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Willingness to pay of multiple stakeholders for non-point source pollution control in a water conservation zone

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Stakeholder engagement is crucial for the effective implementation of Diffused Pollution Control Measures (DPCMs), as it fosters local ownership, improves compliance, and enhances the long-term sustainability of environmental initiatives. However, such engagement remains significantly understudied, particularly in developing regions where institutional and resource constraints are prominent. Addressing this gap, this study analyzes the Willingness-To-Pay (WTP) of 221 diverse stakeholders—including volunteers, villagers, and migrants—in rural North China, by examining the interplay of their environmental concern, policy attitudes, and payment intentions to elucidate their motivations and capacity for participation. Results showed that: (1) Stakeholders exhibited four payment archetypes—Institution-Dependent Group, Ambivalent-Concern Group, Responsibility-Cautious Group, Autonomous-Action Group—reflecting motivational disparities in environmental stewardship. (2) Inverse socioeconomic gradients emerged: less-developed Luanping contributed the highest income proportion (0.85%) despite lower absolute payments (68.3 CNY/year), while wealthier Miyun showed higher absolute (69.1 CNY/year) but lower relative contributions (0.36%). Volunteers demonstrated peak absolute WTP (99 CNY/year), surpassing villagers (67.5) and migrants (59.5). (3) Random forest analysis identified WTP (0.318) and income (0.195) as primary determinants (51.3% variance explained), with education, age, and evaluation of government policies as secondary factors. Gender and tendency to seek help showed negligible impacts. These findings underscore that effective payment for DPCMs must integrate economic capacity with trust in policy, while accounting for nuanced stakeholder motivations. The study provides a actionable framework for designing differentiated and socially equitable payment strategies that enhance stakeholder participation and environmental sustainability across diverse socio-economic contexts.

KEYWORDS

stakeholder, environmental concern, willingness to pay, attitude to pay, diffused pollution control measures

1 Introduction

Water conservation zones are critical for maintaining water quality and safeguarding biodiversity, yet they face persistent threats from non-point source (NPS) pollution (Asfew et al., 2023; Qin et al., 2024). The diffuse nature of NPS pollution challenges conventional governance models reliant solely on government intervention (Tang and Li, 2023; Qin et al., 2024),

underscoring the urgent need to integrate engagement and financial contributions from diverse stakeholders to establish sustainable mitigation frameworks (Xu et al., 2025; Lin et al., 2019). This is particularly salient in rural China, where mitigating rural non-point source pollution (RNSP) is a cornerstone of the national “Building a New Countryside” strategy (Liu et al., 2013).

While Best Management Practices (BMPs)—including both engineering and management measures—have been widely applied (Liu et al., 2009; Qiu et al., 2014), international experience confirms that long-term effectiveness requires robust stakeholder participation beyond mere government investment (Chung and Poon, 2001; Leach et al., 2002). A direct mechanism for fostering this participation is through assessing stakeholders’ willingness-to-pay (WTP) for environmental improvements, an approach well-established using valuation methods like the Contingent Valuation Method (CVM) (Spash, 2000; Del Saz-Salazar et al., 2009; Zhao et al., 2013) and Choice Experiments (CE). Recent studies have effectively applied these methods to rank ecosystem services by public preference (Ali et al., 2020), integrate novel spatial concepts like elevation into economic appraisal (Khan, et al., 2025), and explore stakeholder preferences amidst spatial heterogeneity (Khan, et al., 2022; Khan, et al., 2023). Previous applications have explored WTP for various environmental goods, from air pollution reduction (Ouyang et al., 2019; Yang et al., 2018; Liu et al., 2025; Sreenonchai et al., 2020) to waste management (Han et al., 2018; Han et al., 2019), and have examined influencing socio-economic factors (López-Mosquera, 2016; Zheng et al., 2019), including the assessment of climate change impacts on vulnerable farmers (Ali et al., 2020).

However, critical research gaps persist, particularly in the context of rural China’s unique socio-economic landscape. Firstly, while prior research has advanced our understanding of spatial heterogeneity and stakeholder diversity in abstract (Khan, et al., 2022; Khan, et al., 2023), most of them often focuses on a single, homogenous stakeholder group (e.g., the general “public” (Wang et al., 2010; Han et al., 2019) or NGOs (Doh and Guay, 2006)), neglecting systematic comparisons between distinct, co-existing groups within a community. In China’s watersheds, key stakeholders are not monolithic, they include left-behind villagers (elderly, women, children remaining in villages) and migrant workers (who migrate for work but retain rural ties), groups shaped by the hukou system and rural land policies (Deininger and Jin, 2009; Zhou and Zhong, 2022; Niu et al., 2021). Additionally, external volunteers concerned with water quality represent another critical stakeholder segment. The divergent motivations, economic capacities, and reliance on ecosystem services of these groups are likely to produce starkly different WTP profiles. Secondly, there is an insufficient integration of environmental concern with economic valuation. While studies record WTP amounts and correlate them with factors like income or education (López-Mosquera, 2016; Ntanos et al., 2018), they often fail to segment stakeholders based on underlying motivational archetypes (e.g., institution-dependent, responsibility-cautious) that predict payment behaviors. This limits the ability to design tailored, effective engagement strategies. Thirdly, analyses of payment drivers frequently prioritize absolute monetary contributions while overlooking income-proportional (relative) effort, which is a more equitable metric of commitment, especially in communities with significant income

disparity. Understanding the inverse relationship between absolute payment and proportional income is vital for designing fair and inclusive conservation finance policies. To address these gaps, this study aims to answer the following research questions: (i) What are the disparities in environmental concern and absolute vs. relative WTP among these key groups? (ii) What motivational archetypes explain their payment behaviors? (iii) How do socio-economic factors, including income-proportional effort, determine WTP?

We investigate these questions within the Chaohe River watershed, a critical and representative case study. As a primary upstream source for the Miyun Reservoir—which provides drinking water for over 21.83 million residents in Beijing—the watershed’s protection is of paramount ecological and policy importance. However, the watershed faces significant threats from agricultural and rural non-point source pollution (Wang et al., 2020), which are exacerbated by its complex socio-hydrography. This combination of extreme ecological policy relevance—as a vital water source for a megacity—and the pressing need to manage pollution in a transitioning rural landscape with inherent spatial and social heterogeneity (Khan et al., 2025; Khan et al., 2022), makes the Chaohe watershed a highly representative and critical area for this study. The stakeholders within this basin, including left-behind villagers, migrant workers, and concerned volunteers, embody the very groups whose participation is essential for the success of environmental initiatives across Chaohe watershed. The findings will provide a nuanced framework for policymakers to move beyond one-size-fits-all approaches and craft targeted, efficient, and equitable stakeholder engagement strategies for environmental management in Chaohe watershed and similar contexts.

2 Materials and methods

2.1 Study area

The Chaohe watershed is an important drinking water source and an ecological barrier in Beijing, and it provides nearly half of the municipal water supply (Wang, 2018). The watershed includes Luanping, Fengning, and Miyun counties, covering an area of 4,855.9 km² (Figure 1). By the end of 2016, the annual average *per capita* disposable income of the rural villagers in Miyun County was ¥19,183 CNY (US, \$2,888), while it was 8029 CNY (US, \$1,208.8) and 6,829 CNY (US, \$1,028.2) in Luanping and Fengning counties, respectively. The data were obtained from the 2016 statistical bulletin on national economic and social development. The weighted average exchange rate of USD/RMB in 2016 was 6.6423.

