the estimation results are shown in Table 7. Compared with the results in Table 2, the regression results after the smoothing of sample singular values did not change significantly, indicating that the study findings are more robust.

5. Conclusion and policy recommendations

5.1. Conclusion

In this paper, we divide farmers' participation willingness in GHAAs into three decision stages, namely, whether to participate, mode of participation, and degree of participation, and based on the survey data from 370 aquaculture farmers in Zhejiang province, the triple-hurdle model was applied to analyze the effects of ecological cognition, environmental regulation, and their interaction on farmers' multi-stage participation willingness of in GHAAs, and explored the scale and intergenerational differences. The main conclusions are as follows.

Ecological cognition and environmental regulation both have significant positive effects on farmers' willingness to participate in actions in the first stage, while the impacts on the participation willingness in the second and third stages are different. Specifically, ecological cognition has a significant positive effect on the farmers' three decision stages. In environmental regulation, restrictive policies have a significant positive impact on the willingness of farmers to participate in the first stage and the degree of willingness to participate TGT methods in the third stage. Incentive policies, on the other hand, have a significant positive effect on all three stages of decision-making.

Environmental regulation has a positive moderating effect on the influence of ecological cognition on the farmers' willingness to

TABLE 6 Regression results after replacing the core explanatory variables.

Variable	First stage (whether to participate)	Second stage (mode of participation)	Third stage (degree of participation)	
			TGT	EGT
Ecological cognition	0.513*** (0.116)	0.452*** (0.120)	0.091 (0.064)	0.093 (0.056)
Restrictive environmental regulation policies	0.269** (0.108)	0.169 (0.109)	0.169*** (0.058)	0.081 (0.057)
Incentive environmental regulation policies	0.246*** (0.082)	0.486** (0.094)	−0.041 (0.049)	0.151*** (0.054)
Other variables	Control	Control	Control	Control
Log-likelihood	−175.152	−139.433	−110.634	−92.451
LR chi2	87.34***	89.62***	26.92**	40.53***
Observations	370	267	144	123

TABLE 7 Regression results after smoothing sample singular values.

Variable	First stage (whether to participate)	Second stage (mode of participation)	Third stage (degree of participation)	
			TGT	EGT
Ecological cognition	0.229* (0.135)	0.432*** (0.120)	−0.011 (0.062)	0.093* (0.055)
Restrictive environmental regulation policies	0.910*** (0.133)	0.035 (0.130)	0.358*** (0.062)	0.072 (0.069)
Incentive environmental regulation policies	0.957*** (0.166)	0.413*** (0.156)	0.074 (0.076)	0.376*** (0.087)
Other variables	Control	Control	Control	Control
Log-likelihood	−115.940	−150.247	−101.357	−86.858
LR chi2	205.77***	67.99***	45.48***	51.71***
Observations	370	267	144	123

participate in actions. The restrictive policies will help raise the willingness of farmers with high ecological cognition to participate in GHAAs in the first stage, the incentive policy can promote the participation in EGT methods in the third stage of high ecological cognition farmers.

There are scale and intergenerational differences in the effects of ecological cognition and environmental regulation on farmers' participation willingness. In terms of scale difference, the willingness of large-scale farmers to participate was significantly affected by ecological cognition and restrictive policies, while the willingness of small-scale farmers was mainly affected by incentive policies. In terms of intergenerational differences, the effect of incentive policies on the new generation of farmers is mainly in enhancing the willingness to participate in TGT methods, while the incentive effect on the older generation of farmers is mainly in enhancing the willingness to participate in EGT methods.

5.2. Policy recommendations

Based on the above findings, the following policy recommendations are proposed.

In the promotion of GHAAs, we should further strengthen the publicity about the hazards of traditional farming methods and the benefits of green farming technology to improve the social responsibility of farmers to protect the environment, maintain food safety and stimulate their endogenous motivation for green production. Particularly for the substitution of complementary feed, aquaculture tailwater treatment, and other emerging green production technology relatively unfamiliar to farmers, with the help of training and advocacy, the network, television, and other channels to convey information about the purpose of the application of technology, potential benefits and so on, to improve the level of farmers' cognition, and to ensure that the policy objectives and farmers ecologically rational demand for unity.

