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Do Cooperatives Affect Groundwater Protection? Evidence from Rural China

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Abstract: Groundwater protection is essential for global sustainable development. Due to the lack of motivation among farmers to build harmless disposal facilities for livestock excrement, there is a huge challenge surrounding groundwater protection, which also threatens the achievement of the UN Sustainable Development Goal (SDG) 6: "clean water and sanitation". Aiming to improve the groundwater protection behavior (GPB) of farmers, this study involved the following approach: (1) the use of rural China as a case area; (2) an exploration of the theoretical mechanisms and quantitative impacts of cooperatives as a way to encourage farmers to build harmless disposal facilities for livestock excrement; (3) a discussion about improvement strategies to increase the possibility of farmers building harmless disposal facilities for livestock excrement. The study highlighted the following findings: (1) compared to farmers who did not participate in cooperatives, farmers who were in cooperatives were 1.18% more likely to build harmless disposal facilities for livestock excrement; (2) compared to the basic scenario, the probability of farmers building harmless disposal facilities for livestock excrement could be increased by 50~1300%. The results of this study could help to provide a reference for the introduction of policies to protect groundwater, as well as an experiential reference for the achievement of the UN SDGs 3 and 6.

Keywords: cooperatives; groundwater protection behavior; cleaner production; sustainable development; rural China

1. Introduction

Clean water is an important global issue for the sustainable development of human society [1,2]. However, the crisis concerning clean water supplies has been among the top ten threats to human life since 2012 [3,4]. The WHO [5] reported that approximately 25% of the world's population lacked a clean water supply in 2020c. The United Nations have proposed 17 SDGs and the achievement of SDG 6 is closely related to the achievement of SDG 3 (good health and well-being). For example, an individual's risk of developing cancer increases when polluted water is consumed over the long term [6,7]. In China, the annual economic loss that can be attributed to water pollution is approximately CNY 150 billion (USD 22.70 billion) [8]. Nearly 1000 children die every day worldwide from diarrheal diseases that are caused by consuming unclean water [9]. Moreover, consuming unclean water over long periods has also been linked to cognitive disorders [10].

Groundwater plays an important role in maintaining a sustainable supply of clean water and environmental sustainability; thus, it needs an urgent protection [11–14]. Nevertheless, the quality of groundwater is quickly deteriorating worldwide. For example, several researchers have found that the groundwater in some places in India is polluted with uranium (radioactive uranium is carcinogenic) [15,16]. Several researchers have also found that the groundwater system in China contains an excess of nitrates, which may cause congenital defects and cancers [17–19]. Several researchers have pointed out that a

deterioration in groundwater quality is a significant constraint to achieving global sustainable development [12,20–22]. Thus, the question of how to effectively protect groundwater is a public concern.

Waste prevention and waste management have become important methods for developing cleaner production and improving environmental sustainability [23–25], which are related to the achievement of SDGs 12, 13 and 14. In rural areas, the uncontrolled management of excrement from livestock and humans is a key driving factor that leads to groundwater pollution [26–28]. Silbergeld et al. [29] pointed out that the introduction of pig and chicken manure into water caused a toxic dinoflagellate outbreak in the United States in the 1990s. Sabino et al. [30] found that animal and human excrement induce significant groundwater pollution. Thankfully, the toilet revolution has occurred across most of the world. Large numbers of harmless disposal facilities for human excrement (modern toilets) have been built, which have greatly reduced the negative impacts of human excrement on groundwater. However, the lack of harmless disposal facilities for livestock excrement has directly resulted in excrement being left exposed on pastures [31], which has become the main driving factor of groundwater pollution. Thus, improving the GPBs of farmers (i.e., building harmless disposal facilities for livestock excrement) represents the key to successfully managing the global water supply crisis.

Similar to many cleaner production actions, GPBs have strong externalities (an externality refers to the actions and decisions of one person or a group of people that harm or benefit other people or groups of people). Some studies have revealed that farmers are externally motivated by official commands and market effects [32,33]. Pigou [34] suggested that these "external effect(s)" should be eliminated mandatorily. Guo et al. [35] found that government subsidies are beneficial for soil protection because they encourage farmers to reduce fertilizer use. Further, Li et al. [36] found that government subsidies are beneficial for farming households in terms of the adoption of protective cultivation technologies. In this regard, it has been suggested that policies may sometimes fail. For example, Grutter and Egler [37] discovered that the driving force behind enterprises making the decision to adopt cleaner production is insufficient when government regulations are not sufficiently strong. Thus, motivating farmers to build harmless disposal facilities for livestock excrement using government regulations alone may be insufficient to manage the water supply crisis efficiently. It is urgent to find other ways to encourage farmers to build harmless disposal facilities for livestock excrement to protect groundwater.

