



Does policy cognition affect livestock farmers' investment in manure recycling facilities? Evidence from China

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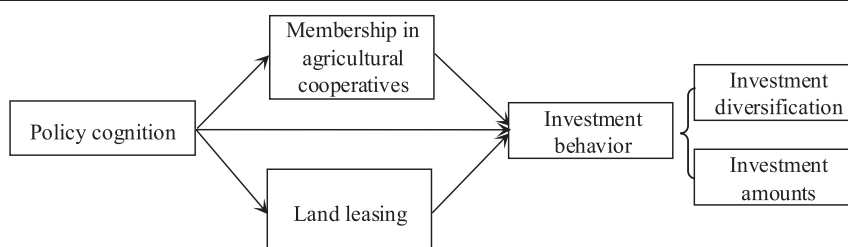
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HIGHLIGHTS

- Policy cognition has a positive impact on farmers' investment in manure recycling.
- Cooperative membership and land leasing show significant partial mediation effects.
- Land leasing promotes higher amounts of investment in manure recycling.
- Cooperative membership promotes more diverse investment in manure recycling.

GRAPHICAL ABSTRACT



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ABSTRACT

An increase in living standards and dietary changes have induced a rapid growth in the livestock sector worldwide, which has led to considerable environmental damages due to inappropriate disposal of livestock manure. Using primary data from a field survey of cattle farmers in China, this paper empirically examines the impact of policy cognition on livestock farmers' investment in manure recycling facilities. The impact is tested through the multiple mediator model to accommodate two potential mediating mechanisms, which are the agricultural cooperative membership and land leasing. Three conclusions arise. First, policy cognition has a significant positive impact on both the diversification and amounts of farmers' investment in manure recycling facilities. Second, membership in agricultural cooperatives and participation in land leasing are two important mediating mechanisms for policy cognition to affect farmers' investment decisions on manure recycling. Finally, for the two mediating variables, leasing additional agricultural land promotes more investment in manure recycling facilities, but less in investment diversification, while cooperative membership has the opposite impact. This study contributes to three areas of literature on the factors affecting investment decisions, the mediating effects of policy cognition and the investment in non-production related assets. Regarding policy implications, we identify the importance of promoting policy awareness and agricultural cooperatives among livestock farmers, as well as developing land lease markets in agricultural regions in promoting investment in manure recycling facilities.

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1. Introduction

An increase in living standards and dietary changes have induced a rapid growth in the livestock sector worldwide, which has led to

considerable environmental damages due to inappropriate disposal of livestock manure (Bouwman et al., 2013; Herrero et al., 2013; Bluemling and Wang, 2018; Bai et al., 2018; Uwizeye et al., 2020; Varma et al., 2021). While it is imperative for the livestock industry to supply animal protein products, reducing adverse environmental impacts from manure disposal raises another dimension of challenge for livestock production. Traditionally, livestock manure has been directly

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applied as fertilizer to agricultural land as a source of nutrients for crop growth (Strom et al., 2018; Robles et al., 2018). With the trend of consolidation in the livestock sector, manure tends to be over-applied to land with the increasing disconnect between livestock production and croplands in many regions across the world (Zhang et al., 2019; Joshi and Wang, 2018; Porter and James, 2020). Therefore, the need for environment-friendly methods of treating and utilizing livestock manure has become imperative (Jayasinghe et al., 2010; Roubik et al., 2018; Mueller and Lassaletta, 2020).

Manure recycling refers to the management of manure to realize its nutrient and potential economic values, such as direct application to land, processed into organic fertilizer, as a substrate for agriculture production and as ingredient to produce biogas (Venier and Yabar, 2017; Wang et al., 2021; Zhang et al., 2021). To a large extent, combining crop and livestock farming is essential for manure recycling. In addition to recycling nutrients, manure recycling can also reduce greenhouse gas emissions (Pratt et al., 2015; Junior et al., 2015; Aguirre-Villegas and Larson, 2017). Public policies aiming to promote manure recycling through various mechanisms can play a vital role in the management of livestock manure to control its pollution of the environment (Roubik et al., 2018).

China is one of the top livestock producing countries in the world, and its management of livestock manure is becoming a world-concerning issue (Bai et al., 2018; Li et al., 2021). In the past, the farm scale in China was small and scattered, mostly at the household level. Therefore, crop and livestock farming were integrated, and livestock manure was typically applied to cropland. With the steady increase of farm scale, the specialization in crop or livestock farming has intensified, resulting in insufficient land to recycle manure as its quantity exceeds the bearing capacity of cropland in the proximity of livestock farms. Official data from the Ministry of Agriculture and Rural Affairs of China reported that livestock and poultry farms in China produce about 3.8 billion tons of manure per year, out of which only 60% is recycled (MARA, 2018). From a global perspective, livestock manure production in China accounts for the largest proportion in the world, accounting for 18.22% (FAO, 2019). China's experience in managing livestock manure can provide important implications to other countries and regions facing similar challenges of livestock manure management.

With environmental pollution from manure becoming a public concern, China has established several policy initiatives to promote livestock manure recycling, especially in the past decade. Traditionally there has been a lump-sum penalty policy in China targeting livestock farms causing water pollution. However, this is a general policy at the national level that relies on local governments for interpretation and implementation so its impact on controlling pollution from inappropriate manure management is uncertain. Since 2018, the Chinese government has launched investment projects to support large livestock producing counties to construct manure recycling infrastructure. In 2019, the coverage of counties eligible for such investment projects was extended to major agricultural production counties. Specifically, these investment projects subsidize farmers to invest in building manure recycling facilities. However, this new incentive-based policy has not yet played a leading role in changing farmers' investment in manure recycling facilities.

