Waste Management 120 (2021) 708–715

Contents lists available at ScienceDirect

Waste Management

journal homepage: www.elsevier.com/locate/wasman

An analysis on determinants of farmers' willingness for resource utilization of livestock manure

Qian Li [a], Shoaib Ahmed Wagan [b], Yubin Wang [c,*]

[a] College of Economics, Beijing Technology and Business University, No. 33 Fucheng Road, Haidian District, Beijing 100048, China
[b] College of Economics and Management, South China Agricultural University, Wushan, Tianhe District, Guangzhou 510642, China
[c] Center of Graziery Economic Research, College of Economics and Management, China Agricultural University, No.17 Tsinghua East Road, Haidian District, Beijing 100083, China

ARTICLE INFO

Article history:
Received 10 August 2020
Revised 13 September 2020
Accepted 25 October 2020
Available online 13 November 2020

Keywords:
Animal farming
Resource utilization of manure
Structural equation
Cognition

ABSTRACT

The increased manure produced in animal husbandry, especially in beef cattle farming, pose a great threat to the environment. Resource utilization of the manure is an effective way to solve the problem and is conducive to the sustainable development of animal husbandry. Based on the theory of planned behavior, this paper attempts to construct a model of farmers' willingness to utilize livestock manure from behavioral attitude, subjective norm and cognitive behavioral control, and makes an empirical test through a questionnaire on beef cattle farmers. As the findings show, farmers' behavioral attitude, subjective norm and cognitive behavioral control have a significantly positive impact on the resource utilization of the manure. Among them, behavioral attitude exerts the greatest impact, followed by cognitive behavioral control and subjective norm. Farmers surveyed share almost the same attitude towards the effects of resource utilization, who may actively or passively take into consideration the corresponding economic, social and ecological benefits. The pressure from the government plays an important role in farmers' subjective norm, while less pressure comes from village cadres and neighbors. Finally, time or labor endowment and economic strength are the core constraints on the resource utilization of livestock manure by farmers, with relatively little constraint on skill acquisition.

© 2020 Elsevier Ltd. All rights reserved.

1. Introduction

Intensive livestock production for human food purposes cannot be uncoupled from a massive production of manure (Vrieze et al., 2019). Even if manure is a resource for preserving the soil fertility, its management has become one of the main problems for the environment (Loyon, 2017), and imposes great harms to human health and environment, if not suitably treated (Zubair et al., 2020; Millner et al., 2014). Resource utilization of livestock manure is considered as a fundamental way to solve environmental pollution in animal husbandry, as well as an important technical support to promote the green and high-quality development of animal husbandry. In China, which is the world's largest producer and consumer of livestock products (Ma et al., 2014), the comprehensive utilization rate of livestock and poultry manure in the country takes up only 60% at present, with the rest to be effectively utilized (Sohu, 2018), according to the official data of the Ministry of Agriculture and Rural Affairs. It is thus particularly urgent to improve the utilization rate as the quantity of livestock and poultry manure continue growing. The main implementers engaged in resource utilization of livestock manure can be farmers, organic fertilizer processors, third-party centralized treatment centers or other socialized service organizations. Farmers are responsible for properly managing manure from their own farm (Li et al., 2020), as the market-oriented channels for resource utilization are not yet well developed. The key for the willingness-guided action and the improvement of the utilization rate of livestock manure is to improve farmers' willingness to recycle manure, with the focus placed on identifying the determinants of farmers' willingness to utilize livestock manure. Therefore, the exploration into farmers' willingness for resource utilization possesses a practical significance in promoting the resource utilization of livestock manure.

Since the beginning of the 21st century, over 30 million tons of livestock manure (N content) have been annually produced worldwide, and such a production takes on a growth trend (FAO, 2019). In 2017, 34.22 million tons of manure were produced, of which about 18.22% came from China (FAO, 2019). China has become the world's main source of livestock manure, and the treatment of the manure in China thus gains certain representativeness. Willingness analysis is an important branch of current academic

* Corresponding author.
E-mail address: wyb@cau.edu.cn (Y. Wang).

https://doi.org/10.1016/j.wasman.2020.10.036
0956-053X/© 2020 Elsevier Ltd. All rights reserved.

research, as well as in the research field related to livestock and poultry farming. The research into farmers' willingness analysis involves insurance participation (Khan et al., 2013), policy acceptance (Ji et al., 2014), social service payment (Kumar et al., 2011), epidemic reporting (Liu et al., 2017), new technology adoption (Zanu et al., 2012), safe input use (Wu et al., 2015), breeding mode selection (Mcleod et al., 2018) and pollution prevention (Claytor et al., 2018), *etc.*, with the research focus gradually shifted to the farming environment. In terms of research method, the existing studies are mainly empirical, mostly using Logit or Probit (Mlote et al., 2013; Zhang et al., 2014), ISM (Li et al., 2019), Heckman's two-stage method (Wang et al., 2019b), conditional valuation method (Budak et al., 2010), Tobit (Zhang et al., 2017), and structural equation model (Lin et al., 2018), which are particularly dominated by the binary logit model, and a few researchers, based on survey data, revealed farmers' behavioral intention through descriptive statistics or correlation analysis. From a research perspective, the vast majority of studies selected a package of potential factors affecting farmers' willingness centering on the characteristics of individual, family, farming and environment (Zhang and Xiao, 2016; Pan, 2017; Xu et al., 2019), and a few studies investigated the impact of a specific factor on farmers' willingness. For example, Yu and Yu (2019) studied the impact of farmers' cognition on resource utilization of livestock and poultry waste upon their participation willingness, and found that farmers' awareness on water pollution by livestock and poultry waste, environmental protection policy and financial subsidy policy had produced a significantly positive effect on their willingness to participate, among which the cognition of financial subsidy policy had had the most significant impact, and that, for farmers, the binding environmental regulation policy was significant in producing positive regulatory effect on the relationship between "water pollution cognition and participation willingness" and between "environmental protection policy cognition and participation willingness".

