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Tou, Lulu; Wang, Jianhua; Chu, May

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From intention to action: Enabling sustainable agriculture in emerging economies through decentralized regulations for manure management

Lulu Tou[1] | Jianhua Wang[2] | May Chu[3]

[1]China Academy for Rural Development, School of Public Affairs, Zhejiang University, Hangzhou, China

[2]School of Business, Jiangnan University, Wuxi, Jiangsu Province, China

[3]Department of Public Administration and Policy, School of Government, University of Birmingham, Birmingham, UK

Correspondence
May Chu and Jianhua Wang.
Email: m.chu@bham.ac.uk and wiwth_99@163.com

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Abstract

This study contributes to the debate about effective regulatory strategies for environmental regulation in achieving sustainable agriculture, particularly in understudied emerging economies. We leverage the case of swine manure recovery in China to illuminate this crucial but under-researched context. Building on the theory of planned behavior, which posits a gap between intention and behavior, we investigate how these regulations and their combinations influence swine farmers' intentions and behaviors toward resource recovery. Findings reveal command-and-control regulations most effectively stimulate initial intentions, while incentive-based regulations work best in bridging the gap between intention and action. Information-based approaches further strengthen this conversion, particularly when combined with incentives. Bridging the disciplines of regulation and behavioral science, this study advances theoretical understanding of the intention-behavior gap in environmental policy. It informs effective regulation design that promote sustainable agricultural practices in developing countries, ultimately contributing to achieving the Sustainable Development Goals.

KEYWORDS

environmental regulation strategies, intention-behavior gap, sustainable agriculture, sustainable development goals, swine manure resource recovery

1 | INTRODUCTION

Sustainable agriculture, a critical component of sustainable development, employs “the best available technology” in a balanced and environmentally responsible way (Sumane et al., 2018). These practices minimize environmental damage while ensuring long-term profitability for farmers (Füsun Tatlıdil et al., 2009). The United Nations has acknowledged the crucial role of sustainable agriculture in achieving the Sustainable Development Goals (SDGs), especially in terms of no poverty, zero hunger, clean water and sanitation, responsible consumption and production, and climate action (United Nations, 2015).

Sustainable agricultural practices offer significant advantages, but emerging economies face distinct challenges in adopting these practices (Cao & Solangi, 2023). First, limited capital restricts investment of these economies in sustainable agricultural infrastructure (Keegan et al., 2013; Nan et al., 2023; Wensing et al., 2019), severely impacting small-scale farmers who often lack the resources and technical knowledge (He et al., 2022). Second, information gaps regarding both policies and environmental practices significantly hamper farmers' understanding and compliance with regulations (Herrero et al., 2015). Third, limited enforcement capabilities and insufficient environmental awareness in these regions further impede the implementation of even theoretically optimal regulations (Swanson et al., 2001; Wang & Wei, 2020; Zheng et al., 2015). These combined challenges create a significant barrier to sustainable agricultural development in emerging economies (He et al., 2022; Tatlidil et al., 2009; Zhang, Halder, et al., 2020), highlighting the need for environmental regulatory system in overcoming these hurdles by providing resources, promoting knowledge dissemination, and ensuring consistent enforcement.

While existing research on environmental regulations often centers on developed Western countries (Buchholz & Musshoff, 2021; Varacca et al., 2023), this knowledge base presents a valuable opportunity for emerging economies. By learning from both the successes and failures of these policies, emerging economies can develop context-specific policy frameworks that effectively address their unique challenges. For example, recognizing that single policy instruments are inadequate for complex sustainability, policy mix theory, developed in Western developed countries, is finding new applications in the developing world (Edmondson et al., 2019; Kivimaa & Kern, 2016). Policy mixes aim to tackle market failures and government shortcomings, while also enhancing the effectiveness of individual policy instruments (Howlett & Rayner, 2007). However, achieving a successful policy mix requires careful consideration, as not all combinations will be complementary or synergistic (Borrás & Edquist, 2013). In the context of sustainable agriculture, further exploration is needed to understand the interactions between different environmental regulations. This will be crucial for designing effective policy mixes that promote sustainable practices.

This study aims to bridge this knowledge gap by investigating how environmental regulation and their mixes influence both farmers' intentions and behaviors concerning sustainable agricultural practices employing the case of swine manure resource recovery in China. Existing literature on regulation identifies three common regulatory strategies—command-and-control, information-based, and incentive-based (Baldwin et al., 2011; Lodge & Wegrich, 2012). The effectiveness of these strategies on both intention and behavior remains an under-explored area in the context of sustainable agriculture. This research addresses the following questions: (1) How effective are environmental regulations in encouraging farmers to adopt sustainable agricultural practices? (2) Do environmental regulations influence the gap between farmers' stated intentions to adopt sustainable agricultural practices and their actual behavior? (3) How do different types of environmental regulation strategies interact to promote farmers' adoption of sustainable agricultural practices?

This paper contributes to the literature by advancing the debate on the relationship between regulatees' intentions and behaviors within the context of regulation strategies. This connection between regulatory and behavioral science literature provides valuable insights into the practical implications of regulatory measures. Also, the critical challenges and opportunities related to SDG implementation at the local government level are frequently overlooked. This study explores the dynamics of Chinese environmental regulation and sustainable agricultural practices within the context of environmental decentralization. This sheds light on the practical implications for achieving the SDGs at the grassroots level, making it a valuable contribution to the field of public administration and environmental regulation in developing countries or regions in the Global South.

2 | LITERATURE REVIEW AND THE CONCEPTUAL FRAMEWORK

This section explores the theoretical foundation and existing research relevant to the study. Specifically, the focus is on exploring the intention-behavior gap in sustainable agriculture among farmers and examining three traditional regulation strategies and their effects on intention and behavior.

2.1 | Intention and intention-behavior gap

Understanding the relationship between intentions and behaviors has garnered significant attention across multiple disciplines such as psychology, behavioral science, environmental science, and marketing. One influential theory addressing this relationship is the theory of planned behavior (TPB) proposed by Ajzen (1991). According to TPB, intentions are shaped by three key factors: attitudes, subjective norms, and perceived behavioral control, which ultimately guide individuals' behaviors. However, a recognized challenge with TPB is that intentions do not always translate into actual behavior. To address this gap, scholars like Gollwitzer (1999) proposed the theory of action phases. This theory highlights the distinction between intention, which arises during the predecisional phase, and actual behavior, which takes place in the actional phase. Gollwitzer's model helps explain why farmers might have good intentions regarding sustainable practices but struggle to translate them into action due to various challenges like limited resources or lack of clear plans.