Cooperatives have significant potential to improve the adoption of cleaner production practices among farmers [38]. Farmers often face production constraints, such as a lack of professional knowledge and difficulty in obtaining credit [39]. Cooperatives can promote collective actions to overcome the production constraints that are faced by individual farmers [40,41]. Abebaw and Haile [42] discussed the impact of cooperatives on the adoption of agricultural technologies and found that the average rate of fertilizer use among cooperative members is increased by about 9~10%. Ji et al. [43] discussed the impact of cooperatives on safe production behaviors and found that cooperatives increase the probability of the safe disposal of waste that is produced by pig farmers, compared to farmers who do not belong to cooperatives. Yu et al. [44] found that cooperatives encourage farmers to adopt green prevention technologies within agricultural production. However, it is not clear whether and to what extent cooperatives improve the behavior of farmers around the harmless disposal of livestock excrement.

The Chinese government is promoting rural revitalization, which is represented in its vision to build ecological villages [45–47]. Farming in rural China largely comprises small-scale enterprises and farmers who are scattered around China, most of whom do not have harmless excrement disposal facilities on their land [48]. Groundwater quality urgently needs to be improved due to the 90% pollution rate in China [20]. Meanwhile, the Chinese government hopes that cooperatives can play an important role in rural revitalization [49,50]. Thus, based on a large sample survey of Chinese farmers, this study aimed to better understand the potential of cooperatives to improve groundwater

protection. This paper also discusses improvement strategies to increase the possibility of farmers building harmless disposal facilities for livestock excrement, which may help decision-makers and farmers achieve the cleaner production goals. The findings of this study could not only provide the Chinese government with several references for the construction of ecological villages but also references for the achievement of the SDGs.

2. Theoretical Analysis

Although cooperative economics has a long history, formal economic studies on cooperatives within the field of agriculture began with the theory of cooperative economics [51] and "consumption cooperation and economic efficiency" [52]. Figure 1 shows how cooperatives play an important role in helping members to gain information, lower investment costs and avoid the tragedy of the commons [53–56]. Such notions may be helpful for improving the GPBs of farmers.
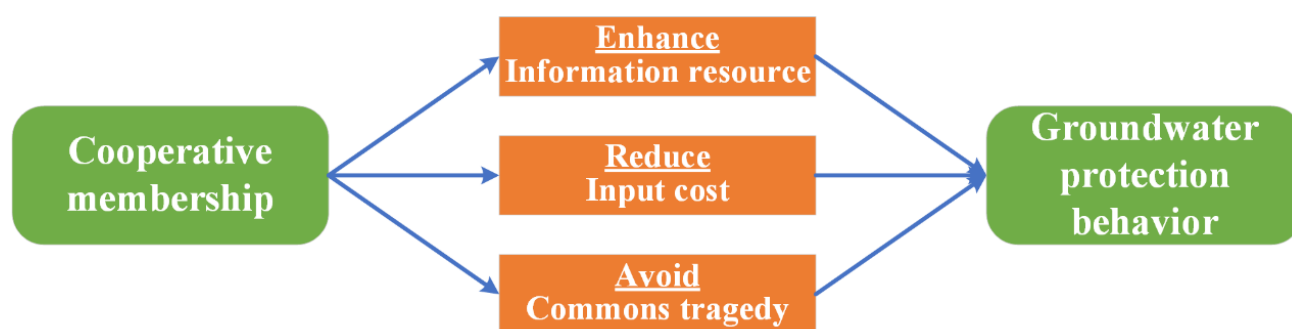

Figure 1. The influence mechanism of cooperative membership on GPBs.

Firstly, famers may be unwilling to build harmless excrement disposal facilities due to a lack of information. One of the primary functions of a cooperative is to provide its members with valuable information [54]. Guinnane [57] found that cooperatives possess sufficient and beneficial information resources and share them among their members. For example, Galappaththi et al. [58] discovered that cooperatives promote information sharing within supply chains. Further, Navroski and Calegari [59] found that cooperatives provide technological information for their members. Moore et al. [60] and Sumelius et al. [61] highlighted that cooperatives are major channels through which farmers can acquire information. Participating in cooperatives can help farmers to gain information and, in turn, become more likely to adopt GPBs.

Secondly, individual farmers are often unwilling to build harmless excrement disposal facilities since they incur extra costs. Rhodes [62] discovered that cooperatives help their members to gain the maximum benefits of the scale economy and manage market competition at a higher operational efficiency. For example, Jia et al. [63], Trebbin [64] and Ma and Abdulai [65] found that cooperatives lower transaction costs for their members within the market and Deng et al. [66], Li et al. [67] and Si et al. [68] concluded that cooperative members prefer environmentally friendly technologies. Consequently, participation in a cooperative is likely to decrease the costs that are associated with building harmless excrement disposal facilities, which could lead to a greater likelihood of farmers adopting GPBs.