The existing studies, especially those related to the prevention and control of animal farming pollution and the resource utilization of manure, mainly focus on pigs, laying hens and dairy cows (Pan, 2016; Jeon et al., 2015; Tancuk et al., 2019; Krishna et al., 2008), and few on resource utilization of beef cattle manure. Among the factors affecting farmers' behavioral intention, some important ones that are difficult to observe cannot be introduced into commonly used discrete selection models, while a structural equation model can tackle the deficiency and has now been widely used. In addition, different from the existing studies, the environmental effect, income effect, production effect, social effect and combined effect of manure recycling are comprehensively considered in this paper, which makes the model closer to reality. Thus, the paper, while taking cattle manure as its research object and drawing lessons from relevant research, adopted a structural equation model to empirically investigate the determinants of farmers' willingness to recycle livestock manure, in an aim to provide theoretical support for guiding farmers to actively participate in the activity of resource utilization.

2. Materials and methods

2.1. Theoretical basis

Fishbein and Ajzen first put forward the theory of reasoned action (TRA) in 1970s, stating that when individuals make behavioral decisions, they will use available information and analysis means to weigh various potential outcomes before making the decision of action or inaction, a process reflecting the individual's behavioral intention determined by two factors, namely, behavioral attitude and subjective norm. Behavioral attitude refers to a positive or negative evaluation of an individual's behavior, while subjective norm refers to the pressure that an individual feels from the surrounding while making a behavioral decision, which is manifested in the surrounding institutions' or individuals' views on whether they should take a certain behavioral decision or not. TRA was further evolved into the theory of planned behavior (TPB), into which cognitive behavioral control, the third factor that determines behavioral intention, is introduced, namely, an individual's perception of the degree of control over decision-making behavior based on considerations of time and opportunity. The theory of planned behavior has a strong explanatory and predictive power for individual behaviors (Myers, 2005), and has been widely used in ecological compensation participation (Zhang et al., 2019), fertilizer reduction by farmers (Tang, 2019) and waste classification intension (Tian et al., 2019), *etc.* Thus, this paper constructed a theoretical analysis framework for farmers' willingness to utilize the livestock manure from the perspectives of behavioral attitude, subjective norm and cognitive behavioral control (Fig. 1) based on the theory of planned behavior, and conducted an empirical test with field investigation data.

2.2. Research hypothesis

Farmers, as rational economists, often make cost-benefit measurement before taking a behavioral decision, which may involve economic, ecological and social benefits. In terms of economic benefits, the utilization of livestock manure can eliminate farming manure in a timely manner, creating a good farming environment, reducing the spread of diseases, and promoting the healthy growth of beef cattle. In addition, the recycling of livestock manure is conducive to economic benefits and can realize "turning waste into wealth" through organic fertilizer sales and manure returning to fields, which can generate income, save costs and increase efficiency. Thus, farmers may be driven by potential economic benefits to take the initiative to conduct resource utilization. On the other hand, ecological and social benefits reflect the positive externalities of recycling livestock manure; timely and effective utilization of livestock manure can reduce the impact on the surrounding environment and to a reasonable extent, avoid government penalties for pollution, as well as conflicts with neighbors or the risk of being reported. Consequently, farmers may be compelled to perform an altruistic act of resource utilization of livestock manure at the potential cost of income loss. Based on that, hypothesis H1 was proposed.

Hypothesis H1. The higher the farmers' evaluation on the economic, ecological and social benefits of resource utilization, i.e., the more positive their behavioral attitude, the greater their willingness to engage in resource utilization of livestock manure.

Although farmers themselves are the direct makers of behavioral decision, the government, village cadres and neighbors are all farming stakeholders, whose legitimate rights and interests cannot be infringed. Livestock farming can affect air, water and soil to a certain extent, endangering the safety of public environment. The government may adopt coercive, economic incentives or mixed policies to guide and regulate farming behavior for environmental reasons; village cadres are closely connected with government departments while deeply rooted in the local community, they act as "agents" of the government and "heads" of the villages (He and Tong, 2002), who are also "village members", such a "triple role" playing multiple supervisory roles on farmers' behavior. On the other hand, neighbors may take measures to persuade or report about farmers who pollute, for the sake of not affecting their own lives. In an acquaintance society, persuasion may be taken as the