The key to a successful manure recycling program lies in attracting investment for construction of recycling facilities, because the facilities can require substantial upfront investment, especially for some commercially available technologies (Drozd et al., 2020). Given that the investment on recycling facilities plays an important role in manure management (Skevas et al., 2018), China set the goal to have at least 95% of large livestock farms install manure treatment facilities and to achieve a nationwide 75% manure recycling rate by 2020 (GOSC, 2017). The goal was postponed in 2020 due to disruptions caused by the COVID-19 pandemic but is expected to resume when the pandemic is over. Under such background, it is important to study farmers' investment behavior in building manure recycling facilities.

Using primary data from a field survey of cattle farmers in China, this paper aims to examine the impact of policy cognition on livestock farmers' investment in manure recycling facilities. Two potential mediating mechanisms of policy cognition on farmers' investment decision-making are explored via a multiple mediator model. We expect our results to provide countries and regions considering policies for livestock manure management with improved information.

The structure of the paper is as follows: Section 2 gives an overview of related literature. Section 3 presents the empirical methods. Section 4 describes the field survey and data used for analysis. Section 5 discusses the results and Section 6 draws the conclusion.

2. Literature review

Investment is a crucial issue in farm management (Sckokai and Moro, 2009; Kousar and Abdulai, 2016; Abdulai et al., 2011; Hertz, 2010). Large investment decisions such as purchasing agricultural machinery (Kingwell, 1996) and land leveling (Ma et al., 2013) require careful discretion. Manure recycling facility investment usually involve fixed assets and of long-term use such as purchasing agricultural machinery and constructing buildings. Specific investment items in manure recycling facility include farmyard manure collector, equipment, wells, land and paving roads. Research has identified that agricultural investments are affected by a range of external factors, including climate risks (Kingwell and Farre, 2009; Takeshima and Yamauchi, 2012), land property rights (Besley et al., 2012; Gao et al., 2019), infrastructure (Fan and Zhang, 2004), off-farm employment opportunity (Mathenge et al., 2015), financing constraints (Ali et al., 2014), whether joining co-operatives (Ma et al., 2017), agricultural policies (Marconi et al., 2015), and risk perception (You, 2014). In addition to these external factors, household characteristics are also important factors affecting investment decisions, including gender, education level, engagement of household head in farming, age of the household head, the farm's managerial competence and organizational learning (C.Maart-Noelck and Musshoff, 2013; Bokusheva et al., 2009; Ndagijimana et al., 2019).

Existing research on agricultural investment mainly focuses on issues related to production, but non-production related investments such as manure recycling is less studied. Several recent studies examine the investment decisions to improve production efficiency in livestock and poultry farms. Skevas et al. (2018) examine the optimal investment path in capital assets for the case of dairy farmers. Samson et al. (2016) study dairy farmers' investment decision to build extra barn space. Tian et al. (2018) analyze the investment decision in disease prevention and control for the case of poultry farms. However, less attention has been paid to investments not directly related to production assets. In the case of manure disposal, recycling manure for proper land application can provide valuable nutrients (e.g., nitrogen, phosphorus and potassium) to crops and lower the production cost of purchasing synthetic fertilizers. It can also improve soil health (e.g., Peterson et al., 2020), decrease nutrient pollution (e.g., Wang et al., 2021), and reduce emissions of greenhouse gases with long-term benefits (e.g., Herrero et al., 2013). Nevertheless, the economic value of manure depends on multiple factors including local prices of synthetic fertilizers and costs of manure collection, storage, treatment, and transportation. As a result, the conventional cost-benefit analysis of investment in manure recycling facilities is more difficult to justify. For example, Anderson and Weersink (2014) resort to a real option approach in evaluating the feasibility of installing farm-based anaerobic digesters. To decide on the best manure management modality, it is necessary to consider multiple impacts beyond the profitability of investment, such as farm specifications, local conditions and particularly the policy perspectives (Burney et al., 1980; Sefeedpari et al., 2019).

The cognition of policy spans multiple dimensions such as understanding of policy motives (Chen et al., 2017), knowledge of policy contents (Rhodes et al., 2014) and attitudinal judgement (Cooper et al., 2016). To measure policy cognition researchers typically construct

an index consisting of the multiple aspects for further analysis (Zhang et al., 2020; Yu et al., 2020). The effect of policy cognition on investment decisions has been studied in two parts. The first part is that policy cognition has a direct impact on investment behavior. Several studies have investigated this direct relationship in electricity consumption (Zhang et al., 2020), consumer purchase intention (Lou et al., 2017; Xiong and Wang, 2020) and agricultural investment (Thu and Goto, 2020). On the other hand, the second part is the indirect impact where policy cognition channels its effect through mediators before eventually reaching onto investment decisions. For example, Fan and Zhang (2019) find that policy cognition affects farmers' attitude, awareness of environmental influences, and social norms. These factors play mediating roles to affect farmers' decision-making process on whether to withdraw from rural homesteads. Similar mediation mechanism is also observed among agents in transportation industry and water-saving programs (Chang et al., 2016; Fu et al., 2020).

We contribute to the literature in at least three ways. First, this paper studies the impact of policy cognition on farmers' investment behavior, which is rarely covered in previous research. To introduce the policy cognition variable into farmers' decision-making framework, this paper employs a factor analysis approach to extract information from four variables to comprehensively measure policy cognition. Second, in addition to the direct impact, we also analyze the indirect effect of policy cognition by introducing two mediating variables: membership in agricultural cooperatives and land leasing. By analyzing the mediating effect, we provide a deeper understanding on the path of policy cognition effect on investment decision-making. Third, this paper examines investment behavior that is not related to production capital. Existing research mainly study investments that aim to improve production efficiency, which can be analyzed under the cost-benefit comparison. Manure recycling investment is difficult to be solely justified by cost-benefit analysis because of its limited profitability. This paper furthers the understanding in this non-production related investment.