Thirdly, individual farmers may be unwilling to participate in groundwater protection since it has positive externalities. Studies have found that clean agriculture production behaviors have strong externalities and that farmers do not usually care about the environmental pollution issues that are caused by agricultural production [69,70]. Staatz [55] and Bijman and Hendrikse [56] posited that cooperatives can internalize externalities through the cooperation of farmers. Hence, participating in cooperatives may be a way for farmers to internalize the positive externalities with respect to building harmless excrement disposal facilities and being more likely to adopt GPBs.

3. Data, Variables and Method

3.1. Data

In the current study, national survey data that were provided by the Social Science Survey Centre of Zhongshan University were used, which covered 29 provinces in mainland China and various research topics, including education, employment, migration, health, social participation, economic activities and primary-level organizations (among others). This survey was a transdisciplinary and large-scale tracking survey. The database that was published by the Social Science Survey Centre of Zhongshan University was also used, which involved 8031 Chinese households. During our analysis, 3167 households were deleted as they were not engaged in agricultural production. Hence, 4846 were analyzed in the current study and the sample distribution is shown in Figure 2.
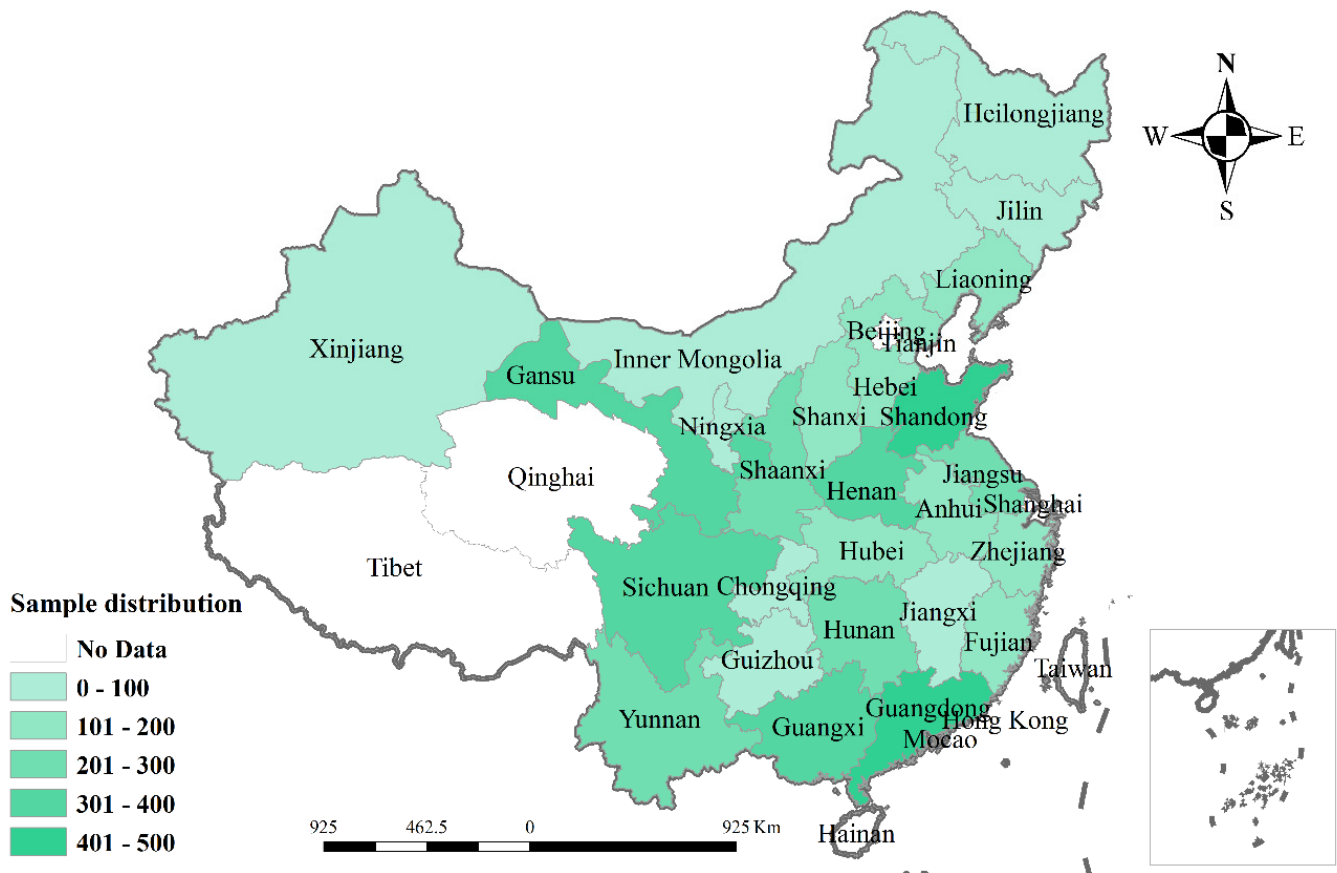
Figure 2. The sample distribution of the study.