The topography of this area is characterized by high mountain ranges, steep slopes, and deep valleys. The mountains are located in the northwestern part of the area, and the low hills are located in the southeast. Only a small part of the watershed consists of flat land and alluvial plains for living and farming (Ou et al., 2017). This study was carried out in a typical farming area. Corn and wheat were the main crops, and they were undergoing intensive cultivation with the application of fertilizers. Animal husbandry played a minor role in the livelihoods of the local residents due to policy restrictions. Thus, water pollutants were mainly sourced from agricultural soils, which affected the water quality of the downstream reservoirs. The

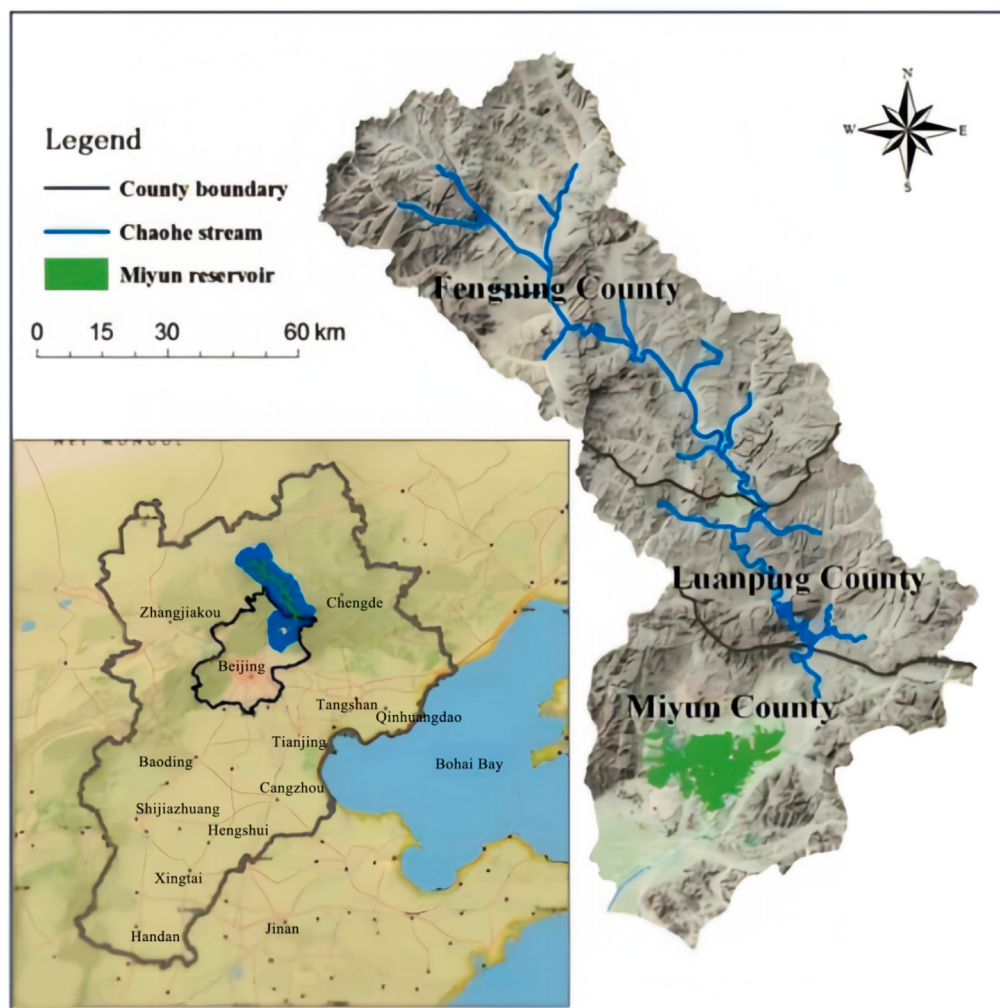


FIGURE 1
Location of and administrative boundaries in the study area.

intense cultivation and overuse of fertilizers have resulted in surface runoff pollution (Yin and Wang, 2014), as well as a higher sediment yield that contains large amounts of nitrogen (N) and phosphorus (P) when rainstorms and erosion occur, which can subsequently cause eutrophication of freshwater (Runzhe et al., 2017). It is thus vital to implement DPCMs to prevent water pollution and ensure the safety of drinking water.

2.2 Questionnaire design and pretesting

The survey instrument was designed following the best practice guidelines for contingent valuation studies (Cai et al., 2025; Ke et al., 2022). To ensure the validity and reliability of the willingness-to-pay (WTP) elicitation, the questionnaire underwent a rigorous pretesting process. The payment values presented to respondents were not predetermined but were derived empirically. Prior to the main survey, a pilot study was conducted with 30 individuals from the target population (including villagers, migrants, and volunteers). In these pilot interviews, WTP was elicited using an open-ended question format: “What is the maximum amount you would be

willing to pay each year for a program that effectively reduces rural pollution and ensures cleaner water?” The distribution of responses from this pilot, along with a review of WTP values found in comparable literature (Cai, et al., 2024; Zhang et al., 2023), informed the selection of the final bid ranges. This process ensured that the values listed on the payment card encompassed the majority of anticipated responses, thereby reducing potential range bias.

To minimize strategic and starting point biases, interviewers were trained to adhere to a strict neutral script when administering this section (Du, et al., 2018). The script explicitly stated: “It is important to know that there is no right or wrong answer. We are interested in your personal opinion.” “Please be aware that stating you are not willing to pay anything (a zero amount) is a completely acceptable answer and will not affect you in any way.” “The amounts on this card are just examples to help you think about what this improvement is worth to you. Your decision should be based on your own budget and preferences.” This standardized approach ensured that respondents’ valuations were not influenced by the interviewer and were based on their own preferences and economic constraints.

Apart from basic questions such as gender, age, education level, and annual income, the other questions are as follows:

1. Are you concerned about the environmental problems associated with water quality and pollution (Never; Once in a while; Often)?
2. Will you seek help when environmental problems occur (No; Yes)?
3. Have you taken part in activities related to water protection (No; Yes)?
4. How do you categorize the current water pollution situation (Have no idea; No pollution; Slight pollution; Serious pollution)?
5. What is your opinion about governmental policies concerning protection of water from pollution (No effect; Do not care; Follow the government policy; Effective)?
6. Are you willing to pay additional money for maintaining DPCMs, such as centralized treatment of sewage and livestock waste (Unwilling to pay; Follow the public opinion; Follow the government policy; Willing to; Very willing to)?
7. What do you consider to be an acceptable range of payment (0; <50 CNY; 50–75 CNY; 76–100 CNY; 101–125 CNY; >125 CNY)? The median value of 113 CNY within the range of 101–125 CNY is first established, followed by the determination of whether to accept this value, as per the guidelines mentioned in Section 2.5, by selecting up or down.

The first five questions are about environmental concerns, and the last two questions are about the attitude to pay (ATP) and the willingness to pay (WTP), respectively.

2.3 Survey protocol and ethical considerations

All face-to-face surveys were conducted by trained interviewers who underwent a standardized protocol training session. This training ensured consistency in question delivery, minimized interviewer effects, and equipped the team to handle ethical considerations. This research received full ethical approval from the local government. Informed consent was obtained from all participants prior to their involvement. The consent process clearly outlined the study's purpose, the voluntary nature of participation, the confidentiality of responses, and the right to withdraw at any time without penalty. Verbal consent was documented for all participants.

2.4 Sampling and recruitment

As the region is predominantly mountainous with scattered village distribution, we adopted household-based surveys to enhance work efficiency and sample representative. During data collection, we encountered practical challenges specific to the population characteristics (e.g., a significant portion of migrant workers were absent from their households). To maximize result reliability and capture population heterogeneity, we implemented a stratified sampling strategy based on population category (left-behind villagers, migrant workers, volunteers), county, and gender. Potential

non-response bias is acknowledged, as the absence of migrant workers and any refusals to participate may mean our sample of left-behind villagers is skewed towards older individuals with lower mobility, which is discussed in the study limitations. The environmental volunteers were recruited through our partner NGO, Friends of the Environment (<https://www.fon.org.cn>). These volunteers were individuals already registered with the NGO and had self-identified as having an interest in environmental activities; they were not randomly selected from the general population. All interviewers underwent a standardized training session on the survey protocol. This training covered the objectives of the study, the precise wording of the CVM scenario and questions, techniques for neutral presentation to avoid bias, and procedures for obtaining informed consent.

Due to the sample size being below the ideal value, we confirmed the validity of the sample by comparing it with reference literature and conducting *post hoc* tests. Our literature review confirms that our sample size ($N = 221$) is comparable to those employed in many rigorous contingent valuation studies in environmental economics, particularly those conducted in rural contexts (Fu, et al., 2022; Baležentis et al., 2025). More importantly, *post hoc* power analysis was conducted using G*Power version 3.1 to address concerns regarding sample size adequacy (Faul et al., 2009). With a pre-set significance level (α error prob) of 0.05, an effect size of 0.3, and a sample size of 221, the actual statistical power ($1 - \beta$ err prob) of the current study was calculated to be 0.95. A power greater than 0.8 indicates sufficient statistical power.

2.5 Contingent valuation method

The CVM was used to analyze stakeholders' willingness to pay for DPCMs, and the utility maximization principle was applied to conduct a monetary evaluation of the respondents' preferences by constructing market illusions (Forleo et al., 2019; Hanley et al., 1998). The double-bounded dichotomy was used as the induction technique, which conforms to the principle of incentive compatibility (Yoo and Yang, 2001). Since the amount of payment (i.e., WTP) is a relatively sensitive issue, we adopted payment ranges to investigate the actual payment capacities of various stakeholders. First, given a reference bid value equivalent to 1% of the average *per capita* income of the three stakeholder groups (113 CNY, \$17), it belongs to the payment range of 101–125 in question 7, so the interview started with this option. If the respondents accepted this value, we offered a second range that was greater than the first range. If the first range was unacceptable, a second smaller range was offered. Based on previous studies of WTP for environmental improvements—such as air quality (Wang and Mullahy, 2006; Tian et al., 2016) and waste management (Han et al., 2019)—as well as the results from our pilot study, we determined that the surveyed payment range should be set at 0%–2% of disposable income, equivalent to 0–225 CNY (approximately \$0–34). The payment range options increased or decreased by a step size of 25 CNY (\$3.8).

