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Original Research

Design of Ecological Compensation Criteria for Livestock Farming Based on Heckman-ISM Model - Evidence from 1069 Farm Household Surveys in 106 Counties

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Abstract

Establishing a payment for environmental services scheme is an effective way to promote the process of cleaner production in livestock husbandry, and the determination of payment for environmental services standards is the key to constructing the scheme for cleaner production in livestock husbandry. Based on 1,629 survey data from 9 provinces of Hunan, Henan, Shandong, Hebei, Hubei, Jiangxi, Liaoning, Anhui and Heilongjiang, this paper uses the Heckman-ISM model to analyze the impact of pig farm households' willingness to accept payment for cleaner production and the influencing factors of anticipated payment level. The study found that the size of the farmer, the operator, experience, perceptions about the payment for environmental services policy, the degree of specialization and the household structure can influence the level of compensation of the policy to some extent. In the influence mechanism of the anticipated level compensation, the awareness of the ecological value of cleaner production and cleaner production policy is the direct factors at the surface; the degree of specialization, government officials and non-local markets county are intermediate indirect factors, while gender, education level and urban residence are deep root factors. Based on these findings, this paper puts forward policy suggestions such as vigorously publicizing payment for environmental services for cleaner production in livestock husbandry.

Keywords: livestock, payment for environmental services, PES standard

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Introduction

China is one of the leading producers of pig farming. Livestock farming is one of the primary sources of non-point pollution, which causes damage to the environment and ecosystem [1]. A number of environmental issues related to climate anomalies, resource depletion and water security caused by livestock farming have already had a serious impact on the living environment of the people in China [2]. With the improvement of the scale and intensification of livestock husbandry, the environmental pollution and ecological damage brought about by the rapid development of China's pig farming have become increasingly prominent [3]. However, the current clean production of livestock husbandry faces higher economic costs and technical thresholds [4]. It is also challenging to achieve long-term development of cleaner production by purely mandatory means. Exploring the PES scheme for cleaner production in livestock husbandry from the perspective of positive environmental externalities is an effective way to speed up the process of cleaner production in livestock husbandry.

The exploratory research on cleaner production in livestock husbandry began in the early 21st century [5]. Based on cleaner production, front-end control methods are used in livestock and poultry breeding. Scientific allocation of feed, improved feeding technology and infrastructure can reduce the residues of toxic and harmful substances in livestock products, reduce nitrogen and phosphorus emissions, and improve the ecological environment [6, 7]. Based on the classification of ecosystem services [8], studies on ecological functions and ecological value assessment of cleaner production in livestock husbandry have begun to emerge in recent years. Some studies found that improving the breeding production efficiency and the pig breeding environment can increase the sustainability of the ecological environment. Chen (2020) [9] used a generalized logistic model to analyze a sample of 2,437 country representative individuals from five European countries and found that consumer preferences and needs can influence the acceptance of implementing cleaner production processes in livestock production The above studies show that the academic community has begun to pay attention to the ecological value of livestock husbandry.

PES is an effective means to solve environmental pollution through economic incentives. PES programs led by the public sector can effectively reduce transaction costs and ensure the durability of incentives, which contributes to achieving ecological protection goals. The PES for cleaner production in livestock farming refers to the economic incentives provided by the government to livestock farmers for their pro-environmental behaviour. It compensates them for the production costs associated with cleaner production to reduce environmental pollution during the farming and management process. In recent years, countries worldwide have widely used agricultural PES to deal with ecological and environmental problems in the agricultural field [10, 11]. In terms of PES for cleaner production in livestock husbandry, David (2015) [12] proposed using subsidies to educate and provide technical assistance to farmers to promote the development of environmentally friendly livestock husbandry development. Eijrond et al. (2019) [13] conducted research based on survey data in Dutch, which showed that livestock husbandry could play a role in soil fertility protection, biological regulation and erosion. Li et al. (2020) [14] pointed out that PES can compensate farmers for the losses caused by significant animal diseases and effectively motivate farmers to invest in disease prevention. Luo et al. (2014) [15] argued that when determining the compensation standard, the willingness to be compensated should be considered in the compensation standard. The research on PES for livestock husbandry in China only started recently, and the relevant research has been concentrated in the last three to five years. One focus is to compensate for reduced stock capacity in grassland and pastoral areas, and the other is to compensate for cleaner production procedures adopted in livestock husbandry. Such as subsidies for environmentally friendly raw materials and reduced usage of environmentally damaging chemicals, payment for epidemic prevention procedures and treatment of sick and dead livestock and poultry [16]. It is feasible and necessary to make reasonable compensation for the ecosystem services provided by cleaner livestock production, which has a theoretical and practical basis. However, because the research on PES for cleaner production in livestock husbandry is still in its infancy, the compensation standard has not yet formed a conclusion.

The concept of ecological compensation has its roots in ecological theory, and Cuperus (1996) [8] considers ecological compensation to be the replacement of damaged ecological functions or qualities. Allen (1996) [1] sees ecological compensation as the restoration of ecologically damaged sites, or the replacement of existing ecological functions or qualities by new ecological sites. International practice of ecological compensation was first focused on Costa Rica and Mexico. Robalino (2008) [17] assessed the effects of forest conservation programmes in Costa Rica and Mexico by comparing deforestation rates in the same area before and after the implementation of ecological compensation and in different areas with and without ecological compensation. Sierra (2006) [18] analyzed the effects of forest conservation programmed in Costa Rica through changes in forest cover in Costa Rica's OSA Peninsula Forest Conservation Compensation Program. In the 1980s, monetary compensation was introduced in the US to incentivize upstream watershed residents to undertake soil and water conservation.