3. Methodology

3.1. Theoretical framework

Cognition determines farmers' preferences and further guides their behavior and decision-making (Denzau and North, 1993). In this study, farmers' policy cognition is defined at the macro level as their awareness of relevant policies, attitude towards local implementation of these policies, and attitude towards overarching policy guidelines. Undoubtedly, there are micro-level dimensions of policy cognition that we are not able to explore in the study but can affect farmers' behavior. Examples are knowledge and understanding of policy details, including policy instruments, regulatory measures, and enforcement procedures. While our survey data does not allow the micro-level dimensions of policy cognition to be assessed, we recognize the complexity of the issue and call for further investigation in future research.

We propose that policy cognition affects farmers' investment behavior in manure recycling facilities via two potential mediating mechanisms, that is, membership in agricultural cooperatives (hereinafter *cooperative membership*) and participation in land leasing (hereinafter

land leasing), as shown in Fig. 1. The representative outcomes of investment behavior are measured by two dimensions, which are the diversification and amount of investment.

3.1.1. Membership in agricultural cooperatives

Agricultural cooperatives (hereinafter referred to as *cooperatives*) is one of the two types of new agribusiness entities in China. Many public funds and programs either directly target cooperatives or distribute funds through cooperatives. For example, one service that cooperatives provide to their members is distributing public subsidies for cattle farm expansion. It is important for farmers to be aware of and understand such policies of agricultural financial support. In addition, the professional requirements of livestock production (e.g., beef cattle breeding) keep increasing with the concentration and consolidation of the sector, which calls for technical guidance, decision-making consultation, and other services to livestock farmers. Cooperatives can meet farmers' needs in these areas. Therefore, the higher the farmers' policy cognition, the stronger is the motivation for farmers to join cooperatives.

Cooperatives affect the production behavior of members through a diverse mechanism (Cai et al., 2019). For livestock farmers, the investment in manure recycling facilities is an important decision. Farmers face two challenges when making such decisions. First, market channels for manure-based products have not been established. Second, due to environmental protection regulations, some regions in China require that livestock farms must be equipped with scale-appropriate facilities for manure disposal such as waste dumps or slurry lagoons, which imposes additional costs. Given these challenges, the cooperatives can play an important role in helping with members' decision of production, either by directly participating in production activities or providing advisory services.

For livestock farmers, cooperatives provide advisory and brokerage service for investing in manure recycling facilities for its members. Large size orders representing multiple members can benefit from the economies of scale. In addition, farmers who join the cooperatives and other similar organizations must also follow the organizations' relevant regulations including environmental protection, such as manure recycling (Kong et al., 2016). Hence, we propose our first hypothesis H1 below.

Hypothesis H1. Policy cognition has a positive impact on livestock farmers' investment in manure recycling facilities by encouraging farmers to join cooperatives.

3.1.2. Land leasing

The most simple and effective way to manage manure is to recycle it back to cropland, which necessitates the integration of planting and farming operations. The advantage of operational simplicity and low implementation costs make it farmers' preferred method of manure disposal under the current regulation policy framework. Therefore, the higher the farmer's policy cognition towards livestock farming, the higher their cognition or acceptance of the combination of crop and livestock production. In some regions, subsidies are available to encourage

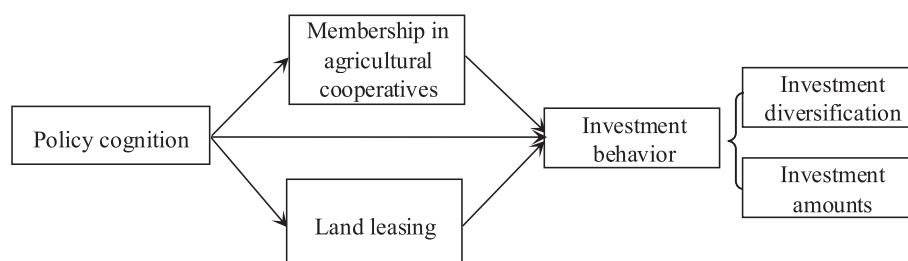


Fig. 1. Theoretical framework.

livestock farmers to plant silage corn and high-quality forage such as alfalfa. Due to the land size needed in this recycling method, the land allocated only for livestock production cannot meet the demand for cropland and associated manure disposal. As a result, demand for land transfer arises naturally. Farmland in China is collectively owned by villages so farmers did not have legal rights to trade or lease their land. In 2016, China revised its land transfer rules to allow farmers to lease land in order to help promote large-scale farms. Therefore, the higher a livestock farmer's policy cognition of the revised land transfer policy, the higher likelihood that the farmer to lease more land for farm operation.

Livestock farmers lease land for two primary reasons. First, more land is needed to build manure recycling facilities or reserved for farming space expansion, such as waste dumps and slurry lagoons. Second, additional land can be used to plant crops where the manure can be applied as is necessary for an integrated planting and farming system. Land availability encourages investment in manure recycling facilities because it can effectively reduce the transaction cost and uncertainty on the disposal of recycled manure products. The treated manure can be internally absorbed by the combination of crop and livestock farming systems within the farm. Therefore, we propose our second [hypothesis H2](#) below.

Hypothesis H2. Policy cognition has a positive impact on livestock farmers' investment in manure recycling facilities by encouraging farmers to lease land.

