Assessing the Impact of Environmental Regulation on Livestock Manure Waste Recycling: Empirical Evidence from Households in China

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Abstract: Livestock manure waste (LMW) has turned into an important source of greenhouse gas emissions. Livestock manure waste recycling (LMWR) has great significance for reducing greenhouse gas emissions in the LMW management process. For a long time, the government has mainly adopted environmental regulation to accelerate LMWR, but the recycling degree is still low. The objective of this study was to assess the impact of environmental regulation on LMWR. Empirical evidence was obtained through methods of in-depth measures and questionnaire investigation from 465 households engaged in breeding pigs in Hebei, Henan, and Hubei, China. The double hurdle model was employed to empirically assess the impact of environmental regulation on household LMWR behavior, and the moderating effects of guiding regulation were further verified. The results were that (1) 62.30% of the households in the sample were willing to implement LMWR behavior, but the recycling degree was only 42.50% of the LMW emission amount. (2) Environmental regulation was found to positively impact household LMWR behavior, while the effects were mainly contributed by imperative and guiding regulation. (3) Guiding regulation was shown to positively moderate the influences of imperative and incentive regulation on household LMWR behavior. (4) The impact of environmental regulation on different scales of household LMWR behavior was found to be heterogeneous. Finally, some recommendations, such as improving subsidy standards, classifying to promote LMWR technology, as well as increasing the matched proportions of planting and breeding, were proposed.

Keywords: greenhouse gas; LMW; recycling; imperative regulation; incentive regulation; guiding regulation

1. Introduction

Global greenhouse gas emissions coming from agriculture and other industries have been causing major environmental issues since the 20th century [1,2]. As for agriculture, livestock manure waste (LMW) has also turned into an important source of agricultural greenhouse gas emissions [3,4]. Moreover, accompanied by continuous expansion of the livestock breeding scale, LMW production has increased gradually, and the pollution has become more serious in recent decades in all countries [5,6]. If not managed properly, LMW has significant negative effects on the environment [7]; air and water pollution, bad smells and flies are possible health risks [8,9]. When managed properly, manure represents a valuable resource and the biogas potential of LMW is two times higher than current biogas generation [10]. Therefore, the major livestock breeding countries are striving to reduce LMW production, strengthen pollution management, and minimize greenhouse gas emissions, especially in...
countries affected by climate warming [11]. At the same time, livestock production in China is growing rapidly, mainly due to Chinese consumption and rising living standards [12]. Furthermore, China is shouldering the urgent tasks of preventing LMW pollution and reducing greenhouse gas emissions [13]. The growth rate of N2O emissions in China was 1.8 times greater than that throughout the world between 1978 and 2012 [14]. The first pollution source census bulletin in China (2013) showed that the chemical oxygen demand (COD), total nitrogen (TN), and total nitrogen (TN) of livestock manure were 12.682, 1.035, and 0.016 million tons, accounting for 95.78%, 37.89%, and 56.34% of agricultural pollutant emissions [15]. Therefore, LMW pollution has become a hot and difficult topic affecting ecological environmental protection following industrial pollution all around the world [16].

The LMW management process produces lots of greenhouse gas, such as CH4 and N2O. It has the characteristics of a large emission amount, high concentration as well as wide diffusion. It is relatively difficult to coordinate economic, social, and ecological benefits by relying solely on industrialized emission standards. Thus, it is necessary and urgent to take the path of livestock manure waste recycling (LMWR) [17]. LMWR refers to the adoption of clean technologies such as composting, biogas fermentation, and other cleaning technologies to convert livestock manure waste into resources or energy. Composting and biogas fermentation are considered to be an excellent agricultural greenhouse gas reduction technology [2]. Smith et al. [18] stated that fertilizer and energy recycling are the main patterns for LMWR. Thien Thu et al. [19] hold that the biogas technology can potentially contribute to solve Vietnam’s current problems with animal manure management. Roubik and Mazancová [20] believed that biogas cook stoves were reported as a substitute for conventional cook stoves, eliminating indoor smoke pollution and related health risks in Vietnam. The most important driving force for LMW management is not only an improvement in the coverage rate but also an increase in the waste recycling rate [21]. In order to motivate households to implement LMWR, the Chinese government mainly promotes LMWR in accordance with a series of environmental regulation measures (such as supervision punishment, facility subsidy, and technical guidance). Therefore, under the realistic situation that the recycling degree is still low, empirical assessment of the impact of environmental regulation on households’ LMWR behaviors is the main purpose of this study.

So, what is environmental regulation? What regulatory tools are included? Environmental regulation is a cross-disciplinary theory that was formed and developed on the basis of environment economics and regulation economics, and it mainly refers to the government’s regulatory measures for intervening and managing micro-behavior. Furthermore, environmental regulation is identified as an institutional arrangement to correct negative environmental externalities and internalize environmental governance costs in view of influencing the market resource allocation and participants’ decision-making, ultimately achieving the goal of improving social welfare [22]. Therefore, scholars mainly describe environmental regulation tools using imperative, incentive, and guiding regulations [23,24].