Compensation standards are the core of ecological compensation, and the reasonableness of compensation standards is directly related to the efficiency and effectiveness of ecological compensation

implementation. The determination of ecological compensation standards has been richly discussed. Due to the complexity of ecosystems and the limitations of economic methods, there is no widely accepted estimation method. Wang (2007) [19] used the RPL model to estimate that residents of Beijing, Xi'an and Ansei were willing to pay 3. 2%, 2. 0% and 2. 2% of their annual income, respectively, for ecological compensation on the Loess Plateau. Johst (2017) [20] developed an eco-economic modelling procedure to enable the detailed design of spatio-temporal arrangements of ecological compensation budgets by species and function and provided quantitative support for the implementation of compensation policies ecological compensation standards usually incorporate the willingness of ecological protectors [21]. Zhang (2022) [22] argues that ecological compensation needs to be based on three things if it is to have the desired effect. The first is the identification of the actual poor, the second is the ability of the poor to participate, and the third is the amount of compensation. Research findings on the factors influencing the willingness and standard of ecological compensation are more abundant in the areas of fisheries closures, wetlands, grasslands and arable land. Li (2014) [23] examined the effects of agroecological compensation policies on plant diversity in Swiss mountain grasslands and concluded that species richness was strongly influenced by management intensity. In summary, the field of agroecological compensation has produced very rich research results. And the discussion on ecological compensation criteria and its influencing factors has been a hot topic of academic debate which can provide important inspiration and reference for this study.

The cleaner production practices of pig farm households refer to the comprehensive measures taken in the three stages of the production chain, including source prevention, process control and end treatment. More specifically, it involves continuous improvement of product design, use of clean energy and raw materials, adoption of advanced technology and equipment, improvement of management. With the comprehensive utilization of the above measures, clean production can reduce pollution from the source, improve resource utilization efficiency, and reduce or avoid the production and emission of pollutants in production and product use. Specifically, it includes six key behaviours of clean infrastructure, clean input, clean production environment, clean feed, resource re-utilization and clean treatment. Pig farm households face higher economic costs and technical thresholds for implementing cleaner production; the ecological service value of cleaner production in livestock husbandry requires them to pay extra costs, which is difficult to achieve by themselves. Moreover, the government adopting coercive measures will raise external costs and reduce productivity, which is challenging to achieve the long-term development of clean production in livestock. Therefore, building a reasonable PES scheme has become a valuable exploration to solve this problem. According to the actual situation in China, ecological compensation includes four forms of government compensation, financial compensation, in-kind compensation and intellectual compensation. Based on the compulsory power of the government, government compensation is currently the primary form of the PES scheme, and it is also a relatively easy compensation method to start [24]. In the early stage of constructing the PES scheme for cleaner production in livestock husbandry, only the state or the higher-level government can act as the main body of implementation and compensation to pay for ecological services. However, unreasonable compensation standards are difficult to achieve effective incentives for cleaner production of pig farms or create excessive incentives, resulting in the phenomenon of "market failure" of the PES scheme [25, 26]. Therefore, discussing the WTA and anticipated payment levels for cleaner production of pig farms can provide a realistic reference for determining PES standards and improving PES policies.

The WTA and anticipated payment levels for cleaner production of pig farms are often affected by multiple variables such as internal factors, external factors, historical experiences, and expectations. In the complex system of influencing factors, the individual characteristics of household heads are the first factors to be considered. Existing studies have generally selected gender, age, and educational level indicators to measure individual differences. In the field of PES, Sun (2019) [16] used a choice experiment approach to investigate farmers' preferences for livestock pollution control policies and found heterogeneity in farmers' preferences for livestock pollution control policies. Farmers' choice of policy options to improve pollution was significantly influenced by their education, farm size and willingness to deal with pollution. Many research results in the field of agricultural PES have verified that the characteristics of household production and management have a significant impact on the willingness of farmers to receive PES. Ecological literacy means that people with ecological literacy must have the knowledge and caring attitude needed to understand the interconnectedness and have the practical ability to act according to knowledge and feelings. The influence of knowledge and ecological cognition on PES willingness is explained as the residents' ecological knowledge can significantly increase their PES willingness [27-30], and ecological cognition also positively affects farmers' PES payment willingness. A social network is a collection of social agents and their relationships and a concentrated expression of their social roles. In the field of agricultural PES, the impact of social networks has been verified in many research results. Yu (2021) [31] analyzed farmers' cleaner production behavior from the perspective of contractual incompleteness and social trust based on field experiment data from Chinese broiler farmers and found that social trust could promote farmers' cleaner production behaviour.

Based on the above analysis, this paper proposes the following hypotheses:

H1: The personal characteristics of the household head will affect the WTA and anticipated payment levels for cleaner production of pig farm households.

H2: The characteristics of household production and operation will affect the WTA and anticipated payment levels for cleaner production of pig farms.

H3: Ecological literacy will affect the WTA and anticipated payment levels for cleaner production of pig farm households.

H4: Social networks will affect the WTA and anticipated payment levels for cleaner production of pig farm households.

PES for cleaner production in livestock husbandry is a relatively new field. Only a few studies on PES are based on a single node of cleaner production in livestock husbandry. The systematic research on the level of willingness to be compensated and the empirical analysis of the influencing machine are insufficient. Based on the survey data of 1,629 pig farm households in 106 counties in 9 provinces of Hunan, Henan, Shandong, Hebei, Hubei, Jiangxi, Liaoning, Anhui and Heilongjiang, this paper intends to evaluate the willingness of pig farm households through the conditional value assessment method. The compensation level was estimated, and the Heckman two-stage model was constructed to analyze the factors affecting the willingness of pig farm households to be compensated for clean production and the willingness to be compensated. The innovations of this paper are followed. (1) Drawing on the idea of PES, based on the ecological service value of cleaner production in livestock husbandry, we try to measure the willingness and level of compensation for cleaner production of pig farms from the perspective of the willingness of pig farms to pay. (2) Using the Heckman two-stage model to empirically analyze the factors affecting the willingness of pig farms to be paid for cleaner production and the level of willingness to be paid in order to overcome the selection bias of the sample and provide relevant departments. It provides an essential reference for formulating PES policies.

