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Study on the influence of environmental regulation on the environmentally friendly behavior of farmers in China

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Rural environmental problems have become a prominent problem in the current environmental field that needs to be solved, and livestock breeding waste is an important problem to the rural environmental pollution management. The government has been combating environmental pollution by strengthening environmental regulation policies, but the effect of environmental regulation implementation needs to be improved. Therefore, exploring the intrinsic mechanism of environmental regulation on farmers' environmental management behavior is an important way to realize the construction of rural civilization. This paper analyzes the influence of environmental regulations on meat duck farmers' environmentally friendly behavior from the perspective of the "cost effect" and "Porter effect." In addition, the potential role of risk perception is explored by analyzing the heterogeneity of farmers' environmentally friendly behavior at different breeding scales. The results show an inverted U-shaped relationship between the intensity of environmental regulations and meat duck farmers' environmentally friendly behavior; different environmental regulations significantly affect the environmentally friendly behavior of farmers. In these regulations, the guiding regulation plays a significant positive role in the resulting environmentally friendly behavior of farmers in terms of constraint regulation and incentive regulation. There is heterogeneity in the impacts of environmental regulation on the environmentally friendly behaviors of farmers of different scales. Risk cognition has a partial mediating effect on the effects of environmental regulations on farmers' environmentally friendly behavior. The research not only enriches the study of environmental governance, but also its relevant findings have important guidance and reference significance for optimizing environmental regulation policies, promoting farmers' cognition of waste environmental pollution management and implementation of environmentally friendly behaviors, and realizing low-carbon and healthy breeding of meat ducks.

KEYWORDS

environmental regulation, risk cognition, breeding scale environmentally, friendly behavior, China

1 Introduction

China is the world's largest producer of livestock and poultry, and also the world's largest producer of waterfowl, waterfowl feeding accounted for more than 75% of the world's total feeding, and meat duck is an important part of waterfowl breeding and plays a pivotal role in the waterfowl industry. With the rapid transformation of traditional livestock and poultry farming to large-scale and intensification, livestock production continues to increase (Gao et al., 2006), while also exacerbating environmental pollution. Livestock and poultry breeding waste has become the most significant emissions of agricultural surface pollution (Wang et al., 2022). It is estimated that 3.8 billion tons of manure are annually generated worldwide[1]. The comprehensive utilization rate of livestock and poultry manure was 76% in2020[2], and wastes that have not been resourcefully utilized have caused serious impacts on the ecological environment. Therefore, the state and governments have formulated a series of environmental policies at all levels to minimize environmental pollution. However, although a relatively complete environmental regulation system has been formed, but the problems of meat duck manure discarded freely, sick and dead ducks are not harmlessly treated remain serious in rural areas. As rational economic actors, the breeding behavior of farmers affects breeding efficiency (Qiao and Zhang, 2019). Under strategic background, the green development has become one of the core development goals of Chinese agriculture. This paper aims to analyzes the real situation of farmers' environmentally friendly behavior under environmental regulation, resource constraints, and explores the regulatory effect of environmental regulation on farmers' environmentally friendly behavior. This research findings have important theoretical and practical significance for optimizing environmental regulation policies, promoting rural environmental governance, solving rural environmental problems, and realizing rural revitalization and ecological civilization construction.

In research on the effects of environmental regulation, domestic and foreign researchers have mainly analyzed the relationship between environmental regulation policies and economic growth (Rubashkina et al., 2015), industrial structure (Fan and Liu, 2017; Liu et al., 2020; Zhang et al., 2021a), and technological progress (You and Jiang, 2018); Other researchers have focused on the effects of environmental policies on total factor productivity (Ma and Tan, 2021), economic performance (Wu and Gao, 2019), environmental performance (Ying, 2019), and enterprise competitiveness (Fu and Li, 2010). Existing studies provide a rich scientific basis for the regulatory effect of environmental policies, but there are still limitations. From the perspective of research, the existing studies were mainly aimed at evaluation of the effects of environmental regulation, but paid less attention to the regulatory objectives of micro subject behavior, and the regional differences between different environmental regulations are important factors affecting the development of the industry (Yan et al., 2020). From the perspective of the research object, the environmental pollution caused by rural livestock and poultry breeding is an important obstacle to the countryside's green environment. As the direct actors guaranteeing the environmental safety of the livestock and poultry industry, their environmental protection and governance behavior can achieve the goal of rural environmental improvement. Therefore, it is particularly important to encourage farmers to implement environmentally friendly behaviors.

Environmentally friendly behavior is an individual's positive concern for environmental issues and the resulting positive attitudes and behavioral tendencies, also known as "pro-environmental behavior", which is based on personal moral values and a sense of social responsibility, and is a conscious eco-environmental behavior (Hines et al., 1987). The paper defines environmentally friendly behavior as the behavior of meat duck farmers in resourceful treatment of farm waste, including the behavior of manure resourceful treatment and harmless treatment of sick and dead ducks. In the analysis of the influencing factors of environmentally friendly behaviors, researchers have mainly focused on personal characteristics, business characteristics, social norms, and risk cognition (Kong et al., 2018; Yu and Yu, 2019). It is generally believed that the income level and social and economic conditions of farmers are key factors affecting farmers' behavior (Tang et al., 2021). In recent years, as the government has strengthened the implementation of environmental regulation policies, researchers have begun to pay attention to the role of environmental regulation on farmers' behavior in environmental governance. However, different researchers have differing views on the impacts of different environmental regulations on farmers' behavior. Li et al. (Li et al., 2019) proposed that incentive regulation has a positive effect on green livestock and poultry breeding behavior, and restraint regulation has no significant impact. Tang et al. (Tang et al., 2021) empirically proved that environmental administrative policy has a better restraining effect on farmers' environmental behavior than environmental economic policy's stimulating effect on farmers' environmental behavior. Si et al. (Si et al., 2019) indicated that the order of the effect of each regulatory dimension on breeding behavior is imperative regulation>incentive regulation>voluntary regulation>guided regulation. There are differences in the implementation

1 Data source: "Notice on Printing and Distributing (Program for Promoting the Pilot Program of Recycling Agricultural Wastes)".

2 Data source: Notice of Printing and Distributing the "14th Five-Year Plan for the Development of the National Animal Husbandry and Veterinary Industry".

methods of various environmental regulations on the environmental behaviors of meat duck farmers, and the degrees of impact of environmental regulations need to be further explored. Moreover, the behavioral choices of farmers are usually subject to the constraints of their resource endowments. Therefore, when farmers facing the choice of whether to engage in environmentally friendly behavior or not, they will choose to give up because their breeding environment and other conditions cannot meet the needs of the corresponding behavior.