3.2. Variables

This paper discusses the impact of cooperatives on the GPBs of farmers. Excrement significantly contributes to groundwater pollution [29,71]. Hence, whether farmers had built animal excrement disposal facilities was used as a proxy variable for the GPBs of farmers (1 = farmer exhibited GPBs; 0 = otherwise). Whether farmers had joined a cooperative was used as an explanatory variable (1 = farmer belonged to a cooperative; 0 = otherwise). In addition, several scholars have explored the quantitative impacts of cooperatives by controlling characteristic variables (e.g., householder, household and region) [65,72–74]. The definitions of the variables and their descriptive statistics are listed in Table 1.

Table 1. The definitions and descriptive statistics of the variables.

Variables	Definition	Mean	SD
GPBs	1 = Farmer exhibits groundwater protection behaviors; 0 = otherwise	0.01	0.08
Cooperative	1 = Farmer belongs to a cooperative; 0 = otherwise	0.02	0.12
Head Farmer Age	The age of the head farmer (years)	53.43	11.87
Head Farmer Gender	1 = Head farmer is male; 0 = otherwise	0.92	0.27
Head Farmer Health	1 = Head farmer is healthy; 0 = otherwise	0.83	0.38
Head Farmer Education	1 = Head farmer has a high school diploma or above; 0 = otherwise	0.10	0.31
Income	The ratio of farm income to total income (%)	47.34	41.79
Internet	1 = Farmer has access to the Internet; 0 = otherwise	0.26	0.44
Land	The area of arable land that is owned by the farmer (Mu)	7.53	14.11
Laborers	The number of laborers engaging in agriculture (Num)	1.13	1.07
Subsidies	1 = Farmer receives government subsidies; 0 = otherwise	0.67	0.47
Distance	The distance from the home to the commercial market town (Km)	7.79	9.69
Terrain 1	1 = Farmer household is located on a plain; 0 = otherwise	0.39	0.49
Terrain 2	1 = Farmer household is located in hilly terrain; 0 = otherwise	0.32	0.47
Terrain 3	1 = Farmer household is located on a mountain; 0 = otherwise	0.28	0.45
Region 1	1 = Farmer household belongs to an eastern province; 0 = otherwise	0.37	0.48
Region 2	1 = Farmer household belongs to a western province; 0 = otherwise	0.36	0.48
Region 3	1 = Farmer household belongs to a central province; 0 = otherwise	0.27	0.44

3.3. Method

Since there were only two options regarding the groundwater protection behaviors of farmers, this study used groundwater protection utility GPB_i^* to express the results, which was calculated using Equation (1). $GPB_i^* > 0$ meant that farmers had a positive utility and participated in groundwater protection (i.e., $GPB_i = 1$).

$$GPB_i = \begin{cases} 1 & GPB_i^* > 0 \\ 0 & GPB_i^* \leq 0 \end{cases} \tag{1}$$

Thus, the GPB was a binary discrete variable and this study used the Probit model for the empirical analysis [75]. The econometric model could be expressed as Equation (2):

$$GPB_i = \beta_0 + \beta_1 Cooperative_i + \beta_2 Control_i + \varepsilon_i \ i = 1, 2, 3, \ldots, n, \ \varepsilon_i \sim N(0, 1) \tag{2}$$

where subscript *i* refers to the household *i* and *GPB* represents the groundwater protection behavior of the farmer, *Cooperative* refers to whether the household belonged to a cooperative and *Control* is the control variable. Finally, β refers to the estimation parameter and ε is the random error.

4. Results

4.1. The Impacts of Cooperatives on GPBs

Since the dependent variable *GPB* was a binary discrete variable, the study used the Probit model for basic regression. Table 2 shows the estimated results for the impacts of cooperatives on GPBs. To eliminate the interference of missing variables on the estimated results as much as possible, this study gradually added control variables. More specifically, in Model (1), only the GPB and cooperative variables were added into the model. In Model (2), the GPB, cooperative and region (Region 2 and Region 3) variables were added into the model. In Model (3), the GPB, cooperative, region and head farmer characteristics variables were added into the model. In Model (4), the GBP, cooperative, region, head farmer characteristics and farmer household characteristics variables were added into the model. In Model (5), the GBP, cooperative, region head farmer characteristics, farmer household characteristics and terrain variables were added into the model. Additionally, this study estimated the marginal effect based on Model (5) and the estimates are shown in the "Marginal Effect" column of Table 2. The values of χ* were significant at the level of

1%, which meant that the Probit model was suitable for the estimations that were made in the current study.

Table 2. The estimated results for the impacts of cooperatives on GPBs.