Specifically, imperative regulation is manifested by the presupposition of laws and regulations to provide definitive guidance for households, and the conduct deviation will inevitably bring unfavorable legal consequences [25]. The Regulations on the Prevention and Control Pollution of Livestock Scale Breeding in China clearly stipulate that households are responsible for harmless LMW recycling disposal, and the livestock department shoulders the responsibilities for supervision and punishment. Incentive regulation is designed by the government according to the market mechanism, and it aims to guide the households to implement environmental behaviors by means of market signals and promotes the control and optimization of the LMW pollution situation [26]. In the context of circular economy development, incentive regulation can effectively reduce the LMWR costs. Guiding regulation makes full use of the information distribution mechanisms formed by agricultural technology promotion, such as government propaganda training, technical guidance, and on-site demonstration to guide the households to participate in environmental governance [27]. Information rationing has an important impact on household production behavior, and it can not only improve the efficiency...
of technology adoption by providing effective technical information, but it can also alleviate the production management risk by optimizing resource allocation [28].

A significant amount of literature includes rich discussions on the factors affecting household LMWR behavior, mainly comprising individual characteristics, such as cognitive status, household head age, and education degree [29,30]; family characteristics, such as population scale and land size [31]; business characteristics, such as breeding scale, period, model, and purpose as well as organizational resources [32,33]; and policy conditions, such as government supervision and subsidy [34,35]. In addition, some scholars have explored the LMWR behaviors of different household scales. The main conclusions have been that (1) due to shortage of manure disposal facilities and simple disposal mode, the environmental pollution of small-scale households is more serious. Nevertheless, large-scale households can receive investment and financial support from government facilities, which spurs on the development of more sound manure disposal facilities, more advanced disposal technologies, and a better treatment effect, but the operation costs are still high [36]. (2) Compared with medium-scale households, there is less manure waste pollution posed in small- and large-scale households. The main factors affecting the recycling degree of different-scale households are the match ratio of planting and breeding, the strength of government supervision, and the intensity of government subsidy [37]. (3) The LMW recycling degree is significantly higher in large-scale households than in small-scale households. Seeking to maximize economic benefits is the main reason for differences in the LMWR degree [38].

However, these literature have mainly studied one or two dimensions of environmental regulation, while household LMWR behavior is subject to a combination of impacts based on different environmental regulation measures. Moreover, relevant research is more focused on the impact of environmental regulation on households’ willingness to implement LMWR and less on effect on the recycling degree.

Therefore, the main purpose of this paper is to assess the impact of environment regulation on the LMWR. Based on evidence from 465 households engaging in breeding pigs in Hebei, Henan, and Hubei, China, environmental regulation is classified into imperative, incentive, and guiding regulations, and the double hurdle model is employed to assess the impact of environmental regulation on household LMWR behavior and empirically test the moderating effects of guiding regulation on the impacts of imperative and incentive regulation on household LMWR behavior. In addition, the heterogeneous effects of environmental regulation on household LMWR behavior based on different-scale households are further explored in order to provide a scientific basis for the government optimization of environmental regulation measures and finally to improve the LMWR efficiency.

2. Study Data and Research Methods

2.1. Study Data

Data collection for the study was carried out from April to June 2018 in Hebei, Henan, and Hubei provinces (Figure 1). The main reasons for selection of the survey areas were that (1) these provinces are dense pig breeding areas. The survey areas belong to the main grain producing areas, coupled with flat terrain, abundant water resources, and convenient transportation, so the breeding scale is relatively large. Breeding pigs has become the pillar industry of agricultural economic development in these provinces. In 2017, the numbers of live pigs in Hebei, Henan, and Hubei were 35.71, 62.20, and 43.00 million, respectively, accounting for 5.2%, 9.0%, and 6.2% of the total amount of breeding pigs in China. (2) These provinces have formulated related policies to encourage households to implement LMWR. Different types of environmental regulations can be implemented simultaneously in each province. The livestock department carries out dynamic supervision and grid management for LMWR; prompts composting fermentation, biogas fermentation, and other technologies for all households; and subsidizes LMWR equipment or facilities. (3) There is a lower LMWR degree in these provinces. Households are less strongly willing to adopt LMWR technologies (such as compost fermentation and
biogas fermentation), and the degree of recycling is still far behind the national goal of 85% by 2020. Discarding, smuggling, and transferring manure are posing challenges for government regulation. Consequently, the use of these three provinces as research areas gave good representation and typicality.

![Figure 1. Distribution of survey areas (Source: National Surveying and Mapping Geographic Information Bureau, China).](image)

In order to have a holistic understanding of the implementation of environmental regulation measures and the status of households’ LMWR behaviors, we mainly adopted methods of in-depth interviews and questionnaire investigation. Firstly, the survey conducted interviews with the relevant person in charge of the county (district) and township (town) livestock departments, finally obtaining 30 interview records and basically mastering the pig industry development, LMWR situation, and more detailed environmental regulation measures. Secondly, the questionnaire was elaborated and repeatedly coupled with households. Then, the finalized questionnaire was investigated using stratified and random sampling methods. The specific sampling steps were used to pick out two to four townships in the sample counties (districts), select four to six villages with different economic development levels in each township, and conduct a random survey in each village. Furthermore, the investigator conducted a field check on the facilities or equipment operation of the LMWR and discovered lots of realistic problems in the process of LMWR. The questionnaire content mainly consisted of households’ basic characteristics, family and business characteristics, environmental conditions, LMWR status, and environmental regulation policies. A total of 500 questionnaires were distributed in the survey, and 465 valid questionnaires were obtained. The effective rate of the questionnaire was 93.00%, including 151, 160, and 154 households in Hebei, Henan, and Hubei, respectively.
2.2. Variable Selection