In December 2021, the Ministry of Agriculture and Rural Affairs issued a notice on the "14th Five-Year Plan for the Development of the National Animal Husbandry and Veterinary Industry", which noted that the large-scale rate of livestock and poultry breeding reached 67.5% in 2020, and it was the fundamental way to promote the transformation and upgrading of animal husbandry. It was clearly proposed that developing moderate-scale farming according to the local conditions, guiding farms (households) to transform and improve infrastructure conditions, and supporting small and medium-sized farmers to integrate into the modern production system. It can be seen that there are differences in the breeding behavior of farmers of different scales. Based on this, this paper considers the heterogeneity of farmers engaged in different scales of farming, the intensity of environmental regulation, and the different choices of environmental regulations and environmentally friendly behaviors. Based on economic theory, this paper analyzes the impacts of environmental regulation on farmers' environmentally friendly behavior from the perspectives of the "cost effect" and "Porter effect". On this basis, micro survey data of meat duck farmers were used to empirically test the relationship between environmental regulation and farmers' environmentally friendly behavior to provide policy inspiration for promoting the implementation of farmers' environmentally friendly behavior, accelerating rural revitalization, and achieving green development.

2 Materials and methods

2.1 Analytical framework and research hypothesis

2.1.1 Game-based analysis of farmers' behavior

In the process of meat duck breeding, meat duck farmers aim to maximize their interests, which affects their production behavior. Drawing on the research of Zhang et al. (Zhang, 2010) and Shu et al. (Shu, 2017), a production function of meat duck breeding was constructed to analyze the economic and ecological benefits of meat duck farmers' environmentally friendly behavior. Assuming that meat duck farmers conduct environmentally friendly behaviors (manure recycling or harmless treatment of dead ducks), their main inputs include the labor input L, capital input K, natural resource input R, and technology input T. Assuming that the total input of production factors of farmers is X, the breeding income is Y_1, the unit breeding cost of producing the main product of duck meat is C_1, the sales price is P_1, the sales volume is Q_1, and the output breeding waste is M. The environmental pollution caused by nontreatment is Z, the output of breeding waste is Q_2, the unit cost of resource treatment is C_2, the unit cost of harmless treatment is C_3, and the unit sales price of resource treatment is P_2, then the C-D production function of meat duck farmers can be expressed as:

$$\begin{aligned} Q_i &= F(L, K, T, M(R_i), Z(\Sigma M_i)) \\ &= AL^{\alpha}K^{\beta}T^{\gamma}R^{\eta}M^{\varphi}\ (\alpha, \beta, \gamma, \eta, \varphi > 0) \end{aligned} \tag{1}$$

According to the theoretical analysis, the environmentally friendly behavior of meat duck farmers is affected by government regulations. On the one hand, there is an incentive-based regulation in which the government subsidizes farmers according to the amount of disposed waste, and the subsidy amount is set at F yuan. On the other hand, there is a constrained regulation of administrative penalties for farmers who discard waste and pollute the environment. The penalty amount is set at G yuan. Assuming other conditions remain unchanged, the economic and ecological benefit functions of farmers have the following situations:

(1) When the government does not regulate and meat duck farmers do not engage in environmentally friendly behaviors, the economic benefits and ecological benefit functions of the farmers are:

$$\pi_{1economy} = P_1Q_1 - C_1Q_1 \tag{2}$$

$$\pi_{1ecology} = -Q_2 \tag{3}$$

(2) When the government does not regulate meat duck farmers engage in environmentally friendly behaviors, the amount of waste from meat duck breeding is reduced by t, the unit breeding cost increases by r, the sales price increases by k, and the output increases by l. The benefit function is:

$$\begin{aligned} \pi_{2economy} &= (P_1 + k) \cdot (Q_1 + l) - (C_1 + r) \cdot (Q_1 + l) - C_2t - C_3t \\ &\quad + P_2t \\ &= (P_1 + k - C_1 - r) \cdot (Q_1 + l) - (C_2 + C_3 - P_2) \cdot t \end{aligned} \tag{4}$$

$$\pi_{2ecology} = -(Q_2 - t) \tag{5}$$

(3) When the government regulates and meat duck farmers do not engage in environmentally friendly behaviors, the economic and ecological benefit functions are:

$$\pi_{3economy} = P_1Q_1 - C_1Q_1 - G \tag{6}$$

$$\pi_{3ecology} = -Q_2 \tag{7}$$

(4) When the government carries out regulations and meat duck farmers also carry out environmentally friendly behaviors, the economic and ecological benefit functions are:

$$\begin{aligned}\pi_{4economy} &= (P_1 + k) \cdot (Q_1 + l) - (C_1 + r) \cdot (Q_1 + l) + F - C_2 t \\ &\quad - C_3 t + P_2 t \\ &= (P_1 + k - C_1 - r) \cdot (Q_1 + l) - (C_2 + C_3 - P_2) \cdot t + F\end{aligned} \tag{8}$$

$$\pi_{4ecology} = -(Q_2 - t) \tag{9}$$

When the government does not conduct environmental regulation, the situation can be discerned by comparing 1) and (2). When $\pi_{2\ economy} > \pi_{1\ economy}$, namely, (P1+k- C1-r)·(Q1+l)-(C2+ C3 -P2)·t>P1Q1-C1Q1, meat duck farmers will choose to engage in environmentally friendly behaviors. At this time, meat duck farmers need to have a certain breeding scale or breeding technology to offset the breeding benefits and costs, So when the government does not carry out environmental protection measures, farmers are reluctant to engage in environmentally friendly behaviors. When the government conducts environmental regulation, the situation can be discerned by comparing 3) and (4). When $\pi_{4\ economy} > \pi_{3\ economy}$, namely, (P1+k- C1-r)·(Q1+l)-(C2+ C3 -P2)·t + F>P1Q1-C1Q1-G, meat duck farmers will choose to engage in environmentally friendly behaviors, and relevant government subsidies and innovative compensation brought by technical treatment will increase the enthusiasm of farmers to apply environmentally friendly behaviors.