Previous research on sustainable agriculture practices has shed light on the intention-behavior gap among farmers adopting organic fertilizers and straw-returning technologies (Li et al., 2024; Ren et al., 2022; Yang et al., 2024). These studies identify factors like education level, farm size, experience, risk tolerance, and environmental concern as influencing this gap. However, less is known about how the intention-behavior gap manifests in the context of manure resource recovery, a crucial component of sustainable agriculture.

Further, although the need for government intervention in situations with externalities (Doshi et al., 2023; Lankoski & Ollikainen, 2003) is well-established, the specific influence of environmental regulations on farmers' intention-behavior gap remains under-explored. Existing research suggests that enhancing farmers' understanding of policies can bridge this gap (He et al., 2022), but it often lacks differentiation between various regulations strategies and their effectiveness within specific contexts. To address the research gap in how environmental regulations influence the intention-behavior gap, this study examines the effects of different regulatory strategies and their combinations on Chinese farmers' decisions regarding manure resource recovery.

2.2 | Regulation strategies

To promote sustainable development, government intervention is established to regulate individual practices (Baldwin et al., 2011; Han et al., 2021; Lodge & Wegrich, 2012; Xie et al., 2017). Command-and-control regulation is a regulatory approach that relies on specific rules and standards that are enforced with penalties including criminal sanctions to prohibit activities that do not conform to the established standards (Keohane et al., 2019). While command-and-control regulations effectively ensure a baseline level of environmental protection for public and ecosystem health (Goren et al., 2023; Reynaers & Parrado, 2017), critics argue they may discourage the adoption of new technologies for sustainable practices (Mickwitz et al., 2008). This is because command-and-control regulations focus on achieving a minimum standard rather than encouraging innovation. Incentive-based regulation, on the other hand, relies on the use of economic incentives to encourage risk reduction. This strategy creates economic incentives for regulated entities to manage their risks through mechanisms such as pollution taxes or subsidies for risk reduction measures (Keohane et al., 2019). Information-based regulation aims to influence behavior by providing information about risks and best practices for controlling risks such as pollution. This approach is based on the idea that if people are better informed, they will be more likely to take action. Information-based regulation can be used in conjunction with other regulatory approaches or as a stand-alone strategy (Lodge & Wegrich, 2012).

By comparing the three types of environmental regulation, we can gain insights into their relative strengths and weaknesses. In promoting sustainable agricultural practices, while command-and-control regulations like bans can have a stronger initial impact on pesticide use and carcass waste recycling behaviors (Huang et al., 2016; Si et al., 2020), their effectiveness hinges on institutional endowment such as robust enforcement and monitoring (Yang et al., 2024). This is often a challenge in developing economies, as evidenced by the limited success of straw burning bans in countries like Russia, India, and China (Hou et al., 2019; Theesfeld & Jelinek, 2017). Conversely, incentive-based and information-based approaches, such as subsidies and educational programs, promote long-term behavioral change among farmers (Buchholz & Musshoff, 2021; Hou et al., 2019). Recognizing the multifaceted nature of sustainable agriculture, it becomes clear that there is no single, universally effective environmental regulation. This complexity necessitates a multi-pronged approach that leverages the strengths of different regulatory types to achieve lasting environmental improvements within the agricultural sector.

Policy mixes, combining different policy and regulatory tools, are becoming a recognized strategy as a way to address complex challenges like climate change and sustainable transition (Bouma et al., 2019; van den Bergh et al., 2021). However, their effectiveness hinges on understanding how regulations interact and influence behavior (Rogge & Reichardt, 2016). Research on policy mixes has flourished in the industrial sector, focusing on issues like curbing carbon emissions (Niemeyer & Vale, 2022; Rodríguez-Barillas et al., 2024; Zha et al., 2023). Illustrating this point, Wu et al. (2023) highlight the potential of a mix of information-based and incentive-based regulations in curbing carbon emissions in the industrial sector. Their study found that this combination effectively addressed the challenge, whereas command-and-control regulations alone were insufficient due to rent-seeking behavior by local officials. This example underscores the importance of considering the interplay between different regulatory tools and the specific institutional context when designing policy mixes for sustainable agriculture.

2.3 | Conceptual framework and hypotheses

The study adopts a conceptual framework that incorporates the above three regulatory strategies to investigate the impact of these strategies on farmers' intentions to engage in sustainable agricultural practices and their ability to bridge the intention-behavior gap. Building on policy mix theory (Howlett & Rayner, 2007), we further propose that information-based regulation may exhibit significant positive coordination with the other two regulatory types. In essence, information-based regulation can promote regulatees' understanding of command-and-control regulation and incentive-based regulation. This can be achieved through increased policy publicity, educational programs, and the provision of technical guidance. By improving farmers' knowledge of these regulations, information-based approaches can help them navigate the regulatory landscape and make informed decisions about sustainable agricultural practices, ultimately bridging the intention-behavior gap.

Building on the theoretical foundation and research objectives outlined above, the following hypotheses are proposed:

Hypothesis 1a Command-and-control regulation positively influences farmers' intention to participate in sustainable agricultural practices.

Hypothesis: 1b Command-and-control regulation reduces the intention-behavior gap in sustainable agricultural practices among farmers.

Hypothesis 2a Incentive-based regulation positively influences farmers' intention to participate in sustainable agricultural practices.

Hypothesis 2b Incentive-based regulation reduces the intention-behavior gap in sustainable agricultural practices among farmers.

Hypothesis 3a Information-based regulation positively influences farmers' intention to participate in sustainable agricultural practices.

Hypothesis 3b Information-based regulation reduces the intention-behavior gap in sustainable agricultural practices among farmers.

Hypothesis 4a Information-based regulation moderates the relationship between command-and-control regulation and farmers' intention to participate in sustainable agricultural practices.

Hypothesis 4b Information-based regulation moderates the relationship between command-and-control regulation and farmers' intention-behavior gap in sustainable agricultural practices.

Hypothesis 5a Information-based regulation moderates the relationship between incentive-based regulation and farmers' intention to participate in sustainable agricultural practices.

Hypothesis 5b Information-based regulation moderates the relationship between incentive-based regulation and farmers' intention-behavior gap in sustainable agricultural practices.