2.6 Demographic characteristics

The statistics of the surveyed stakeholders are presented in Table 1. A total of 221 stakeholders participated in the survey, including 18 environmental volunteers, 73 left-behind villagers, and

TABLE 1 Descriptive statistics of stakeholders.

Variable	Option (code)	LBV	MW	EV	Total
Gender (%)	Male (1)	58.9	50.8	38.9	49.5
	Female (2)	41.1	49.2	61.1	50.5
	Total	100	100	100	100
Age ^a (%)	18–24 (1)	2.7	4.6	50.0	11.5
	25–34 (2)	6.9	11.5	27.8	16.0
	35–44 (3)	5.5	17.7	11.1	16.4
	45–60 (4)	35.6	45.4	11.1	33.1
	>60 (5)	49.3	20.8	0	23.0
	Total	100	100	100	100
Education ^a (%)	Illiterate (1)	16.4	23.9	0	15.0
	Primary school (2)	37.0	23.1	0	20.6
	Middle school (3)	34.3	30.8	5.6	27.5
	High school (4)	12.3	19.2	11.1	21.3
	College or above (5)	0.00	3.1	83.3	15.7
	Total	100	100	100	100
Annual income (CNY) ^a (%)	<20,000 (1)	64.4	49.2	100	52.6
	20,001 to 40,000 (2)	19.2	36.9	0	33.8
	40,001 to 60,000 (3)	9.6	10.0	0	9.1
	>60,000 (4)	6.9	3.9	0	4.5
	Total	100	100	100	100

^aIndicates significant differences between the different stakeholders based on the Chi-square test.

LBV: Left-behind villagers; MW: migrant workers; EV: environmental volunteers.

130 migrant workers. The left-behind villagers stood out as being older and having a lower educational level compared to both the migrant workers and volunteers. Specifically, nearly half (50%) of the left-behind villagers were over 60 years old, and a significant proportion (87.7%) had an education level below middle school. Additionally, a substantial portion (64.4%) of the left-behind villagers and half (50%) of the migrant workers earned an annual income of less than 20,000 CNY (\$3,011). The environmental volunteers were younger and had a higher education level. The average annual income of all of the volunteers was less than 20,000 CNY (\$3,011).

Comparative analysis between the sampled populations from three counties and the general population (Table 2) revealed demographic alignment in sex ratio. However, due to the limited age stratification in the Statistical Yearbook, only the proportion of individuals aged ≥ 60 years could be validated against population-level data. Notably, a higher illiteracy rate was observed in the sample (23%) compared to the general population (3.31%), likely attributable to the overrepresentation of older left-behind villagers in the surveyed cohort. Despite this discrepancy, these individuals constitute the core residents and grassroots managers of rural communities, playing a pivotal role in rural governance and development. The predominance of junior high school education levels in both the sample and population further supports the representativeness of the study cohort.

2.7 Data analysis

The collected data were analyzed using the chi-square test and cross-tabulation analysis. The chi-square test is a widely employed non-parametric statistical test used to describe the magnitude of the discrepancy between the observed data and the data expected to be obtained under a specific hypothesis (Frykblom and Shogren, 2000). Cross-tabulation analysis is a method used to quantitatively analyze the relationships between multiple variables (Kamakura, 1997). Stepwise regression analysis was applied to identify key factors influencing payment amounts across distinct regions, while the random forest algorithm was utilized to assess the relative importance of determinants affecting payment amounts within the entire watershed.

3 Results

3.1 Descriptive statistics of environmental concern, WTP, and ATP

The results of the statistical analyses are presented in Table 3. It was found that 25.3% of the stakeholders were often concerned about the water quality and pollution problems, 30.8% were not

TABLE 2 Demographic characteristics of three counties (data sourced from the Statistical Yearbook).

County	Gender (%)		Age (%)			Education (%)				
	Female	Male	0–14	15–59	60.00	College or above	High school	Middle school	Primary school	Illiterate
Miyun	51.10	48.90	12.70	64.20	23.10	24.10	18.94	36.79	17.50	2.69
Luanping	50.78	49.22	18.46	59.51	22.03	10.53	13.22	41.87	30.28	4.10
Fegnning	50.82	49.18	17.75	58.63	23.62	10.47	14.01	38.32	33.53	3.68
Total	50.94	49.06	15.52	61.46	23.02	16.89	16.13	38.50	25.17	3.31

TABLE 3 Descriptive statistics of question options.

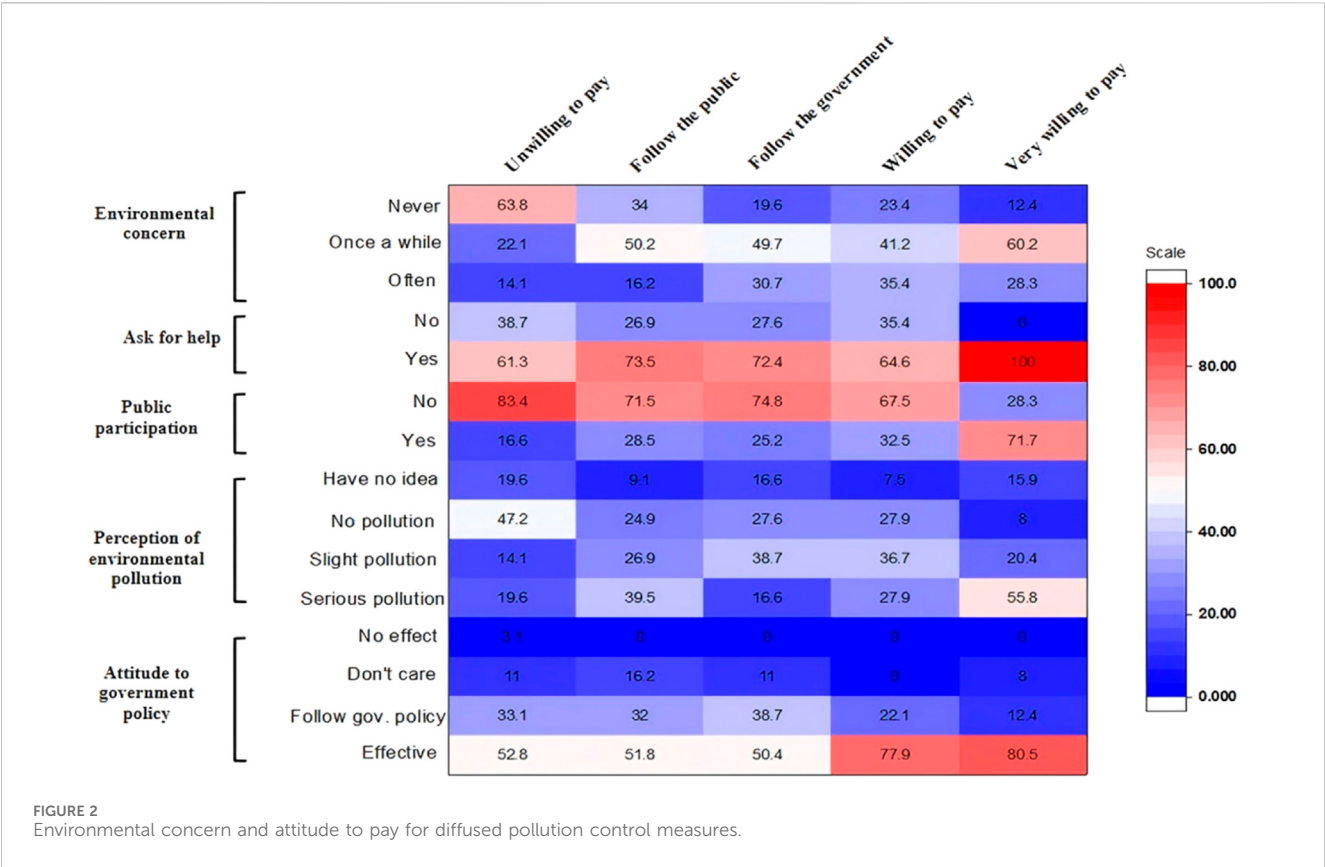
Questions	Options (code)	Percentage (%)
Are you concerned about environmental problems associated with water quality and pollution?	Never (0)	30.8
	Once a while (1)	43.9
	Often (2)	25.3
Will you seek help when environmental problems occur?	No (0)	28.5
	Yes (1)	71.5
Have you taken part in activities related to water protection?	No (0)	67.9
	Yes (1)	32.1
What is your understanding of the current water pollution situation?	Have no idea (1)	12.2
	No pollution (2)	28
	Slight pollution (3)	29
	Serious pollution (4)	30.8
What is your opinion about governmental policies concerning the protection of water from pollution?	No effect (1)	0.5
	Do not care (2)	8.6
	Follow the government policy (3)	28.1
	Effective (4)	62.9
Are you willing to pay additional costs for maintaining DPCMs?	Unwilling to pay (1)	16.3
	^a Follow the public opinion (2)	25.3
	^b Follow the government policy (3)	16.3
	Willing to (4)	30.8
	Very willing to (5)	11.3
What do you consider to be an acceptable range of payment (CNY)?	0 (0)	17.2
	<50 (1)	32.6
	50–75 (2)	10.4
	76–100 (3)	16.3
	101–125 (4)	6.3
	>125 (5)	17.2