2.1.2 Theoretical analysis of the decision framework

Environmental regulation has always been a hot issue that researchers have paid attention to. The research on the effect of environmental regulation mainly revolves around the "Porter Hypothesis" and the "Pollution Paradise Hypothesis." It is said that environmental regulations are relatively loose, and high-pollution enterprises will move to areas with loose environmental regulations, resulting in the phenomenon of "pollution shelters," while the "Porter Hypothesis" states that, environmental regulations will stimulate technological innovation and gain "Innovation Compensation" (Zhang et al., 2021a). Farmers are beneficiaries and polluters of the environment (Tang et al., 2021), who pursue maximum profits, but they are constrained by policies and institutions in their practice, and the externalities of manure emission make it impossible for livestock and poultry breeding to be completely separated from the government's environmental regulation. According to economic theory, in the short term, farmers have a "following cost" effect on environmental regulation (Barbera and Mcconnell, 1990). Farmers need to purchase relevant treatment equipment for environmental governance, increasing the purchase cost of cleaning elements and the cost of environmental restoration. When farmers do not carry out corresponding environmentally friendly behaviors, additional government penalties and reputation losses will be added under environmental regulations, and other profitable investments will have a "crowding out effect" (Ma and Tan, 2021). In the long run, according to the "Porter Hypothesis", a reasonable environmental regulation policy will encourage farmers to make technological improvements, thereby promoting the efficiency of resource allocation and upgrading the breeding structure. Farmers will not only get incentives from the government, but also save breeding costs by recycling livestock and poultry waste, for example, the production of biogas saves farmers' energy consumption (Zhang et al., 2019); In addition, it has corresponding environmental benefits, improves the livestock and poultry breeding environment, promotes the quality of livestock and poultry products, and increases sales prices. The increased cost of environmental governance is compensated for by the benefits brought by the innovation effect. Farmers will carry out environmental governance behaviors according to the balance between the benefits and costs of environmental governance to maximize the benefits under constraints.

The state controls the environmental pollution of livestock and poultry waste by formulating relevant environmental regulation policies which promote the environmental pollution prevention and control in farmers. Among them, government constraints can promote the waste treatment behavior of farmers (Jiang et al., 2016). When the private marginal cost is less than the social marginal cost, farmers will make irregular dispositions of livestock and poultry waste, resulting in negative externalities of the environment; when the private marginal benefit is less than the social marginal benefit, farmers will recycle livestock and poultry waste. As representatives of public interests, the government intervenes in the economic activities of market entities by formulating relevant policies to achieve the internalization of external effects, thereby compensating for market failures (Qiao and Zhang, 2019). The government's environmental regulation policy plays an important role in managing the environmentally friendly behavior of livestock and poultry farmers and coordinating the economic development of the livestock and poultry industry. Yang et al. (Yang and Ma, 2020) noted that environmental regulation policies directly affect farmers' environmentally friendly behavior, but different environmental regulation policies have varying effects on farmers' environmentally friendly behavior (Si et al., 2020). Scott W (Scott, 1995) pointed out that strict government supervision, regulation and regulatory pressure can promote the voluntary implementation of environmental governance, and the "top-down" governance method of environmental

regulation also has a positive effect on farmers' behavior (Zhang et al., 2021b).

According to the analysis, when the government implements environmental regulation policies, it realizes constraints on farmers' behavior by changing farmers' breeding costs. The stricter the constrained environmental regulation is, the higher the default cost for farmers, and the greater the possibility of promoting them to participate in environmentally friendly behavior. On the other hand, we promote, publicize and incentivize subsidies to farmers for environmentally friendly behavior to enhance their awareness and farming efficiency. The greater the publicity intensity is, the greater incentive subsidies, and the greater the relative income of farmers, so farmers have a stronger enthusiasm to participate in environmentally friendly behavior. Therefore, farmers will continuously adjust their environmental pollution control behavior according to the trade-off between cost and benefit to achieve the optimal stability strategy. Based on this, the proposed hypothesis to be tested is as follows:

H1a: Constraining regulation will positively affect the environmentally friendly behavior of farmers.
H1b: Incentive regulation will positively affect the environmentally friendly behavior of farmers.
H1c: Guiding regulation will positively affect the environmentally friendly behavior of farmers.

According to the theory of planned behavior, personal characteristics, cognition of things, and other factors affect an individual's attitude, subjective norms, and behavioral control. An individual's cognition level is an antecedent of behavior (Gan et al., 2018), which plays an important role in an individual's behavior choice (Guo et al., 2019). In the process of livestock and poultry breeding, the stronger the environmental risk awareness of farmers is, the higher the possibility of farmers carrying out environmentally friendly behaviors, and the cognitive characteristics of pro-environmental behaviors have an important impact on environmental behavior (Tang, 2015). According to the cognition-situation-behavior theory, contextual factors may affect farmers' cognition and behavior (Guo and Zhao, 2014), and environmental regulation policies can affect the implementation of environmentally friendly behavior by improving farmers' environmental cognition (Tang et al., 2020). Sang et al. (Sang et al., 2021) found that ecological cognition plays a partial mediating role in policy incentives on farmers' organic fertilizer use behavior; Zhu et al. (Zhu et al., 2021) proposed that guiding environmental regulation can indirectly treat farmers' manure resources through cognition. In meat duck breeding, a series of publicity and technical promotion efforts for waste recycling by the government can promote farmers to have a deeper understanding of environmental pollution, regulate their behavior, and reduce the breeding risk. The government's supervision of waste recycling and the implementation of relevant subsidy policies can lead farmers to pay attention, think about relevant policies, can result in farmers having a deeper understanding of waste recycling and increased awareness of green production. Based on the above analysis, the following hypotheses are proposed:

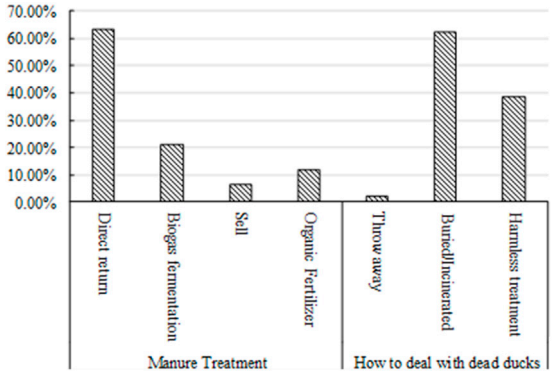

FIGURE1
Status of waste disposal methods of meat duck farmers.

H2a: Constraining regulation indirectly affects farmers' environmentally friendly behavior through risk perception.
H2b: Incentive regulation indirectly affects farmers' environmentally friendly behavior through risk perception.
H2c: Guided regulation indirectly affects farmers' environmentally friendly behavior through risk perception.

2.2 Empirical research design

2.2.1 Data collection

The data for the paper were obtained from survey data of meat duck farmers conducted by the economic post team of the National Waterfowl Industry Technology System in Shandong, Anhui, Jiangsu, Inner Mongolia, Henan, and other provinces in 2021. Due to differences in regional and meat duck breeding scale, both affect the choice of meat duck farmers' waste disposal behaviors. The industry system team, based on the principles of science and diversity, has investigated meat duck breeding enterprises in the those provinces, they have used the random sampling survey method to conduct one-to-one questionnaire surveys of farmers in different regions. To make the samples representative and avoid sample deviation, targeted visits to meat duck farmers were conducted. The research content mainly includes the basic personal characteristics of the meat duck farmers, and family management, environmental regulation policies, the related situation of the farmers' manure recycling, and the harmless disposal of sick and dead ducks. After excluding invalid questionnaires, 1093 valid questionnaires were obtained,

TABLE 1 Description of the basic characteristics of the sample farmers.