3 | RESEARCH CASE: SWINE MANURE RESOURCE RECOVERY IN CHINA

Our research delves into the critical issue of swine manure resource recovery in China for two reasons. First, within the framework of sustainable agriculture, bioenergy derived from swine manure is a promising avenue. This process converts manure into biogas, electricity, or heat through technologies like anaerobic digestion, which not only reduces reliance on fossil fuels but also contributes to environmental safety and carbon neutrality goals (Pirelli et al., 2021). Second, China, the world's leading pork producer, presents a unique case study. The Chinese government's comprehensive policy mix, with ambitious targets like the Ministry of Agriculture and Rural Affairs' goal of achieving an 80% livestock and poultry manure utilization rate by 2025 (Ministry of Agriculture and Rural Affairs, 2021), provides a fertile ground for our research due to its diverse strategies and ambitious goals.

Successfully implementing resource recovery requires addressing existing challenges. Traditionally, treated manure was used as fertilizer, but China's low per capita arable land area makes this method inefficient (Skovsgaard & Jensen, 2018). Biogas production from manure is a promising supplement. However, despite a high willingness among Chinese farmers to utilize this method, as evidenced by a survey in Hubei Province where 90.5% expressed interest in biogas production using manure, the actual utilization rate remains low (He et al., 2022). National surveys reveal a significant gap between intention and behavior. For example, the implementation rate for resource utilization of organic materials like crop straw is low across the country, with only 0.68% of farmers in 15 provinces adopting this practice (Fang et al., 2019). Similarly, low average usage rates (43.36%) of biogas were found among households with digesters in Sichuan, Hubei, Jiangxi, and Guizhou provinces (Wang et al., 2019). This substantial gap highlights the need to explore the decision-making mechanisms of farmers concerning swine manure resource recovery, particularly from the perspective of policy intervention to design effective regulatory strategies.

However, crafting effective regulations is not simply a matter of understanding farmer behavior. This complexity is particularly evident in China's unique political system. China's political system is characterized by a centralized government structure, where decisions and policies are formulated at the national level and cascaded down to lower administrative levels. Meanwhile, in line with the principles of 'environmental federalism', the authority for managing environmental affairs in China has gradually shifted from the central government to local governments (Zhang, Yang, & Song, 2020). This decentralization aims to improve the pertinence and effectiveness of environmental pollution control by empowering local governments to adopt policies that align with local conditions and reflect the preferences of residents (van't Veld & Shogren, 2012).

To promote the resource recovery of swine manure, the Chinese government has established a series of regulatory measures. These measures can be classified into three categories: command-and-control regulation, incentive-based regulations, and information-based regulations. These regulations guide local governments in developing region-specific implementation measures that align with central policies and local conditions. However, it is worth noting that the environmental regulation framework for swine manure treatment at the regional level in China faces challenges. Weak policy constraints, such as limited enforcement mechanisms, the absence of subsidies, limited guidance, and limited outreach (Li et al., 2020; Peng et al., 2018), all contribute to potentially affecting the effectiveness of policies. Therefore, establishing productive relationships between farmers, policies, and local-level implementation and aligning their interests to enhance the regulatory framework is essential.

4 | METHODOLOGY

To investigate the effects of various environmental regulation strategies on farmers' intentions and behaviors, we employed a survey methodology to address our research questions and collect data concerning farmers' perceptions, attitudes, and actions related to swine manure management. Surveys offer a standardized approach to data collection, ensuring the consistency of variable measurement across respondents and enhancing the reliability of the gathered data. This standardization is particularly crucial when examining subjective factors, such as farmers' perspectives on local government regulation strategies and their intentions regarding resource recovery of swine manure. Moreover, given our objective of comprehending farmers' viewpoints and behaviors in multiple locations within a province, a survey provides a practical and feasible means of data collection.

4.1 | Data collection and sample

Data for this study was collected through a comprehensive survey of farmers in 30 counties (districts) across six cities in Shandong Province, China during the period of July to September 2018. Shandong Province was chosen as the sample region for several reasons. Firstly, it represents a significant area in China for livestock and poultry breeding, with small and medium-sized farmers playing a major role, and a trend toward larger-scale breeding operations. This mirrors the prevailing situation in many parts of China. Secondly, given the extensive scale of livestock and poultry breeding and the substantial amount of waste generated, Shandong Province faces a heightened risk of pollution from livestock waste and encounters substantial pressure to find effective solutions for swine manure utilization. The province's growing farming scale and mounting environmental challenges are indicative of the current state of animal husbandry development in China, while also sharing similarities with conditions in other developing Asian countries such as Vietnam and India (Huong et al., 2020). Lastly, Shandong Provincial Government enacted the "*2017 Plan for Accelerating the Resource Utilization of Livestock and Poultry Breeding Waste in Shandong Province*", which reinforced the policy framework related to livestock waste utilization, providing an ideal context for studying the impact of environmental regulation strategies on farmers' behavior.

To obtain a representative sample, we employed a stratified design and random sampling method. We selected six diverse locations within Shandong Province, including Jinan City, Weifang City, Taian City, Linyi City, Dezhou City, and Heze City (refer to Figure 1). These locations were chosen due to their varying gross domestic product levels, significant livestock and poultry farming activities, rapid agricultural industry development, and substantial poultry breeding waste generation. We divided the counties (districts) of each city based on their regional economic development levels into five categories: very high, high, moderate, low, and very low. Then, one county (district) is randomly selected from each category. Within these sampled counties or districts, townships or streets were ranked based on the number of livestock and poultry farmers. Subsequently, we randomly chose one township or street from the top 50% in terms of the number of farmers. In the selected township (street), we randomly picked two administrative villages. Finally, based on the roster provided by the village committees, we employed an equidistant sampling method to randomly select 7–10 farmers in each administrative village.