Material and Methods

Data Sources

The data used in this article come from a survey of pig farm households in 106 districts (counties) in 9 provinces of Hunan, Henan, Shandong, Hebei, Hubei, Jiangxi, Liao, Anhui, and Heilongjiang from July to October 2021. There are three types of survey methods: First, we conducted face-to-face field research with pig farm households in Ningyang County and Yishui County (Shandong Province), Pingqiao District and Zhengyang County (Henan Province), Jiangxia District and Sui County (Hubei Province), Feidong County (Hunan Province) and Kaiyuan City (Liaoning Province). Second, we organized college students who reside near pig farm households to carry out questionnaires on surrounding farm households during the summer vacation. These students are mainly from Shandong Agricultural University, Northeast Agricultural University, Hebei Agricultural University, and Huazhong Agricultural University. The third is to entrust local government animal husbandry departments to conduct questionnaire surveys on pig farm households within the jurisdiction. Fig. 1 shows the cities covered in the survey of this paper (In Red).

In order to overcome the sample bias, the research team has strictly regulated the survey process. To avoid information bias, we explained the origin of PES, the requirements for cleaner production in animal husbandry, the practical background and policy implications of PES for cleaner production in animal husbandry, etc. The nine provinces of Hunan, Henan, Shandong, Hebei, Hubei, Jiangxi, Liaoning, Anhui and Heilongjiang cover the four geographical divisions of Central China, East China, North China and Northeast China in terms of geographical location and are essential pig breeding areas in the country. [1]In 106 research areas, 68 large counties mainly serve non-local markets (referred to as NLM counties in this paper), accounting for 64.15% of the total number of surveyed areas. A total of 2,000 questionnaires were distributed in this survey, and 1,629 qualified questionnaires were recovered. Among them, 1,114 samples came from NLM counties, accounting for 68.39% of the total questionnaires (refer to Table 1 for details). The essential characteristics of the respondents are detailed in Table 2.

Variable Selection

There are two dependent variables in this paper. One is the willingness to accept payment for cleaner production of pig farm households, and the other is the anticipated level of compensation for cleaner production of farm households. Under the framework of PES, pig farm households can be encouraged to implement cleaner production through material rewards to reduce breeding pollution and achieve the purpose of protecting the ecological environment. The questionnaire reflects the willingness to accept payment for cleaner production of pig farm households, “Are you willing to implement cleaner production on the premise that the government provides compensation?” in the questionnaire. The anticipated compensation level for cleaner production is reflected by the question, “If the

[1] According to the „China Statistical Yearbook 2021”, Hunan, Henan, Shandong, Hebei, Hubei, Jiangxi, Liaoning, Anhui, and Heilongjiang ranked the 2nd, 3rd, 5th, 6th, 7th, 10th, 11th, 12th and 14th respectively in the slaughter volume of 31 provinces in 2021, the slaughter volume of live pigs in the above mentioned nine provinces accounted for 49.69% of the total national volume.

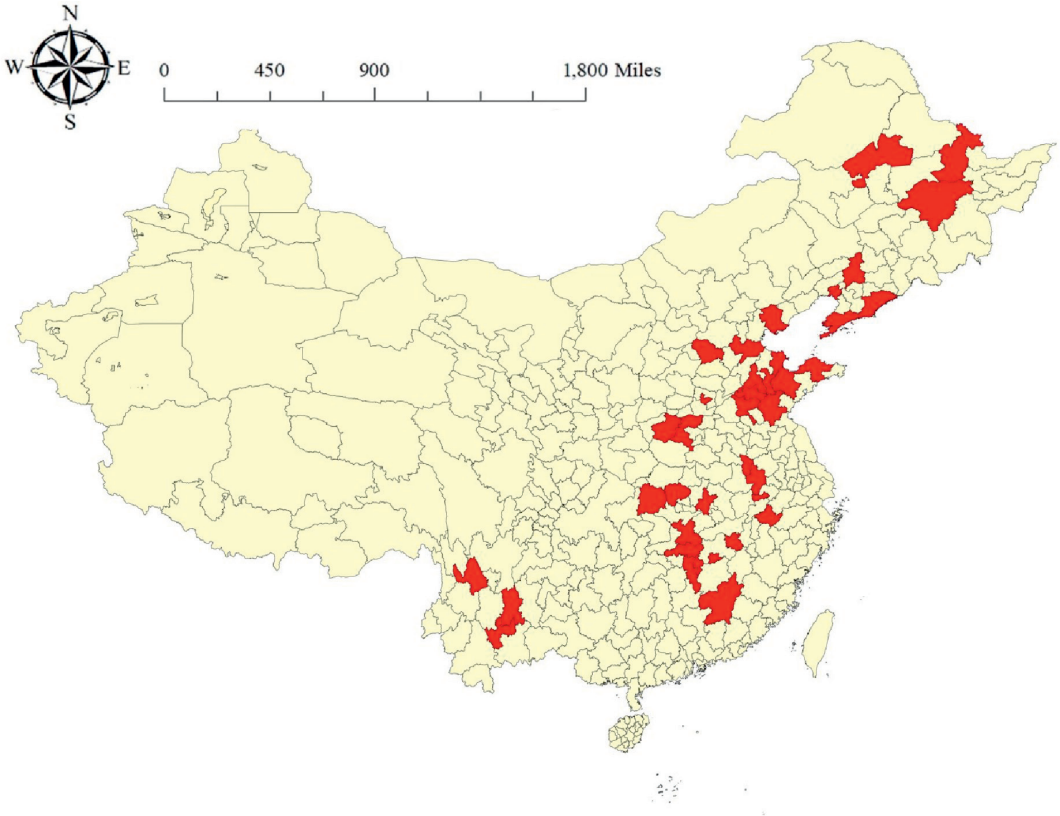

Fig. 1. Sources of survey data.

government subsidizes cleaner production in animal husbandry, what is the minimum compensation amount per pig per year that will encourage you to implement cleaner production?" The answer options for this question are designed into a payment card, considering the increased cost of cleaner production, the assessed ecological value.

As mentioned above, this paper draws on the existing research in the field of agricultural PES and designs independent variables from four aspects: individual characteristics of household heads, family production and management characteristics, ecological cognition and social network. The individual characteristics of the household head were reflected by three indicators of gender, age, and education background. The family production and management characteristics were reflected by four indicators: the number of household labour, the logarithm of the pig breeding scale, the pig breeding experience, and the degree of specialization. Among them, the degree of specialization is measured by the proportion of income from pig raising to total family income. Ecological cognition is measured by two indicators: cognition of ecological service of clean production and cognition of PES policy for clean production. A social network is assessed in three aspects, if there are government officials in the family, does the interviewee has an urban residence and if the interviewee resides in an NLM county.