Variable	Feature	Sample size	Proportion
Gender	Meal	960	87.83%
	Female	133	12.17%
Age	≤40 years old	302	27.54%
	41–59 years old	728	66.60%
	≥60 years old	63	5.76%
Education level	Elementary school and below	143	13.08%
	Junior high school	639	58.46%
	High school or Secondary school	256	23.42%
	College and above	55	5.04%
State of health	Poor	0	0.00%
	Generally	101	9.24%
	Good	992	90.76%
Breeding years	5 years and below	545	49.86%
	6–10 years	339	31.02%
	11–15 years	147	13.45%
	16 years and above	62	5.67%
Breeding scale (ten thousand)	≤5	331	30.28%
	>5 ≤ 10	392	35.86%
	>10 ≤ 15	245	22.42%
	>15 ≤ 20	41	3.75%
	>20	84	7.69%
Farming income (million)	≤5	51	4.67%
	>5 ≤ 10	448	40.99%
	>10 ≤ 20	404	36.96%
	>20 ≤ 30	99	9.06%
	>30	91	8.32%
Organizational form	Compact	898	82.16%
	Loose	195	17.84%
Risk appetite	Risk Aversion	209	19.12%
	Risk Neutral	442	40.44%
	Risk Appetite	442	40.44%
Terrain of the breeding area	Plain	735	67.25%
	Hills	316	28.91%
	Mountain	42	3.84%

and the effective rate of the questionnaires was 93.26%. To test the validity of the questionnaire, the reliability and validity of the questionnaire were tested. The overall Cronbach coefficient of the questionnaire was 0.748 (greater than 0.7), indicating that the reliability of the questionnaire was good, and the KMO value was 0.799 (greater than 0.6). This indicates that factor analysis can be carried out; the total variance of the main factor explained was 71.40% (greater than 60%), indicating that the overall structure effect of the questionnaire is good.

According to the survey data, the waste disposal of meat duck farmers mainly includes the disposal of manure and dead ducks. Among them, the treatment methods of manure mainly include a direct return to the field, biogas fermentation, sale, and organic fertilizer. The treatment methods of dead ducks mainly include discarding, deep burial/incineration, and handing over to the harmless treatment department. Figure 1 reports the waste disposal of meat ducks by the interviewed farmers. As shown in Figure 1, more than half of the farmers surveyed returned the manure directly to the field, and 39.43% of the farmers carried out the recycling of manure. In the treatment of sick and dead ducks, 62.31% of the farmers buried or burned the sick and dead ducks, and 38.33% of the farmers handed them over to the harmless treatment department. At the same time, the farmers used a combination of methods to treat waste. In general, the investigation of farmers' environmentally friendly behavior needs to be further strengthened.

TABLE 2 Variable definition, assignment and descriptive statistics.

Variable name	Variable assignment and meaning	Mean	SD
Explained variable			
Environmentally friendly behavior	At least one environmental governance action = 1; No environmental action = 0	0.381	0.486
Core variable			
The intensity of environmental regulation	Amount invested by farmers in environmental governance (10,000 yuan)	0.858	1.524
Quadratic term of environmental regulation intensity	The secondary item of the amount of investment in environmental governance by farmers (10,000 yuan)	3.057	28.621
Constrained regulation	The number of times the local government supervised the disposal of meat duck breeding waste (very few = 1; relatively few = 2; general = 3; relatively many = 4; very much = 5)	3.608	1.099
Incentive regulation	The extent to which the local government subsidizes the disposal of meat duck breeding waste (the same value as above)	2.244	1.315
Guided regulation	The number of times the government has promoted the disposal of meat duck breeding waste (assignment is the same as above)	3.704	1.605
Personal characteristics			
Age	The actual age of the main person in charge of the farm (years)	46.154	8.683
Education	Education status of the main person in charge of the farm (primary school and below = 1; junior high school = 2; high school or technical secondary school = 3; college and above = 4)	2.206	0.726
Health condition	Poor = 0; Fair = 1; Good = 2	1.908	0.290
Served as a village cadre	No = 0; Yes = 1	0.070	0.256
Risk appetite	Risk Aversion = 1; Risk Neutral = 2; Risk Appetite = 3	2.214	0.743
Operating characteristics			
Farming labor	Number of laborers engaged in meat duck farming (person)	1.897	1.173
Farming income	Annual income of meat duck breeding (ten thousand yuan)	17.358	20.311
Breeding experience	Years engaged in meat duck farming (years)	6.698	4.622
Breeding scale	Annual slaughter volume of breeding (10,000)	10.017	12.364
Degree of organization	Whether an industry-related organization was joined (No = 0; Yes = 1)	0.833	0.531
Natural features			
Topography	Type of farming area (plain = 1; hilly = 2; mountain = 3)	1.363	0.557

The personal characteristics and the management characteristics of farmers in the survey sample are shown in Table 1. In terms of farmers' characteristics, 87.83% of the respondents were male, 66.60% of the farmers were between 41 and 59 years old, and their education level was junior high school level, accounting for 58.46%, and 90.76% of the farmers were in good health. For the characteristics of meat duck breeding and management, farmers with more than 5 years of experience in meat duck breeding accounted for 49.86% of the sample size. The breeding scale was mainly distributed between 50,000 and 100,000 animals per year, 77.95% of the farmers noted an annual breeding income of between 50,000 and 200,000 yuan, 82.16% of the sample farmers were in the form of tight organizations, and the farmers joined enterprise organizations. The degree of organization is relatively high, and the organizational form of "company +" is the main form. The breeding areas are mainly flat plains or hills.

2.2.2 Model settings

To further analyze the relationship between environmental regulation and the environmentally friendly behavior of farmers and verify the hypothesis in the theoretical analysis, this paper establishes an econometric model for quantitative analysis. Since the explained variable constructed in this study is discrete, the paper selected the Probit model for estimation analysis. The specific model is as follows:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \varepsilon \quad (10)$$

Where Y is the explained variable (the environmental governance behavior of the farmers); X_1 is the environmental regulation, which is represented by the intensity of environmental regulation and the constraint environmental regulation, the incentive environmental regulation, and the guiding environmental regulation; X_2 denotes the individual characteristics of the farmers, where X_3 is the management characteristic of the farmers, X_4 is the natural characteristic, β_0 is the constant term, β_1, β_2, β_3, β_4 is the regression coefficient, and ε is the random disturbance term.