The dependent variables in this paper were the willingness of households to implement LMW recycling (hereinafter referred to as RW) and the LMW recycling degree (hereinafter referred to as RD). The former is a binary discrete variable—if the households were willing to implement LMWR, the assignment value was 1. If the contrary was true, the assignment value was 0. The recycling degree was expressed by the ratio of LMW recycling to the amount of LMW discharge. Considering that it is difficult to measure the amount of manure waste, this paper referred to research by Guo [39], in which the amount of manure discharge was evaluated by multiplying the number of live pigs by the annual discharge amount per pig (1.1 tons). In addition, the LMWR technologies mainly consist of compost fermentation and biogas fermentation in the sample areas. Compost fermentation requires fermentation beds, and through inquiring about the number of beds and times that fermentation beds are used (6.15 tons of manure is usually treated per fermentation bed), the amount of recycling was determined. Biogas fermentation requires fermentation pools, and through inquiring the number of pools and times of fermentation pools used (8.5 tons of manure is usually treated per fermentation pool), the amount of recycling was calculated. The household LMWR status quo in different provinces is shown in Figure 2.

![Figure 2. Status quo of household livestock manure waste recycling (LMWR).](image)

The independent variables are environmental regulation, which mainly includes imperative, incentive, and guiding regulation. Specifically, (1) imperative regulation is measured by the indicator “government supervision policy”, that is, the supervision and punishment measures are applied by the livestock department to constrain household LMW behavior; (2) incentive regulation is measured by the indicator “government subsidy policy”, that is, the government subsidizes LMWR equipment or facilities (such as compost beds and biogas digesters); (3) guiding regulation is measured by the indicator “government technical promotion”, that is, the livestock department disseminates the compost fermentation and biogas fermentation technologies to households through agricultural technology promotion.

It should be noted that the provincial government in the sample area has been implementing the requirements of the central government and simultaneously carrying out environmental regulation. However, in specific practices, the county, township (town) government, and animal husbandry departments implement environmental regulation constrained by insufficient personnel and financial pressure. There are large deviations in environmental regulation implementation. For example, some livestock departments pay attention to imperative regulation and lack incentive and guiding regulation. Therefore, although they coexist in different dimensions of environmental regulation on
paper, at the same time, they are probably not playing by the rules. For every regulated household, the intensity of environmental regulation is different. Referring to Dasgupta et al. [40] with regard to the comprehensive index measurement method, this paper assigned the impact intensity of the indicators by conducting a household evaluation on the environmental regulation measures, where 1 represents that there is not any effect at all, and 5 represents that the impact is great.

In addition, drawing on related research by Kalungu et al. [41] and Pratt et al. [42], the household heads’ characteristics (such as sex, age, and education level), family characteristics (such as number of laborers and cultivated area), operating characteristics (such as breeding income proportion, breeding period, and breeding scale), and environmental conditions (such as distance between pen and livestock department) were selected as control variables. The assignment of variables and descriptive statistics are shown in Table 1.

Table 1. Assignment of variables and descriptive statistics.

| Variables                  | Assignment of Variables                        | Mean    | Std. Error |
|----------------------------|------------------------------------------------|---------|------------|
| Dependent variable         | Willing = 1, unwilling = 0                     | 0.623   | 0.207      |
| Recycling willingness      | Ratio of LMWR amount to LMW discharge amount   | 0.425   | 0.301      |
| Recycling degree           | Impact intensity of government regulatory policy (1–5) | 3.356   | 1.004      |
| Independent variable       | Impact intensity of government subsidy policy (1–5) | 3.712   | 1.406      |
| Imperative regulation      | Impact intensity of government technical guidance (1–5) | 4.478   | 1.850      |
| Guiding regulation         |                                               |         |            |
| Control variable           | Gender Male = 1, female = 0                    | 0.855   | 0.926      |
|                            | Age Actual age (years)                        | 50.121  | 9.579      |
|                            | Education level Actual years of schooling (years) | 8.205   | 2.550      |
|                            | Number of laborers Number of laborers over 16 years old (people) | 3.102   | 0.650      |
|                            | Cultivated area Cultivated area for agricultural planting (hectares) | 0.418   | 0.102      |
|                            | Breeding income proportion Ratio of income from breeding pigs to the total household income | 0.723   | 0.863      |
|                            | Breeding period Breeding pig period (year)     | 8.262   | 3.135      |
|                            | Breeding scale Sum of pig stock amount and released amount (head) | 285.132 | 26.101     |
|                            | Distance between pen and livestock department Distance between pen and livestock department (km) | 6.232   | 2.781      |