3.2. Empirical model

As summarized above, policy cognition may impact farmers' investment in manure recycling facilities through two mediating channels, which are cooperative membership and land leasing. This type of indirect causal relationship is best described in the framework of mediation effect, which was proposed by [Baron and Kenny \(1986\)](#) and further developed by [Pearl \(1995\)](#) and [Pearl and Mackenzie \(2018\)](#). In this study, a multiple mediator model is constructed to test the two hypotheses:

$$Y^d = \alpha_0^d + \alpha_1^d P + \sum \alpha_k^d X_k + \varepsilon_1^d \quad (1d)$$

$$Y^a = \alpha_0^a + \alpha_1^a P + \sum \alpha_k^a X_k + \varepsilon_1^a \quad (1a)$$

$$M^c = \beta_0^c + \beta_1^c P + \sum \beta_k^c X_k + \varepsilon_2^c \quad (2c)$$

$$M^l = \beta_0^l + \beta_1^l P + \sum \beta_k^l X_k + \varepsilon_2^l \quad (2l)$$

$$Y^d = \gamma_0^d + \gamma_1^d P + \gamma_c^d M^c + \gamma_l^d M^l + \sum \gamma_k^d X_k + \varepsilon_3^d \quad (3d)$$

$$Y^a = \gamma_0^a + \gamma_1^a P + \gamma_c^a M^c + \gamma_l^a M^l + \sum \gamma_k^a X_k + \varepsilon_3^a \quad (3a)$$

where Y denotes a farmer's investment behavior, with Y^d representing investment diversification and Y^a representing investment amounts; P denotes the farmer's policy cognition; M is the mediating variable, with M^c representing cooperative membership and M^l representing land leasing; X_k is a group of control variables that may affect a farmer's investment behavior, cooperative membership and land leasing; α , β and γ are the regression coefficients of corresponding independent variables, and ε is the residual disturbance term. Because the estimation procedure follows three steps (see below), we number the equations into three sets (1), (2) and (3), with each set consisting of two equations corresponding to different independent variables or different mediating variables. For example, in equation set (1), the d in the numbering of Eq. (1d) stands for investment diversification, and the a in the numbering of Eq. (1a) stands for investment amounts. Similarly, in equation set (2), the c in the numbering of Eq. (2c) stands for cooperative membership, and the l in the numbering of Eq. (2l) stands for land leasing.

The procedure to identify the causal path and net effect is summarized as the front-door criterion ([Pearl and Mackenzie, 2018](#)) and

consists of three steps. The first step is to estimate equation set (1) to test whether a farmer's policy cognition has a significant impact on the farmer's investment in manure recycling facilities. If α_1 is significant, the next step will be carried out. Otherwise, the mediating effect analysis stops. The second step is to estimate equation set (2) to test whether the farmer's policy cognition has a significant impact on the status of cooperative membership and land leasing. The third step is to estimate equation set (3) to test whether the farmer's policy cognition has a significant impact on the investment in manure recycling facilities along with each of the mediating variables. If both β_1 and γ_c (or γ_l) are significant, the mediating effect of M^c (or M^l) on Y is significant. If γ_1 is also significant at the same time, there is a partial mediating effect in Y ; otherwise, there is a complete mediating effect. If either β_1 or γ_c (or γ_l) is insignificant, Sobel test is needed to determine the significance of the net mediating effect of M^c (or M^l) on Y . In the presence of mediating effects, α_1 is the total effect of the farmer's policy cognition on the investment in manure recycling facilities, and $\beta_1 \gamma_c$ (or $\beta_1 \gamma_l$) is the mediating effect or indirect effect of the mediating variable M^c (or M^l).

4. Data

4.1. Field survey and sample

Data used in the empirical analysis is obtained from a field survey of livestock farms in the Henan Province of China during July–August 2018. Four prefecture-level cities in Henan (Zhuzhadian, Kaifeng, Luoyang and Nanyang) were selected as survey sites because of their sizable cattle feeding industry ([Fig. 2](#)). Henan is the main production area of beef cattle in the Central Plain of China. In 2017, the beef production of Henan accounted for 5.5% of the total beef production in China, ranking the seventh in China ([National Bureau of Statistics of China, 2018](#)). The sum of cattle stocks in the four surveyed cities accounted for 35.8% of the total cattle stock in Henan in 2016 ([Survey Office of the National Bureau of Statistics in Henan, 2017](#)), indicating our study site a good representation of the main beef production areas in the Central Plain of China. In each city, three counties with the largest cattle ending stock were selected. For each county, 25 cattle farms were randomly selected to perform field survey. The survey was conducted in person through one-on-one interviews with cattle farmers. A total of 289 questionnaires were obtained, with a response rate of 96.3%. After eliminating invalid responses with self-contradiction or missing variables, 276 valid responses are obtained, with an effective rate of 95.5%.

4.2. Variables and descriptive statistics

The explained variable of interest is cattle farmers' investment in manure recycling facilities, which is measured by investment diversification and investment amounts ([Fig. 2](#)). The investment diversification of manure recycling facilities represents the number of different types of facilities. There are five types of manure recycling facilities available to farmers in China: manure storage yards, slurry lagoons, tertiary treatment facilities, organic fertilizer processing equipment, and biogas digesters. Hence, investment diversification is coded with integer values of 0–5, where zero denotes that farmers do not invest in any manure recycling facility and 5 denotes that the farmers invest in all five types of facilities. In the survey data, farms with no investment in any facility accounts for 19.6% of observations, while only one farm owns all five types of facilities. The investment amounts of manure recycling facilities refer to the total amount of money spent by farmers on the purchase, installation and/or construction of facilities for manure recycling. In the sample, the largest investment amount by a farmer is 510,000 RMB (about \$78,000), and the average investment amount is 47,000 RMB (about \$7200).