^aFollow the public opinion means that the stakeholder's decision will be influenced by their neighbors and relatives.

^bFollow the government policy means that the stakeholder's decision will be unconditionally subject to the government's policy arrangements.

concerned, and 43.9% were occasionally concerned. Most of the interviewees (71.5%) reported that they would seek help when environmental problems arose. About 32% of the stakeholders

had participated in water protection activities. Interestingly, 62.9% of the stakeholders thought that the governmental policies to protect water were effective, and 28.1% did not question the

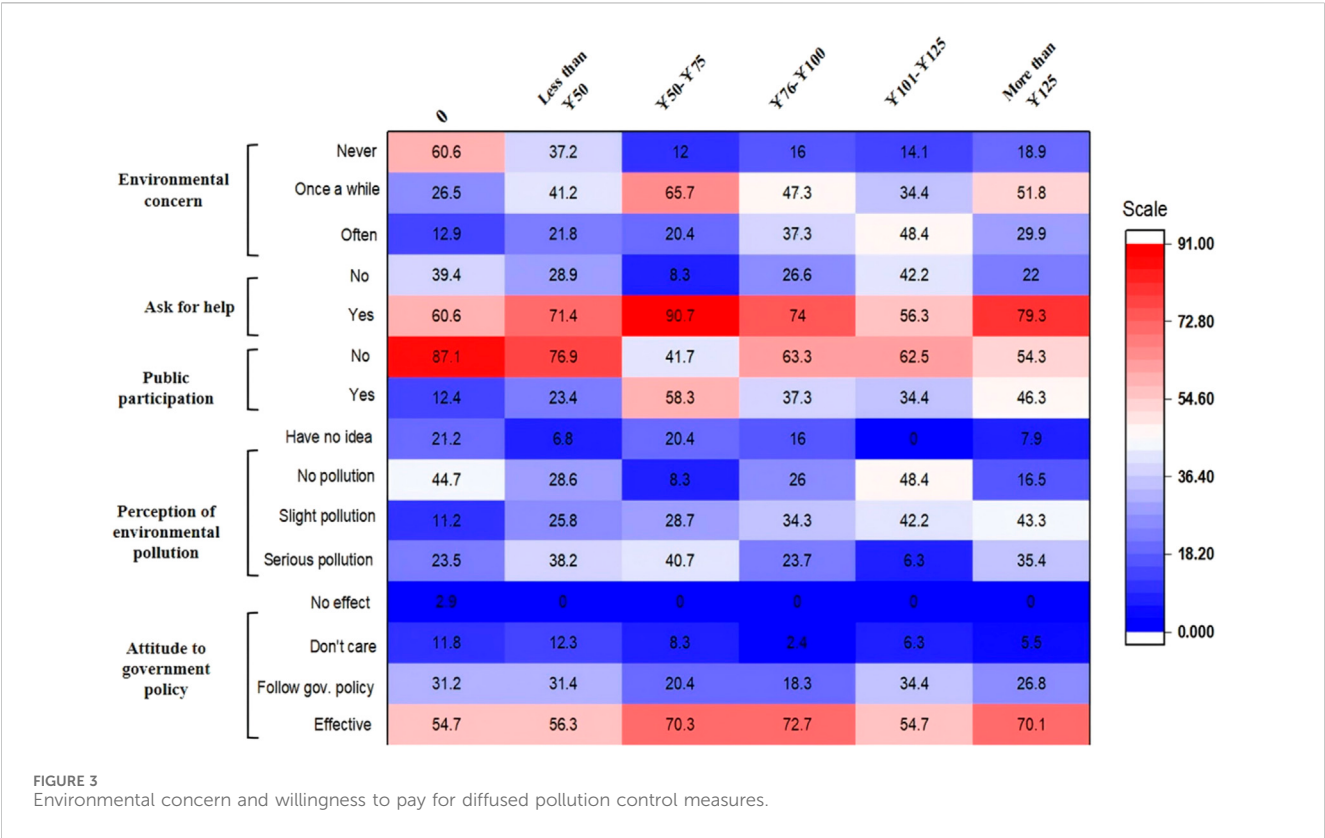


government policies. Concerning payment, 16.3% of the stakeholders were unwilling to pay for DPCMs. Those who were neither willing nor unwilling to pay either followed the government policy (16.3%) or the public opinion (25.3%) without a strong individual opinion. According to the survey results, 30.8% of stakeholders clearly expressed that they were willing to pay; and 11.3% were very willing to pay for DPCMs. In terms of the WTP, only 23.5% of the stakeholders can accept an amount equivalent to 1% of the *per capita* disposable income (i.e., 113 CNY) or above (Table 2). Most of the stakeholders' WTP was lower than the given value. Specifically, 32.6% were willing to pay less than 50 CNY, and 10.4% were willing to pay between 50 CNY and 75 CNY. Only 17.2% reported that they were not willing to pay.

3.2 WTP and ATP regarding environmental concern

The ATP and environmental concern were further analyzed to determine the responses of different people (Figure 2). Stakeholders exhibits the lowest environmental engagement among all, named institution-dependent group. This group was characterized by minimal environmental concern (63.8% never pay attention), the poorest public participation (83.4% did not join protection activities), and a distorted pollution perception where nearly half believe the water is pollution-free (47.2%). Critically, despite high confidence in governmental efficacy (52.8% deem policies effective), this group demonstrates reluctance to take personal action, reflecting deep reliance on institutional solutions rather than

individual responsibility. These stakeholders exhibit no willingness to pay for DPCMs. The Ambivalent-Concern Group demonstrates decision-making heavily influenced by external forces. This group exhibits the second-highest pollution alertness among all categories, with 39.5% perceiving severe water contamination. It also shows the strongest help-seeking tendency, as 73.5% would actively request assistance when facing environmental issues. However, behavioral autonomy remains severely constrained, with 32.0% blindly complying with government arrangements and 16.2% expressing complete indifference toward policy effectiveness. This creates a fundamental conflict where heightened environmental crisis awareness fails to translate into self-initiated actions, ultimately positioning this group as the silent majority in environmental governance. The tension between their cognitive recognition of ecological threats and behavioral passivity defines their ambivalent stance toward environmental responsibility. Therefore, their payment decisions demonstrate conformity with prevailing public opinion. The Responsibility-Cautious Group exhibits a marked disconnect between environmental concern and risk assessment. Despite showing moderate environmental awareness (30.7%–35.4% report frequent concern), this group displays the lowest severe pollution recognition (16.6%). Behavioral patterns indicate institutional reliance, with 22.1%–38.7% deferring to governmental directives. A pronounced intention-action gap is observed: while 72.4% express help-seeking willingness, only 25.2% engage in protection activities. This profile reflects cautious navigation between responsibility acknowledgment and consistent ecological threat underestimation. Their payment intentions demonstrate either



compliance with government policies or conditional willingness. The Autonomous-Action Group demonstrates endogenous responsibility-driven engagement across all dimensions. As the sole cohort exhibiting cognitive-behavioral synergy, this group displays the highest pollution awareness (55.8% perceive severe contamination) and rational policy trust (80.5% acknowledge effectiveness without blind compliance). Behavioral consistency is evidenced by universal help-seeking propensity (100%, exclusive to this group) and peak activity participation (71.7%). Payment commitment is absolute, with 100% expressing strong willingness to financially contribute. They show explicit commitment to payment.