	Model (1)	Model (2)	Model (3)	Model (4)	Model (5)	Marginal Effect
Cooperative	0.8093 ***	0.7832 ***	0.7807 ***	0.8298 ***	0.7846 ***	0.0118 **
	(0.2725)	(0.2674)	(0.2729)	(0.2934)	(0.2901)	(0.0047)
Head Farmer Age			−0.0121	−0.0194	−0.0234	−0.0004
			(0.0342)	(0.0360)	(0.0383)	(0.0006)
Head Farmer Age 2			0.0001	0.0002	0.0002	0.0000
			(0.0003)	(0.0003)	(0.0004)	(0.0000)
Head Farmer Gender			−0.1785	−0.2224	−0.2227	−0.0034
			(0.2262)	(0.2380)	(0.2350)	(0.0036)
Head Farmer Health			0.1854	0.1922	0.2462	0.0037
			(0.2174)	(0.2154)	(0.2191)	(0.0034)
Head Farmer Education			0.3881 **	0.4706 ***	0.4896 ***	0.0074 **
			(0.1653)	(0.1652)	(0.1680)	(0.0029)
Income				0.0068 ***	0.0071 ***	0.0001 ***
				(0.0017)	(0.0016)	(0.0000)
Internet				0.2614 *	0.3110 **	0.0047 *
				(0.1492)	(0.1520)	(0.0024)
Land				−0.0334 *	−0.0287 *	−0.0004 *
				(0.0178)	(0.0162)	(0.0002)
Laborers				0.0597	0.0443	0.0007
				(0.0553)	(0.0558)	(0.0008)
Subsidies				−0.1243	−0.0931	−0.0014
				(0.1397)	(0.1449)	(0.0022)
Distance					−0.0046	−0.0001
					(0.0084)	(0.0001)
Terrain 2					0.0276	0.0004
					(0.2206)	(0.0033)
Terrain 3					0.5192 **	0.0078 **
					(0.2096)	(0.0033)
Region 2		0.1367	0.1532	0.1542	−0.0177	−0.0003
		(0.1507)	(0.1595)	(0.1655)	(0.1704)	(0.0026)
Region 3		−0.0264	0.0078	0.0265	−0.0494	−0.0007
		(0.1830)	(0.1838)	(0.1968)	(0.2048)	(0.0031)
Constant	−2.5474 ***	−2.5958 ***	−2.2588 **	−2.4217 **	−2.5460 **	
	(0.0683)	(0.1184)	(0.9443)	(0.9630)	(1.0670)	
χ^2	8.8209 ***	9.1812 **	25.1137 ***	108.1069 ***	116.3047 ***	116.3047 ***
Observation	4864	4864	4864	4864	4864	4864

Note: Standard errors in parentheses; * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

As shown in Table 2, the cooperative variable in Models (1–5) was significant at the level of 1% and was greater than zero, which meant that belonging to a cooperative significantly and positively affected GPBs. Specifically, compared to farmers who did not participate in cooperatives, farmers who participated in cooperatives tended to take actions to protect groundwater. Based on the estimates of the marginal effect, the probability of adopting GPBs was 1.18% higher for farmers who were in cooperatives than for those who were not.

The variables of head farmer education, income and Internet were greater than zero and significant at the level of 10%. This reflected the following findings: (1) head farmers with a good level of education tended to protect groundwater; (2) farmers who depended on agriculture for their livelihoods tended to protect groundwater; and (3) farmers with Internet access tended to protect groundwater. Conversely, the land variable was less than zero and significant at the level of 10%. This meant that farmers with more land tended not to protect groundwater.

4.2. Improving GPBs through Education and Internet

It has been suggested that environmental problems in developing countries are more serious [76]. China is the largest developing country in the world [77,78] and its use of harmless management for livestock excrement may help to provide new ideas for developing countries to help them to solve their water pollution problems. This study found that education and Internet use had a positive impact on improving the groundwater protection behaviors of farmers, which was consistent with the findings of Deng et al. [79], Yuan et al. [80] and Zheng et al. [81], who also concluded that education and Internet access play an important role in promoting environmentally friendly behaviors among farmers. Lin et al. [39] found that education could have a positive correlation with participation in cooperatives. Deng et al. [79] pointed out that the development of the Internet is profoundly changing the rural areas of China. Thus, based on Model (5), this study predicted the probability of farmers building harmless disposal facilities for livestock excrement, as shown in Table 2. This study also tested for improvements in that probability using the different scenarios of participating in cooperatives, improving education and accessing the Internet.