2.3. Research Methods

The dependent variables used in this study were RW (discrete variable) and RD (continuous variable), but we did not employ the Probit and Tobit models. The reasons were that the value 0 commonly appeared in the RD. In the empirical analysis of economics, when these observations of 0 appear in the dependent variables, the restricted dependent variable model (such as Tobit model) is usually employed [43]. The Tobit model is an econometric model in which the value of the dependent variable satisfies a certain constraint, that is, the dependent variable is a restricted variable compared with the general discrete model and the continuous variable model [44]. However, the Tobit model has a false hypothesis, such as \( \text{prob}(y_i < 0) \) in practical applications. Due to the influences of the constraints on the dependent variables, they are liable to neglect some non-measurable factors, resulting in the sample selection bias of the restricted dependent variable model. Furthermore, the dependent variable used in this study consisted of two stages of RW and RD, and the two stages were not completely dependent on each other, that is, if households are willing to implement LMWR, they are not necessarily willing to implement the LMWR, and the value of the RD may be 0. Therefore, referring to the related research of Cragg [45] and Xie et al. [46], the double hurdle model was employed to assess the impact of environmental regulation on household LMWR behavior. The double hurdle model can combine two dependent variables into the same model for estimation. The double hurdle model is built as described below.

Firstly, this paper analyzed households’ RW using the following equation:

\[
\text{probit}(y_i = 0|x_{1i}) = 1 - \phi(ax_{1i})
\]

\[
\text{probit}(y_i > 0|x_{1i}) = \phi(ax_{1i})
\]  

(1)
where \( y_i \) represents whether households are willing to implement LMWR behavior, \( x_{1i} \) represents environmental regulation, \( \varphi(\cdot) \) is a cumulative function of the standard normal distribution, \( \alpha \) is the corresponding coefficient to be estimated, and \( i \) is the observation samples.

\[
E[y_i > 0, x_{2i}] = \beta x_{2i} + \eta \lambda(\beta x_{2i}/\eta),
\]

where \( E(\cdot) \) represents the conditional expectation, that is, the LMW recycling degree; \( \lambda(\cdot) \) is the inverse Mills ratio, \( \beta \) is the corresponding coefficient to be estimated, and \( \eta \) is the standard deviation of the normal distribution for interception. Other symbols have the same meaning as described above.

According to Equations (1) and (2), the log-likelihood function was established:

\[
L = \sum_{y_i=0} \left[ \ln[1 - \varphi(ax_{1i})] \right] + \sum_{y_i>0} \left[ \ln \varphi(ax_{1i}) - \ln \varphi(\beta x_{2i}/\eta) - \ln(\eta) \right] + \ln \varphi\left( \left( y_i - \beta x_{2i}/\eta \right) \right)
\]

Lastly, this study adopted the maximum likelihood estimation method to estimate the log-likelihood function value of \( \ln L \) and then obtained the relevant parameters values needed for the study. A research framework diagram of this paper is shown in Figure 3.

![Research Framework Diagram](image_url)

**Figure 3.** Research framework diagram.

### 3. Results

#### 3.1. Multi-Collinearity Diagnosis

Before the double hurdle model was estimated, considering the possible internal correlation between the explanatory and control variables, multi-collinearity diagnosis was performed on each variable. Generally, when variance inflation factor (VIF) = 1, it can be considered that there is no multi-collinearity between each variable; when VIF > 3, there is a certain degree of multi-collinearity between each variable; and when VIF > 10, each variable can be considered to have high multi-collinearity. Due to space limitations, this paper only shows the diagnostic results of “imperative regulation” as the dependent variable and the other variables as independent variables (Table 2). Based on the results of all diagnoses, the multi-collinearity degree between the dependent variable and independent variable was within a reasonable range, indicating that there was no significant multi-collinearity. In addition, we furthermore present the multi-collinearity of key data for imperative, incentive, and guiding regulations. The diagnosis results show that the average VIF value was 1.542, indicating that there was no multi-collinearity between different regulations.
probability of a household’s willingness to implement LMWR will increase by 12.52%. However, the variables of the models have statistically significant effects. The chi-square values were 64.129, 64.200, 65.205, and 65.704 from Model 1 to Model 4, respectively. In the estimation results (Table 3), the model was shown to have good overall fit. The log-likelihood values were all less than 0.001, which indicates that at least some of the explanatory factors have statistically significant effects.