Constrained policies can significantly increase the willingness of farmers to adopt green production technology, especially traditional green production technology. To this end, it is necessary to further improve the aquaculture quality and safety supervision system, increase the crackdown on illegal acts such as the use of fake and substandard veterinary drugs, banned drugs, and unlicensed additives, and improve the penalties for violations, timely disclosure of relevant supervision and inspection information, restraint and guide farmers to spontaneously adopt the reduction of drugs, aquaculture density control and other traditional green production technology.

The incentive policy plays a prominent role in promoting farmers' willingness to adopt new green production technology. On the one hand, focus on the substitution of compound feed, aquaculture tailwater treatment, and other emerging green production technology, and provide subsidy support in the procurement of compound feed, tailwater treatment equipment purchase, aquaculture pond renovation, and other aspects to reduce the cost of technology adoption by aquaculture farmers. On the other hand, the green aquatic product certification, pollution-free aquatic product certification, the acquisition of contractual arrangements, and other product market terminals, increase the examination of the use of compound feed, aquaculture tailwater treatment effect, improve the expected return on the adoption of emerging green production technology by farmers, and enhance farmers' technology adoption motivation.

In the process of green production technology promotion, based on different scales of technology adoption, differentiated supporting policies should made for different scales and different ages farmers. For farmers with the insufficient willingness to green production transformation, we should strengthen policy advocacy and play the guiding and supervising role of restrictive policies, and for farmers who already have the willingness to green production transformation, we should focus on the role of the incentive policies to boost and improve their technology adoption. At the same time, we should fully consider the difference in aquaculture scale and age, implement the policy combination of Propaganda, supervision, and incentives, and improve the efficiency of green production technology promotion.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent from the participants was not required to participate in this study in accordance with the national legislation and the institutional requirements.

Author contributions

QC organized the database and wrote the first draft of the manuscript. QX performed the statistical analysis. QC, QX, and XY wrote parts of the manuscript. All authors contributed to the article and approved the submitted version.

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Conflict of interest

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

References

Bbxa, B., Eds, C., and Qtkn, A. (2021). Stakeholder perceptions towards sustainable shrimp aquaculture in Vietnam – science direct. *J. Environ. Manag.* 290:112585. doi: 10.1016/j.jenvman.2021.112585

Burke, W. J., Myers, R. J., and Jayne, T. S. (2015). A triple-hurdle model of production and market participation in Kenya's dairy market. *Am. J. Agri. Econ.* 97, 1227–1246. doi: 10.1093/ajae/aav009

Chen, J. H., (2017). *Atlas of Aquaculture Regional Distribution and Water Resources in China-Zhejiang*. Shanghai Scientific & Technical Publishers, Shanghai.

Chen, Y. S., and Fang, R. J. (2011). Empirical analysis on factors affecting fishery drug application behavior of mariculturists. *Chin. Rural Econ.* 320, 72–80.

Chen, H. W., and Mu, Y. Y. (2022). Policy incentives, value perception and farmers' adoption of water-saving technologies: an empirical analysis based on 1188 farmers in Hebei, Shandong and Henan. *Resour Sci* 44, 1196–1211. doi: 10.18402/resci.2022.06.08

Chen, Y., Wang, F., Li, H. J., Aftab, S., and Liu, Y. Q. (2020). Triple-hurdle model analysis of the factors influencing biogas digester building, use and processing by Chinese pig farmers. *Sci. Total Environ.* 761:143259. doi: 10.1016/j.scitotenv.2020.143259

Cooke, R., and Sheeran, P. (2004). Moderation of cognition-intention and cognition-behaviour relations: a meta-analysis of properties of variables from the theory of planned behaviour. *Br. J. Soc. Psychol.* 43, 159–186. doi: 10.1348/0144666041501688

Dimara, E., and Skuras, D. (2003). Adoption of agricultural innovations as a two-stage partialobservability process. *Agric. Econ.* 28, 187–196. doi: 10.1111/j.1574-0862.2003.tb00137.x

Doss, C. R. (2010). Analyzing technology adoption using microstudies: limitations, challenges, and opportunities for improvement. *Agric. Econ.* 34, 207–219. doi: 10.1111/j.1574-0864.2006.00119.x