Method

The conditional value assessment method is based on the imaginary market environment, directly asking and investigating the willingness of the respondents to be compensated. It is often used to measure the utilization value of the ecological environment. Compared with traditional methods, it is more advantageous. It has been widely used by environmental economists and is suitable for assessing the willingness to pay for cleaner production (WTA) of pig farmers. When designing a questionnaire, the form of payment card is adopted, and the options are set in intervals so that the recipients' willingness can be directly obtained from the original data. We have set up a new processing method. The WTA of each pig farm household is replaced by the median value of its bidding interval. When dealing with the maximum interval value of the WTA of pig farm households, the one with the highest WTA frequency is selected to avoid extreme effects. The equation is given as:

$$E(WTA) = \sum_{i=1}^{k} A_i P_i \quad (1)$$

where A_i represents the i-th first bid quote of a sample pig farm household, and P_i represents the probability of the pig farm household choosing A_i.

The Heckman two-stage model is an econometric method to correct sample selection bias. Heckman pointed out the existence of sample selection bias, which

Table 1 Research Areas (unit: piece, copy, %)

Province	Hunan	Hebei	Shandong	Hebei	Hubei	Jiangxi	Liaoning	Anhui	Heilongjiang	Total
Number of counties investigated	4	9	39	12	8	6	7	9	12	106
Number of large counties that mainly serves non-local market	4	5	28	6	6	5	3	6	5	68
Number of questionnaires	197	134	364	201	183	152	179	98	121	1629
Number of questionnaires as opposed to total number of questionnaires (%)	12.09	8.23	22.34	12.34	11.23	9.33	10.99	6.02	7.43	100
Slaughter ratio (%)	8.84	8.18	6.35	5.52	4.99	4.21	4.13	4.08	3.40	49.69

Note: The slaughter ratio is calculated based on the slaughter volume data of the above provinces in 2020 in the "China Statistical Yearbook 2021"

should be corrected before conducting econometric Analysis [32]. This method has been widely used in social science research. A choice model was constructed and estimated in the first stage of the study. The WTA of pig farm households to adopt cleaner production is regarded as a binary random variable, where $Y_i = 1$ means that pig farm household i is willing to accept PES for cleaner production, and $Y_i = 0$ means pig farm household i is reluctant to accept PES. The decision-making process will be affected by many factors, so the characteristic variable X_{i1} is constructed, a series of influencing factors affecting the willingness of pig farm households to get compensated for cleaner production. ∂_1 is an estimated parameter vector. The inverse Mills ratio λ_i can be obtained from estimates in the first stage, and the specific equation is as follows:

$$\Pr obit(Y_i = 1) = \Phi(\partial_1 X_{i1}) \tag{2}$$

In the second-stage outcome model estimation, further research is conducted on pig farm households that are willing to accept PES for cleaner production. The variable Z_i is constructed to estimate the level of WTA of these pig farm households. X_{i2} is defined as the series of factors influencing farm households' level of WTA. The inverse mills ratio λ_i is added to the model as one of the independent variables to overcome the sample selection bias. β_1 is the estimated parameter vector, and μ_i is the random error term. The multiple linear regression model was used to investigate the influencing factors of the level of WTA in pig farmer households. The specific equation is given as:

$$Z_i = \beta_0 + \beta_1 X_{i2} + \delta\lambda_i + \mu_i \tag{3}$$

The basic principle of the Interpretive Structural Model (ISM) is to translate complex system elements into clear structural relationships. The idea of ISM model is to use some basic assumptions, directed graphs and matrices to process the selected factors, solve and decompose the reachable matrices, and decompose the system into intuitive multi-level recursive structural forms. It is beneficial to improve the overall understanding of the system. Given that the final point of this paper is to determine the ecological compensation standard for cleaner production in animal husbandry. This paper takes the dependent variable of the Heckman second stage outcome model. The mechanism of the influence of the willingness to be compensated level of cleaner production of pig farmers is developed as an example. Equation (4) represents the willingness of pig farmers to be compensated for cleaner production by S_0. It indicates the k significant influences on the level of compensation for the willingness of pig farmers to clean production. The adjacency matrix is constructed based on the expert's judgment of the logical relationship between the elements: if S_i has influence on S_j, a_{ij} is assigned a value of 1, and if there is no influence on, a_{ij} is assigned a value of 0. The matrix R formed by a_{ij}

Table 2 Basic characteristics of respondents (unit: %)

Variable	Definition	Frequency	Proportion	Variable	Definition	Frequency	Proportion
Gender	male	566	34.70	Age	35 years old and below	334	20.50
	Female	1063	65.30		36~45 years old	448	27.50
Educational level	Elementary school and below	189	11.60		46~55 years old	613	37.63
	junior high school	579	35.54		56 years old and above	234	14.36
	Secondary school or high school	383	23.51	Scale of Production	100 heads and below	484	29.71
	College or Undergraduate	410	25.18		101 to 200 heads	379	23.27
	postgraduate	68	4.17		201 to 500 heads	330	20.26
Degree of specialization	35% and below	326	20.01		501 to 1500 heads	231	14.18
	35%~50%	330	20.26		1501 heads and above	205	12.58
	51%~70%	299	18.35	Breeding experience	3 years and below	443	27.19
	71%~90%	272	16.70		4 years to 10 years	705	43.28
	91% and above	402	24.68		11 years to 15 years	252	15.47
NLM county	Yes	1114	68.39		16 years to 20 years	156	9.58
	No	515	31.61		21 years and above	73	4.48

is the adjacency matrix between the elements. According to Equation (5) and following the Boolean operator, the adjacency matrix R is transformed into the reachable matrix M, where I is the unit matrix. The highest level factor is then determined according to Equation (6). After determining the top-level element set, the elements in the L_1 layer are removed from the reachable matrix to obtain the matrix M', and then M' is used to obtain the second element set L_2, and so on, to obtain the element set in the third and last layer. By connecting the elements of each layer with directed edges according to the hierarchy, we can obtain the associated hierarchy among the elements.