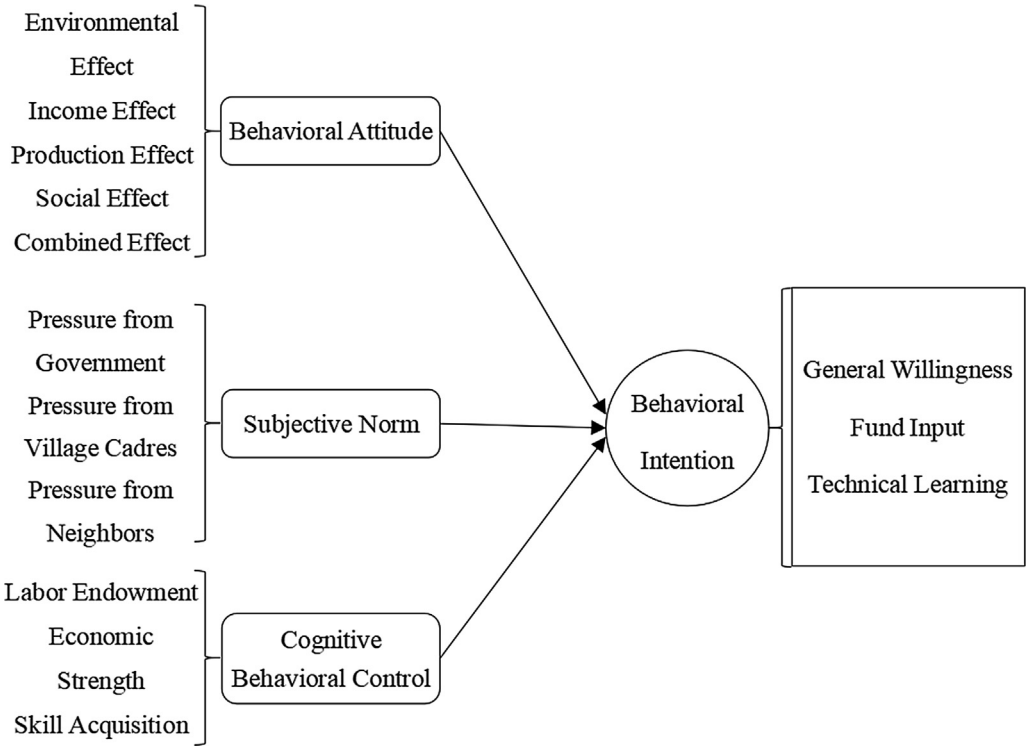

Fig. 1. Theoretical analysis framework of farmers' willingness to utilize livestock manure.

preferred strategy. Therefore, the attitude of farming stakeholders is one of the external constraints on farmers' behavioral decision-making, especially under the current pressure of environmental protection. Farmers must take into consideration the demands or appeals from different stakeholders and correspondingly take effective response measures. Based on that, hypothesis H2 was proposed.

Hypothesis H2. The more pressure farmers perceive from the government, village cadres, and neighborhood, i.e., the stronger the subjective norm, the greater their willingness to engage in resource utilization of livestock manure.

In terms of the cost of resource utilization, a certain amount of manpower, together with material and financial resources, is to be invested, and farmers can maximize their income through the allocation of existing resource elements. Technology constitutes the core of the resource utilization of livestock manure, and different modes of resource utilization have different technical requirements, among which the simple compost returning mode is relatively low-tech and widely used in reality, while the modes, such as those involving biogas production and organic fertilizer processing, have higher technical requirements. Funding, as the basis for the resource utilization of farming manure, is the key element that constrains the resource utilization by farmers. Construction of manure dumps and sewage ponds as well as the purchase of tertiary treatment facilities requires large investment, while farmers complain in general about low farming efficiency and difficult capital turnover. Labor force, the main executor of resource utilization, is directly constrained by the availability of labor within the household on the one hand, and indirectly by financial strength on the other hand, for example, the lack of internal manpower having to be supplemented by hire hands. Consequently, the degree of utilization and participation is constrained by farmers' resource endowments, and sufficient resource elements become the basic guarantee for the resource utilization of livestock manure. Based on that, hypothesis H3 was put forward.

Hypothesis H3. The higher the farmers' evaluation of their own labor abundance, economic strength and skill acquisition, i.e., the greater the control of perception behavior, the greater their willingness to utilize livestock manure.

2.3. Model building

Based on the theory of planned behavior, this paper constructed a structural equation model from farmers' behavioral attitude (AT), subjective norm (SN), and cognitive behavioral control (BC) in order to explore their willingness to utilize livestock manure. As behavioral attitude, subjective norm and cognitive behavioral control were all latent variables, which were difficult to be directly observed and accurately measured, the structural equation model (SEM) was used with reference to the research made by Bukhari et al. (2020) and Wang et al. (2019a) as demonstrated below.

$$WR = \beta_{1i} WR_i + \varepsilon_1$$

$$AT = \beta_{2i} AT_i + \gamma_1 WR + \varepsilon_2$$

$$SN = \beta_{3i} SN_i + \gamma_2 WR + \varepsilon_3$$

$$BC = \beta_{4i} BC_i + \gamma_3 WR + \varepsilon_4$$

In the structural equation model above, *WR*, *AT*, *SN* and *BC* are four latent variables corresponding to behavioral intention, behavioral attitude, subjective norm and cognitive behavioral control. WR_i, AT_i, SN_i and BC_i respectively represent the observable variable vector corresponding to these four potential variables, and *i* takes the values of 1, 2, 3…, indicating the number of observable variables; γ_1, γ_2, and γ_3 represent path coefficients between potential

variables; β_{1i}, β_{2i}, β_{3i} and β_{4i} represent the load coefficients between the latent variable and the observable variable; and ε_1, ε_2, ε_3 and ε_4 indicate residual terms.

2.4. Scale design

With reference to the existing research, and through expert consultation and field investigation, 14 observable variables corresponding to the four latent variables were finally identified. Among them, there were five indicators for behavioral attitude, including environmental effect (AT1), income effect (AT2), production effect (AT3), social effect (AT4) and combined effect (AT5); there were three indicators for subjective normative, namely, government-level pressure (SN1), village cadre-level pressure (SN2), and neighborhood-level pressure (AT3); three indicators for cognitive behavioral control included labor endowment (BC1), economic strength (BC2) and skill acquisition (BC3); and three indicators for behavioral intention included general intention (WR1), fund input (WR2) and training study (WR3). 5-point Likert scale was used for all measurement items, with 1 standing for the weakest in positive strength and 5 for the strongest, as shown in Table 1.

2.5. Data source

The data used in this paper were sourced from the field investigation conducted by the research team. In July 2018, the research team selected Biyang County, Queshan County and Pingyu County in Zhumadian City, Henan Province for pre-investigation, based on which the questionnaire was then improved. In August 2018, a formal investigation was launched. The multi-stage, stratified random sampling was adopted in the investigation. Four prefecture-level cities, Zhumadian, Kaifeng, Luoyang and Nanyang, were selected after a comprehensive consideration on economic development, regional location and beef cattle farming scale in Henan Province. The four surveyed are large prefecture-level cities in beef cattle farming, and as the beef stock in these cities in 2016 accounting for 35.8% of the Province's total, they can be taken as a good representation of the Province which is a main producing area of beef cattle. Besides, the beef cattle stock in the main beef producing areas of the Central Plains (Henan, Shandong, Hebei and Anhui) accounts for about 16.9% of the whole country, so the sampling is also very representative at the national level. By the same method, three sample counties were selected from each city, and 25 beef cattle farmers were randomly selected from each sample county. Questionnaire survey was conducted in the form of one-to-one interviews, and 289 from 300 questionnaires were actually received. By the research needs of this paper, 276 valid questionnaires were finally obtained after eliminating the invalid ones which were self-contradictory or lacking in key variables, with an effective rate being 95.5%.