Duan, W., Jiang, Y. C., and Ouyang, B. (2022). Trend of conflict between community livelihood sand nature reserves: based on the intergenerational differences of rural households' natural resource utilization behavior. *Resour. Sci.* 44, 1267–1279. doi: 10.18402/resci.2022.06.13

Fei, H. M., Sun, L. M., and Wang, L. (2022). Decision making of farmers' black land conservation tillage behavior: value perception or policy driving? *J. Nat. Resour.* 37, 2218–2230. doi: 10.31497/zrzyxb.20220902

Guo, Z., Chen, X., and Zhang, Y. (2022). Impact of environmental regulation perception on farmers' agricultural green production technology adoption: a new perspective of social capital. *Technol. Soc.* 71:102085. doi: 10.1016/j.techsoc.2022.102085

Guo, L. J., and Zhao, J. (2014). Mechanisms of farmers' pro-environmental behavior and policy interventions: take straw treatment as an example. *Issues Agric Econ.* 35, 78–84+112. doi: 10.13246/j.cnki.iae.2014.12.010

Han, L. M., Ren, G. Y., and Qin, H. (2007). The basic connotation and specificity of the three-fishing-issues. *Issues Agric. Econ.* 112, 93–96. doi: 10.3969/j.issn.1000-6389.2007.06.020

Huang, Y. Z., Luo, X. F., Tang, L., and Yu, Z. W. (2020). Influence of market trust on farmers' application behavior of biological pesticides: regulatory effect analysis based on institutional environment. *Resour. Environ Yangtze Basin* 29, 2488–2497. doi: 10.11870/cjlyzyyhj202011016

Hukom, V., Nielsen, R., Asmild, M., and Nielsen, M. (2020). Do aquaculture farmers have an incentive to maintain good water quality? The case of small-scale shrimp farming in Indonesia. *Ecol. Econ.* 176:106717. doi: 10.1016/j.ecolecon.2020.106717

Jin, R. R., Li, S. P., and Nan, L. (2022). Effects of capital endowment, perceived value, and government subsidies on farming households' adoption behavior of clean heating. *Resour Sci.* 44, 809–819. doi: 10.18402/resci.2022.04.13

Joffer, O. M., Poortvliet, P. M., and Klerkx, L. (2019). To cluster or not to cluster farmers? Influences on network interactions, risk perceptions, and adoption of aquaculture practices. *Agric. Syst.* 173, 151–160. doi: 10.1016/j.agsy.2019.02.011

Kim, J., Goldsmith, P., and Thomas, M. H. (2010). Economic impact and public costs of confined animal feeding operations at the parcel level of Craven County, North Carolina. *Agric. Hum. Values.* 27, 29–42. doi: 10.1007/s10460-009-9193-x

Lei, J. L. (2010). Strategy consideration for industry construction of Chinese marine culture. *J. Fish. Sci. China* 17, 600–609.

Li, J., Feng, S., Luo, T., and Guan, Z. (2020). What drives the adoption of sustainable production technology? Evidence from the large-scale farming sector in East China. *J. Clean. Prod.* 257:120611. doi: 10.1016/j.jclepro.2020.120611

Li, B. W., and Xu, X. (2018). Spatial effect of cultivation agglomeration and technology supporter on farmers' adoption of new agricultural technology: take freshwater aquaculture as an example. *J. Nanjing Agric. Univ. (Soc. Sci. Ed).* 18, 124–136.

Li, F. N., Zhang, J. B., and He, K. (2019). Impact of informal institutions and environmental regulations on farmers' green production behavior: based on survey data of 1105 households in Hubei Province. *Resour. Sci.* 41, 1227–1239. doi: 10.18402/resci.2019.07.04

Liu, L. J., and Peng, K. (2021). Research progress on substitution of iced trash fish with aquatic compound feed. *Feed Res.* 44, 141–144. doi: 10.13557/j.cnki.issn1002-2813.2021.21.031

Luo, L., Yang, X. F., Niu, W. J., and Li, Y. (2022). Cognitive norms, institutional environment and multi-stage dynamic process of fruit farmers adopting green production technology: an analysis based on the triple-hurdle model. *J. Agrotech. Econ.* 330, 98–113. doi: 10.13246/j.cnki.jae.20211228.001