### 3.2. Impact of Environmental Regulation

In order to assess the impact of environmental regulation on household LMWR behavior, we employed Stata13.0 software and the double hurdle model to perform a hierarchical regression. From the estimation results (Table 3), imperative regulation has a positive and significant influence on household LMWR behavior. The results show that (1) imperative regulation has a positive and significant influence on household LMWR behavior. The possible explanations are that on the one hand, the department is considered as the most important influencing factor for household LMWR behavior. The results show that (1) imperative regulation has a positive and significant influence on household LMWR behavior. The possible explanations are that on the one hand, the department is considered as the most important influencing factor for household LMWR behavior.
hand, the government carries out dynamic and strict inspections on household LMWR behavior in the form of environmental supervision, imposes administrative punishment on discarding, smuggling, and other improper disposal, and may even revoke a household’s business license in accordance with related laws; on the other hand, the investment in production equipment for LMWR is large, while the income from LMWR products such as manure organic fertilizer is relatively low. Under the condition of information asymmetry, the risk aversion awareness of households is quite weak, and secret smuggling, trans-shipment and trafficking of manure appear frequently. (2) The impact of incentive regulation on household LMWR behavior is not significant (Model 2). The possible explanation for this is that the scope of government subsidies is narrow, and only the LMWR equipment or facilities are subsidized. The subsidy policy with regard to the subsidy amount in line with the LMWR amount has not yet been formulated, and so it is extremely difficult to drive households to actively implement LMWR behavior. Furthermore, the subsidy intensity is extremely low. Approximately 2500 and 1500 yuan are subsidized for each fermentation tank and fermentation bed, respectively. Therefore, the subsidy amount is far less than the households’ investment in equipment or facilities, and it is also hard to disperse input costs so that households are not reluctant to implement LMWR. (3) Guiding regulation positively and significantly impacts household LMWR behavior (Model 3). If the intensity of guiding regulation increases by one unit, the probability of households’ willingness to implement LMW recycling will increase by 19.89%, and the recycling degree will increase by 14.30%. The possible explanations for this are that the technical requirements for LMWR are quite high and the technology acquisition is very difficult; these have become bottleneck factors for promoting LMWR. However, the livestock department in the sample area has made a concerted effort to provide households with LMWR technology regarded as rural public goods, and by cultivating new cooperative agricultural enterprises, such as professional cooperatives and leading enterprises, the diffusion, influence, and driving effects of LMWR technologies will be gradually improved. At the same time, the livestock department also implements centralized LMW disposal, and the centralized disposal organization has mature LMWR technologies, so it is inclined to increase the recycling degree. (4) It is emphasized that when imperative, incentive, and guiding regulations are incorporated into the double hurdle model (Model 4), the results show that incentive regulation has a positive and significant impact on household LMWR behavior. If the intensity of incentive regulation increases by one unit, the probability of households’ willingness to implement LMWR increases by 16.10% and the recycling degree increases by 19.23%. Moreover, the margin effects of imperative and guiding regulations are enhanced, indicating that there are moderating effects of guiding regulation on the imperative and incentive regulations. Therefore, this study empirically tested the moderating effects to reveal the existing correlations within different regulatory measures.

In terms of the control variables, the age of the household head was shown to positively and significantly influence household LMWR behavior, and the age square was found to have a negative impact on it, indicating that there is an inverted U-shaped relationship between the age of the household head and household LMWR behavior. The possible explanation is that young households have a shorter breeding period, family investment is mainly for aquaculture, and the LMWR awareness is relatively weak, causing an inability to raise funds for LMWR. The breeding period of middle-aged households is longer, the funds are quite abundant, and they have a higher economical ability to implement LMWR. The old-age households mainly carry out small-scale aquaculture, LMW is directly applied to cultivated land, and the motivation for LMWR is insufficient. In addition, other results show that the greater the education level is, the stronger the ecological environmental awareness of a household is, and the more inclined they are to implement LMWR. The larger the cultivated area is, the wider the application range of organic fertilizers and other recycling products is, and the better the material conditions for LMWR are. Furthermore, the larger the breeding scale is, the greater the manure excretion amount is, and more abundant the raw materials for LMWR are. Therefore, these factors drive households to be more inclined to implement LMWR to some extent.
3.3. Moderating Effects of Guiding Regulation

According to the above, there are departmental correlations between different dimensions of environmental regulation. As some scholars have found in the agricultural environmental governance, the government’s policy propaganda and technical guidance not only reduce the government’s environmental supervision pressure, but also improve farmers’ satisfaction with environmental governance subsidies, ultimately improving the participation of farmers in environmental governance [47,48]. In order to further test the moderating effects of guiding regulation in the influence of imperative and incentive regulation on household LMWR behavior, this study further introduced the interactive items of guiding and imperative regulation, as well as guiding and incentive regulation, and the model estimation results from Models 5 to 7 are shown. Furthermore, in order to eliminate the high correlations between the interaction items and the variables involved in the interaction, this study centralized the variables before construction of the interaction items. At the same time, it was possible for the multi-collinearity problem to exist between variables, so multi-collinearity diagnosis was further carried out. The diagnosis results showed that the maximum value of VIF was 1.657, the minimum value was 1.068, and the average value was 1.341, indicating that there was no multi-collinearity between dependent variables.

The results (Table 4) show that (1) guiding regulation has a positive moderating effect on the impact of imperative regulation on household LMWR behavior. If the intensity of guiding regulation increases by one unit, imperative regulation can drive the probabilities of household RW and RD to increase by 21.52% and 10.23%, respectively (Model 5). The livestock department mainly adopts technology promotion, on-site guidance, and typical demonstration to strengthen composting fermentation and biogas fermentation promotion. When the livestock department expands the scope of technology promotion and increases the frequency of technology promotion, household awareness of the supervision and punishment policies constantly improves, and they can holistically evaluate the beneficial results of LMWR in various aspects, thus activating the internal driving forces for LMWR and also reducing the supervision pressure of the livestock department. (2) Guiding regulation positively moderates the impact of incentive regulation on household LMWR behavior. If the intensity of guiding regulation increases by one unit, incentive regulation can increase the probability of households’ willingness to implement LMWR by 12.21%, and the recycling degree will increase by 11.09% (Model 6). When the livestock department provides matching LMWR technical training, it can reduce the deviation in household understanding of policy and technology, help to improve household remuneration and satisfaction with government subsidies, enhance technical compliance, and continuously increase the LMW RD. Therefore, it can be seen that the guiding regulation plays the role of “enhancing agent” in influencing imperative and incentive regulations on household LMWR behavior, that is, the greater the intensity of guiding regulation is, the stronger the impact of imperative and incentive regulations on household LMWR behavior. (3) When the interaction items of guiding and imperative regulation as well as the interaction items of guiding and incentive regulation are introduced into the double hurdle model at the same time, guiding regulation still has moderating effects on the impacts of imperative and incentive regulation on household LMWR behavior, indicating that these moderating effects of guiding regulation exist simultaneously, and the different dimensions of environmental regulation are inseparable (Model 7).
### Table 4. Estimation results of the moderating effects of guiding regulation.