Table 1
Measurement items and codes of farmers' willingness to recycle livestock manure.

Latent variable	Measure item	Code
Behavioral Attitude (AT)	Resource utilization of cattle manure is beneficial to improving the environment	AT1
	Resource utilization of cattle manure has increased the breeding income	AT2
	Resource utilization of cattle manure has promoted the healthy growth of beef cattle	AT3
	Resource utilization of cattle manure has improved neighborhood relations	AT4
	Resource utilization of cattle manure is an inevitable trend in the future	AT5
Subjective Norm (SN)	The government thinks that I should recycle cattle manure	SN1
	Village cadres think that I should recycle cattle manure	SN2
	Neighbors think that I should recycle cattle manure	SN3
Cognitive Behavioral Control (BC)	I have enough time/staff to recycle cattle manure	BC1
	I have the economic strength to recycle cattle manure	BC2
	I have certain skills in recycling cattle manure	BC3
Behavioral Intention (WR)	Are you willing to recycle cattle manure	WR1
	Are you willing to invest money in the resource utilization of cattle manure to buy equipment	WR2
	Are you willing to take the initiative to participate in trainings related to cattle manure treatment and learn certain skills	WR3

3. Results and discussion

Model identifiability is the prerequisite for parameter estimation of structural equation model, and the identification results include just-, over- and under-identification, in which parameter estimation can be made in both just-identification and over-identification, but in statistical index of the overall fit test of a just-identification model, χ^2 value is 0 , other statistical indexes cannot be estimated, and as just-identification does not have practical application value (Tabachnick and Fidel, 2007), over-identification is much ideal in providing results. With the *t* test rule adopted, and assuming that *p*, *q* and *t* respectively refer to the number of exogenous measurement indicators, endogenous measurement indicators and free parameters to be estimated, the degree of freedom *df* of the model was expressed as $(p+q)(p+q+1)/2-t$. If *df* is positive, the model is over-identified, just identified if *df* is zero, and under-identified when *df* has a negative value. The structural equation model in this paper had 11 exogenous measurement indicators, 3 endogenous measurement indicators, 34 free parameters to be estimated, and the calculated degree of freedom was 71, which was significantly positive, indicating that the model was over-identified.

3.1. Questionnaire reliability test

The clarity of the investigator's statement and the respondents' attitude have a direct impact on the reliability of the questionnaire, so it is necessary to test the stability and consistency of the questionnaire through reliability analysis before the survey data is used. Reliability can be divided into internal reliability and external reliability. External reliability refers to the consistency of the scale measured at a different time, which is generally tested through repeated measurement and quite costly to operate; internal reliability refers to whether all measurement questions under a certain construct consistently point to the construct itself, which can be tested by technical means of data processing. Therefore, internal consistency coefficient (Cronbach's α value) is usually adopted for testing. SPSS20.0 and Amos22.0 were comprehensively used to test the reliability of 14 observable variables of four latent variables: behavioral attitude, subjective norm, cognitive behavioral control and behavioral intention, with the results shown in Table 2. The Cronbach's α values of the four latent variables were between 0.827 and 0.913, and the Cronbach's α value in total scale was 0.879, all greater than the general discriminant criterion of 0.70; the composite reliability of the four latent variables was between 0.830 and 0.914, all greater than the general criterion value of 0.60, collectively indicating that the scale in this study had a good reliability.

Table 2
Reliability and validity of test results.

Latent variable	Observable variable	Factor loading	Cronbach's α value	KMO value	Bartlett's test of sphericity	Composite reliability	Extraction of mean variance
Behavioral Attitude (AT)	AT1	0.755	0.851	0.850	543.489 (p = 0.000)	0.853	0.537
	AT2	0.756					
	AT3	0.746					
	AT4	0.712					
	AT5	0.692					
Subjective Norm (SN)	SN1	0.916	0.913	0.754	576.987 (p = 0.000)	0.914	0.780
	SN2	0.886					
	SN3	0.847					
Cognitive Behavioral Control (BC)	BC1	0.819	0.845	0.724	345.059 (p = 0.000)	0.846	0.648
	BC2	0.831					
	BC3	0.763					
Behavioral Intention (WR)	WR1	0.814	0.827	0.706	313.504 (p = 0.000)	0.830	0.619
	WR2	0.789					
	WR3	0.756					

3.2. Questionnaire validity test

The validity analysis is used to test whether the questionnaire has virtually obtained the expected research content, namely, the closeness between the research results and the expected goals, for which content validity test, criterion validity test and structural validity test are commonly used. In this paper, content validity and structural validity were chosen for testing.

(1) In terms of content validity, this paper first designed a questionnaire based on relevant literature and theoretical research, and experts in economic and technical posts in animal husbandry were consulted. Before the formal investigation, case investigation and questionnaire pre-survey were carried out, and the questionnaire was modified and improved, based on the suggestions from 20 relevant experts and actual investigation, to ensure a rational design and effective samples.
(2) In terms of structural validity, exploratory factor analysis was first conducted. As shown in Table 2, the *KMO* values of the four latent variables ranged from 0.706 to 0.850, and the *KMO* value of the total scale was 0.857, all greater than the general criterion value of 0.70; and the approximate chi-square values of Bartlett spherical test had statistical significance at the level of 1%, indicating a good validity of the questionnaire. In the assignment of a single factor, the factor loadings of 14 observable variables ranged from 0.692 to 0.916, all greater than the general criterion value of 0.60, indicating that the model had good reliability and validity. Structural validity can be further divided into convergence validity and discrimination validity. The convergence validity of the questionnaire was evaluated with the extraction value of mean variance. As shown in Table 2, mean variances extracted for the four latent variables ranged from 0.537 to 0.780, which were greater than the general criterion value of 0.50, indicating that the questionnaire had good convergence validity. As shown in the results of discrimination validity test in Table 3, the difference in degrees of freedom between unconstrained and constrained models for any two latent variables was 1, and the chi-square difference values ranged from 108.043 to 151.129, with the probability value *p* in significance test of chi-square difference all less than 0.05, which reached a significant level, indicating the good discrimination validity among the four latent variables. To sum up, this questionnaire had good structural validity.