The independent variable of interest is farmers' policy cognition. We comprehensively measure the policy cognition at the macro level from three aspects: awareness of relevant policies, attitude towards policy

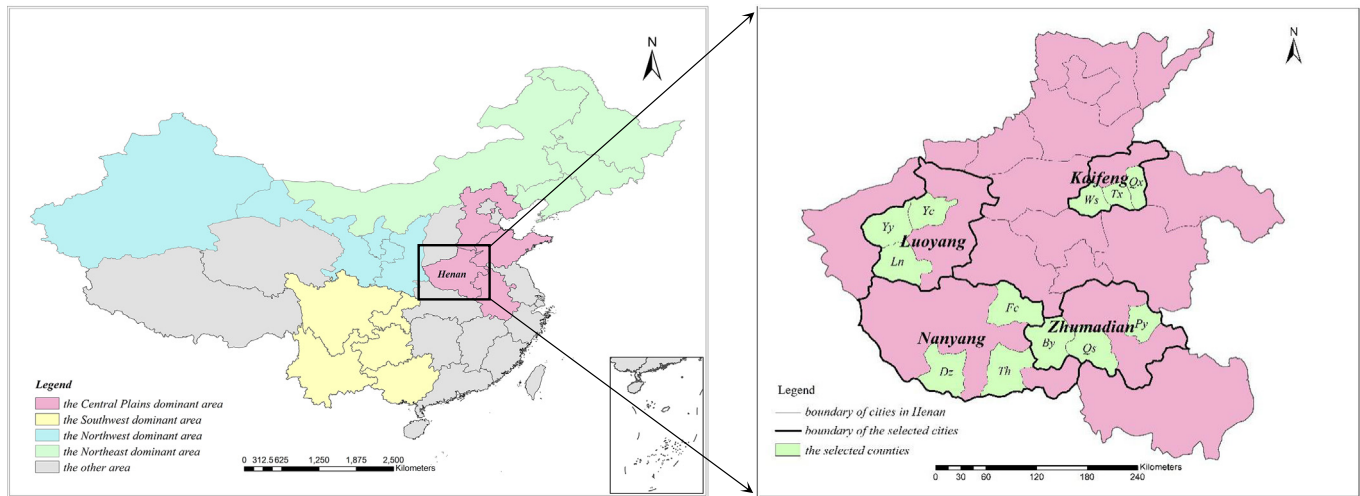


Fig. 2. Maps of the study site.

implementation, and attitude towards overarching policy guidelines. We measure awareness of relevant policies based on the question: “Are you aware of policies on livestock farming (e.g., monitoring, penalties and subsidies)?”. Attitude towards policy implementation is measured by the question: “Do you think the local government has strict supervision over the environmental performance of livestock farming?”. Two leading policy guidelines adopted by China for environment protection are the “polluter pays” principle (i.e., “the one who pollutes the environment should be responsible for it”) and the philosophy of “green development” (i.e., “lucid waters and lush mountains are invaluable assets”) as part of China's national policy guidelines. Consistent with Yu et al. (2020), we measure attitude towards overarching policy

guidelines based on two questions: “Do you agree that ‘the one who pollutes the environment should be responsible for it?’” and “Do you agree that ‘lucid waters and lush mountains are invaluable assets?’”. A set of four variables for policy cognition are generated from the four questions, as shown in Table 1.

Factor analysis is performed to extract information from the four variables to synthesize a new comprehensive indicator for policy cognition. Factor analysis is preferred in the context of the study for two reasons. First, it reduces potential multi-collinearity caused by simultaneous introduction of the four individual variables for policy cognition. Second, it alleviates potential loss of information from using only one of the four individual variables. Thus, factor analysis maximizes the information

Table 1
Variable definitions and summary statistics.

Variable name	Variable definition	Mean	SD
Dependent variable			
Investment diversification	Types of manure recycling facilities	1.52	1.01
Investment amounts	Total amount of money spent on manure recycling facilities (1000 RMB)	47.3	83.3
Independent variable of interest			
Policy cognition	An index extracted via factor analysis	0.00	0.41
Are you aware of policies on livestock farming (e.g., monitoring, penalties and subsidies)?	A 5-point Likert scale from very unfamiliar to very familiar	3.08	1.04
Do you think the local government has strict supervision over the environmental performance of livestock farming?	A 5-point Likert scale from very loose to very strict	4.30	0.77
Do you agree that “the one who pollutes the environment should be responsible for it?”	A 5-point Likert scale from strongly disagree to strongly agree	4.05	1.00
Do you agree that “lucid waters and lush mountains are invaluable assets?”	A 5-point Likert scale from strongly disagree to strongly agree	4.43	0.87
Mediator variables			
Cooperative membership	Member of cooperatives or not (1 = yes, 0 = no)	0.35	0.48
Land leasing	Leased land or not (1 = yes, 0 = no)	0.53	0.50
Control variables			
Individual characteristics			
Gender	1 = Male, 0 = female	0.94	0.23
Age	Age (years)	47.25	10.23
Education	Years of education (years)	8.12	3.28
Physical health	From very poor to very good, assign from 1 to 5	4.23	0.90
Risk preference	1 = Risk aversion, 2 = risk neutral, 3 = risk seeking	1.77	0.75
Family size	Number of household members	5.34	2.06
Farm characteristics			
Farm size	Number of cattle in stock at the end of 2017 (heads)	97.8	189.19
Farm location	Distance from the farm to downtown (kilometers)	5.52	3.63
Local topography	1 = Plain, 2 = hill, 3 = mountain	1.58	0.68
Farming experience	Years in the cattle farming industry (Years)	7.01	5.92
Manure handling difficulty	If difficult to handle manure (1 = yes, 0 = no)	0.52	0.50
Credit accessibility	If difficult to get loan (a 5-point Likert scale from very difficult to very easy)	2.24	1.06
Recycle benefits cognition	Manure recycling can increase farm income or not (a 5-point Likert scale from strongly disagree to strongly agree)	3.84	1.08

Table 2
Key results of the mediator model.