In total, 453 valid questionnaires were collected during the survey period. We acknowledge the limitations of the moderate sample size in this study and took measures to ensure the reliability of the findings. The sample size determination was based on widely

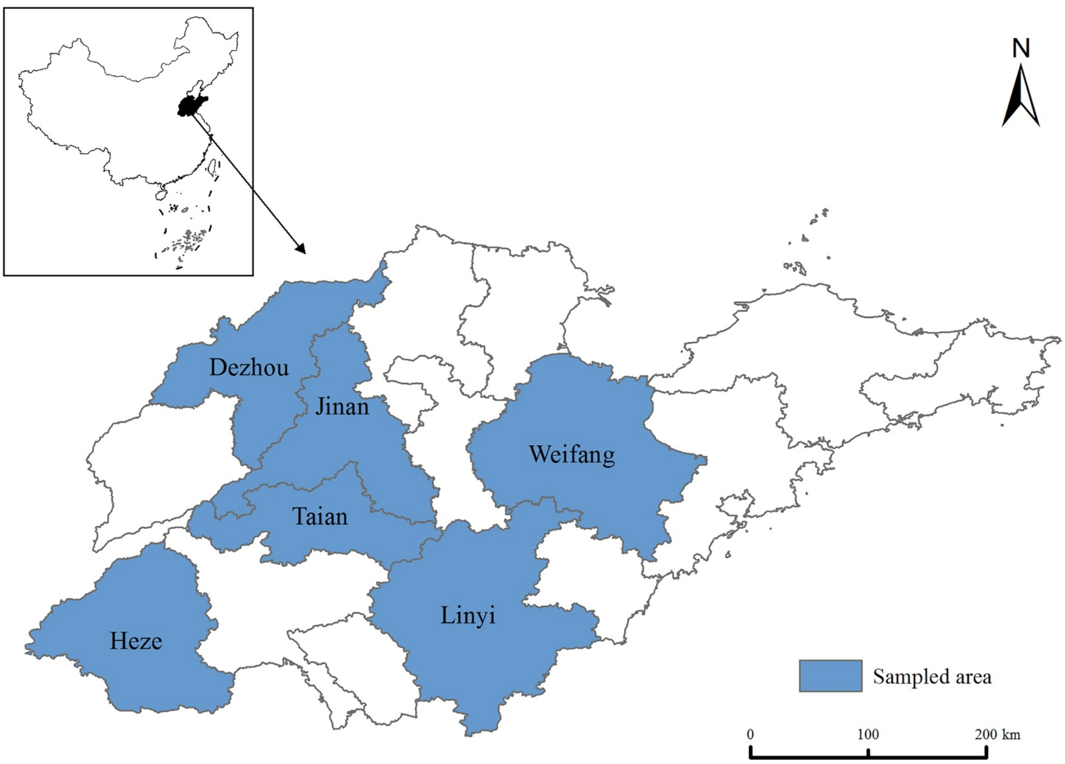


FIGURE 1 Location of the sample areas in China. The data utilized in this analysis was obtained from a survey conducted among farmers residing in rural areas of six municipalities within Shandong province, China.

accepted guidelines and the Events per Variable method.[1] The majority of respondents were male farmers with an average age of 46, low educational level, an average annual income of about 80,000 yuan (approximately 1,1461 USD), and an average of two people engaged in farming work at home. Furthermore, most farmers were part-time and operated small to medium-sized farms. These characteristics are reflective of the typical profile of farmers in China.

4.2 | Variables and measurement

4.2.1 | Dependent variables

Swine manure management approaches are categorized into six types: random discarding, untreated field application, fermentation composting, biogas digester utilization, organic fertilizer processing, and direct sale. Random discarding and untreated field application are considered waste pollution practices without productive use, while the other four approaches are categorized as recycling behaviors that convert manure into a useful resource, either as fertilizer or as a source of energy.

The study focuses on two dependent variables related to farmers' swine manure management behavior. The first variable is farmers' intention. If a farmer expresses their intention to engage in swine manure resource recovery through any of the aforementioned resource recovery methods, coded as 1, otherwise coded as 0. The second variable is the intention-behavior gap. In this study, we determine their behavior by asking whether they have adopted at least one method of resource recovery for handling livestock and poultry manure. A gap is defined as the lack of resource recovery method adoption by farmers who have the intention, coded as 0, while no gap exists if farmers with the intention have chosen at least one resource recovery method, coded as 1.

4.2.2 | Independent variables

This study builds on the environmental regulation measurement methods developed by Dasgupta et al. (2001), Si et al. (2020), and Zheng et al. (2015) to assess the impact intensity of the three main regulatory types: command-and-control, incentive-based, and information-based.

Command-and-control, the traditional approach, relies on supervision and penalties, which form the basis to measure its impact intensity (Zhao et al., 2022). Incentive-based instruments that utilize economic incentives, such as preferential pricing and facility subsidies (He et al., 2012), are considered when measuring the impact intensity of this type of regulation. Information-based regulation suggests the provision of technical information to farmers (Berger, 2001). Technical training and publicity education programs are used as indicators to measure the impact intensity of this approach.

While the methods described above address the objective intensity of regulations, as environmental decentralization evolves, it is increasingly vital to comprehend how farmers perceive and respond to these regulatory policies. Following Dasgupta et al. (2001), this study measures the perceived intensity of each regulatory tool using a five-point scale ranging from "very weak" to "very strong" based on farmer surveys. This approach captures the psychological impact of regulations on farmer behavior concerning swine manure management. Mean values of these indicators are used to measure each of the regulatory strategies.

4.2.3 | Control variables

To address potential model estimation bias caused by missing variables, we included four types of control variables, drawing on previous studies as references (Fang et al., 2021; Guo et al., 2022; He et al., 2022). We first controlled for demographic factors such as gender, age, and education level. Second, we included family characteristics, including annual household income and the number of individuals engaged in farming labor. Third, we controlled for factors related to the management of the farm, such as the type of farming (full-time or part-time) and the scale of farming (number of heads of livestock raised). Finally, we controlled for variables related to village infrastructure, specifically the presence or absence of agricultural waste disposal facilities near the breeding area.

All variable definitions and descriptive statistics are shown in Table 1.

4.3 | Model

This study examines two critical stages in farmers' engagement in resource recovery of swine manure: the first stage evaluates whether farmers possess the intention to participate in manure resource recovery, and the second stage scrutinizes whether farmers translate their intention into action. In both stages, the dependent variables are binary (0–1) to avoid reflection problems that can arise in linear models. We use binary logistic regression models to analyze the influence of environmental regulation

[1]Obtaining data for this study presented challenges as it involved conducting a field survey targeting pig farmers, resulting in a moderate sample size. To ensure the reliability of the research findings, two methods were employed to determine an appropriate sample size. Firstly, a widely accepted guideline suggests that the sample size should be 10–15 times the number of independent variables. Considering the 11 independent variables in this study, a minimum sample size of 110–165 was deemed necessary, and the obtained valid sample size met this requirement. Secondly, the Events per Variable (EPV) method, commonly used in research, was applied. Analyzing Table 2, it was observed that 38.59% of farmers exhibited an intention-behavior gap. With the recommended EPV value of and 11 independent variables, the minimum required sample size for farmers with an intention-behavior gap was calculated as $11 \times 10 = 110$. Consequently, the total required sample size would be 110 divided by the proportion of farmers with an intention-behavior gap (38.59%), resulting in 285. It is worth noting that the analysis involved a valid sample size of 355, which satisfied the prerequisites for logistic regression analysis. Additionally, measures were taken to assess multicollinearity among variables, and robustness tests were conducted by substituting the empirical model and performing bootstrap sampling estimation, ensuring the reliability and robustness of the research outcomes. For more details on the two methods, please refer to Peduzzi's (1996) study.