3.3. Model fit test

The model fit is normally used to evaluate whether the diagram of constructed path analysis model is compatible with the data obtained from the research, i.e., the matching between theoretical model and actual data. Following the recommendations of Hair et al. (1998), the model fit test was preceded by the violation estimation, which showed no negative error variance, the correlation coefficient of standardized estimation coefficients between covariances was less than 1, and the standardized parameter coefficients were less than 0.95, there existed no large standard error, and the covariance matrix or correlation matrix was positive definite, indicating that there were no estimation violations in this model. The overall model fit was then tested in terms of absolute fit, incremental fit and parsimonious fit (Wu, 2010). As shown in Table 4, all fit indexes except χ^2 value had passed the significance test. On the whole, the theoretical model constructed in this paper matched well with the actual data.

3.4. Result analysis and interpretation

The maximum likelihood estimation method was applied to estimate the model, with results shown in Table 5. All parameters of the structural equation model passed the significance test, indicating that the interactive relationship existed among behavioral attitude, subjective norm, cognitive behavioral control and behavioral intention, and that farmers' behavioral attitude, subjective norm and cognitive behavioral control had a significant positive effect on their willingness to recycle livestock manure. Comparing the three effects, behavioral attitude had the largest impact on farmers' willingness to participate in the resource utilization, scored 0.385, followed by cognitive behavioral control, with the score of 0.299, and subjective norms, only scored 0.240. The findings were consistent with those obtained by Bin et al. (2017), indicating that behavioral attitude was the main driving force affecting farmers' willingness to utilize livestock manure, with a relatively small but not negligible impact from external factors on it.

The standardized regression coefficient for the effect of behavioral attitude on farmers' willingness to utilize livestock manure scored 0.385, which was significant at the statistical level of 1%, indicating that the more positive farmers' cognitive attitude towards the utilization of livestock manure, the greater their willingness to participate. Hypothesis H1 was thus confirmed. Of the five measures of behavioral attitude, the standardized path coefficient of environmental effect (AT1), income effect (AT2),

Table 3
Result of discriminant validity test among latent variables.

Classification	Model	DF	CMIN	P	NFI delta-1	IFI delta-2	RFI rho-1	TLI rho-2
AT & SN	Constrained Model	1	150.949	0.000	0.129	0.131	0.178	0.182
AT & BC	Constrained Model	1	151.129	0.000	0.159	0.162	0.22	0.227
AT & WR	Constrained Model	1	132.329	0.000	0.134	0.137	0.183	0.188
SN & BC	Constrained Model	1	145.822	0.000	0.154	0.155	0.254	0.258
SN & WR	Constrained Model	1	108.043	0.000	0.113	0.114	0.184	0.187
BC & WR	Constrained Model	1	121.825	0.000	0.165	0.167	0.269	0.275

Note: Assuming model unconstrained to be correct.

Table 4
Results of the overall model fit test for structural equation modeling analysis.

Statistical test volume	Fit criteria or critical values	Test result value	Model fit determination
Absolute Fit Index			
χ^2 Value	P > 0.05 (not significant)	p = 0.000	No
RMR Value	<0.05	0.029	Yes
RMSEA Value	<0.05, excellent; <0.08, good	0.056	Yes
GFI Value	>0.90	0.936	Yes
AGFI Value	>0.90	0.905	Yes
Incremental Fit Index			
NFI Value	>0.90	0.937	Yes
RFI Value	>0.90	0.919	Yes
IFI Value	>0.90	0.969	Yes
TLI Value (NNFI Value)	>0.90	0.960	Yes
CFI Value	>0.90	0.969	Yes
Parsimonious Fit Index			
PGFI Value	>0.50	0.633	Yes
PNFI Value	>0.50	0.731	Yes
PCFI Value	>0.50	0.756	Yes
CN Value	>200	133.222	No
χ^2 Freedom Ratio	<2.00	1.876	Yes
AIC Value	The theoretical model value less than the independent model value and the saturated model value	201.222 < 210.000, 201.222 < 2129.276	Yes
CAIC Value	The theoretical model value less than the independent model value and the saturated model value	358.316 < 695.142, 358.316 < 2193.962	Yes

production effect (AT3), social effect (AT4) and combined effect (AT5) was 0.755, 0.756, 0.746, 0.712 and 0.692 respectively. On the whole, farmers' behavioral attitudes towards the various effects of resource utilization of livestock manure were comparable, and the income effect occupied an absolute advantage, with the income effect being dominant and the combined effect being relatively minimal. Farmers are the market economic actors who pursue the maximization of their individual interests. Under the high pressure of environmental protection, the marginal cost or marginal revenue of their behavior has changed (Li and Wang, 2018), which leads to the boundaries of their personal interests expanding from economic benefits to social and ecological ones. Moreover, they show a strong positive awareness of the ecological benefits with positive externalities, and even the satisfaction with the ecological effect is higher than that with economic effect or social effect (Bin and Wen, 2017), which is beneficial for jointly promoting farmers to actively participate in the resource utilization of livestock manure.