Figure 3 depicts the environmental concern and the ATP for DPCMs. Among the people who were unwilling to pay, more than half (60.6%) did not care about environmental problems, 87.1% never participated in environmental protection activities, and 54.7% believed the government policy was effective or very effective. However, 60.6% of the stakeholders said they would seek help from others when environmental problems occurred, which is consistent with the characteristics of the dependent groups.

People who were willing to pay less than 50 CNY occasionally paid attention to environmental issues. They believed that the water environment was polluted, but their level of public participation was low. More than half (54.7%) thought the government's measures were effective, and others said they followed the government's policies (31.4%) or did not care whether the measures were effective (12.3%).

Those whose WTP was within 50–75 CNY and more than 125 CNY were occasionally concerned for the environment.

They had a higher level of public participation (58.3% and 45.3%, respectively), and most of these people (90.7% and 79.3%, respectively) said they would seek help from others when environmental problems occurred. A relatively high percentage of people thought the water environment was seriously polluted.

Those who were willing to pay 76–100 CNY and those who were willing to pay 101–125 CNY paid more attention to the environment and were often concerned it (37.3% and 48.4%, respectively), and most of them (74% and 56.3%, respectively) said they would seek help from others when environmental problems occurred. Their level of public participation was moderate compared to the other people.

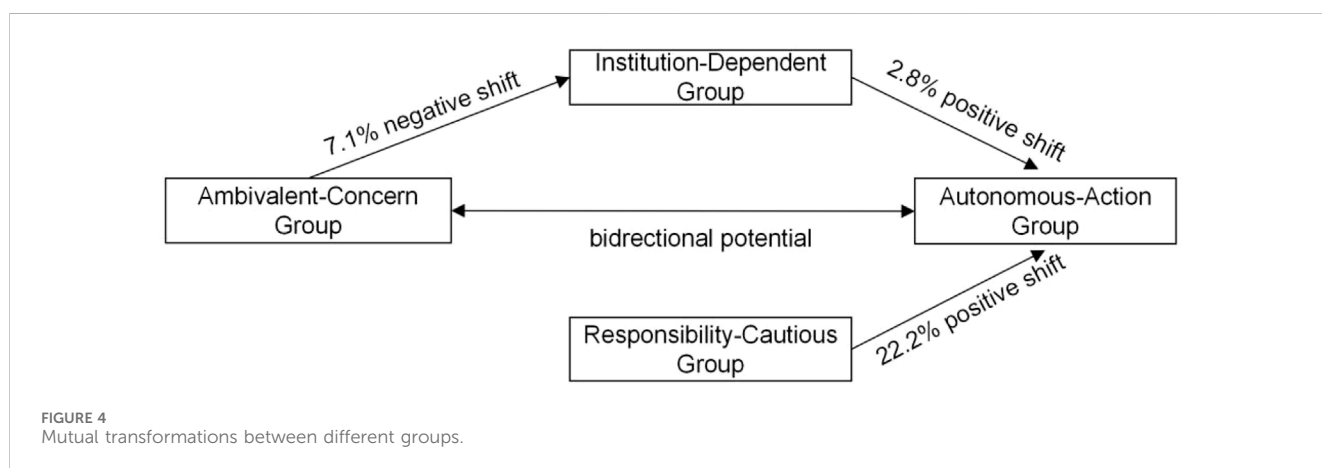
Those who were willing to pay more than 125 CNY paid attention to the environment occasionally (51.8%), most of them would seek help when the environment was in trouble (79.3%), about half of them would not participate in water environment protection activities, 34.3% thought that the water environment was slightly polluted, and 35.4% thought that the water environment was seriously polluted. Most people believed that government policies were effective (70.1%).

3.3 Cross-tabulation analysis and transformation mechanism analysis

Based on the behavioral typology and empirical data presented in Figure 2 and Table 4 of the manuscript, distinct transformation pathways exist among the four stakeholder groups regarding their engagement in diffused pollution control measures (DPCMs), as

TABLE 4 Cross-tabulation analysis between WTP and ATP.

WTP ATP	0	Less than 50 CNY	50–75 CNY	76–100 CNY	101–125 CNY	More than 125 CNY	Total
Unwilling to pay	97.2	0.0	0.0	2.8	0.0	0.0	16.3
Follow public opinion	7.1	67.9	10.7	7.1	0.0	8.9	25.3
Follow the government	0.0	36.1	8.3	19.4	13.9	22.2	16.3
Willing to	0.0	26.5	13.2	27.9	11.8	20.6	30.8
Very willing to	0.0	12.0	20.0	20.0	4.0	44	11.3
Total	17.6	32.6	10.4	16.3	6.3	17.2	100.0



shown in Figure 4. The institution-dependent group (characterized by minimal environmental concern, low participation, and reliance on institutional solutions) demonstrated limited but notable potential for positive transition. Specifically, 2.8% of this group expressed a willingness to pay amounts exceeding 125 CNY/year (Table 4), indicating possible progression toward more proactive engagement categories.

The ambivalent-concern group (exhibiting high pollution awareness but constrained behavioral autonomy) displayed heterogeneous payment behaviors. While 7.1% reported zero payment—aligning with institution-dependent tendencies—the majority (67.9%) were willing to pay below 50 CNY/year (Table 4). This dispersion suggests bidirectional mobility, where stakeholders could regress toward dependency or advance toward action-oriented groups depending on contextual influences.

Within the responsibility-cautious group (moderate environmental concern but underestimation of risks and institutional reliance), 22.2% of those complying with government policies exhibited higher payment levels (>125 CNY/year, Table 4). This subgroup holds potential for transition toward autonomous action, particularly through enhanced trust-building or participatory mechanisms.

The autonomous-action group (endogenous responsibility, cognitive-behavioral synergy, and high payment commitment) served as a stability anchor, with no observed regression to passive groups. Its members demonstrated consistent willingness-to-pay (WTP) alignment, where 100% expressed payment intent and 44% contributed >125 CNY/year (Table 4).

3.4 Different stakeholders' attitude and willingness to pay for DPCMs

3.4.1 Different types of stakeholders

Figure 5 shows the different types of stakeholders in terms of the payment amounts. Nearly half of the left-behind villagers (47.1%) expressed willingness to pay a certain amount for implementing and maintaining DPCMs, while 27.1% expressed reluctance to pay. The ATP was rather decentralized. Most of the migrant villagers did not have strong personal opinions and followed public opinion, thus having a close relationship with the public, or they heeded government policies. The amount these people were able to pay was concentrated between 0 and 50 CNY. They were usually absent from their residences all year round because their jobs were in urban areas. Overall, the volunteers had the highest WTP, and 85% of the volunteers expressed willingness to pay a certain amount for implementing the best management measures. Their payments were concentrated between 76 CNY and 100 CNY and above 126 CNY. Despite the willingness of all of the volunteers to pay, 11.1% of the volunteers exhibited inconsistency between willingness and action in terms of the payment amount for DPCMs.

In this study, we selected the middle value of the WTP range to calculate and compare the average WTP of the different stakeholders. The results of the weighted calculation are presented in Table 5. The volunteers were willing to pay the highest average amount (99 CNY), followed by the left-behind villagers (67.5 CNY), and the migrant workers were willing to pay the smallest amount (59.5 CNY).