$$S_i(i = 1,\ 2,\ \ldots, k) \tag{4}$$

$$M = (R+I)^{\tau+1} = (R+I)^{\tau} \neq (R+I)^{\tau-1} \neq \ldots \neq (R+I)^2 \neq (R+I) \tag{5}$$

$$L_1 = \{S_i | P(S_i) \cap Q(S_i) = P(S_i); i = 0,1,\ldots, k\} \tag{6}$$

Results and Discussion

Descriptive Statistics

Table 3 displays the descriptive statistics of the complete sample and the sample group's willingness to accept payment for cleaner production. According to the conditional value method, the level of compensation for cleaner production of pig farm households to clean production is 10.62 yuan/head-year.

Select Model Regression Results and Marginal Effects

After the multicollinearity test, this paper uses the Heckman model to estimate the influencing factors of the WTA for cleaner production and the anticipated compensation level. The inverse mills ratio coefficient is 1.4205, which is not significant at the 1% level 0 (P = 0.000), indicating a selection bias in the sample, and the selection of the Heckman model is reasonable. However, the benchmark regression model can only give the direction of the effect of the change of the independent variable on that of the dependent variable. The marginal effect of the independent variable on the dependent variable should be estimated by the marginal effect model. Table 4 exhibits the estimated results and marginal effects of the factors affecting the WTA for cleaner production of pig farm households.

As shown in Table 4, variables gender, age and age squared significantly impact the willingness of pig farm households to accept payment for cleaner production. This confirms hypothesis 1. For every unit increase in gender, the willingness to be compensated for cleaner production of pig farm households increases by 0.1159 units. Male respondents are more willing to be compensated for cleaner production than female respondents. The reason for such a difference in decision-making is that women focus on short-term benefits because they pay attention to details, while men focus on winning long-term benefits. In the long run, individual economic interests can be safeguarded through the realization of the value of ecological products, so overall male respondents are more inclined to implement cleaner production. For every unit increase in age, the WTA for cleaner production of pig farm households will decrease by 0.0086 units, and for an increase in the square of age by 1 unit, the WTA for clean production will increase by 0.0001 units. The relationship between WTA for cleaner production and the age of respondents exhibits a U-shaped curve. The older the age, the lower the willingness to be compensated for cleaner production, but the willingness of pig farm households to be compensated for cleaner production increases after a certain age level. Possible reasons for the U-shaped relationship could be that the average age of the respondents is over 44 years old, and older groups are reluctant to participate in emerging conduction such as cleaner production; however, after exceeding the age threshold. It is not ruled out that some elderly pig farm households may involve in short-term speculative behaviour of receiving ecological compensation but do not act accordingly.

Pig production scale, pig farming experience, and degree of specialization significantly impact the willingness of pig farmers to be paid for cleaner production. Hypothesis 2 has been partially verified. For every unit of increase in the pig breeding scale, the willingness of pig farm households to be compensated for clean production decreases by 0.0374 units. The explanation for this could be that there are three steps to reducing pollution and emissions and practicing environmentally friendly pig breeding activities will inevitably impose certain technical thresholds and financial pressures and will also consume more time and energy for pig farm households. The larger the breeding scale, the more difficult it is to implement. For each additional unit of pig farming experience, the WTA for cleaner production of pig farm households decreases by 0.0055 units. The possible explanation is that the more pig farming experience is, the more "inertial thinking" of pig farm households has been formed, and they tend to follow the original farming habits and management skills without much change or other inputs. For every 1 unit increase in specialization, the WTA for clean production of pig farm households increases by 0.1188 units. This is because the higher the degree of specialization, the more vulnerable the livelihood of pig farm households and the more concerned about the changes in the development environment, especially the policy environment of the pig industry. Compared with pig farmers with a high degree of concurrent employment, they have the inherent economic motivation to engage in cleaner production under the premise of ecological compensation.

Table 3. Variable Definition and Descriptive Statiscs.

Variable	Variable Description	Complete sample		WTA Group	
		Average Value	Standard Deviation	Average Value	Standard Deviation
Explained Variable					
Willingness to accept payment (WTA) for CP	If the interviewee is willing to accept payment for adopting clean production, no = 0, yes = 1.	0.90	0.30	1	0
Anticipated payment level	If the interviewee is positive with WTA, state the anticipated minimum payment level (unit: CNY per year)	-	-	10.62	8.38
Explaining Variable					
Gender	Gender of interviewees: female = 0, male = 1.	0.65	0.48	0.68	0.47
Age	Age of interviewees in 2021.	44.28	10.94	44.36	11.00
Education Background	Level of education: primary school degree and less = 1, junior high school degree = 2, high school degree = 3, bachelor's degree and equivalent = 4, master and PhD degree = 5.	2.75	1.19	2.74	1.21
Number of Household Labors	The number of laborers within a family in 2020.	2.89	1.58	2.88	1.52
The scale of Production (log)	A number of pigs were sent for slaughter in 2020; a log form was taken to the data for statistical purposes.	2.29	0.80	2.28	0.79
Experience in Breeding	Years engaged in pig farming until 2021.	8.86	6.87	8.74	6.74
Degree of Specialization	The proportion of income from pig farming over total income.	0.72	0.28	0.63	0.26
Ecosystem Service Perception	The interviewee's response to the statement "clean production provides ecosystem services" is firmly disagree = 1, disagree = 2, neutral = 3, agree = 4, strongly agree = 5.	3.24	1.17	3.25	1.19
PES policy perception	Interviewee's response to the statement "the government should provide payment for clean pig production", strongly disagree = 1, disagree = 2, neutral = 3, agree = 4, strongly agree = 5.	3.77	1.13	3.82	1.12
Government official	If anyone in the family is a government official, no = 0, yes = 1.	0.40	0.49	0.41	0.49
Urban residence	If the interviewee has lived in urban areas for six months and more, no = 0, yes = 1.	0.42	0.49	0.41	0.50
NLM county	If the residential county sends more slaughtered pigs to non-local markets, no = 0, yes = 1.	0.68	0.34	0.55	0.49

Note: The number of observations totals 1629, and the number of observations in the WTA group amounts to 1467.