The standardized regression coefficient for the effect of subjective norm on farmers' willingness to utilize livestock manure was 0.240, which was significant at the statistical level of 1%, indicating that the greater the pressure from external norms, the stronger their willingness to participate in the utilization of livestock manure. Hypothesis H2 was confirmed. Among the three measures of subjective norm, the standardized path coefficient of the pressure from the government (SN1), village cadres (SN2) and neighbors (SN3) was 0.916, 0.886 and 0.847 respectively, indicating that government-level pressure was an important source of farmers' subjective norm, with comparatively small contribution of pressure from village cadres and neighbors. The result is consistent with the research made by Hou et al. (2018) who found that the pressure from governmental regulations is a key factor that stimulates manure treatment. From the government to the village cadres and then to the neighbors, the external pressures felt by farmers gradually decreased, consistent with the intrinsic attribute of the pressure sources. The pressure at the government level mainly embodied in the constraints of the formal institution, which was mandatory by the state, the pressure from the neighborhood level was mainly reflected in the non-formal institution of public opinion and moral constraint, which was less obligatory, but it played a stronger binding role than legal norms in an acquaintance society (Wang, 2016), while the essence of the village-level norms at the intermediate level lay between the formal and non-formal institutions, with the attributes from the both. In fact, being deeply rooted in the local society, farmers have to take into account the feedback from their fellow villagers. On the one hand, in an acquaintance society like a village, most farming practitioners are village members, and the human relationship mechanism turns the society into a micro-power relationship network, in which each individual is expected to abide by certain human relationship norms (Chen, 2011), a situation easy to form the effect of public opinion (Wang, 2016). On the other hand, neighbors may report animal farming pollution to free their living environment from being disturbed. In the investigation, a small number of farmers were reported by neighbors for farming pollution, thus turning a non-formal institutional constraint into a formal one. Therefore, social pressures from different levels are very crucial to farmers' willingness to participate in the resource utilization of livestock

Table 5
Estimates of path coefficients of the structural equation model.

Path	Unstandardized path coefficient	Standard error	C.R. Value	Results	Standardized path coefficient
AT → WR	0.448	0.085	5.281	Accepted	0.385
SN → WR	0.197	0.049	4.014	Accepted	0.240
BC → WR	0.300	0.069	4.355	Accepted	0.299
AT1 → AT	1.000	——	——	——	0.755
AT2 → AT	1.161	0.097	12.000	Accepted	0.756
AT3 → AT	1.042	0.088	11.848	Accepted	0.746
AT4 → AT	1.004	0.089	11.298	Accepted	0.712
AT5 → AT	0.946	0.086	10.978	Accepted	0.692
SN1 → SN	1.000	——	——	——	0.916
SN2 → SN	0.880	0.042	20.846	Accepted	0.886
SN3 → SN	0.907	0.047	19.329	Accepted	0.847
BC1 → BC	1.000	——	——	——	0.819
BC2 → BC	1.028	0.075	13.675	Accepted	0.831
BC3 → BC	0.866	0.068	12.830	Accepted	0.763
WR1 → WR	1.000	——	——	——	0.814
WR2 → WR	0.957	0.074	12.972	Accepted	0.789
WR3 → WR	0.856	0.069	12.484	Accepted	0.756

manure. The more pressure farmers feel from the government, village cadres and neighbors, the stronger motivation they may have for the resource utilization.

The standardized regression coefficient for the effect of cognitive behavioral control on farmers' willingness to utilize livestock manure was 0.299, which was significant at the statistical level of 1%, indicating that the stronger the cognitive behavioral control of farmers, the greater their willingness to participate in the resource utilization of livestock manure. Hypothesis H3 was thus confirmed. Of the three measures of cognitive behavioral control, the standardized path coefficient of labor endowment (BC1), economic strength (BC2) and skill acquisition (BC3) scored 0.819, 0.831 and 0.763 respectively, suggesting that time or labor endowment and economic strength were the core elements of farmers' cognitive behavioral control, with economic strength being the most important and skill acquisition contributing relatively little to cognitive-behavioral control. The findings are consistent with the research made by Lin et al. (2018), which suggests economic capacity is the most important factor to consider when farmers make use of livestock manure. The survey found that livestock manure were mainly utilized through simple, low-technology composting, which, in nature, was a labor-intensive mode of resource utilization. In most cases, livestock manure were left on land, sun-dried and possibly sold for applying on arable farms (Sefeedpari et al., 2019). Farmers acquired knowledge and skills from traditional farming experience, which were significantly deficient compared to biogas production, commercial organic fertilizer processing and other technology-intensive utilization modes for livestock manure. Moreover, farmers had limited learning capacity and were slow to accept new technologies (Bin and Wen, 2017). Therefore, farmers were weak in skill acquisition in terms of cognitive behavioral control. Farmers' resource utilization of livestock manure was preconditioned by input constraints in labor, fund and technology. Livestock farming required large fund investment and had a long profit cycle, and most farmers in the survey reported the difficulty of capital turnover, but for the simple or primary mode of resource utilization of livestock manure, various factor inputs were relatively insignificant, and farmers had certain labor endowment, economic strength, knowledge and skills to utilize the manure. On the whole, the current resource utilization behavior of livestock manure shows low requirements for economic and knowledge conditions, and behavioral implementation is less restricted by the behavioral cost and conditions (Lin et al., 2018).

4. Conclusions

In this paper, based on the theory of planned behavior, a model of farmers' willingness to utilize livestock manure was constructed at three levels: behavioral attitude, subjective norm and cognitive behavioral control, and the empirical test was conducted through a questionnaire on beef cattle farmers. The results show that farmers' behavioral attitude, subjective norm and cognitive behavioral control had a significantly positive impact on the resource utilization of livestock manure, among which behavioral attitude exerted the greatest impact, followed by cognitive behavioral control and subjective norm; farmers shared almost the same attitude towards the various effects of resource utilization of livestock manure, who may actively or passively weigh up the corresponding economic, social and ecological benefits; the pressure from the government played an important role in farmers' subjective norm, with fewer contribution from village cadres and neighbors; and time or labor endowment and economic strength were the core constraints on the resource utilization of livestock manure by farmers, with relatively little constraint on skill acquisition.