TABLE 1 Variable definition and descriptive statistics.

Categories	Variable	Descriptions of variables	Full sample			Samples with bioenergy production intentions		
			Obs	Mean	Std.	Obs	Mean	Std.
Dependent variables	Intention	If the respondent is willing to participate in swine manure resource recovery = 1, otherwise = 0	453	0.784	0.412	—	—	—
	Intention-behavior gap	If there is no gap between intention and behavior = 1, otherwise = 0	—	—	—	355	0.614	0.488
Independent variables	Command-and-control regulation	The mean value of regulation intensity of supervision and penalty.	453	2.664	0.981	355	2.885	0.877
	Incentive-based regulation	The mean value of regulation intensity of preferential pricing and facility subsidy.	453	2.278	0.879	355	2.586	0.792
	Information-based regulation	The mean value of regulation intensity of technical training and publicity education.	453	2.660	0.864	355	2.718	0.770
Control variables	Gender	Male = 1, Female = 0	453	0.623	0.485	355	0.628	0.484
	Age	Under 30 years old = 1, 30–39 years old = 2,40–49 years old = 3,50–59 years old = 4,60 years old and above = 5.	453	3.119	1.101	355	3.023	1.084
	Education level	Junior high school and below = 1, high school or technical secondary school = 2, junior college = 3, undergraduate course = 4, graduate student and above = 5.	453	1.459	0.813	355	1.507	0.858
	Annual household income	Under 50,000 yuan = 1, 50,000–80,000 yuan = 2; 80,000–100,000 yuan = 3; 100,000–150,000 yuan = 4; 150,000 yuan or more = 5.	453	2.614	1.328	355	2.704	1.326
	Number of people engaged in farming labor	Number of household members engaged in livestock and poultry farming in farmer households	453	1.982	0.839	355	2.051	0.822
	Farmers' type	Part-time farmers = 1, full-time farmers = 0.	453	0.748	0.434	355	0.704	0.457
	Farming scale	Below 100 heads = 1, 100–500 heads = 2, 500–1000 heads = 3, 1000–3000 heads = 4, 3000–5000 heads = 5, 5000–10000 heads = 6, 10,000 heads or more = 7	453	2.249	1.760	355	2.414	1.857
	Infrastructure	If there is a agricultural waste disposal facilities near respondent's breeding area = 1, otherwise = 0.	453	0.11	0.316	355	0.14	0.395

strategies on the dependent variables. This approach allows us to explore the potential regulatory effects of environmental regulation, building on the work of Brock and Durlauf (2001) to account for the non-linear relationships of personal characteristics affecting these variables.

5 | RESULTS

5.1 | Dependent variable: Farmers' intention and behavior in swine manure resource recovery

As illustrated in Table 2, among the 453 valid observations, 355 observations are willing to participate in swine manure resource recovery, accounting for 78.4% of the total valid observations. However, despite this intention, only 218 out of the 355 farmers (61.41%) actually implemented resource recovery methods. The remaining 38.59% of farmers did not translate their intention into behavior, indicating the existence of an intention-behavior gap in swine manure resource recovery.

5.2 | Binary logistic regression

Table 3 presents the results of the binary logistic regression analysis.[2] Columns (1) and (4) are benchmark models that include only demographic characteristics, family characteristics, and management characteristics as independent variables. In columns (2) and (5), we add three environmental regulation strategies as independent variables. The Nagelkerke R^2 of column (2) increased by 110.99%

[2]Consideration of multicollinearity among variables is crucial for ensuring consistent and unbiased regression results. In this study, we diagnosed the independent variables for multicollinearity before regression analysis. A Variance Inflation Factor (VIF) greater than 3 indicates a certain degree of multicollinearity, while a VIF greater than 10 indicates a high degree of collinearity. The results suggest that the collinear correlation degree between the independent variables is within a reasonable range.

TABLE 2 General description of the relationship between respondents' intention and behavior.

	With intention to participate in swine manure resource recovery		Without intention to participate in swine manure resource recovery	
	Number of persons	Proportion (%)	Number of persons	Proportion (%)
Swine manure resource recovery has been implemented	218	61.41	31	31.63
Swine manure resource recovery has not been implemented	137	38.59	67	72.04
Total	355	100	98	100

TABLE 3 Binary logistic regression results.

	Dependent variable: Intention			Dependent variable: Intention-behavior gap		
Variables	(1)	(2)	(3)	(4)	(5)	(6)
Command-and-control regulation		0.789***	0.778***		0.376**	0.388**
		(0.152)	(0.149)		(0.151)	(0.152)
Incentive-based regulation		0.420**	0.381**		0.462**	0.464**
		(0.164)	(0.169)		(0.223)	(0.227)
Information-based regulation		0.166	0.149		0.362*	0.343*
		(0.164)	(0.164)		(0.207)	(0.207)
Gender	−0.009	−0.270	−0.306	−0.028	−0.093	−0.087
	(0.249)	(0.273)	(0.281)	(0.264)	(0.279)	(0.279)
Age	−0.198	−0.140	−0.135	−0.394***	−0.374***	−0.379***
	(0.131)	(0.143)	(0.147)	(0.123)	(0.132)	(0.135)
Education level	0.233	0.269	0.274	0.033	0.052	0.041
	(0.175)	(0.195)	(0.212)	(0.166)	(0.166)	(0.170)
Annual household income	0.031	−0.170	−0.159	0.405***	0.264**	0.263**
	(0.104)	(0.121)	(0.123)	(0.098)	(0.108)	(0.109)
Number of people engaged in farming labor	0.413*	0.334	0.347	0.466***	0.530***	0.528***
	(0.231)	(0.207)	(0.213)	(0.180)	(0.200)	(0.203)
Farmers' type	−1.036***	−1.118***	−1.118***	−0.258	−0.321	−0.317
	(0.386)	(0.421)	(0.421)	(0.301)	(0.326)	(0.330)
Farming scale	0.173*	0.056	0.068	0.211***	0.175**	0.171**
	(0.089)	(0.096)	(0.095)	(0.080)	(0.084)	(0.084)
Infrastructure	—	—	1.778**	—	—	0.645
			(0.746)			(0.400)
Pseudo R^2	0.091	0.192	0.210	0.159	0.215	0.220
Observations	453	453	453	355	355	355

Note: $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$, and the standard error is in brackets.

compared to column (1), indicating that environmental regulation strategies have a significant impact on farmers' intention to participate in swine manure resource recovery. Column (5) shows a 35.22% increase in Nagelkerke R^2 compared to column (4), highlighting the importance of regulation strategies in reducing farmers' intention-behavior gap. To address potential infrastructural influences on farmers' swine manure disposal, we include a control variable for infrastructure in columns (3) and (6).