The cognition of the ecological compensation policy for cleaner production has a significant positive impact on the willingness of pig farmers to be compensated for cleaner production. Hypothesis 3 has been partially verified. For every unit increase in the awareness of the clean production ecological compensation policy, the WTA for clean production of pig farm households increases by 0.0277 units. Based on the judgement that it is necessary to compensate for clean production, farm households are affirmative that the PES scheme contributes to the implementation of cleaner production and are willing to cooperate in practical actions.

The variables of a government official and NLM county significantly positively impact the willingness of pig farm households to be compensated for cleaner production. Hypothesis 4 has been partially verified. When the variable government official increase by 1 unit, the pig farm households' willingness to accept payment for clean production increases by 0.0424 units. The possible explanation is that from the perspective of social role theory, village and town officials take on conscious and prescribed roles, and apart from the basis of their responsibilities, efforts are made to use their actions to infect the people around them. That is, they have the sense of responsibility to implement good social behaviour norms, values, etc., so households with government employees are more willing to accept compensation for cleaner production. The variable

Table 4. Estimated results (selection model) and marginal effects of factors affecting the willingness to accept payment for cleaner production of pig farm households.

Variable name	Coefficient	Standard error	dy/dx	Delta standard error
Gender	0.7376 ***	0.1015	0.1159 ***	0.0160
Age	-0.0546 **	0.0258	-0.0086 **	0.0041
Age squared	0.0007 **	0.0003	0.0001 **	0.0004
Educational level	-0.0369	0.0395	-0.0058	0.006
Number of household labour	0.0054	0.0273	0.0008	0.0043
The scale of Production (logarithmic)	-0.2379 ***	0.0665	-0.0374 ***	0.0105
Pig farming experience	-0.0352 ***	0.0070	-0.0055 ***	0.0011
Degree of specialization	0.7548 ***	0.1976	0.1186 ***	0.0310
Ecological Value Cognition of Cleaner Production	0.0377	0.0398	0.0059	0.0062
Cognition of Ecological Compensation Policy for Cleaner Production	0.1764 ***	0.0369	0.0277 ***	0.0058
Government official	0.2701 ***	0.1009	0.0424 ***	0.0158
Urban residence	-0.0642	0.1078	-0.0101	0.0169
NLM county	0.1972 **	0.1031	0.0310 *	0.0162
Constant	1.6375	0.6059	-	-

Note: ***, **, * represent significant at the 1%, 5%, and 10% statistical levels, respectively.

NLM county increases by 1 unit, and the WTA of pig farm households increases by 0.0310 units. There are incentive policies for NLM counties that dates to 2007; the rewards provided by the government are used for a pig house renovation, introduction of improved breeds, epidemic prevention management, manure treatment and loan interest discounts, etc. Therefore, pig farm households situated in NLM counties may enjoy more preferential policies, and they are better equipped to implement cleaner production in terms of renovating the pig house and treating manure and pollutants, contributing to more willingness to implement cleaner production under the PES scheme.

Outcome Model Regression Results and Marginal Effects

Table 5 exhibits the estimated results and marginal effects of the factors affecting the anticipated level of compensation for cleaner production of pig farm households. The variables of a government official, urban residents, and NLM county significantly impact the willingness to pay for cleaner production of pig farm households.

When gender increases by 1 unit, the level of anticipated compensation for adopting cleaner production of pig farm households decreases by 0.2609 units. According to the upper echelon's theory, there are apparent differences in the decision-making preferences of men and women. Female respondents pay attention to details and are more sensitive to costs and expenditures and are more sensitive to the amount of ecological compensation. Under the influence of the traditional perception that „men take care of business outside of the household while women are in charge of the domestic affairs", male respondents often have more opportunities to go for training or socialize. They are more likely to contact new dynamic information in the industry, thus making them more innovative in professional business decision-making. In addition, men often make up the vast majority of village and town officials at the grassroots level.And the number of female government officials is still minimal. The educational level increases by 1 unit, level of anticipated compensation for adopting cleaner production of pig farm households decreases by 0.8854 units. Educational level is a crucial factor affecting the public's environmental awareness. The higher the educational level of pig farm households, the stronger the sense of social responsibility, the more active they are in participating in environmentally friendly production conduct, and the less demanding you are on the amount of ecological compensation.

When the degree of specialization increased by 1 unit, the anticipated level of payment for clean production of pig farm households increased by 2.6931 units. The reason is that, with the improvement of the degree of specialization, the input of production factors of pig farm households in pig breeding activities will increase. Correspondingly, the expectation of the amount of compensation for cleaner production will naturally increase under the circumstance of high capital input. Second, the higher the degree of specialization,

Table 5. Estimated results (outcome model) and marginal effects of factors affecting the anticipated level of compensation for cleaner production of pig farm households.

Variable name	Coefficient	Standard error	dy/dx	Delta standard error
Gender	-0.06849 **	1.1594	-0.2609 **	0.5074
Age	0.0427	0.1199	0.0597	0.1002
Age squared	-0.0009	0.0014	-0.0012	0.0012
Educational level	-0.9007 ***	0.1984	-0.8854 ***	0.1895
Number of household labour	-0.0493	0.1444	-0.0507	0.1447
The scale of Production (logarithmic)	0.2934	0.4229	0.3705	0.2983
Pig farming experience	-0.0682	0.0594	-0.0558	0.0344
Degree of specialization	2.9501 **	1.3676	2.6931 ***	0.9333
Ecological Value Cognition of Cleaner Production	0.7579 ***	0.1857	0.7464 ***	0.1805
Cognition of Ecological Compensation Policy for Cleaner Production	0.2445 *	0.3377	0.0465 *	0.1944
Government official	-2.4469 ***	0.5691	-2.5378 ***	0.4464
Urban residence	1.1058 **	0.4914	1.1321 **	0.4815
NLM county	1.0304 *	0.5369	0.9615 **	0.4659
Constant	9.7497 ***	2.7563	-	-

Note: ***, **, * represent significant at the 1%, 5%, and 10% statistical levels, respectively.

the more dependent the pig farm households are on pig breeding activities. A high level of payment can reduce economic pressure or deal with unknown risks of cleaner production.