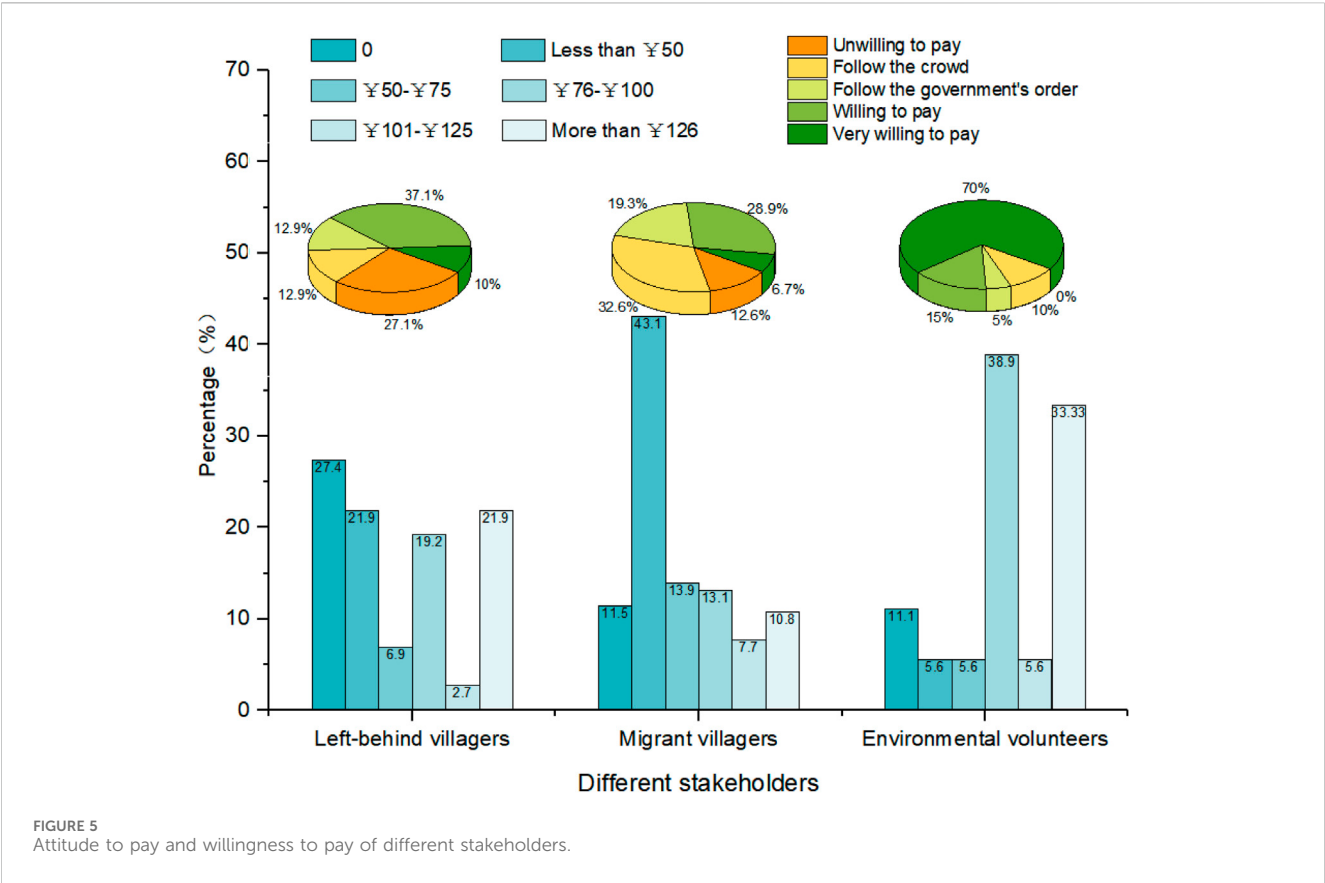


TABLE 5 Different stakeholders' WTP.

Willingness to pay range (CNY)	Middle value (CNY)	Left-behind villagers	Migrant workers	Environmental volunteers
0	0	27.4%	11.5%	16.7%
Less than 50	25	21.9%	43.1%	5.6%
50–75	62.50	6.9%	13.9%	5.6%
76–100	88	19.2%	13.1%	38.9%
101–125	113	2.7%	7.7%	5.6%
126–150	138	1.4%	0.8%	5.6%
151–175	163	13.7%	4.6%	0.0%
176–200	188	4.1%	0.8%	5.6%
201–225	213	2.7%	4.6%	16.7%
Average value [yuan/(capita year)]		67.5	59.5	99.0

3.4.2 Different counties

As shown in Figure 6, the ATP and WTP in the three counties exhibited some differences. Compared with Luanping County and Fengning County, the ATP of the stakeholders in Miyun County was relatively dispersed, among which 27.9% were unwilling to pay, 15.5% followed the public opinion, 14.7% followed the arrangement of the government, 34.9% were willing to pay, and 7% were very willing to pay. The payment amount exhibited polarization, and

most of the stakeholders were willing to pay less than 50 CNY or more than 126 CNY.

In Luanping County, 53.8% of the interviewees were willing to pay and 15.4% were very willing to pay. The proportion of people who were willing to pay ¥50–¥75 CNY was the largest. However, the stakeholders in Fengning County showed clearly no ATP. No one expressed a willingness to pay ¥0, and the vast majority of people's ATP was <¥50 CNY.

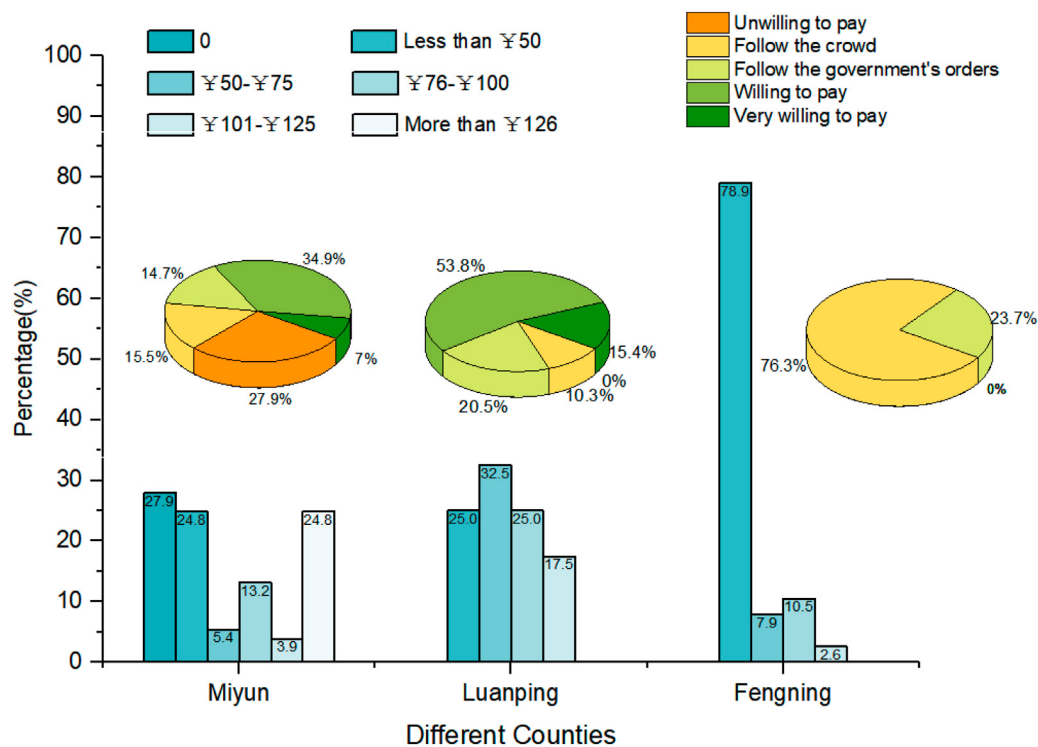


FIGURE 6
Attitude to pay and willingness to pay of stakeholders in different counties.

TABLE 6 Different counties' WTP.

ATP (CNY)	Mid-value	Miyun	Luanping	Fengning
0	0	27.9%	0	0
Less than 50	25	24.8%	25.0%	79%
50–75	62.50	5.4%	32.5%	7.9%
76–100	88	13.2%	25.0%	10.5%
101–125	113	3.9%	17.5%	2.6%
126–150	138	3.1%	0	0
151–175	163	12.4%	0	0
176–200	188	3.1%	0	0
201–225	213	6.2%	0	0
Average annual payment (CNY)		69.1	68.3	36.9
Payment amount as a percentage of disposable income		0.36%	0.85%	0.54%

By calculating the ability of the stakeholders in the three counties to pay (Table 6), it was found that the maximum payment amount was ¥69.1 CNY in Miyun County, followed by Luanping County (¥68.3 CNY) and Fengning County (¥36.9 CNY). All three counties paid less than 1% of the *per capita* disposable income. The payment amount in Fengning County accounted for 0.54% of the *per capita* disposable income, while that in Miyun County accounted for 0.36% of the *per capita* disposable income, and that in Luanping County accounted for 0.85% of the *per capita* disposable income.

3.5 Multiple linear regression analysis with willingness to pay as a variable

In the multiple linear regression analysis we conducted, we selected the amount to pay (y) as the dependent variable and gender (x_1), age (x_2), education (x_3), annual income (x_4), environmental concern (x_5), perception of environmental pollution (x_6), attitude toward government policy (x_7), willingness to pay (x_8), public participation (x_9), and willingness to ask for help (x_{10}) as

TABLE 7 Regression analysis results for the willingness to pay.