2.2.3 Variable selection

According to externality theory, planned behavior theory and other related theories, previous studies, interviews with farmers in meat duck research areas, and exchanges between key meat

duck breeding enterprises and relevant technical personnel, the paper constructs factors influencing environmental friendly behavior of farmers from different dimensions. The mean and standard deviation of the independent variables and sample variables are shown in Table 2.

Explained variable: Based on the research of Liu (Liu and Zhou, 2018), Pan et al. (Pan and Kong, 2015), combined with the relevant content of the paper, the implementation of environmentally friendly behavior of farmers is analyzed in two aspects: manure resourceization and harmlessness of dead meat ducks. The farmer's "biogas fermentation, sale, production of organic fertilizer" treatment of manure is regarded as manure resource treatment. Handing over to "relevant departments for treatment" is regarded as harmless treatment, and "deep burial/incineration" of sick and dead ducks is regarded as simple resource treatment. In the questionnaire design, "participate in at least one environmental resource treatment" is set to "1," and "do not carry out any environmentally friendly behavior" is set to "0" as the explained variable.

Core explanatory variables: Government environmental regulation is measured through three dimensions: constraint regulation, incentive regulation, and guiding regulation. Based on the research of Si et al. (Si et al., 2020), Zhang et al. (Zhang et al., 2015), Yang et al. (Yang and Ma, 2020), combined with the relevant environmental regulation policies of meat duck breeding, the constraint-type regulation is assigned a value by asking "the number of times the local government supervised the disposal of meat duck farming waste" in the questionnaire; the incentive-type environmental regulation is assigned a value through "the extent of the local government's subsidy for the disposal of meat duck farming waste"; and guided environmental regulation is assigned a value through "the number of times the government publicizes the disposal of meat duck breeding waste." Referring to the research of Copeland et al. (Copeland and Taylor, 1994), the intensity of environmental regulation is expressed by "the input cost of farmers in environmental governance," but environmental regulation may increase the cost of farming and have a negative impact on the environmentally friendly behavior of farmers; however, in the long run, environmental regulation will enable meat duck breeding to obtain innovative compensation effects and encourage farmers to engage in environmentally friendly behaviors. Therefore, the "quadratic term of environmental regulation intensity" is used to reflect the uncertainty of the environmental regulation intensity effect on farmers' environmentally friendly behavior.

Control variable: Referring to the research of Qiao et al. (Qiao and Zhang, 2019) and Zhao et al. (Zhao et al., 2019), the individual characteristics of farmers (age, education level, health, whether they serve as a village cadre, risk preference, etc.), management characteristics (farming labor force, farming income, farming experience, farming scale, degree of organization, etc.), natural features (topography and landforms) and other factors that affect the environmentally friendly behavior of meat duck farmers were used as control variables.

3 Results and discussion

3.1 Benchmark regression results

Before performing the regression analysis, considering the multicollinearity between the variables, a collinearity diagnosis was performed. The results show that the correlation coefficients between the variables were all less than 0.6, indicating that there was no strong multicollinearity question between the variables. Eq. 1 analyzes the impact of environmental regulation intensity on the environmentally friendly behavior of meat duck farmers. Eqs 2–5 further analyze the impacts of different environmental regulations on the environmentally friendly behavior of meat duck farmers. To test the fitting degree of the model to the sample observations, a goodness-of-fit test was carried out, and the results was 85.18% (greater than 60%), which is good. The related regression results are shown in Table 3.

Relevant studies have shown that the impact of environmental pollution on economic development may have a "Kuznets curve effect" (Chen and Chen, 2018), and there is a nonlinear relationship between environmental regulation and environmental pollution. To explore the impacts of environmental regulation intensity on farmers' environmentally friendly behavior, the quadratic term of the environmental regulation intensity was included in the model for the empirical test. The results show that the intensity of environmental regulation has a significant positive impact on farmers' implementation of environmentally friendly behavior. While the quadratic term of the environmental regulation intensity significantly negatively affects farmers' behavior. There is an obvious nonlinear relationship between the intensity of environmental regulation and the implementation of environmentally friendly behaviors by farmers, showing an "inverted U shape"; in other words, when the intensity of environmental regulation exceeds a certain level, the probability of farmers implementing environmentally friendly behaviors will decrease with the intensity of environmental regulation. When the government sets the intensity of environmental regulation, farmers generally reduce pollution emissions in two ways. One is to directly control pollution by increasing pollution control expenditures, the other is to use manure recycling technology through the "innovative compensation effect" to increase production and profits as well as more funds for pollution control. At present, the actual level of environmental regulation in rural areas is mostly still in an inverted U-shaped rising stage (Tang et al., 2021). Different environmental regulations have varying influences on farmers' implementation of environmentally

TABLE 3 Impacts of environmental regulation on farmers' environmentally friendly behavior: benchmark regression results.

Variable	Equation 1	Equation 2	Equation 3	Equation 4	Equation 5
	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient
The intensity of environmental regulation	0.175***(0.042)	—	—	—	—
Quadratic term of environmental regulation intensity	−0.008***(0.002)	—	—	—	—
Constrained regulation	—	0.671***(0.052)	-	—	0.350***(0.072)
Incentive regulation	—	—	0.506***(0.043)	—	0.353***(0.046)
Guided regulation	—	—	—	0.579***(0.053)	0.169**(0.072)
Age	0.003 (0.005)	0.004 (0.006)	0.001 (0.006)	0.004 (0.006)	0.001 (0.006)
Education	0.051 (0.066)	0.042 (0.073)	0.037 (0.076)	0.132*(0.071)	0.073 (0.079)
State of health	0.112 (0.142)	−0.272*(0.159)	0.606***(0.167)	−0.260*(0.156)	0.198 (0.179)
Served as a village cadre	−0.278 (0.179)	−0.193 (0.162)	−0.177 (0.174)	−0.147 (0.163)	−0.149 (0.168)
Risk appetite	0.158 (0.059)	−0.072 (0.066)	0.093 (0.068)	−0.092 (0.065)	0.034 (0.072)
Farming labor	−0.054 (0.056)	−0.028 (0.058)	−0.023 (0.056)	−0.057 (0.056)	−0.031 (0.059)
Farming income	0.001 (0.003)	0.001 (0.002)	0.003 (0.003)	0.002 (0.003)	0.002 (0.003)
Breeding experience	0.013 (0.010)	0.028***(0.010)	0.013 (0.011)	0.024**(0.011)	0.023**(0.011)
Breeding scale	0.016***(0.006)	0.012**(0.005)	0.012***(0.004)	0.014***(0.005)	0.010**(0.005)
Degree of organization	0.234*(0.146)	0.092 (0.098)	0.139 (0.110)	0.126 (0.110)	0.048 (0.085)
Topography	0.880***(0.090)	0.629*** (0.087)	0.728***(0.090)	0.630***(0.091)	0.606***(0.092)
Wald test	150.82***	270.66***	238.76***	223.92***	296.55***
R2	0.153	0.289	0.308	0.237	0.360