Obubuafo, J., Gillespie, J., Paudel, K., and Kim, S. A. (2008). Awareness of and application to the environmental quality incentives program by cow calf – producers. *J. Agric. Applied Econ.* 40, 357–368. doi: 10.1017/s1074070800028169

Pannell, D. J., and Claassen, R. (2020). The roles of adoption and behavior change in agricultural policy. *Appl. Econ. Perspect. Policy.* 42, 31–41. doi: 10.1002/aepp.13009

Phong, T. N., Thang, V. T., and Hoai, N. T. (2021). What motivates farmers to accept good aquaculture practices in development policy? Results from choice experiment surveys with small-scale shrimp farmers in Vietnam. *Econ. Anal. Policy.* 72, 454–469. doi: 10.1016/j.eap.2021.09.015

Prochaska, J. O., and Diclemente, C. C. (1983). Stages and processes of self-change of smoking: toward an integrative model of change. *J. Consult. Clin. Psychol.* 51, 390–395. doi: 10.1037/0022-006X.51.3.390

Schreinemachers, P., Chen, H.-P., Nguyen, T. T. L., Buntong, B., Bouapao, L., Gautam, S., et al. (2017). Too much to handle? Pesticide dependence ofsmallholder vegetable farmers in Southeast Asia. *Sci. Total Environ.* 593-594, 470–477. doi: 10.1016/j.scitotenv.2017.03.181

Tang, Q. S., Ding, X. M., Liu, S. L., Wang, Q. Y., Nie, P., He, J. G., et al. (2014). Safeguard measures and policy recommendations for green and sustainable development of Chinese aquaculture. *Chin. Fish. Econ.* 32, 5–11. doi: 10.3969/j.issn.1009-590X.2014.02.001

Xie, J. H., Yang, G. J., Zhang, J., and Wang, G. (2021). Mechanism of farmers' ecological cognition affecting their clean energy utilization behaviors in the Yangtze River Economic Belt: an empirical analysis of farmers in 5 districts(cities). *J. Huazhong Agric. Univ.* 40, 52–63. doi: 10.13300/j.cnki.hnlkxb.2021.03.007

Yan, T. W., Zhang, D. K., He, K., and Zhang, J. B. (2017). Study on farmers' decision behavior of crop straw recycling of returning to field: based on a survey in seven provinces including Anhui and Lu. *Issues Agric. Econ.* 38, 39–48+110–111. doi: 10.13246/j.cnki.iae.2017.04.005

Yang, Z. H., Wang, J., and Yang, X. (2020). Self-sufficiency or outsourcing: how does small rural household adopt the practice of soil conservation? Based on the perspective of social capital. *China Land Sci.* 34, 89–98. doi: 10.11994/zgtdkx.20200824.094427

Yu, W. Z., Luo, X. F., and Li, R. R. (2017). The paradox between farmer willingness and their adoption of green technology from the perspective of green cognition. *Resour. Sci.* 39, 1573–1583. doi: 10.18402/resci.2017.08.13

Zhang, H. N., Ge, X. H., Jie, Y. M., and Zheng, Y. C. (2019). A study on the influence of ecologicalcognition on river basin residents' willingness to participate in ecological compensation. *China Popul. Resour. Environ.* 29, 109–116. doi: 10.12062/cpre.20190606

Zhang, W. B., and Ma, X. Z. (2020). China's aquaculture development trends since 2000 and future directions. *J. Shanghai Ocean Univ.* 29, 661–674. doi: 10.12024/jsou.20190502673

Zhang, T. Y., Yan, T. W., and Wang, Z. (2020). Social networks, income uncertainty and the self-employedwomen's adoption behavior of conservation tillage technology. *J. Agrotech. Agrotech. Econ.* 304, 101–116. doi: 10.13246/j.cnki.jae.2020.08.008

Zhao, K., Zhang, R. H., and Sun, P. F. (2022). The impacts of capital endowment on farmers' adoption behaviors of agricultural socialization services: from the perspective of family life cycle. *Res. Agric. Mod.* 43, 121–133. doi: 10.13872/j.1000-0275.2021.0118

Zhu, J. F., and Deng, Y. Y. (2022). Green transformation of agricultural production: logic of formation, dilemma and practical strategy. *Reform Econ. Syst.* 234, 84–89.