From the above conclusions, certain implications can be drawn. First of all, the publicity of policies related to the resource utilization of livestock manure should be increased, and the level of policy awareness be improved among farmers, so as to stimulate their enthusiasm for participating in the resource utilization and enhance the supervisory role of other interested stakeholders. Secondly, within the scope of government financial permission, the subsidy support for the resource utilization of livestock manure can be appropriately increased, the mode of policy support be innovated, with the compensation provided to farmers for the positive externalities of farming behavior, the cost of resource utilization as well as financial constraint on farmers' utilization of livestock manure be reduced, and at the same time, the supervision of environmental law enforcement in livestock and poultry farming can be strengthened, together with severe punishment imposed on farming pollution. Thirdly, technological research and development in resource utilization for livestock manure can be improved, new technologies and new models characterized with strong applicability, low cost and sustainability be promoted, and the diversity of modes for resource utilization of livestock manure be increased, which should have a demonstration effect and can drive more farmers for active participation in resource utilization. The above research showed technology had less constraint on farmers' resource utilization of livestock manure, but it was

low-tech for primary resource utilization; on the whole, the quality of the resource utilization of livestock manure has yet to be further improved to adapt to the new circumstances in the development of livestock farming.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

This work was supported by the National Social Science Foundation of China (No. 18BJY133).