The variable "command-and-control regulation" in columns (3) and (6) demonstrates a significant positive effect on farmers' intention ($\beta = 0.778$, $p < 0.01$) and intention-behavior gap ($\beta = 0.388$, $p < 0.05$), respectively, supporting hypotheses H1a and H1b. This indicates that command-and-control regulation not only enhances farmers' intention to participate in swine manure resource recovery but also facilitates the translation of intention into behavior. Similarly, the variable "incentive-based regulation" exhibits a significant positive effect on farmers' intention ($\beta = 0.381$, $p < 0.05$) and intention-behavior gap ($\beta = 0.464$, $p < 0.05$) in columns (3) and (6), supporting hypotheses H2a and H2b. This suggests that incentive-based regulation not only enhances farmers' intention to participate in swine manure resource recovery but also promotes consistency between intention and behavior. In column (3), the variable "information-based regulation" is not significant ($\beta = 0.149$, $p > 0.1$); however, it shows a significant positive effect ($\beta = 0.343$, $p < 0.1$) in column (6), rejecting hypothesis H3a and marginally supporting H3b. This indicates that while information-based regulation alone may not enhance farmers' intention to participate in swine manure resource recovery, it can motivate them to translate their intention into action.

Regarding the control variables, their effects on farmers' intention and intention-behavior gap were examined. The effects of age ($\beta = -0.379$, $p < 0.01$) and family annual income ($\beta = 0.263$, $p < 0.05$) on intention-behavior gap were significant, respectively. The effect of farmers' type ($\beta = -1.118$, $p < 0.01$) on intention was significantly negative, indicating that full-time farmers are more likely to form the intention to participate in swine manure resource recovery. In contrast, the variables of farming scale ($\beta = 0.171$, $p < 0.05$) and number of people engaged in farming labor ($\beta = 0.528$, $p < 0.01$) were only statistically significant in their effects on intention-behavior gap. Furthermore, the effect of infrastructure on intention was significantly positive ($\beta = 1.778$, $p < 0.05$), indicating that the presence of an agricultural waste disposal facility near the respondent's breeding area can increase the likelihood of farmers forming the intention to participate in swine manure resource recovery.

5.3 | Endogeneity test

To address concerns related to endogeneity, we employ a conditional mixed-process model (CMP) with instrumental variables, following the approach outlined by Roodman (2011). In constructing instrumental variables, we leverage aggregated data at the regional level. This approach is supported by previous studies (Qing et al., 2023; Rozelle et al., 1999) as it helps mitigate potential biases arising from endogeneity. Specifically, we select the mean levels of environmental regulation strategies at the township (street) level, excluding the surveyed farmer, as our instrumental variables. The CMP consists of two stages: In the first stage, we estimate the impact of instrumental variables on the three types of environmental regulation strategies to examine the correlation between instrumental variables and endogenous explanatory variables. In the second stage, we incorporate the results from the first stage into the regression model to estimate the influence of environmental regulation strategies on farmers' intention and intention-behavior gap. Furthermore, we evaluate the exogeneity of variables using endogenous test parameters derived from the regression results, specifically atanhrho_12, atanhrho_13, and atanhrho_14. A significant deviation from 0 in these test parameters suggests endogenous issues in the benchmark model, implying that CMP estimation results are more reliable.

Table 4 shows the results of CMP. The regression results of the first stage indicate that the three instrumental variables selected in this study passed the significance test, indicating that the instrumental variables conform to the correlation conditions. Regarding the influence of environmental regulation strategies on farmers' intention, the regression results of the second stage show that the endogenous test parameters failed the significance test, indicating that there is no endogenous problem in the model, and the estimation results of the benchmark regression are more reliable. However, when examining the influence of environmental regulation strategies on farmers' intention-behavior gap, the second-stage regression results show that atanhrho_13 and atanhrho_14 passed the significance test, implying the need to correct the endogenous problems in the benchmark regression model. After correcting for endogeneity, the impact of environmental regulation strategies on farmers' intention-behavior gap remains significant, indicating the reliability of the results.

5.4 | Moderating effect test

Table 5 presents the results of the moderation effect of information-based regulation. The interaction effect between "information-based regulation" and "command-and-control regulation" is not significant on farmers' intention ($\beta = -0.127$, $p > 0.1$) or intention-behavior gap ($\beta = -0.013$, $p > 0.1$), suggesting that information-based regulation does not strengthen the influence of command-and-control regulation on farmers' intention or intention-behavior gap. As a result, hypotheses H4a and H4b are both rejected. On the other hand, the interaction effect between "information-based regulation" and "incentive-based regulation" is not significant on farmers' intention ($\beta = -0.250$, $p > 0.1$) but significantly positive on farmers' intention-behavior gap ($\beta = 0.465$, $p < 0.1$). Therefore, hypothesis H5a is rejected while H5b is marginally supported. These findings suggest that while information-based regulation mighty not directly strengthen the impact of incentive-based regulation on farmers' intention, it can play a positive role in bridging the intention-behavior gap. This highlights the potential effectiveness of a comprehensive policy mix that combines these instruments.

To visually demonstrate the moderating effect of information-based regulation on incentive-based regulation and the intention-behavior gap, a simple slope analysis was conducted, and the results are shown in Figure 2. The results reveal that the impact of incentive-based regulation on the intention-behavior gap is statistically significant in both the high information-based regulation condition ($\beta = 0.941$, $p < 0.01$) and the low information-based regulation condition ($\beta = 0.476$, $p < 0.05$). Moreover, the linear slope in the high information-based regulation condition is notably larger than that in the low information-based regulation condition. This indicates that as information-based regulation strengthens, the influence of incentive-based regulation on the intention-behavior gap also increases.