***, **, * represent the statistical significance at the levels of 1%, 5% and 10%, respectively, and the data in brackets are t values.

friendly behaviors. Specifically, constraint-type environmental regulations, incentive-type regulations, and guidance-type regulations all have a significant positive impact on the environmentally friendly behavior of meat duck farmers, this is in general agreement with the findings of Si et al. (Si et al., 2020) and Zhu et al. (Zhu et al., 2021). When the government strengthens the supervision of manure recycling and harmless treatment of sick and dead ducks and provides subsidies to farmers who implement environmentally friendly treatment, by promoting and awareness campaigns related to pollution control technologies, the innovative compensation effect brought by it exceeds the increased "cost effect", thereby promoting the implementation of environmentally friendly behaviors by farmers.

3.2 Differential analysis of the impacts of environmental regulation on the environmentally friendly behavior of farmers

From the above results, it can be seen that the scale of breeding has a significant impact on the environmentally friendly behavior of meat duck farmers, but there are differences in the resource endowment and breeding cognition of farmers of different scales. Whether there are differences in the impacts of different environmental regulations on farmers of different scales remains to be verified. The annual output of meat duck farmers is more than 2,000, all of which are large-scale farmers; therefore, according to the "Definition Standard for Large-scale Livestock and Poultry Farms and Professional Livestock and Poultry Breeding," the annual output is 2,000–50,000 for small-scale farmers, the annual slaughter volume is between 50,000 and 100,000 for medium-scale farmers, and the annual output is more than 100,000 for large-scale farmers. Table 4 shows the effects of environmental regulation on the environmentally friendly behavior of farmers of different scales. The results show that different environmental regulations have varying effects on the environmentally friendly behavior of farmers of different scales. Specifically, environmental regulation can promote environmentally friendly behaviors of medium and large-scale farmers. Small-scale farmers are mainly affected by incentive-type environmental regulation, while restraint-type and guiding-type environmental regulations have no significant impact. A possible reason is that the resource endowment conditions of small-scale farmers are limited, and the "cost effect" of environmentally friendly behavior treatment exceeds the innovation compensation effect. Although increasing the supervision and punishment of environmental governance and the promotion of related technologies will improve farmers' awareness, due to the limited resource conditions of small-

TABLE 4 Influence of environmental regulation on the environmentally friendly behavior of farmers of different scales.

Variable	Small scale	Medium scale	Large scale
	Coefficient	Coefficient	Coefficient
Constrained regulation	−0.086 (0.186)	1.111***(0.244)	0.405**(0.184)
Incentive regulation	0.391***(0.123)	0.468***(0.116)	0.467***(0.115)
Guided regulation	−0.194 (0.129)	0.356*(0.222)	0.346***(0.144)
Control variable	controlled	controlled	controlled
Wald test	35.27***	109.20***	156.56***
R2	0.153	0.504	0.644

***, **, * represent the statistical significance at the levels of 1%, 5%, and 10%, respectively, and the data in brackets are t values.

scale farmers, they may choose not to implement environmentally friendly behaviors or withdraw from farming under environmental regulations.

3.3 Endogenous test

Since the questionnaire data of farmers were used in the research in this paper, there may be some uncontrollable factors that lead to deviations in the measurement of variables, and the government's technical guidance, promotion, and publicity (guidance regulation) may interact with farmers' environmentally friendly behaviors. It is easier for farmers to obtain more technical support from government departments for the resource treatment of meat duck breeding waste. According to the research of Frnankle J et al. (Frankel and Romer, 1999), geographical factors are considered the primary factors for the selection of instrumental variables. Referring to the selection of instrumental variables by Tang et al. (Tang et al., 2021), the "distance between the farm and the animal husbandry bureau" was selected as the instrumental variable. On the one hand, the distance from the farm to the Animal Husbandry Bureau is the geographical distance, which is only affected by the relocation of farmers and changes in the administrative region, which satisfies the exogenous nature of instrumental variables. On the other hand, the distance from the breeding area to the Animal Husbandry Bureau is an important factor in the publicity and promotion of relevant policies, which satisfies the requirements of the correlation between instrumental variables and endogenous variables. To eliminate the problem of weak instrumental variables, the validity of the instrumental variable "distance between farm and animal husbandry bureau" in this paper was tested. The results show that the AR and Wald values are 12.54 and 8.31, respectively, both of which are significant at the 1% level, so there is no weak instrumental variable problem. To test whether instrumental variables are needed to correct endogeneity bias, this paper conducted the D-W-H test. The results show that the p value of the guided environmental regulation is 0.0049 (less than 0.05), indicating that the null hypothesis that the variable is exogenous can be rejected and that there is an endogenous effect. The estimation results of the first stage show that the "distance between the farm and the animal husbandry bureau" has a significant negative impact on the guiding regulation, indicating that it meets the requirement of correlation as an instrumental variable. The results of the second stage show that after correcting the endogeneity problem, environmental regulation still significantly affects the environmentally friendly behavior of farmers, which verifies the robustness of the results. The related results are shown in Table 5.

3.4 Discussion

3.4.1 Analysis of environmental regulations effect on farmers' environmental friendly behavior through risk cognition

Drawing on the research of Liu et al. (Liu and Zhou, 2018), Tang (Tang, 2015), and Sang et al. (Sang et al., 2021), combined with the actual situation of meat duck breeding, the risk perception was quantified by designing a 5-level scale, using its arithmetic mean for representation, based on "the degree to which the environmental pollution caused by meat duck breeding faces fines", "the environmental pollution caused by meat duck breeding reduces the impact of neighbor relations", and "the impact of environmental pollution caused by meat duck breeding on health." The related results are shown in Table 6.

Regression1, 4, and 7 are the results of the influence of constraint-type, incentive-type, and guidance-type environmental regulation, respectively, on the overall environmentally friendly behavior of farmers. The regression coefficients of the constraint type and the incentive type passed

TABLE 5 Analysis of endogeneity test results.