Category	Stakeholder groups	Samples	Fitting equation	Independent variables	Significance
Different counties	Fengning	38	$y = 1.362 - 0.613x_1 + 0.762x_8$	Gender (x_1)*, willingness to pay (x_8)**	0.000
	Luanping	40	$y = 4.093 - 0.537x_6$	Perception of environmental pollution (x_6)**	0.019
	Miyun	125	$y = -1.464 + 0.699x_3 + 1.135x_8 + 1.646x_9$	Education (x_3), willingness to pay (x_8)**, public participation (x_9)*	0.000
Different stakeholders	Left-behind villagers	135	$y = -0.917 + 0.575x_3 + 0.926x_8 + 1.605x_9$	Education (x_3), willingness to pay (x_8)**, public participation (x_9)*	0.000
	Migrant workers	68	$y = 1.037 - 0.917x_1 + 0.310x_4 + 0.896x_8$	Gender (x_1)*, annual income (x_4)**, willingness to pay (x_8)**	0.000
	Volunteers	18	$y = 6.427 - 4.057x_1 + 1.445x_8$	Gender (x_1)*, willingness to pay (x_8)**	0.001

the independent variables. The factors influencing the WTP were analyzed using the stepwise regression method.

The regression analysis results (Table 7) reveal that various factors affected the WTP among the stakeholders in the different counties. Specifically, the factors influencing the WTP varied across the counties. In Fengning County, a positive attitude toward paying was associated with a higher payment amount. Conversely, gender had a negative influence, with women demonstrating a lower WTP compared to men. In Luanping County, a perception of severe environmental pollution negatively affected the WTP, i.e., those who perceived the pollution to be more severe were willing to pay less. Notably, those who believed that those who cause the pollution should pay tended to have a corresponding attitude toward their WTP as the pollution severity increases. In Miyun County, both the education level and public participation positively influenced the WTP, with a higher education and greater involvement in public activities corresponding to higher WTP.

For the different stakeholders, their WTP was positively affected by their attitude toward paying. The left-behind villagers were also affected by the education level and public participation. The annual income and ATP had positive effects on the migrant workers' WTP. For the migrant workers, they mainly left the rural area to work in cities for higher wages. Therefore, their income level had a great influence on their WTP. The higher their income was, the higher the WTP was. The volunteers' WTP was influenced by gender and the ATP. As with the other gender-influenced groups, the women's WTP was lower than the men's WTP.

3.6 Factors influencing amount to pay

Understanding what drives ATP can provide rich information for sustainable regional environmental management. The random forest regression analysis (Figure 7) demonstrated that the model achieved a variance explanation of 86.5% (test set $R^2 = 0.865$) for the target variable "affordable amount," significantly exceeding the predefined threshold of 85%, thereby validating the rationality of feature selection. Feature importance analysis revealed that WTP (importance score = 0.318) and income level (0.195) were the core drivers, collectively accounting for 51.3% of the explanatory power, highlighting the direct association between economic capacity and individual payment

decisions. Secondary factors included education level (0.142), age (0.121), and evaluation of government policies (0.098), indicating moderating effects of sociodemographic structure and trust in policies on payment behavior. In contrast, the negligible impacts of gender (0.005) and tendency to seek help (0.002) suggested weak correlations with environmental payment behavior.

4 Discussion and policy implications

4.1 More developed areas vs. less developed areas

The Chinese central government has made substantial investments in rural development under national policy frameworks (Ye et al., 2018). However, this investment has been imbalanced, contributing to widening regional disparities (Liu et al., 2013), as evident in the contrasting cases of Miyun, Fengning, and Luanping counties. Miyun County, located within Beijing, benefits significantly from strong municipal government investment, resulting in a more advanced economic status and environment quality compared to the other two counties situated in Hebei province. Meanwhile, this high levels of government intervention fostered stakeholder dependency. This dependency, potentially diminishing their perceived personal responsibility and initiative (evidenced by sentiments like "If the government handles it, why should I pay extra?"), can lead stakeholders to perceive individual contributions as less impactful, thereby reducing their incentive to pay. As for Fengning County, it is one of Hebei's poorest counties. According to conventional economic theory, assuming baseline environmental quality is constant, stakeholders with higher incomes are generally expected to demonstrate a greater willingness to pay (WTP) for environmental protection than those with lower incomes (Ivanova and Tranter, 2004). Consistent with this expectation, poor economic development in Fengning County has led to noticeably lower absolute payments for environmental protection compared to the other two counties.

However, this economic disparity in payment levels does not fully capture local environmental attitudes. A previous study in the region revealed that Fengning County exhibited higher NPS pollution (Geng et al., 2015) and the highest acceptance of environmental best management practices (Du et al., 2019), suggesting a strong

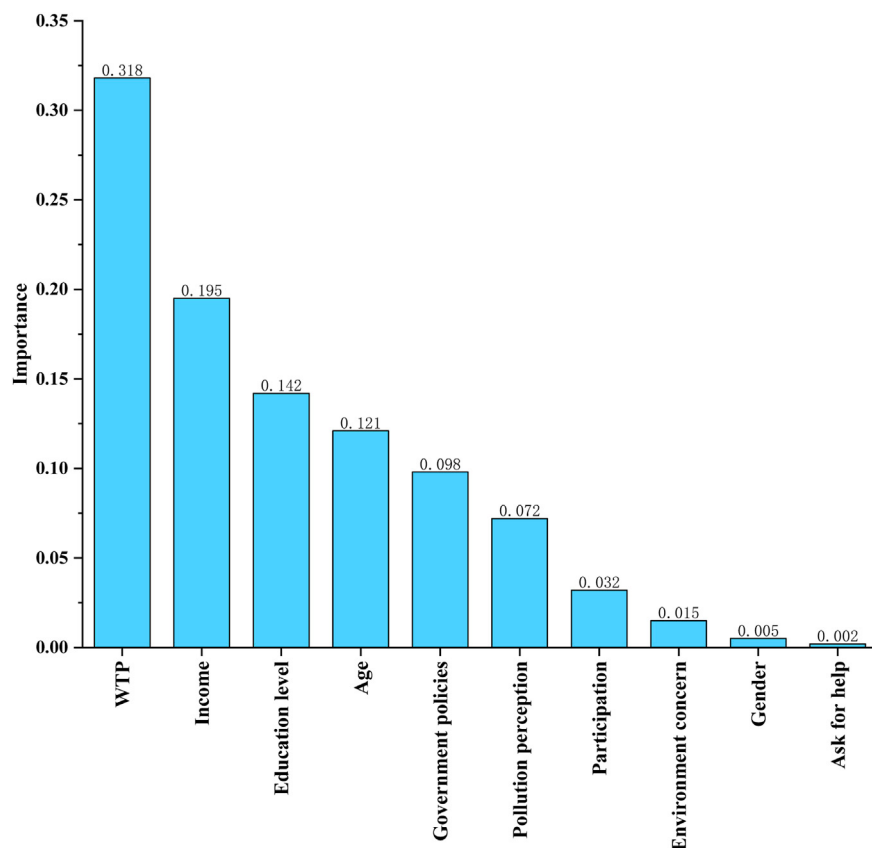


FIGURE 7
Factor importance ranking derived from the random forest model.

underlying desire for environmental improvement despite economic constraints. Furthermore, our own findings indicate a more nuanced picture: stakeholders in the less developed Fengning County were actually willing to pay a higher proportion of their income towards environmental protection compared to stakeholders in the relatively affluent Miyun County. This is consistent with some research that people in less developed and rural areas are more likely to have pro-environmental attitudes and behaviours, since they are deeply aware of the adverse effects of environmental pollution (Liu et al., 2020; Wang et al., 2019; Andrew et al., 2024). Indeed, research suggests that the more individuals condition their own environmental behavior on the actions of others, the lower their fundamental willingness to pay tends to be (Wang et al., 2010; Meyer and Liebe, 2010).

Therefore, beyond government funding, it is crucial to enhance the enthusiasm and initiative of stakeholders to participate in environmental management. Cultivating this intrinsic motivation is essential for ensuring the long-term effectiveness of environmental initiatives.

4.2 Personal responsibility vs. social responsibility

To some extent, the difference in the WTP and attitude toward paying reflects the differences in the individual responsibility felt by the different stakeholders. Survey results indicated that environmental

volunteers, who participated in more environmental protection activities and demonstrated greater environmental awareness, consequently exhibited a stronger sense of social responsibility. This sense of personal responsibility—reflecting an individual's feeling of obligation to support DPCMs and environmental management (Piyapong et al., 2019)—directly influenced their willingness to pay, with volunteers contributing ¥99 CNY toward DPCM implementation and maintenance. In contrast, migrant workers reported the lowest willingness to pay at ¥59.5 CNY.