TABLE 4 Regression results of instrumental variable.

	Dependent variable: Intention		Dependent variable: Intention-behavior gap	
	First stage	Second stage	First stage	Second stage
Command-and-control regulation	—	0.455**	—	0.382**
		(0.233)		(0.180)
Incentive-based regulation	—	0.672**	—	0.552***
		(0.282)		(0.123)
Information-based regulation	—	−0.109	—	0.353**
		(0.194)		(0.156)
IV_{COM}	0.986***	—	0.941***	—
	(0.129)		(0.156)	
IV_{INC}	0.728***	—	0.429**	—
	(0.146)		(0.207)	
IV_{INF}	1.364***	—	1.382***	—
	(0.124)		(0.153)	
atanhrho_12	—	−0.011	—	0.172
		(0.211)		(0.155)
atanhrho_13	—	0.094	—	0.496***
		(0.157)		(0.128)
atanhrho_14	—	−0.415	—	1.994***
		(0.301)		(0.712)
Control variables	YES	YES	YES	YES
Observations	453	453	355	355

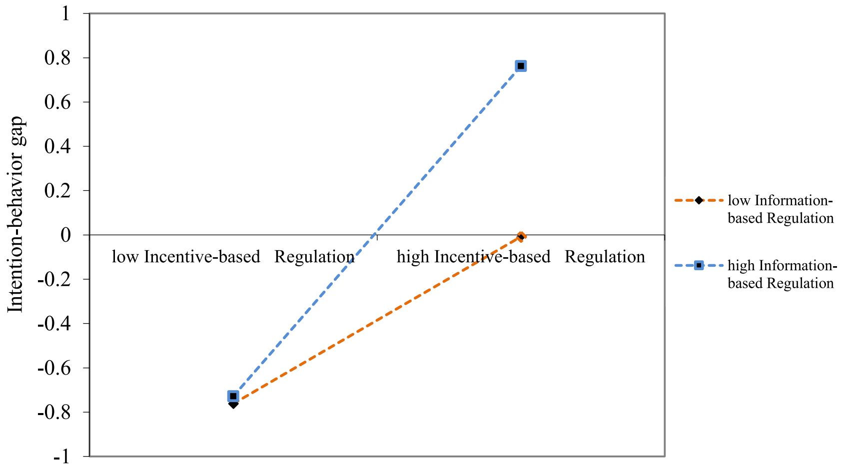
Note: *$P < 0.1$, **$P < 0.05$, ***$P < 0.01$. Standard errors are shown in parentheses. IV_{COM}, IV_{INC}, IV_{INF} represent the mean levels of command and control regulation, incentive-based regulation and information-based regulation at the township (street) level, excluding the surveyed farmers themselves), respectively.

TABLE 5 Tests on the moderating effect of information-based regulation.

	Dependent variable: Intention		Dependent variable: Intention-behavior gap	
	(7)	(8)	(9)	(10)
Command-and-control regulation	0.755***	0.779***	0.385**	0.375**
	(0.153)	(0.148)	(0.159)	(0.154)
Incentive-based regulation	0.384**	0.349**	0.465**	0.476**
	(0.169)	(0.167)	(0.229)	(0.225)
Information-based regulation	0.099	0.077	0.343*	0.402*
	(0.167)	(0.175)	(0.201)	(0.220)
Information-based regulation × command and control regulation	−0.127	—	−0.013	—
	(0.134)		(0.167)	
Information-based regulation × incentive-based regulation	—	−0.250	—	0.465*
		(0.151)		(0.254)
Control variables	YES	YES	YES	YES
Pseudo R^2	0.212	0.215	0.220	0.228
Observations	453	453	355	355

Note: *$P < 0.1$, **$P < 0.05$, ***$P < 0.01$. Standard errors are shown in parentheses.

FIGURE 2 **The moderating effect of information-based regulation on "incentive-based regulation - farmers' intention-behavior gap".** The results of simple slope analysis demonstrate that the magnitude of the linear slope is greater in the high information-based regulation condition compared to the low information-based regulation condition.



5.5 | Robustness test

To enhance the reliability and credibility of the research findings, we conducted a regression analysis using the probit model, and the analysis results are presented in Annex A. The results indicate that the significance of command-and-control regulation, information-based regulation, and incentive-based regulation remains consistent even under the alternative model. This suggests that our main estimates are robust, confirming the robustness of the benchmark regression results.

Given the limited sample size, another robustness test was further performed using the bootstrap method. This method involves resampling the dataset repeatedly to establish confidence intervals for the parameters, allowing for a more reliable assessment of the regression results with small sample data. Annex B presents the outcomes of the bootstrap method, indicating that the estimated coefficients for various environmental regulation strategies align with those previously reported. This reaffirms the robustness of the regression results.

6 | DISCUSSION

The findings from the binary logistic regression analysis reveal valuable insights into how environmental regulation strategies influence farmers' decisions regarding swine manure resource recovery. Command-and-control regulations, when implemented individually, are most effective in driving farmers' intention to participate. This is likely because the fear of penalties for improper manure disposal outweighs other considerations (Guo et al., 2022). Incentive-based regulations effectively enhance both intentions and the alignment of intention with behavior. By providing subsidies for essential equipment, these regulations alleviate financial burdens, reduce perceived risks, and encourage farmers to adopt practices that align with environmental goals (Baldwin et al., 2011). While previous research (Guo et al., 2022; Si et al., 2020) demonstrated the ability of information-based regulation to encourage green production practices, our findings suggest a more nuanced role. Information-based regulation appears to be particularly effective in bridging the intention-behavior gap among farmers, rather than directly boosting their intrinsic motivation for sustainable practices.

While both command-and-control and incentive-based regulations influence farmers' decisions, they do so through different mechanisms than information-based regulation. The former two primarily target farmers' external controlling motivations, such as fear of penalties or desire for subsidies motivations (Charatsari et al., 2017; Deci, 1971; Zepeda et al., 2013). In contrast, information-based regulation aims to foster intrinsic motivation, which refers to a genuine interest or passion for sustainable practices. Our findings suggest that information-based regulation, in its current form, may have a limited impact on cultivating intrinsic motivation for sustainable practices among farmers who are not already predisposed (Liao et al., 2019). This underscores the importance of knowledge dissemination and awareness-raising in promoting sustainable practices, particularly in developing countries where the education levels among farmers are relatively low. Long-term strategies for improving environmental literacy through targeted publicity education are even more crucial in these contexts (Charatsari et al., 2017). Building a strong knowledge base is essential for fostering intrinsic motivation and ultimately encouraging widespread adoption of sustainable practices.