| Explanatory Variables | Model 5 | Model 6 | Model 7 |
|-----------------------|---------|---------|---------|
|                       | RW      | RD      | RW      | RD      | RW      | RD      |
| Guiding regulation ×  | 0.2152  | **      | 0.1023  | *       | 0.1352  | *       | 0.1023  | *       |
| Imperative regulation | (0.1076)| (0.0553)|         |         | (0.0738)| (0.0538)|         |         |
| Guiding regulation ×  | 0.1221  | *       | 0.1109  | **      | 0.0921  | **      | 0.0857  | *       |
| Imperative regulation | (0.0654)| (0.0465)| (0.0409)| (0.0467)|         |         |         |         |
| Guiding regulation ×  | 0.1291  | **      | 0.1109  | **      | 0.1358  | **      | 0.1129  | **      |
| Imperative regulation | (0.0751)| (0.0502)| (0.0510)| (0.0585)|         |         |         |         |
| Guiding regulation    | 0.1458  | **      | 0.1225  | **      | 0.1358  | **      | 0.1129  | **      |
| Incentive regulation  | (0.1283)| (0.0994)| (0.0966)| (0.2783)|         |         |         |         |
| Guiding regulation    | 0.1645  | ***     | 0.1430  | **      | 0.1745  | **      | 0.1482  | **      |
| Incentive regulation  | (0.0531)| (0.0752)| (0.0552)| (0.0896)|         |         |         |         |
| Control variable      | Control | Control | Control | Control |         |         |         |         |
| Log-likelihood        | –324.102|         | –325.321|         | –324.135|         |         |         |
| Chi-square value      | 61.105  | ***     | 61.250  | ***     | 61.455  | ***     |         |         |

Note: *, **, and *** represent significance at the 10%, 5%, and 1% probability levels, respectively. Values outside the parentheses represent the marginal effect values. Values in parentheses represent the standard error of robustness.

### 3.4. Impact of Environmental Regulation Based on Different Breeding Scales

The literature on the environmentally friendly behavior of households mainly regards the breeding scale as the classification standard, that is, the larger the breeding scale is, the more inclined households are to implement environmentally friendly behaviors [49]. However, some scholars hold that it is impossible to explain the environmentally friendly behavior of households based on the breeding scale [50]. Therefore, it is necessary to further assess the impact of environmental regulation on the LMWR behaviors of different household scales. With reference to Wu et al. [51], the number of live pigs is considered as the classification standard of households. Households are divided into small-scale households (for example, if the live pig breeding scale is from 1 to 49 heads, the household is classified as a small-large household), professional households (live pig breeding scale from 50 to 499 heads), and large-scale households (live pig breeding scale of more than 500 heads). Considering that the capital endowments, economic structure, and social structure of the different-scale households are quite different, the disposal ability of LMWR is obviously heterogeneous. Therefore, this study further analyzed the impact of environmental regulation on the LMWR behaviors of small-scale, professional, and large-scale households (Table 5). There were 155 small-scale breeding households, 180 professional breeding households, and 130 large-scale breeding households. Consequently, model fitting estimates were made for different households.

### Table 5. Estimation results of the environmental regulation moderating effects based on different breeding scales.

| Explanatory Variables | Model 8 Small-Scale Households | Model 9 Professional Households | Model 10 Large-Scale Households |
|-----------------------|---------------------------------|---------------------------------|---------------------------------|
|                       | RW | RD | RW | RD | RW | RD | RW | RD |
| Guiding regulation ×  | 0.1460 | ** | 0.1048 | ** | 0.1420 | ** | 0.1518 | ** |
| Imperative regulation | (0.0544) | (0.0875) | (0.0906) | (0.1492) | (0.1423) | (0.0822) |         |         |
| Guiding regulation    | 0.1640 | ** | 0.1048 | ** | 0.1420 | ** | 0.1518 | ** |
| Incentive regulation  | (0.0655) | (0.0492) | (0.0654) | (0.0643) | (0.0201) | (0.0350) |         |         |
| Control variables     | Control | Control | Control | Control |         |         |         |         |
| Log-likelihood        | –176.125 |         | –225.356 |         | –210.130 |         |         |         |
| Chi-square value      | 57.155  | ***     | 62.230  | ***     | 59.418  | ***     |         |         |