Variable	First stage		Second stage	
	Coefficient	S.E	Coefficient	S.E
Distance between the farm and the animal husbandry bureau	−0.004***	0.001	—	—
Constrained regulation	0.577***	0.036	0.355**	0.326
Incentive regulation	−0.008	0.023	1.564***	0.543
Guided regulation	—	—	0.178**	0.076
Control variable	controlled	controlled	controlled	controlled
Number of observations	1093		1093	
F value	38.19***		—	
Wald test	—		215.26***	
R2	0.337		—	

***, **, * represent the statistical significance at the levels of 1%, 5%, and 10%, respectively.

TABLE 6 Impacts of environmental regulation and risk perception on farmers' environmentally friendly behavior.

Variable	Model 1			Model 2			Model 3		
	Return 1	Return 2	Return 3	Return 4	Return 5	Return 6	Return 7	Return 8	Return 9
Constrained regulation	0.175*** (0.011)	0.301*** (0.034)	0.143*** (0.012)	—	—	—	—	—	—
Incentive regulation	—	—	—	0.158***(0.012)	0.366*** (0.021)<	0.132*** (0.013)	—	—	—
Guided regulation	—	—	—	—	—	—	0.064* (0.036)	0.139* (0.077)<	0.049* (0.030)
Risk perception	—	—	0.108*** (0.015)	—	—	0.073*** (0.016)<	—	—	0.105*** (0.019)
Control variable	controlled	controlled	controlled	controlled	controlled	controlled	controlled	controlled	controlled
F	54.10	47.20	70.40	50.72	69.75	48.52	15.54	35.93	25.03
Prob>F	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
R2	0.330	0.343	0.367	0.371	0.439	0.385	0.227	0.285	0.266

***, **, * represent the statistical significance at the levels of 1%, 5%, and 10%, respectively, and the data in brackets are t values.

the 1% significance test, and the guided type regression coefficient passed the 10% significance test. This indicates that environmental regulation has a significant positive impact on farmers' environmentally friendly behavior. Regression2, 5, and 8 are the results of the effects of constraint-type, incentive-type, and guidance-type environmental regulation on farmers' risk perception, respectively. The regression coefficients of constraint-type and incentive-type environmental regulation were 0.301 and 0.366, respectively, and passed the 1% significance test; the regression coefficient of guided environmental regulation was 0.139 and passed the 10% significance test. This shows that different environmental regulations have a significant impact on farmers' risk perception; that is, as the government increases supervision, subsidies, and training, farmers' risk perception gradually improves. Regression3, 6, and 9 show the direct effects of constraint-type, incentive-type, and guidance-type environmental regulation, respectively, on the environmentally friendly behavior of farmers after controlling for risk perception. Regression3 shows that the regression coefficients of constraint regulation and risk perception are both significant at the 1% level. Regression6 shows that the regression coefficients of incentive environmental regulation and risk perception are both significant at the 1% level. Regression9 shows that the regression coefficients of guided environmental regulation and risk perception are significant at the 10% and 1% levels, respectively. According to Wen et al. (Wen and Ye, 2004), the test method of the mediating effect is proposed. Both coefficient a and coefficient b are

significant, indicating that the indirect effect is significant. In the model, the regression coefficients c of different environmental regulations are all significant, and a, b, c have the same sign, indicating that there is a partial mediation effect on risk perception, and the mediation effect accounted for 18.58%, 16.91%, and 22.80% of the total effect, respectively. This indicates that 18.58%, 16.91%, and 22.80% of the effects of constraint-based environmental regulation, incentive-based environmental regulation, and guidance-based environmental regulation on farmers' environmentally friendly behaviors are achieved through the mediating effect of risk cognition, respectively. In other words, the government promotes farmers' environmental risk perceptions through regulatory instruments such as public education, increased subsidies and penalties, which in turn enhance the implementation of environmentally friendly behaviors by farmers.

\To fully test the indirect effect of risk cognition in the process of environmental regulation encouraging farmers to carry out environmentally friendly behaviors, referring to Fang et al. (Fang and Zhang, 2012), Preacher et al. (Preacher and Hayes, 2004) obtained more accurate confidence intervals and had higher test power by performing an interval test by the bias correction nonparametric percentile bootstrap method. Therefore, this article set the confidence level of the confidence interval to 95%, used 5000 repeated samplings, and judged the significance of the effect according to whether the 95% confidence interval contained a "0" value (Sang et al., 2021). The Table 7 show that the confidence intervals of the mediation effect of risk cognition in the relationship between constraint regulation, incentive regulation and guidance regulation on farmers' environmentally friendly behavior are (0.192, 0.229) (0.178, 0.208), and (0.021, 0.199), respectively, and the confidence interval does not contain 0, indicating that the mediating effect of risk perception is significant.

3.4.2 Moderating effect of guiding environmental regulation on other environmental regulations

Constraint regulation and incentive regulation comprise result policy, while guiding regulation is cause policy. Guiding regulation exerts a policy effect on the waste recycling behavior of meat duck farmers through constraint and incentive regulation. Theoretically, guiding environmental regulation plays an important role in promoting the environmentally friendly behavior of farmers and also plays a moderating role in the process of restrictive regulation and incentive regulation affecting the environmentally friendly behavior of meat duck farmers (Zhu et al., 2021). Therefore, to test the regulatory effect of guiding environmental regulation, after centralizing guiding, restraining, and incentivizing environmental regulation, the interaction terms "guidance regulation × restraint regulation" and "guided regulation × incentive regulation" were introduced, and regression was carried out. As shown in Table 8, the interaction items "guidance regulation × restraint regulation" and "guidance regulation × incentive regulation" are both significant, and the coefficients are positive, indicating that the guiding regulation plays a significant positive regulating role in the restraining regulation and incentive regulation affecting farmers' environmentally friendly behavior, this further validates the findings of Zhu et al. (Zhu et al., 2021).

3.4.3 Robustness check

To determine if some uncontrollable factors caused estimation bias in the benchmark regression results, this paper further conducted a robustness test using the following methods.

3.5 Substitute core explanatory variables

This paper used the average value of the three kinds of regulation arithmetic of constraint, incentive, and guiding regulation to characterize environmental regulation, represent a new environmental regulation variable, and regress it. The robustness test results of replacing the core explanatory variables are shown in Table 9. The results show that environmental regulation is significant at the 1% level, and the coefficient is positive, indicating that the regression results are robust.

3.6 Redefining the characteristics of the surveyed farmers

Among meat duck farmers, compared with young farmers, elderly farmers are relatively weak in terms of their health status

TABLE 7 Bootstrap test of the mediating effect of risk perception in environmental regulation encouraging farmers to engage in environmentally friendly behaviors.

Variable	Mediation effect		95% confidence interval	
	Coefficient	S.E	Lower limit	Upper limit
Constrained regulation	0.210	0.009	0.192	0.229
Incentive regulation	0.193	0.008	0.178	0.208
Guided regulation	0.189	0.056	0.021	0.199

TABLE 8 Moderating effect test of guided environmental regulation.