The analysis of policy mix effects reveals interesting interactions between information-based regulation and other regulatory strategies. It does not seem to strengthen the influence of command-and-control regulations on farmers' intention or the intention-behavior gap. This might be because government-led persuasion campaigns, inherent to information-based regulation, may focus more on fostering farmers' enthusiasm for resource recovery (Frantz & Mayer, 2014), rather than emphasizing the risks of penalties for improper manure disposal. Consequently, awareness of command-and-control regulations might receive less attention.

However, information-based regulation appears to positively moderate the effect of incentive-based regulations on the intention-behavior gap. This suggests that a policy mix combining information-based and incentive-based approaches can lead to better policy outcomes. This positive interaction likely stems from the influence of subsidies on economic behavior. Information-based regulation can enhance farmers' understanding of subsidy policies, making them more receptive to the compensation levels and less hesitant to translate their intention into action (Baldwin et al., 2011; Liao et al., 2019).

While this study focuses on the influence of command-and-control, information-based, and incentive-based regulations on farmers' decisions regarding swine manure resource recovery, it is important to acknowledge the broader landscape of potential governance modes explored in recent public policy research (Mols et al., 2015). Two additional approaches gaining traction are "networks" and "nudging".

Networks, considered informal institutions, emphasize stakeholder involvement, allowing farmers to self-regulate and monitor each other's behavior. These networks can also have complex interactions with formal regulations (Xie et al., 2023). Nudging, on the other hand, utilizes behavioral science principles to subtly influence decision-making by altering the "choice architecture" (Banerjee & John, 2024). While nudging has garnered significant interest, concerns regarding overreliance and potential ethical issues have been raised by critics (Goodwin, 2012; Leggett, 2014). Effective nudging strategies often require collaboration between formal and informal institutions to achieve long-term behavior change through internalized norms.

These emerging approaches highlight the importance of exploring hybrid regulatory systems that combine different regulatory instruments and governance modes, as discussed by Niemeyer and Vale (2022). However, integrating these strategies presents challenges. In the context of China's environmental decentralization, state-led regulations remain central due to the government's ultimate control and responsibility for governance (Jian & Mols, 2019). This study lays the groundwork for future research exploring the interactions between formal and informal institutions, particularly the potential for combining nudging strategies with traditional regulatory approaches in promoting sustainable agricultural practices. By examining the effectiveness of hybrid systems that incorporate nudging alongside existing regulations, researchers can contribute valuable insights for policymakers aiming to bridge the intention-behavior gap and encourage widespread adoption of sustainable practices among farmers.

7 | CONCLUSION AND POLICY IMPLICATIONS

This research bridges the disciplines of regulation and behavioral science, examining how regulatory strategies influence farmers' decisions regarding swine manure resource recovery within the context of environmental decentralization. It goes beyond analyzing direct impacts and delves into the dynamic interaction between regulatory strategies, revealing how they can work together to influence farmers' behavior. The study shows that command-and-control and incentive-based regulations not only stimulate farmers' intention to utilize manure but also encourage them to act on that intention. Additionally, information-based regulation appears to help bridge the intention-behavior gap, particularly when combined with economic incentives.

The findings of this study offer valuable insights for local governments navigating environmental decentralization in the context of promoting sustainable agricultural practices, particularly regarding swine manure resource recovery. A multi-pronged approach that leverages the strengths of different regulatory strategies while recognizing the unique challenges faced at the local level is crucial. Local governments, due to their proximity to farmers, are well-positioned to strengthen enforcement mechanisms through an improved multi-level grid management system encompassing national, township, and village levels. Increased inspections and stricter enforcement of penalties for non-compliance, especially among small-scale farmers prone to evading regulations, can deter improper manure disposal practices. Economic incentives can play a significant role in encouraging widespread adoption of swine manure resource recovery technologies. Local governments can implement targeted financial support programs to help farmers purchase necessary recycling facilities and equipment, alongside offering preferential electricity tariffs and tax breaks for those utilizing these technologies. Knowledge dissemination and capacity building are essential for fostering long-term commitment to resource recovery. Local governments can play a vital role by promoting and demonstrating relevant technologies through demonstration projects and extension services. Furthermore, public education campaigns emphasizing the importance of sustainable agricultural practices and the economic and environmental benefits of manure resource recovery can help farmers overcome technical challenges and cultivate intrinsic motivation for continued participation.

A well-coordinated policy mix is critical. Local governments should invest in research exploring the interactions between different policies, including command-and-control, information-based, and incentive-based approaches. By understanding how these policies interact, local authorities can develop a diverse combination of tools and strategies tailored to their specific circumstances. Focusing on enhancing the coordination between information-based and incentive-based regulations can be particularly effective in bridging the intention-behavior gap and prompting action.

Given their proximity to farmers, local authorities are uniquely positioned to deliver interventions tailored to specific needs. For farmers yet to consider resource recovery, targeted communication campaigns can be effective. These campaigns should emphasize the punitive consequences of improper disposal alongside the economic and environmental benefits of resource recovery. For farmers who have already expressed an intention to participate, local governments can build upon existing regulations by offering targeted technical training programs. This additional support can ensure successful implementation of resource recovery practices and empower farmers to overcome technical challenges, ultimately achieving long-term success.

By implementing a comprehensive approach that combines strengthened enforcement, targeted incentives, educational initiatives, and a well-coordinated policy mix, local governments can play a critical role in promoting widespread adoption of swine manure resource recovery practices. This, in turn, can contribute significantly to achieving sustainable agricultural development and environmental goals in the contexts of environmental decentralization and emerging economies.

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CONFLICT OF INTEREST STATEMENT

The authors confirm that they do not have any competing interests.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

PRACTICE IMPACT STATEMENT

In light of the increasing emphasis on environmental decentralization in developing countries, our research highlights the need for well-structured regional environmental regulation policies to foster sustainable agricultural practices. By exploring how farmers respond to various environmental regulation strategies and uncovering the dynamic interplay among these approaches, we contribute to the effective governance of agricultural pollution in developing nations. This insight supports the development of contextually relevant and impactful regulatory frameworks that promote the achievement of the SDGs.

ORCID

Lulu Tou https://orcid.org/0000-0001-6996-3858
Jianhua Wang https://orcid.org/0000-0002-4354-9744
May Chu https://orcid.org/0000-0003-4878-8186

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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