Note: *, **, and *** represent significance at the 10%, 5%, and 1% probability levels, respectively. Values outside the parentheses represent the marginal effect values. Values in parentheses represent the standard error of robustness.
The results show that (1) environmental regulation positively and significantly influences the LMWR behaviors of small-scale households, but this promotion is mainly caused by incentive and guiding regulations, and the effect of imperative regulation is not obvious. At the same time, guiding regulation effectively moderates the impact of incentive regulation on the LMW RW of small-scale households, while the moderating effects on RD were not found to be significant. If the intensity of guiding regulation increases by one unit, the probability of small-scale households’ willingness to implement LMWR will increase by 13.38% (Model 8). The possible explanations for this are that, firstly, the breeding scale of manure generation of small-scale households’ is low, and the environmental pollution degree is weak, which is not the main supervision target of the livestock department. Secondly, biogas fermentation technology is mainly adopted by the small-scale households, the cost of technology is lower, and the energy supply effect of methane or other energy sources is better. Consequently, owing to the government subsidies, small-scale households are more motivated to build biogas digesters. Lastly, the government has continuously improved the scope of agricultural technology promotion and enhanced the acquisition ability of biogas fermentation technology by the small-scale households, so the LMW RW has been significantly improved. (2) Environmental regulation positively and significantly impacts the LMWR behaviors of professional households, mainly due to imperative and guiding regulations. At the same time, guiding regulation positively moderates the effects of imperative and incentive regulation on the LMWR behaviors of professional households. Specifically, if the intensity of guiding regulation increases by one unit, imperative regulation will increase the probabilities of professional households’ RW and RD by 14.06% and 9.24%, respectively. If the intensity of guiding regulation increases by one unit, incentive regulation will increase the probabilities of professional households’ RW and RD by 18.35% and 12.20% (Model 9). The possible explanations for this are that, on the one hand, professional households mainly carry out production management in the form of cooperatives and large farms. The amount of manure emissions is large, while the LMW disposal capacity is quite low. Consequently, professional households have become the main target of government agricultural technology promotion, as well as the main target of livestock department supervision and subsidy; on the other hand, professional households mainly adopt compost fermentation technology, which is subsidized by the government, for fermentation beds. The government also carries out special training on compost fermentation technology, which is beneficial for reducing the cost pressure on purchasing equipment. Therefore, professional households are capable of regulating and controlling water, temperature, and pH values, etc., so the carbon and nitrogen ratio of manure will be continuously improved, and the market value of organic fertilizer products will be greatly increased. (3) Environmental regulation positively influences the LMWR behaviors of large-scale households, but the influence is mainly caused by the moderating effects of imperative and guiding regulations. In addition, guiding regulation positively moderates the impact of incentive regulation on the LMWR behaviors of large-scale households. If the intensity of guiding regulation increases by one unit, incentive regulation will increase the probabilities of large-scale households’ RW and RD by 12.54% and 10.12%, respectively (Model 10). The possible explanations are that firstly, the large-scale households, who are mainly local leading enterprises, also become the economic entities supported by the government and form a cooperative relationship with the livestock department. Therefore, the livestock department has a low level of supervision and punishment on them. Secondly, large-scale households have the largest amount of manure output, but due to the disposal period of LMWR equipment, it is difficult to form a cycle processing capability that is compatible with the amount of LMW emissions. Lastly, large-scale households more frequently act as carriers of government agricultural technology promotion. Through the mechanism of large-scale households providing technical training and on-site demonstrations with other households, large-scale households are able to obtain subsidies and paid services and continuously improve the RW.
4. Discussion

LMW has become an important source of agricultural greenhouse gas emissions, and manure waste recycling exerts an important impact on greenhouse gas emission reduction. Over the past 40 years of reform and opening up in China, the breeding scale has been gradually increasing, and it is also facing serious problems regarding manure pollution. Since 2016, the Chinese government has been concentrating on the comprehensive management of the rural ecological environment and has adopted a series of environmental regulation measures such as supervision policy, subsidy policy, and technology promotion, which aim to actively promote household LMWR behavior. However, due to the current situation where the LMW RD is still low, empirical assessment of the impact of environmental regulation on household LMWR behavior is the main purpose of this study. Compared with the other studies, this paper further discusses our results as follows.

4.1. Analysis from the Multi-Dimensional Perspective

Empirical results show that incentive regulation such as facility subsidy cannot drive households to implement LMWR behavior, and the imperative regulation (supervision punishment) and guiding regulation (technical promotion) have been playing major roles as policy tools. In other words, the existing subsidy policy does not directly affect the households’ LMWR behaviors. These results differ from the finding of other authors such as Outhwaite et al. [25], Pan et al. [37], and Shao et al. [52]. The possible reasons for the difference in research conclusions are that these scholars mainly studied one or two dimensions of the environmental regulation, and some key variables in environmental regulation tools, such as guiding regulation, were omitted, and the effects of some environmental regulation tools on household LMWR behavior are overestimated. However, this study constructed an environmental regulation index system including imperative, incentive, and guiding regulation. The influence of environmental regulation on household LMWR behavior is found to be significant, but the effects of the different dimensions of environmental regulation are not balanced, and there is an obvious barrel effect. Therefore, if any dimension of environmental regulation is neglected, it is difficult to comprehensively evaluate the effects of environmental regulation.