Dependent variable	Investment diversification	Investment amount	Cooperative membership	Land leasing	Investment diversification	Investment amount
Regression	(1d)	(1a)	(2c)	(2l)	(3d)	(3a)
Policy cognition	0.3315*** (0.1038)	4.5129*** (1.6587)	0.4488* (0.2354)	0.4078* (0.2213)	0.2936*** (0.1022)	3.8127** (1.6564)
Cooperative membership					0.1384* (0.0720)	2.4844* (1.2754)
Land leasing					0.2004*** (0.0773)	2.3631* (1.2606)
F test of control variables	114.88***	4.37***	27.82*	37.08***	95.84***	3.63***
Chi ²	143.93	81.71	37.01	50.99	150.71	89.93
Pseudo R ²	0.0788	0.0505	0.1034	0.1337	0.0856	0.0556
Sample size	276	276	276	276	276	276

Note: The values in parentheses are robust standard errors; ***, ** and * represent 1%, 5% and 10% statistical significance levels, respectively.

utilization of the original variables and simplifies succeeding analysis. We use the SPSS software to conduct the factor analysis in three steps. First, Bartlett Test of Sphericity is employed to determine whether the four variables are suitable for factor analysis. With the approximate Chi² value at 70.31, the test result rejects the null hypothesis, that is, the four variables are suitable for factor analysis. Second, a factor variable is extracted by principal component analysis and named as 'policy cognition'. Finally, the scores of the factor variable are regressed to obtain the value of policy cognition. The resulting new variable for policy cognition comprehensively represents farmers' cognition of livestock farming policies. The mean value of the policy cognition variable is 0.00, with a standard deviation of 0.41 (Table 1).

As described in our theoretical framework, two mediator variables are used in this study. The first mediator variable is farmers' membership in agricultural cooperatives, which is a binary variable with 1 indicating that a farmer is a member of an agricultural cooperative and 0 if not. In our sample, 35.1% of the farmers (97 farmers) are members of cattle farming cooperatives. The other mediator variable is land leasing. None of the farmers in our sample have leased out land while 53.3% of them (147 farmers) have leased land. Land leasing is defined as a binary variable with 1 indicating that a farmer leased land and 0 otherwise.

Referring to the existing study (He et al., 2016; Triguero et al., 2016; Li et al., 2020; Huong et al., 2020), we include in the model a group of control variables, as listed in Table 1. Individual characteristics for the farm decision maker include gender, age, education attainment, physical health, risk preference, and family size. Farm characteristics include farm size, location, local topography, farming experience, manure handling difficulty, credit accessibility, and cognition of monetary benefits from manure recycling. In the empirical analysis, in order to reduce the possibility of multicollinearity among independent variables, the variables of interest - policy cognition, cooperative membership, and land leasing - are decentralized.

5. Results

We conducted a total of six regressions corresponding to the six equations in our empirical model. Regression results are reported in Table 2. We report the impact of policy cognition on investment diversification and investment amount respectively. Then we present robustness checks.

5.1. Impact of policy cognition on investment diversification

The dependent variable - investment diversification - in Eqs. (1d) and (3d) has non-negative integer value and conforms to the characteristics of a count model. Hence, we employ Poisson regression in estimation. In Eq. (2l), the dependent variable - leased land - is a discrete binary variable. Therefore, a binary probit model is used. Stata 15.0 is used to estimate the regressions and the results are shown in Table 2.

The results of regression (1d) show that policy cognition significantly increases investment diversification in manure recycling facilities even without considering the mediating effect. The higher the farmer's policy cognition, the more diversified investment in constructing facilities for manure recycling. For mediating effects, both mediating

pathways are significant. The influence of policy cognition on both cooperative membership and land leasing is significant at the statistical level of 10%. The estimated coefficients are positive, indicating that farmer's policy cognition increases the likelihood to join cooperatives and lease land. In Eq. (3d), after introducing the two mediating variables, farmers policy cognition remains significant, so do the two mediators. The estimated coefficient of policy cognition variable decreased from 0.3315 to 0.2936. After combining the results of regressions (1d), (2c), (2l) and (3d), the ordinal test shows that the two mediating variables exert a partial mediating effect. In order to make the results more rigorous and standardized, Sobel test was also used to test the mediating effect (Hu et al., 2017). The Z values of Sobel test are 1.3536 and 1.5020 respectively, which passed the significance test. The mediating effect is significant. Therefore, the overall test shows that policy cognition has a positive impact on investment diversification in manure recycling facilities by itself as well as through cooperative membership and land leasing. Hence, the hypotheses H1 and H2 are confirmed.

To further understand the relative importance of the two mediating variables, we calculate their contribution to the total effect, using the formula $\beta_1\gamma_1^d/\alpha_1^d$ and $\beta_1\gamma_1^l/\alpha_1^l$. The results are shown in Table 3. The combined contribution of the mediating effect from the two variables is 43.38% of the total effect. The mediating effect of land leasing is 24.65%, while the effect of cooperative membership is slightly smaller at 18.73%. This is probably because the main reason for farmers joining cooperatives is to learn how to meet the minimum scale requirement to receive subsidies for cattle farming. The overall participation rate of farmers in beef cattle cooperatives is low according to the survey. Moreover, there are relatively few cooperatives that actively function.