As shown in Figure 3, Scenario I represented the current scenario, in which farmers were the whole sample. Scenario II referred the scenario of participating in cooperatives, in which farmers who participated in cooperatives were the sample. Scenario III referred to the scenario of improving education, as shown in Figure 3a (the scenario of accessing the Internet is shown in Figure 3b), in which farmers who had a high school diploma or above (or access to the Internet) were the sample. Scenario IV represented the scenario of participating in cooperatives and improving education, as shown in Figure 3a (the scenario of participating in cooperatives and accessing the Internet is shown in Figure 3b), in which farmers who had a high school diploma or above (or access to the Internet) and participated in cooperatives were the sample. Compared to Scenario I, Scenario II, III and IV significantly increased the mean probability (white line) of building harmless disposal facilities for livestock excrement by 563.83% (*t*-value = 23.28), 156.34% (*t*-value = 15.98) and 1301.11% (*t*-value = 23.20), respectively, as shown in Figure 3a or by 563.83% (*t*-value = 23.28), 48.70% (*t*-value = 7.73) and 695.21% (*t*-value = 17.00), respectively, as shown in Figure 3b.
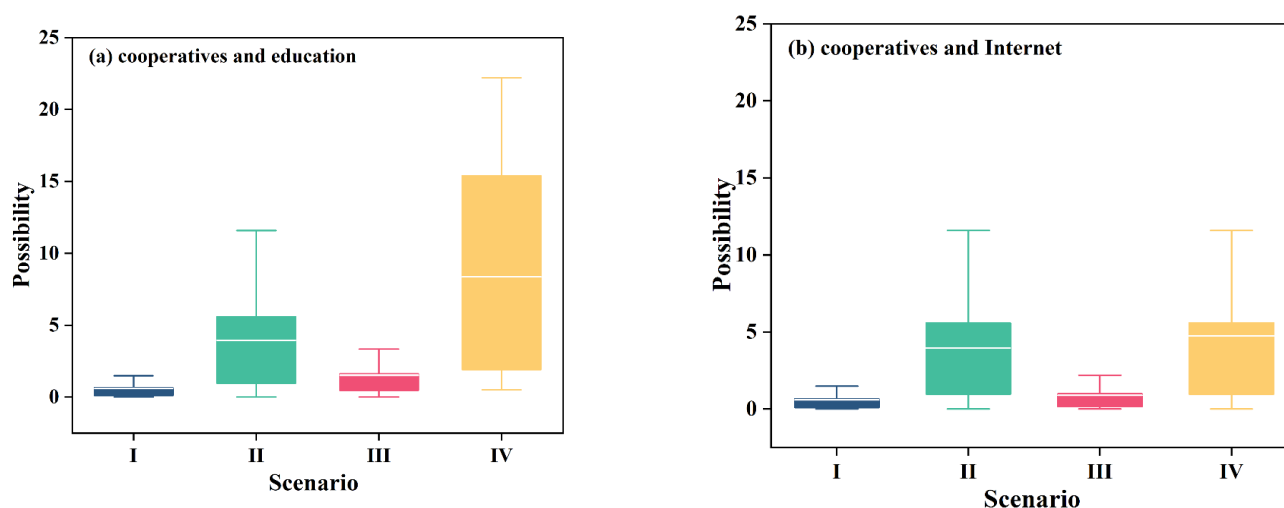

Figure 3. The probability of farmers building harmless disposal facilities for livestock excrement in the different scenarios.

When exploring the important roles of cooperatives, education and Internet access in cleaner production and sustainable development in rural areas, the Chinese government has put in a lot of effort. First, the Chinese government promulgated the "Compulsory Education Law" in 1986, which included elementary and junior high schools within the scope of compulsory education and greatly improved the education level of Chinese rural

residents [82]. In recent years, the Chinese government has continued working hard to improve the educational level of rural residents. For example, the Chinese government provided farmers with free vocational skills training [83]. Second, the Chinese government issued the "Professional Farmer Cooperatives Law" in 2007, which aims to provide a good institutional environment for the development of agricultural cooperatives [84]. Third, the Chinese government continues to improve the Internet infrastructure in rural areas. By the end of 2020, 99% of villages in China had access to broadband Internet [85]. In short, these efforts are playing an active role, either individually or in combination, in helping to realize the sustainable development of China's rural areas. This also sends the message to other developing countries around the world that in order to revitalize rural areas and sustainable development, the government needs to make more effort in promoting cooperatives, education and access to information.

5. Discussion

5.1. Robustness Testing

A stepwise addition of the variables helped to prevent the negative impacts of missing variables on our estimation results, but it still did not completely eliminate those negative impacts. To weaken the impacts of any missing variables and reciprocal causations on the estimation results, a robust test was conducted using the instrumental variables that were used in the study. With reference to the studies by Deng et al. [79], Deng et al. [86] and Deng et al. [87], the current study selected the instrumental variables (i.e., the proportion of households within the same village that were in cooperatives) based on the cohort effect. For comparison to the results in Table 2, the estimation results of the instrumental variables adopted the stepwise addition of the variables. The estimation results from the Probit model using the instrumental variables are shown in Table 3. The settings of Models (1–5) were consistent with those in Table 2. As shown in Table 3, the cooperative variable in Models (1–5) was significant at the level of 1% and was greater than zero. This reflected the following finding: cooperatives significantly and positively affected GPBs. In other words, the results that are presented in Table 3 showed that cooperatives significantly and positively affected the GPBs of the farmers.