This paper further analyzed the LMWR behavior of small-scale, professional, and large-scale households. Coinciding with He et al. [38] and Rao et al. [50], the results showed that the effects of environmental regulation on different-scale households’ LMWR behaviors have significant differences, and they also indicate that environmental regulation is unable to accurately explain household environmental behavior by regarding the breeding scale as a classification criterion—with a larger breeding scale, the impact of environmental regulation is not necessarily stronger. Therefore, the impacts of environmental regulation and different dimensions on households’ LMWR behaviors are obviously heterogeneous. The possible explanation is that capital endowments of different scales of households are quite different, and the land, labor and funds that they invest in LMWR are different, which leads to significant differences in different-scale households’ willingness to recycle and degree of recycling. Hence, the government should not think of breeding scales as the classification criteria but should focus on certain regulatory measures as well the economic and social structures embedded in small-scale, professional, and large-scale households. Only by considering the subjective willingness and objective conditions of different-scale households can the effects of environmental regulation be fully determined.

4.2. Policy Strategies Implications

The Chinese government is mainly concerned about how environmental regulation policies improve the efficiency of LMWR. However, this policy orientation is not sufficient as a result of the fact that LMW has occupied a large amount of cultivated land and other resources, and the opportunity cost of using land and resources to rear livestock rather than their use for other food or non-food purposes is high. Therefore, coinciding with Garnett [4], the paper argues for policy
strategies that explicitly combine greenhouse gas mitigation with measures to improve food security and concludes with suggestions for further research. Specifically in dealing with the manure waste pollution, the government should improve environmental regulation measures and give full play to policy effectiveness. In addition, the structure of meat food should be also adjusted, the area and quality of cultivated land should be improved, and the food security must be guaranteed especially in developing countries.

4.3. Limitations and Future Research

There are also some shortcomings in this paper. Firstly, there is a subjective bias in measuring the intensity of environmental regulation by relying solely on the evaluation of households. Determining how to design a more objective program is an important part of future research. Secondly, the LMWR includes lots of technologies such as compost fermentation and biogas fermentation, and the costs and benefits of different technologies are quite different. Therefore, the impact of environmental regulation on household LMWR behavior from the cost and benefit perspective should be further analyzed. Thirdly, both environmental economics and regulatory economics indicate that environmental governance should give full play to the governance path combining morality, autonomy, as well as law. Consequently, the LMWR should also be promoted by a variety of standard measures combining the rules of morality, autonomy, and law. Lastly, the environmental governance mode led by the social service supply has become the mainstream trend. Hence, the government should explore the social service supply model by strengthening the combination of market and non-market entities. In addition, special training, technical guidance, and recycling product R&D for different households are also focuses of future research.

5. Recommendations

As the largest developing country in the world, China’s LMWR-related measures can be used as reference values for other developing countries and countries along the Belt and Road. Therefore, we propose some policy recommendations to optimize environmental regulation measures and continuously improve the efficiency of LMWR. Firstly, the government should provide special subsidies in accordance with the amount of LMWR and subsidize the market taxation of recycling products, consequently reducing the LMWR cost pressure and enhancing the economic benefits of households. Secondly, the government should promote the LMWR technologies. Specifically, for small-scale households, the livestock department should introduce and promote the LMWR technologies which have the characteristics of low construction costs, easy operation, and relative cleanliness, aiming at continuously improving the collection and disposal capacity of small-scale households. For professional and large-scale households, which own better temperature and humidity control equipment, as well as being rich in land resources, the government should promote fermentation bed breeding technology, which has the advantages of zero discharge, no odor, less mosquitoes, low manure yield, and high recycling capacity is high. Thirdly, the government should further increase the matched proportions of farming and breeding, make the livestock breeding scale adapt to the carrying capacity of farmland, optimize the layout of livestock production, and explore the combined micro-governance model of the agriculture and livestock industries. Through the benign docking of farming and aquaculture, the efficiency of LMWR will be ultimately improved.

6. Conclusions

Environmental regulation measures have been implemented for a long time, but the RD in China is still low. Based on empirical evidence from 465 households in Hebei, Henan, and Hubei, China, this study described environmental regulations from imperative, incentive, and guiding regulation points of view, and the double hurdle model was employed to empirically assess the impact of environmental regulation on household LMWR behavior. The main conclusions were that more than 60% of households in the sample stated that they were willing to implement LMWR behavior,
but the recycling degree was found to be less than 50%. Therefore, the enthusiasm of households toward participating in LMWR should be further strengthened, which also makes this research more necessary and meaningful. Environmental regulation was found to have a positive and significant impact on household LMWR behavior; this effect was mainly shown to be controlled by imperative and guiding regulations, and the influence of incentive regulation was not obvious. Moreover, although environmental regulation generally played a driving role in the LMWR, this promotion was shown to be weakened as a whole due to the insufficient effect of incentive regulation. Guiding regulation was shown to positively moderate the influences of imperative and incentive regulations on household LMWR behavior, and the two moderating effects were shown to exist simultaneously. In addition, the impact of environmental regulation on the LMWR behavior of different scales of households was found to be heterogeneous. Therefore, the government should implement environmental regulation measures in accordance with different scales of households when promoting LMWR.

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