The full results of the mediator model are presented in Table A1 of the appendix. Regression (3d) in the table shows that, among all the control variables, only education and manure handling difficulty pass the significance test. Both variables have a statistically significant positive impact on investment diversification in manure recycling facilities. The higher a farmer's education level, the more diversified manure recycling facilities the farmer tends to invest in, probably because farmers with higher education levels are more capable of accessing relevant policy information and learning alternative manure recycling technologies. This implies that agricultural extension services or education programs targeting livestock farmers with low education levels might be effective for promoting investment in manure recycling facilities. As for manure handling difficulty, the more difficult it is to handle manure for a farm, the more diversified manure recycling facilities are invested on the farm. This is as expected because increasing difficulty of handling manure can force farmers to invest in diverse manure recycling facilities so as to cope with the challenge of manure handling from the perspective of long-term development. The rest of the control

Table 3
Mediating effects on investment diversification.

Mediating mechanism	Total effect	Indirect effect	Indirect/total
Cooperative membership	0.3315	0.0621	18.73%
Land leasing	0.3315	0.0817	24.65%

Table 4
Mediating effects on investment amounts.

Mediating mechanism	Total effect	Indirect effect	Indirect/total
Cooperative membership	4.5129	1.1150	24.71%
Land leasing	4.5129	0.9637	21.35%

variables have statistically insignificant impact on investment diversification in manure recycling facilities.

5.2. Impact of policy cognition on investment amount

The other dependent variable – investment amount in Eqs. (1a) and (3a) – has 78 observations (28.3% of the total sample) with values of zero because those farms have no investment in manure recycling facilities. This is a typical left-truncated distribution. With such data structure, OLS estimation cannot deliver consistent estimates (Wooldridge, 2015). As a result, we use the Tobit model (Tobin, 1958) which can correct the estimation bias from truncated dependent variable distribution and obtain consistent estimation results. Therefore, Eqs. (1a) and (3a) are estimated by Type I Censored Tobit model.

As displayed in Table 2, the results of regression (1a) show that without considering the mediating effect, policy cognition alone has a significant positive impact on the investment amount in manure recycling facilities. The higher the farmer's policy cognition, the greater investment amounts in constructing facilities for manure recycling. After introducing the two mediating variables in Eq. (3a), we find that all three variables of interest – policy cognition, cooperative membership, and land leasing – pass the significance test. Combining the results of Eqs. (1a), (2c), (2l) and (3a), the sequential test indicates that the two mediating variables also show partial mediating effects. The values of Sobel test are 1.3625 and 1.3141, respectively, which pass the significance test and confirm the existence of mediating effects. Therefore, the comprehensive test shows that policy cognition has a positive impact on the investment amounts in manure recycling facilities through cooperative membership and land leasing. Hence, the hypotheses H1 and H2 are confirmed again.

Furthermore, we calculate the relative contribution of the two mediating variables on the investment amounts, using the formula $\beta_3^c \gamma_c^d / \alpha_1^d$ and $\beta_4^l \gamma_l^d / \alpha_1^d$. The results are shown in Table 4. The combined contribution of the mediating effect from the two variables is 46.06% of the total effect. The mediating effect of land leasing is 21.35%, while the effect of cooperative membership is slightly higher at 24.71%. This is contrary to the prior analysis on investment diversification, where the contribution of land leasing is higher. This is probably because the investment amounts vary with different types of manure recycling facilities. Generally, the construction cost of manure storage and slurry lagoons is low, while it is higher for tertiary treatment facilities, biogas digester, and organic fertilizer processing equipment. According to the survey, the leased land is mainly used for cropping and animal production with only a small portion used for recycling facilities. Leasing more land does not promote the upgrading or expansion of facilities, but just secures more cropland for manure application. On the other hand,

farmers who join cooperatives have advantages for accessing information on subsidies and technologies, which encourages investment in higher grade facilities with greater capital requirements, such as biogas digesters and organic fertilizer processing equipment.

As for control variables, the full regression results (regression (3a) in Appendix Table A1) shows that education, farm size, and recycle benefits cognition pass the significance test with positive impacts on investment amounts in manure recycling facilities. For the control variable of education, the higher a farmer's education level, the greater the amount the farmer invests in manure recycling facilities. This reinforces the previous policy implication on extension or education programs targeting farmers with low education levels. For the control variable of farm size, the larger a farm is, the greater the amount that is invested in manure recycling facilities, probably due to economies of scale in farm management and manure recycling. For the control variable of recycle benefits cognition, the stronger a farmer's cognition of monetary benefits from manure recycling, the more the farmer invests in manure recycling facilities, which is as expected. The rest of the control variables have statistically insignificant impact on the investment amounts in manure recycling.

5.3. Robustness tests

To enhance the reliability of empirical results, the robustness of the multiple mediating effect model is tested. We test the robustness by using alternative core explanatory variables of the model. In the previous specification, the policy cognition variable is reduced by factor analysis. In the robustness test, the policy cognition variable is synthesized by the simple weighted average of responses to the four policy cognition questions in Table 1. We use this redefined policy cognition variable to re-estimate all six regressions.

The results are shown in Table 5. Consistent with the main results, policy cognition has a significant positive impact on the investment of manure recycling facilities. In regression (3d) that focuses on investment diversification, the coefficient of the policy cognition variable is significant at 1% level with its magnitude lowered from 0.2363 in regression (1d) to 0.2117. The two mediating variables remain significant with expected positive signs. The sequential test shows that the two mediating variables also have partial mediating effects. The Z values of Sobel test for the two mediating variables are 1.3604 and 1.3952 respectively, both of which pass the significance test. Hence, the mediating effects exist. In regression (3a) that focuses on the investment amount, the coefficient of the policy cognition variable remains positive and significant after introducing the two mediating variables, with its magnitude decreased from 3.0575 in regression (1a) to 2.5928. Moreover, both cooperative membership and land leasing have significant positive effects on the investment amounts. Both the sequential test and Sobel test show that the two mediating variables also have partial mediating effects. Therefore, both the hypotheses H1 and H2 are confirmed for investment diversification and investment amounts, which confirms the robustness of our results.