If the awareness of the ecological value of cleaner production increases by 1 unit, the anticipated level of payment for clean production of pig farm households increases by 0.7464 units. The more comprehensive the awareness of the ecological value of cleaner production is, the higher the asking price of ecological services provided, which is essentially the same as all market transactions. The awareness of the cleaner production compensation policy increases by 1 unit, and the anticipated level of payment for clean production of pig farm households increases by 0.0465 units. On the premise that the government provides compensation, pig farmers always hope to receive a higher amount.

The variables of government official increase by 1 unit, and the anticipated level of payment for clean production of pig farm households decreases by 2.5378 units. At the grassroots level, village and town officials are the representatives of the government. They play an exemplary role in responding to the environmental protection demands of the government and the public. So, they are "willing" to take less amount of the ecological compensation, resulting in a relatively low anticipated level of compensation for cleaner production. Local government officials have a more comprehensive social network, more information channels, and a higher degree of contact with the mass media, so they have a higher degree of awareness of cleaner production-related content. When there is an increase of 1 unit of urban residence, an increase of 1.1321 units occurs for the anticipated payment level of pig farm households. It may be because urban residents' income, consumption, cultural dissemination, and policy perception differ from residents in rural areas. Pig farm households with urban life experiences differ from those without value judgment, and their willingness to pay for cleaner production is relatively high. The variable NLM county increased by 1 unit, and the anticipated level of payment for clean production of pig farm households increased by 0.9615 units. This is because the pig farm households in NLM counties have a relatively larger breeding scale and a higher degree of specialization. Compared with pig farms in non-NLM counties, the difficulty and cost of implementing cleaner production are more significant. So the willingness to be compensated is naturally higher.

Robustness Test

This paper uses a permutation test and dependent variable data indentation for the robustness test. The model estimation results are shown in Table 6, suggesting that the estimation results of the benchmark regression model are robust.

Analysis of Influence Mechanism Based on ISM

In the ISM analysis, S_0 is used to denote the level of willingness to be compensated for cleaner

Table 6. Robustness Test Results: Model Permutation Tests and Dependent Variable Tails.

Variable name	Login/Ordered Logit		Dependent variable tailing	
	Choose a model	Outcome model	Choose a model	Outcome model
Gender	1.4326 ***	-0.2081 *	0.7329 ***	-0.2463 **
Age	-0.0962 **	0.0049	-0.0431 *	0.0154
Age squared	0.0012 **	-0.0009	0.0005 *	-0.0006
Educational level	-0.0525	-0.1420 ***	-0.0366	-0.9131 ***
Number of household labour	-0.0032	-0.0325	0.0044	-0.0468
The scale of Production (logarithmic)	-0.4720 ***	0.0571	-0.2361 ***	0.2292
Pig farming experience	-0.0652 ***	-0.0183	-0.3489 ***	-0.0799
Degree of specialization	1.3821 ***	0.7614 ***	0.7776 ***	3.1921 **
Ecological Value Cognition of Cleaner Production	0.0562	0.1475 ***	0.0352	0.7701 ***
Cognition of Ecological Compensation Policy for Cleaner Production	0.3281 ***	0.0149 *	0.1764 ***	0.0853 **
Government official	0.4840 ***	-0.5033 ***	0.2699 ***	-2.3666 ***
Urban residence	-0.0877	0.2541 **	-0.0637	1.0748 **
NLM county	0.3795 **	0.1347 **	0.1981 *	1.0924 **
Constant	2.9047 ***	-	1.4482 **	9.7179 ***

Note: ***, **, * represent significant at the 1%, 5%, and 10% statistical levels, respectively.

production among pig farmers. S_0, S_1, S_2, S_3, S_4, S_5, S_6, S_7 and S_8 are used to indicate gender, education level, specialization level, awareness of ecological value of cleaner production, awareness of cleaner production compensation policy, whether the household is a cadre, whether the household has urban living experience, and whether the household belongs to a NLM. Based on the ISM analysis, it is concluded that S_4 and S_5 are in the second level, S_3, S_6 and S_8 are in the third level, and S_1, S_2 and S_7 are in the fourth level, forming a chain of influencing factors with logical relationships. The factors between adjacent levels and at the same level are connected by directed edges. We obtained the association and hierarchy between the factors influencing the level of compensation of pig farmers' willingness to clean production as shown in Fig. 2.

As shown in Fig. 2, the perception of ecological value of cleaner production and the perception of cleaner production compensation policy are the direct factors at the surface level in the influence mechanism of the willingness of pig farmers to be paid for cleaner production. They have a significant influence on the level of willingness to be compensated for cleaner production of pig farmers. For every 1 unit increase in the perception of ecological value of cleaner production, the willingness of pig farmers to be compensated for cleaner production will increase by 0.7464 units. This is since the higher the ecological value of cleaner production is perceived by pig farmers, the higher the price they ask for the ecological products produced by cleaner production, which is essentially the same as other market transaction behaviors. For every 1 unit increase in the perception of cleaner production compensation policy, the level of willingness to be paid for cleaner production of pig farmers increases by 0.0465 units. The reason is that a higher level of policy awareness is the knowledge base for the implementation of cleaner production behavior, and pig farmers always want to receive a higher compensation amount under the premise that the government provides compensation.