Variable	Equation 6		Equation 7	
	Coefficient	S.E	Coefficient	S.E
Constrained regulation	0.622***	0.066	—	—
Incentive regulation	—	—	0.432***	0.043
Guided regulation	0.091*	0.059	0.379***	0.055
Guided*Constrained regulation	0.192***	0.032	—	—
Guided* Incentive regulation	—	—	0.053*	0.031
Control variable	controlled		controlled	
Wald test	303.47***		297.45***	
R2	0.304		0.342	

***, **, * represent the statistical significance at the levels of 1%, 5%, and 10%, respectively.

TABLE 9 Robustness test.

Variable	Environmentally friendly behavior	Environmentally friendly behavior	Environmentally friendly behavior
	(1)	(2)	(3)
Environmental regulation	0.914***(0.167)	—	—
Constrained regulation	—	0.344**(0.073)	0.631***(0.142)
Incentive regulation	—	0.352***(0.048)	0.634***(0.093)
Guided regulation	—	0.178**(0.073)	0.297**(0.143)
Control variable	controlled	controlled	controlled
Observations	1093	1030	1093
R2	0.356	0.367	0.366

***, **, * represent the statistical significance at the levels of 1%, 5%, and 10%, respectively, and the data in brackets are t values.

and cognitive ability due to their weak physical fitness, cognition, and learning ability. Considering that the elderly over 60 years old cannot carry out the environmental pollution treatment of meat duck breeding due to physical and other reasons, the article excluded 60 years old farmers and above. The relevant results are shown in Table 9. The results show that constraint, incentive, and guidance regulation still significantly and positively affect farmers' environmentally friendly behavior, which confirms the robustness of the regression results.

3.7 Changing the regression analysis model

Since the explained variables of the article are discrete variables, the logit model was used for regression analysis, and the correlation analysis results are shown in Table 9. The results show that under the changed regression model, the constraint regulation, incentive regulation, and guiding regulation are still significant for the environmentally friendly behavior of farmers, which shows that the benchmark regression results are reliable.

4 Conclusion, policy implications, and future research

4.1 Conclusion

Based on the survey data of farmers in large meat duck breeding provinces, this paper analyzed the impact of environmental regulation on the environmentally friendly behavior of meat duck farmers. The Probit model from the perspective of the cost effect and Porter effect were applied. Further heterogeneity analysis of the environmentally friendly behavior of farmers at different scales were performed.

The main conclusions of this study are given below.

First, there is an "inverted U-shaped" nonlinear relationship between the intensity of environmental regulation and farmers' implementation of environmentally friendly behaviors. With the increase in the intensity of environmental regulation, farmers directly control pollution by increasing pollution control expenses; in addition, the utilization of manure recycling technology can increase productivity and profits and allow for more funds to be used for pollution control through the "innovative compensation effect".

Second, constraining, incentive, and guiding environmental regulation all have the significant positively effect on the environmentally friendly behavior of meat duck farmers, among which the impact of restraining environmental regulation is relatively high.

Third, there is heterogeneity in environmental regulation on the environmentally friendly behavior of farmers of different scales, the impacts of environmental regulation on the environmentally friendly behavior of medium-scale and large-scale farmers are more significant, and small-scale farmers are mainly affected by incentive regulation.

Fourth, risk perception has a partial mediating effect on the impact of environmental regulation on farmers' environmentally friendly behavior. Its mediating effect in the restriction regulation, incentive regulation, and guiding regulation accounts for 18.58%, 16.91%, and 22.80% of the total effect, respectively. Meanwhile, guidance regulation plays a significant positive role in affecting farmers' environmentally friendly behavior.

4.2 Policy implications

This research aimed to evaluate the healthy and stable development of meat duck breeding and the realization of ecological civilization construction. Thus, it investigated the optimization of effective measures to promote environmental regulation for the environmentally friendly behavior of meat duck farmers in order to provide a relevant reference for promoting the resource treatment of meat duck manure and the harmless treatment of sick and dead ducks.

First, local governments should formulate and implement environmental regulation policies according to the local conditions at all levels. This could accelerate the innovation of environmental protection systems, increase the intensity of environmental regulation, and avoid excessive regulation effects that may lead farmers to quit farming. At the same time, it is necessary to strengthen the awareness campaigns of manure recycling and harmless treatment of sick and dead ducks. It is important to improve relevant system for farmers to participate in environmental protection, and reasonably combine environmental supervision, punishment, rewards, and strengthening the related technologies. The assistance mechanism of the system maintains the mutual coordination of environmental policies and avoids "cask effect."

Second, the local governments should improve the breeding capacity of meat duck farmers, strengthen the publicity and promotion of new technologies for environmental pollution control of meat duck breeding, and conduct publicity and related training on the importance of environmental pollution control. This can improve farmers' awareness of environmental risks and their willingness to engage in environmentally friendly behaviors, thereby promoting the implementation of farmers' environmentally friendly behaviors.

Finally, farmers are encouraged to carry out moderate-scale farming, actively participate in local cooperative organizations when resource endowment conditions permit, rely on leading enterprises to carry out meat duck breeding. They could obtain information on meat duck breeding and production on time, get advanced relevant technical support from the organization, reduce the risk of breeding, and improve farmers' environmental awareness through subsidy policies. By participating in the organization of enterprises, the cost of resource processing can be reduced so that the innovative compensation brought by environmentally friendly behaviors can exceed its "cost effect." Thereby accelerating the green and efficient breeding mode of meat ducks and promoting the optimal allocation of environmental resources for low-carbon emission and healthy breeding of meat ducks.

4.3 Limitations of the study and future research

Our research has provided compelling evidence for improving environmentally friendly governance of meat duck farmers. However, some limitations are worth noting. First, although we used the micro-survey data of the National Waterfowl Industry Technology System in 2021 for empirical analysis, the number of samples is not large enough to represent the whole picture of the country. The data used in this study only focused on the main production areas of meat duck farming in China, yet, the farming situation in areas with relatively little meat duck farming was not studied deeply enough. Also, our study has only focused on 1 year of data on meat duck farming behavior, which may affect the length of the study. Future research needs to update the data to investigate the changes in environmentally friendly behavior of meat duck farming in different regions of China at different times.

Data availability statement

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

Author contributions

Conceptualization: JZ and LL. data curation: JZ and JD. formal analysis: JZ, LL, and JQ. funding acquisition: LL. investigation: JZ, LL, and JD. methodology: JZ. project administration: LL. resources: JZ and LL. supervision: LL. validation: JZ, LL, and JQ. visualization: JZ, JQ, and JD. writing—original draft: JZ. writing—review and editing: LL, JQ, and JD.

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Conflict of interest

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

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