Table 6 shows the results of the impacts of policy cognition on investment diversification and investment amounts. For investment

Table 5
Results of robustness tests.

Dependent variable	Investment diversification	Investment amount	Cooperative membership	Land leasing	Investment diversification	Investment amount
Regression	(1d)	(1a)	(2c)	(2l)	(3d)	(3a)
Policy cognition	0.2363*** (0.0692)	3.0575*** (1.1430)	0.3143* (0.1614)	0.2520* (0.1530)	0.2117*** (0.0676)	2.5928** (1.1410)
Cooperative membership					0.1369* (0.0720)	2.4718* (1.2764)
Land leasing					0.2024*** (0.0771)	2.4079* (1.2596)
F test of control variables	115.71***	4.38***	28.29*	36.73***	96.72***	3.63***
Chi ²	145.04	81.45	37.17	50.29	152.25	89.79
Pseudo R ²	0.0793	0.0504	0.1038	0.1318	0.0861	0.0555
Sample size	276	276	276	276	276	276

Note: The values in parentheses are robust standard errors; ***, ** and * represent 1%, 5% and 10% statistical significance levels, respectively.

Table 6
Mediating effects in robustness tests.

Mediating mechanism	Investment diversification		Investment amounts	
	Indirect	Indirect/total	Indirect	Indirect/total
Cooperative membership	0.0430	13.68%	0.7769	25.41%
Land leasing	0.0510	16.23%	0.6068	19.85%

diversification, the mediating effect of cooperative membership accounts for 13.68% of the total effect, which is lower than that of land leasing at 16.23%. Hence, the mediating effect of land leasing takes a larger share for investment diversification. For investment amounts, the mediating effect of cooperative membership accounts for 25.41% of the total effect, which is higher than that of land leasing at 19.85%. Hence, the mediating effect of cooperative membership accounts for a bigger proportion of the total effect for investment amounts. These estimations are consistent with the main results and further support the robustness of our results.

6. Conclusion and discussion

This paper investigates how policy cognition affects livestock farmers' investment in manure recycling facilities. Besides the direct impact channel, we additionally identify that policy cognition exerts impacts through two mediating transmission mechanisms, which are cooperative membership and land leasing. Based on primary data from a field survey of beef cattle farmers in China, we use a multiple mediating effect model to empirically test two theoretical hypotheses. The results show that: (1) policy cognition has a significantly positive impact on the investment diversification and amounts in manure recycling facilities; (2) cooperative membership and land leasing are important mediating transmission mechanisms with significant mediation effects, through which policy cognition affects the investment in manure recycling facilities; and (3) for the two mediating variables, leasing additional agricultural land has a larger impact on investment amounts than on investment diversification in manure recycling facilities, while cooperative membership has the opposite impact. These results are consistent with the literature that, in general, farms with access to a greater pool of expertise (e.g., agricultural cooperatives) and that are at a larger scale (e.g., with more land under leasing) are likely to be more technically and managerially sophisticated, including in relation to environmental management and regulation.

Compared with the existing literature, we make three contributions. First, in addition to the factors that have been identified to affect farmers' investment decisions, we find a new factor - policy cognition - that is an important determinant in the investment diversification and amounts. Second, in addition to the direct impact of policy cognition, we identify there is an indirect effect path through two mediating variables, which are the membership in agricultural cooperatives and leased agricultural land. This finding corroborates previous literature that policy cognition is a complicated issue with multiple dimensions of impact transmission channels. Third, this paper adds to the understanding of investment behavior in non-production related projects. Investments in manure recycling facilities do not generate reliable profits but are mainly motivated by environmental regulation compliance. We find the awareness of relevant policies, including both regulations and subsidies, is an important factor in non-production related investments. This finding contributes to the analysis framework of the existing literature.

The findings of this paper have solid policy implications for promoting manure recycling facilities in countries and regions facing similar challenges of livestock manure management. First, this study highlights the importance of policy cognition among livestock farmers to promote the adoption of manure recycling facilities. Emphasis can be placed on improving the awareness of environmental regulations and incentive-based policies among farmers. Second, the promotion of manure

recycling facilities can be assisted by the development of agricultural cooperatives and improvement of their services provided to farmers. Lastly, this study provides evidence that land lease markets in rural China encourage livestock manure recycling by promoting integrated crop-livestock production systems. The evidence supports the development of land lease markets in regions that are intensive in livestock production but lack such markets.

A potentially fruitful line of research would investigate the effects of policy cognition on farmers' investment behavior of resource recycling in other agricultural sectors and other regions. Open questions for future research include neighborhood or peer effects, mediating effects of agricultural extension services and education programs, and the impact of the information provision approach on policy cognition.

The full results of the mediator model are presented below as supplementary information. Supplementary data to this article can be found online at <https://doi.org/10.1016/j.scitotenv.2021.148836>.

CRediT authorship contribution statement

Yubin Wang: Investigation, Funding acquisition, Software. **Jingjing Wang:** Writing – review & editing, Methodology, Formal analysis. **Xiaoyang Wang:** Writing – review & editing, Methodology, Formal analysis. **Qian Li:** Investigation, Writing – review & editing, Methodology, Funding acquisition, Formal analysis, Supervision.

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.

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