Table 3. The estimated results for the impacts of cooperatives on GPBs using the IV-Probit method.

	Model (1)	Model (2)	Model (3)	Model (4)	Model (5)
Cooperative	5.1758 ***	5.1375 ***	5.2807 ***	6.5261 ***	6.5607 ***
	(1.1155)	(1.1144)	(1.0916)	(0.9155)	(1.0194)
Head Farmer Characteristics	No	No	Yes	Yes	Yes
Farmer Household Characteristics	No	No	No	Yes	Yes
Terrain	No	No	No	No	Yes
Region	No	Yes	Yes	Yes	Yes
χ^*	21.5278 ***	21.9481 ***	46.7998 ***	233.3437 ***	265.8252 ***
Observation	4864	4864	4864	4864	4864

Note: Standard errors in parentheses; *** $p < 0.01$.

Additionally, based on the studies by Ma and Abdulai [65], Ma et al. [88] and Ma and Zhu [84], a farmer's decision to join a cooperative represents a self-selection behavior. Thus, selection bias could have affected the accuracy of the estimation results in this study. For this reason, Deng et al. [86] recommended the use of binary choice models with binary endogenous regressors (i.e., the endogenous switching of Probit and ESP was provided by Lokshin and Sajaia [89]) for robustness testing. The average treatment effect on the treated results (ATT) and the average treatment effect on the untreated results (ATU), which were calculated using the ESP method, are presented in Table 4. The ATT value represented the difference between the actual and the estimated probability of farming households that were in cooperatives having positive GPBs. The ATU value represented the difference between the estimated and actual probability of households that were not in cooperatives

having positive GPBs. Table 4 shows that the ATT and ATU values were greater than zero, which meant that being in a cooperative improved the GPBs of the farmers.

Table 4. The estimated results for the impacts of cooperative on GPBs using the ESP method.

	ATT	**ATU**
GPB	0.0411 (0.1999)	0.2311 (0.4002)

Note: The ATT and ATU values were predicted using the ESP method; standard deviations in parentheses.

5.2. Impacts of Agricultural Cooperatives on Cleaner Production within the Livestock Industry of China

As shown in Figure 4, the number of large animals, pigs and sheep that are farmed in China has exceeded 800 million each year over the past 20 years. In addition, China also raises approximately 7.43 billion poultry animals each year. The large scale of livestock breeding in China has brought about huge challenges for groundwater protection. Aravani et al. [90] estimated that the excrement that was produced by livestock in China between 2010 and 2018 reached 216.5 Mt/y. NBS [91] pointed out that 500 million people still live in rural areas in China. If livestock excrement cannot be treated in a harmless way, the residents of rural China could face serious problems from the resulting environmental pollution.
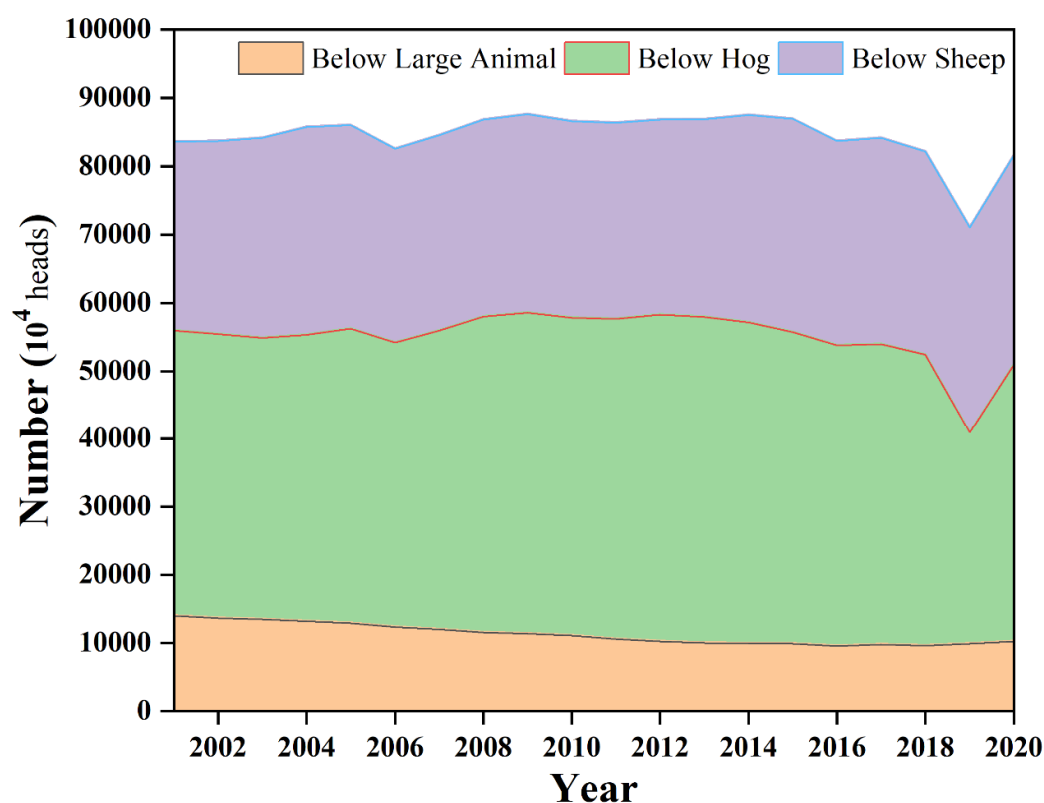
Source: National Bureau of Statistics of China