The degree of specialization, whether it is a cadre household and whether it belongs to a NLM county are the middle-level indirect factors that have a significant effect on the level of willingness of pig farmers to be compensated for cleaner production. The reason is that with the increase of specialization degree, the production factor input of pig farmers in pig breeding activities will increase accordingly. In the case of higher capital requirements, the expectation of the amount of compensation for cleaner production will be increased. Second, the higher the degree of specialization, the stronger the pig farmers' livelihood dependence on pig farming activities, which can reduce the economic pressure or cope with the unknown risks of cleaner production through higher ecological compensation amount. Compared with pig farmers with a high degree of part-time farming, pig farmers with a high degree of specialization obviously pay more attention to the ecological value of cleaner production and the ecological compensation policy. For every 1 unit increase in government official, the level of willingness

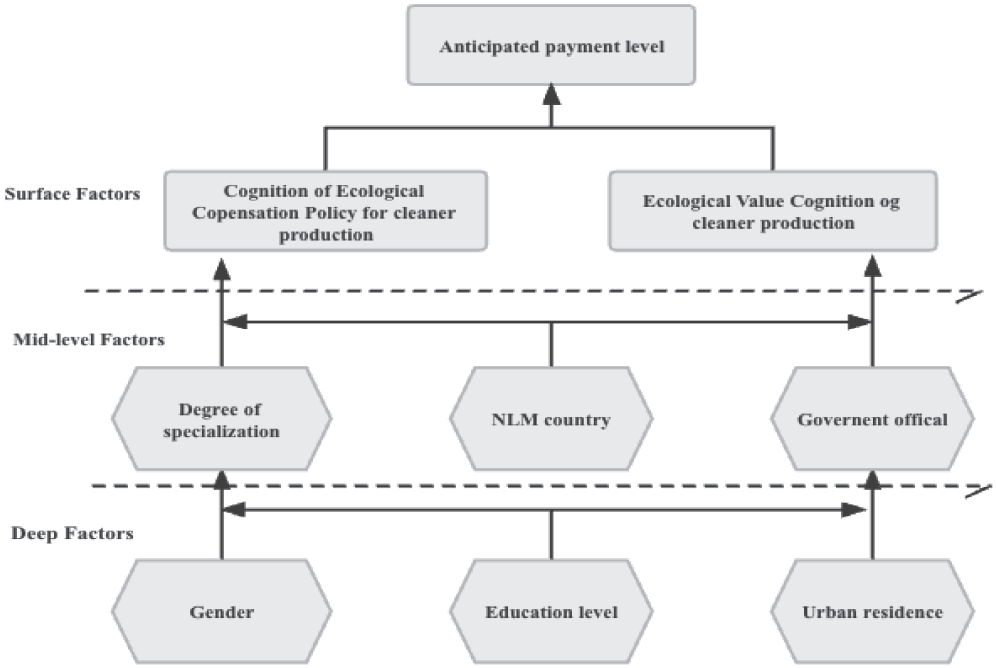

Fig. 2 Influence mechanism of willingness to be paid level of cleaner production.

to be compensated for cleaner production of pig farmers will decrease by 2.5378 units. The possible reason for this is that cadres play a pioneering role in responding to the environmental demands of the government and the public. This is reflected in the "willingness" of cadre households to give up a portion of the ecological compensation amount, and thus their willingness to be compensated for cleaner production is relatively low. For every 1 unit increase in whether they belong to NLM counties, the level of willingness to be compensated for cleaner production of pig farmers will increase by 0.9615 units. This is because pig farmers in NLM counties are relatively larger in scale and more specialized, and they need more capital to implement cleaner production, plus they enjoy the experience of rewards from NLM counties, compared with pig farmers in non-NLM counties. They are also more optimistic about the support policy of cleaner production, and thus the higher the level of willingness to be compensated. Gender, education level and the presence of urban living experience are deep-rooted root factors that have a significant effect on the level of willingness of pig farmers to be compensated for cleaner production.

Conclusions

It is a relatively new subject to apply the PES theory to cleaner production in animal husbandry. The establishment of a PES scheme is an effective way to promote the process of cleaner production in animal husbandry. Based on survey data from 1,629 questionnaires issued in 106 counties (districts) of 9 provinces, we analyzed pig farm households' WTA for clean production and its affecting factors by employing the Heckman-ISM model. The significant findings are as follows. First, households have a strong willingness to accept payment with the following characteristics: smaller scale farm households with male operators, shorter pig farming experience, higher degree of specialization, more comprehensive awareness of the PES policy for cleaner production, family members who are government officials and reside in NLM county. Notably, the relationship between age and the willingness of pig farm households to be paid for cleaner production is a U-shaped curve. Second, households have a higher anticipated level of compensation with the following characteristics: farm households with female operators, lower education level, a higher degree of specialization, more comprehensive awareness of the ecological value of cleaner production and the PES policy for cleaner production, no government officials in the family, urban residence experience and situates in NLM county.

The above research conclusions have pivotal policy implications. First, publicizing PES for cleaner production in animal husbandry to improve the ecological literacy of pig farm households is necessary. Online lectures on cleaner production can be organized regularly to gradually improve the ecological cognition of the public especially livestock farmers. Second, implement a coherent and systematic support policy to create a sound institutional environment for cleaner production of pig farms. Taking NLM counties as the starting point, implement the policies in an orderly way from large-scale farms to medium and small-sized farmers. Farm households with a high degree of specialization or family members who are government

employees can be given priority to pilots of PES for cleaner production to establish a pilot demonstration and promote cleaner animal husbandry production in an orderly manner. Finally, strengthen the analysis of the endowment characteristics of pig farm households, and enhance the internal vitality of the breeding practitioners. Due to the differences in the acceptance of the new practices, cleaner production in animal husbandry by the main breeding subjects, the knowledge, technology and economic strength of implementing cleaner production are also different. There is pronounced heterogeneity in the PES for cleaner production in animal husbandry. Therefore, individual differences such as gender, age and educational level of decision-makers in actual operation should attract special attention from relevant functional departments. Establishing a certain "involution" in the breeding group can enhance the group's vitality and accelerate the construction and implementation of PES policy schemes in animal husbandry. Based on the theoretical framework of the PES for cleaner production in animal husbandry, the discussion on PES and its corresponding compensation level currently stays at the theoretical level. And systematic practices of PES for cleaner production in animal husbandry are somewhat limited. We hope that this paper will facilitate the implementation of the systematic PES policy for cleaner production in animal husbandry as soon as possible to promote the development of cleaner production.

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Conflict of Interest

The authors declare no conflict of interest.

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