References

Bin, M.R., Wen, K.L., 2017. Research on the performance of circular agricultural technology adoption based on farmers' satisfaction - A case study of livestock and poultry breeding waste utilization. Jiangxi Soc. Sci. 38, 93–99.
Bin, M.R., Wen, K.L., Zhou, F.M., 2017. Willingness and behavior of farmers' livestock waste resource utilization in the lake area: A case study of Dongting lake ecological economic zone. Econ. Geogr. 37, 185–191.
Budak, D.B., Budak, F., Kacira, O.O., 2010. Livestock producers' needs and willingness to pay for extension services in Adana province of Turkey. Afr. J. Agric. Res. 5, 1187–1190.
Bukhari, F., Hussain, S., Ahmed, R.R., Streimikiene, D., Soomro, R.H., Channar, Z.A., 2020. Motives and role of religiosity towards consumer purchase behavior in western imported food products. Sustainability 12, 356.
Chen, B.F., 2011. On the acquaintance community: An ideal-type exploration of the mechanism in the village order. Chin. J. Sociol. 31, 223–241.
Claytor, H.S., Clark, C.D., Lambert, D.M., Jensen, K.L., 2018. Cattle producer willingness to afforest pastureland and sequester carbon. Forest Policy Econ. 92, 43–54.
[dataset] FAO, 2019. Manure management. http://www.fao.org/faostat/en/#data/GM.
Hair, J.F., Anderson, R.L., Tatham, R.L., Black, W., 1998. Multivariate Data Analysis. Prentice Hall, Upper Saddle River, NJ.
He, X.F., Tong, Z.H., 2002. On social solidarity of villages – Also on the social basis of village order. Soc. Sci. China 23, 124–134.
Hou, Y., Velthof, G.L., Case, S.D.C., Oelofse, M., Grignani, C., Balsari, P., Zavattaro, L., Gioelli, F., Berna, M.P., Fangueiro, D., Trindade, H., Jensen, L.S., Oenema, O., 2018. Stakeholder perceptions of manure treatment technologies in Denmark, Italy, the Newtherlands and Spain. J. Clean. Prod. 172, 1620–1630.
Jeon, J.H., Park, C.G., Bernard, A.E., 2015. Evaluating effects of poultry waste application on phosphorus loads to Lake Tenkiller. Sustainability 7, 10115–10134.
Ji, I.B., Kwon, O.S., Song, W.J., Kim, J.N., Lee, Y.G., 2014. Estimating willingness to pay for livestock industry support policies to solve livestock's externality problems in Korea. J. Rural Dev. 37, 1–20.
Khan, M.A., Chander, M., Bardhan, D., 2013. Willingness to pay for cattle and buffalo insurance: an analysis of dairy farmers in central India. Trop. Anim. Health Prod. 45, 461–468.
Krishna, P.P., Wayne, M.G., John, V.W., Larry, M.H., 2008. Factors influencing and steps leading to the adoption of best management practices by Louisiana dairy farmers. J. Agric. Appl. Econ. 40, 203–222.
Kumar, S., Mirajkar, P.P., Singh, Y.P., Singh, R., 2011. Analysis of willingness to pay for veterinary services of the livestock owners of sangli district of Maharashtra. Agric. Econ. Res. Rev. 24, 149–154.
Li, Q., Wang, Y.B., 2018. On the choices of government behaviors in utilization of livestock and poultry manure resources. Rural Econ. 36, 55–61.
Li, Q., Wang, J.J., Wang, X.Y., Wang, Y.B., 2020. The impact of alternative policies on livestock farmers' willingness to recycle manure: Evidence from central China. China Agric. Econ. Rev. https://doi.org/10.1108/CAER-09-2019-0158.
Li, X.H., Zhang, Y.Y., Wang, J.Y., Sun, S.M., 2019. Analysis of influencing factors and mechanism of willingness to pay for environmental protection in livestock and poultry farms based on ISM - Empirical analysis based on 383 questionnaires in Shandong province. Resour. Dev. Mark. 35, 667–672.
Lin, L.M., Liu, Z.B., Du, Y.Q., Su, S.P., Zheng, Y.F., 2018. Psychological cognition of pollution prevention of family-oriented scale pig breeders and environmental regulation influence effects. Chin. J. Eco-Agric. 26, 156–166.
Liu, M.Y., Lu, Q., Zhang, S.X., 2017. Calculation of compensation standard for avian influenza encouraged on farmers' desire to reporting chicken disease. J. Northwest A & F Univ. (Soc. Sci.) 17, 82–89.
Loyon, L., 2017. Overview of manure treatment in France. Waste Manage. 61, 516–520.
Ma, Y.X., Lu, W.C., Bergmann, H., 2014. Economic and environmental effects of nutrient budgeting strategies in animal excreta treatment. China Agric. Econ. Rev. 6 (4), 598–615.
Mcleod, E., Jensen, K., Griffith, A.P., Delong, K.L., 2018. Tennessee beef producers' willingness to participate in a state-branded beef program. J. Agric. Appl. Econ. 50, 579–601.
Millner, P., Ingram, D., Mulbry, W., Arikan, O.A., 2014. Pathogen reduction in minimally managed composting of bovine manure. Waste Manage. 34, 1992–1999.
Mlote, S.N., Mdoe, N.S., Isinika, A.C., Mtenga, L.S., 2013. Factors affecting agro-pastoralist and pastoralists' willingness to adopt beef cattle fattening in the lake zone in Tanzania. J. Agric. Sci. 5, 140–154.
Myers, D.G., 2005. Social Psychology. McGraw-Hill Companies Inc..
Pan, D., 2016. The design of policy instruments towards sustainable livestock production in China: An application of the choice experiment method. Sustainability 8, 611.
Pan, D., 2017. Willingness of different scale farmers to accept livestock pollution control policy: Based on choice experiment method. J. China Agric. U 22, 188–197.
Sefeedpari, P., Vellinga, T., Rafiee, S., Sharifi, M., Shine, P., Pishgar-Komleh, S.H., 2019. Technical, environmental and cost-benefit assessment of manure management chain: A case study of large scale dairy farming. J. Clean. Prod. 233, 857–868.
Sohu, 2018. 3.8 billion tons of livestock and poultry waste is only used 60% every year. Experts explain three reasons. http://www.sohu.com/a/221877155_114986 (accessed 9 February 2018).
Tabachnick, B.G., Fidel, L.S., 2007. Using Multivariate Statistics. Pearson/Allyn and Bacon.
Tancuk, M., Junga, R., Alicja, K.W., Niemiec, P., 2019. Assessment of the energy potential of chicken manure in Poland. Energies 12, 1244.
Tang, Y., 2019. Analysis of factors affecting farmers' intention to reduce fertilization under organic certification system. J. Arid Land Resour. Environ. 33, 29–34.
Tian, M., Pu, B., Chen, Y.N., Zhu, Z.A., 2019. Consumer's waste classification intention in China: an extended theory of planned behavior model. Sustainability 11, 6999.
Vrieze, J.D., Colica, G., Pintucci, G., Sarli, J., Pedizzi, G., Willeghems, G., Bral, A., Varga, S., Prat, D., Peng, L., Spiller, M., Buysse, J., Golsen, J., Benito, O., Garballa, M., Vlaeminck, S.E., 2019. Resource recovery from pig manure via an integrated approach: A technical and economic assessment for full-scale applications. Bioresour. Technol. 272, 582–593.
Wang, H., Qiao, J., Li, B.L., 2019a. Farmers' willingness to participate in standardized farms construction and its determinants: An analysis based on survey data from pig breeders in for provinces. China Rural Surv. 40, 111–127.
Wang, J.H., Tao, J.Y., Chen, L., 2019b. Farmers' willingness to accept compensation for livestock and poultry waste resource utilization and its influential factors. China Popul. Resour. Environ. 29, 144–155.
Wang, S.T., 2016. The community residents' environmental behavior based on the premise of "acquaintance society". Chongqing Social Sci. 13, 59–63.
Wu, H., Qi, Y.B., Yu, W.Y., 2015. Analysis on the willingness of farmers to adopt safe feed and its influencing factors – Based on the empirical study of 613 farmers. Rural Econ. 33, 104–109.
Wu, M.L., 2010. Structural Equation Model: Operation and Application of AMOS. Chongqing University Press, Chongqing.
Xu, X.Y., Yue, M.F., Li, J.G., Liu, L.L., 2019. Analysis of factors influencing the willingness of livestock and poultry farmers to control pollution in coastal areas: A case study of Yancheng, Jiangsu. J. Nat. Resour. 34, 1974–1986.
Yu, T., Yu, F.W., 2019. The impact of cognition of livestock waste resource utilization on farmers' participation willingness in the context of environmental regulation policy. China Rural Econ. 35, 91–108.
Zanu, H.K., Antwiwaa, A., Agyemang, C.T., 2012. Factors influencing technology adoption among pig farmers in Ashanti region of Ghana. Int. J. Agric. Technol. 8, 81–92.
Zhang, H.N., Ge, Y.X., Jie, Y.M., Zheng, Y.C., 2019. A study on the influence of ecological cognition on river basin residents' willingness to participate in ecological compensation. China Popul. Resour. Environ. 29, 109–116.
Zhang, Y., Xiao, H.F., 2016. Analysis on ranchers' choice and influencing factors of vertical collaboration: A case study of cashmere industry. Res. Agric. Modern. 37, 709–715.
Zhang, Y.Y., Yang, Z.Y., Wu, Y., 2014. Analysis on influencing factors of fry purchase intention of smallholders: Evidence from all-female paralichthys olivaceus fries. China Fish. Econ. 33, 153–159.
Zhang, Y.Y., Zhan, J.T., Chen, C., 2017. The impact of specialization and cognition degree on farmers' demand for swine price index insurance products: An empirical analysis. China Rural Econ. 33, 70–83.
Zubair, M., Wang, S.Q., Zhang, P.Y., Ye, J.P., Liang, J.S., Nabi, M., Zhou, Z.Y., Tao, X., Chen, N., Sun, K., Xiao, J.H., Cai, Y.J., 2020. Biological nutrient removal and recovery from solid and liquid livestock manure: Recent advance and perspective. Bioresour. Technol. 301, 122823.