Figure 4. The number of livestock in China (2001–2020).

This study found that cooperatives helped to improve the GPBs of farmers. Compared to farmers who did not participate in cooperatives, farmers who participated in cooperatives were more likely to build harmless disposal facilities for livestock excrement by 1.18 percentage points. The findings of this study were consistent with those of Chen et al. [92], Ma et al. [93] and Yu et al. [44], who found that agricultural cooperatives play an important role in cleaner production. Although the ratio (1.18 percentage points) was not very high, the additive effect has a lot of potential. According to incomplete statistics, at the end of 2020, China had 2.241 million legally registered cooperatives with 66.828 million members [94]. Generally, only one person from each family participates

in the cooperative. Based on the above data, approximately 1.2 million rural households participate in the protection of groundwater. As a result, this contributes to the achievement of the UN Sustainable Development Goal 6 (i.e., clean water and sanitation).

5.3. Enhancing the Sustainable Development Capabilities of Farmers through Cooperatives

Clean water is essential for human health [95,96] and is related to the achievement of the UN Sustainable Development Goal 3 (i.e., good health and well-being). The UN [9] pointed out that nearly 1000 children die worldwide every day from diarrheal diseases that are caused by consuming unclean water. Pan et al. [8] pointed out that the annual economic loss that is caused by water pollution in China is about CNY 150 billion. The findings of this study were consistent with those of Van Fan et al. [24] and Jiang et al. [25], who found that waste management could enhance global sustainability. This study found that cooperatives helped farmers to participate in groundwater protection, which could help to reduce the negative impacts of unclean water on the health of the farmers. The findings of this study were also consistent with those of Ma and Abdulai [65], Ma et al. [88] and Ma and Zhu [84], who found that cooperatives can improve the economic welfare of farmers. The findings of this study could create a link between cooperatives and the health of farmers, which could in turn help to improve the human capital of farmers and enhance the sustainable development capabilities of farmers.

6. Conclusions and Implications

Based on a large survey of famers in China's rural areas, the impact of participation in cooperatives on the GPBs of farmers was quantitatively assessed. Using a theoretical analysis, basic regression and robustness testing, the results were as follows:

(1)　Compared to farmers who did not participate in cooperatives, farmers who participated in cooperatives were more likely to build harmless disposal facilities for livestock excrement by 1.18 percentage points;

(2)　Compared to the basic scenario, the probability of farmers building harmless disposal facilities for livestock excrement could be increased by 50~1300% by participating in cooperatives, improving the education of farmers and having access to the Internet.

Based on the above findings, several implications arose. First, cooperatives can help to improve the GPBs of farmers, which can in turn help to guide the promotion of joining cooperatives among farmers. For example, farmers in economically underdeveloped regions are not adequately equipped to spontaneously create cooperatives; thus, village collectives can help to organize cooperatives to meet farmer demands within this space. To achieve this objective, the government should provide subsidies that initiate funding for cooperatives. Second, access to the Internet and increased education levels also help to improve the GPBs of farmers. This finding can help to improve access to the Internet in rural areas and provide relevant training for farmers. For example, the government could cooperate with communication companies to provide a special helpline that allows farmers to inquire about their agricultural needs. The government could also set up professional training schools in rural areas to provide an avenue for farmers to receive further education. Third, owning large amounts of land was found to negatively impact the GPBs of farmers. This finding could help to strengthen farmers' awareness and use of scientifically developed organic fertilizers and, in turn, guide them to shift their farming from traditional to more modern practices.

Finally, this study also had several limitations and it is expected that future studies will take these shortcomings into account. Cooperatives increase the GPBs of farmers; thus, future studies should further examine the quantitative impacts of cooperatives on environmental sustainability. Based on a case study of rural areas, the Chinese government has recently committed itself to increasing the quality of agricultural cooperatives.

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