The reason for this is that although they resided in the countryside, they had a lower sense of belonging to the town in which they resided since they spent a long period of time in the city to work. They enjoyed an urban education, medical services, and other services, and they had no strong desire to support rural development, so they had a lower sense of responsibility. Regarding the left-behind villagers, they had been living in the countryside for a long time and had higher requirements regarding the rural conditions. However, due to the limitations of the economic level, even though they had a strong sense of personal and social responsibility, they could not afford to pay much (¥67.5 CNY), but they paid more than the migrant workers.

Usually, stakeholders focus more on their interests, while the government often designs policies and measures from the perspective of managers without considering the stakeholders' perspectives (Lafreniere et al., 2013). Further efforts are needed to integrate the individual responsibilities of different stakeholders

into social responsibilities. Rather than only analyzing stakeholder relationships, it is also necessary to determine the structural relationships between the stakeholders and the diversified issues with which stakeholders are associated. A possible way to achieve this is to establish a round-table mechanism and make participation meaningful through round-table negotiations (Holifield and Williams, 2019). In addition, the simultaneous participation of multiple stakeholders can monitor and promote transparency of the local government regarding environmental management and the use of funds, eliminate their concerns about the use of funds, and improve the credibility of the government.

4.3 Verbal promises vs. practical actions

In this study, it was assumed that the attitude toward paying represents a verbal promise, while the WTP represents practical action. Although not strongly prevalent, this phenomenon was observed in our study. However, it should be noted that some respondents expressed willingness to pay in principle but ultimately reported a payment amount of zero. This represents a willingness to pay but a change of mind in the context of the payment amount involved. These people are mainly environmental volunteers, among whom 11.1% (2 people) expressed willingness to pay to follow the public opinion, but the amount of payment was ¥0. The general situation in China is that the public is concerned about the outcome of environmental management but has no understanding of the policy-making process and how to participate in governance. This leads to high environmental concerns and low participation (Li, 2018). This is why the verbal promises and practical actions of some stakeholders' are inconsistent; that is, an increase in pro-environmental awareness does not always yield consistent pro-environmental activity (Du et al., 2019; Wang et al., 2010). An ambivalent attitude reflects the simultaneous existence of positive and negative dispositions (Costarelli and Colloca, 2004) toward the WTP, which is a strong predictor of behavioral intentions.

In this research field, in-depth research on the causes of stakeholders' ambivalence has not been conducted. Yet, research in 32 countries has revealed that the association between concern and behavior was weaker in societies characterized by higher levels of distrust, belief in external control, and the present orientation (Tam and Chan, 2017). In addition, previous studies have pointed out that regardless of the objective and subjective reasons, ambivalent people are likely to have a low behavioral intention to act in an environmentally friendly manner (Thompson et al., 1995). Moreover, this could be an important predictor of environmental behavior. The underlying causes are complex, including social, political, economic, and other factors, so policies involving the environmental behavior of stakeholders need to be carefully formulated.

4.4 Top-down approach vs. bottom-up approach

Environmental governance is a dynamic process in which conflicts and interests among various stakeholders need to be negotiated and coordinated (Zhang et al., 2019). A top-down approach (initiated by a government agency, NGO, or

government-funded adviser to deliver public policy) is most common in projects with primarily public benefits, such as managing protected areas (Prager, 2015). China's centralized model has faced criticism for marginalizing public participation in environmental decision-making (Chunmei and Zhaolan, 2010). Public frustration with the government may stem from policy alienation (Tummers, 2012) and a lack of institutional trust (Macaulay et al., 2022). It has led to a passive acceptance of policy, as well as minimum efforts or inaction, rather than proactive changes and adaptation based on their own interests (Dermont et al., 2017). That is when policies neglect community participation, payment behaviors exhibit a "passive compliance" feature rather than active support (Chen et al., 2016), such as passive acceptance of energy infrastructure projects (Anderson et al., 2012; Aaen et al., 2016).

The results of this study show that the degree of the public participation of stakeholders was relatively low in our study area. Obedience to the government's arrangement is ostensibly a belief in the government, but in actuality, the stakeholders are powerless under the top-down policy. This is why many stakeholders choose to follow public opinion or to follow the government arrangement without a clear opinion. This also provides a new idea for environmental management. Bottom-up advisory processes involve actively encouraging the participation of local stakeholders as producers rather than only as receivers of knowledge of a policy created using the top-down approach (Reinecke, 2015).

International experience provides evidence that good role models can impact grass-root people (Crofton and Mitchell, 1998). In rural China, the influence of role models has a great potential because of the complex interests of stakeholders in the same village. Government credibility and good or bad role models can cause mutual transformation between different stakeholder groups (Figure 4). Thus, instead of restricting the involvement of stakeholders in environmental management, governments should give them more opportunity to participate in policy-making that could effectively deal with environmental problems (Glasbergen, 2000). Yet, in a complex rural context, the lack of a systematic bottom-up participation mechanism could cause management confusion and conflicts of interest. One international success story involved incorporating broad participatory (or bottom-up) and expert-led (or top-down) methods (Failing et al., 2007; Prager, 2015). It is widely recognized, particularly in Europe and also increasingly in North America, that both science and local stakeholder knowledge are important in decision making (Failing et al., 2007; Fraser et al., 2006; Ye et al., 2018).

Critically, the bidirectional transitions in Figure 4 highlight how top-down policies may inadvertently reinforce dependency (e.g., high government trust but low initiative in the "dependent" group), whereas bottom-up approaches—such as local role models (e.g., volunteers' high WTP) and participatory budgeting—could catalyze positive shifts from "wait-and-see" to "proactive" engagement.

4.5 Limitations

As the region is predominantly mountainous with scattered village distribution, we encountered practical challenges specific to the population characteristics (e.g., migrant workers being absent from households), resulting in the final sample size falling short of

the ideal target. While stratified random sampling was implemented to enhance sample representativeness, this study has several key limitations. First, we acknowledge that a larger sample would be desirable. However, our sample size ($N = 221$) is comparable to many rigorous contingent valuation studies in environmental economics conducted in rural settings (Fu et al., 2022). Future research should aim to recruit a larger and more demographically diverse sample from a broader geographic area to enhance the generalizability of the findings and allow for a more robust estimation of public willingness to pay. Second, our participant pool focused exclusively on farmers (including both left-behind villagers and migrant workers) and local volunteers, thereby excluding key stakeholders such as entrepreneurs, tourists, and government regulators within the watershed. The absence of multi-stakeholder perspectives—particularly from policymakers and tourism operators—limits the generalizability of findings to broader environmental governance contexts. Prior evidence suggests that integrating organizational preferences (e.g., cost-benefit thresholds for industries) with individual WTP can significantly improve the implementation efficacy of pollution control measures (Ren et al., 2020; Zhang et al., 2023). Future studies should prioritize multi-agent surveys to establish inclusive policy frameworks that balance ecological integrity with socioeconomic development. Third, while the inclusion of volunteers adds important participants to the study, it must be noted that these individuals are characterized by a high level of enthusiasm, sense of identity, and responsibility toward water environmental protection. Their perspectives, attitudes, and willingness to pay (WTP) are not representative of the general public. Since the sample consists of self-selected environmentally concerned individuals, their strong intrinsic motivation and values lead them to demonstrate a willingness to pay far above the societal average. However, the purpose of this study is not necessarily to estimate the average WTP of the entire population but rather to identify and understand the “key group” or “core supporters” who are most likely to pay for environmental protection. This is crucial for assessing whether an environmental project has a dedicated group of supporters willing to contribute financially. They represent the most potential contributors to mechanisms such as crowdfunding and ecological compensation funds. Additionally, non-response bias is a common limitation in survey-based studies. It is possible that individuals with more strong opinions (either positive or negative) were more likely to participate. This could mean that our results reflect the views of the more engaged stakeholders rather than the entire population.

5 Conclusion and policy implications

This study systematically analyzed the willingness-to-pay (WTP) of 221 rural stakeholders (volunteers, villagers, migrants) in North China through environmental concern and income-proportional frameworks, offering novel insights for diffused pollution control measures (DPCMs). Our findings provide direct answers to the three research questions posed:

1. Regarding environmental concern across stakeholders, we identified four distinct behavioral archetypes—Institution-

Dependent, Ambivalent-Concern, Responsibility-Cautious, and Autonomous-Action Groups. This typology reveals that environmental concern is not monolithic but varies systematically across stakeholders, reflecting divergent motivations and levels of commitment to environmental stewardship.

2. Concerning the magnitude of WTP for DPCMs, we found significant disparities. While absolute payments were comparable across economic strata (68.3 CNY/year in less-developed Luanping vs. 69.1 in wealthier Miyun), relative contributions revealed a striking paradox: lower-income respondents contributed a substantially higher proportion of their income (0.85% vs. 0.36%). Furthermore, volunteers demonstrated exceptional absolute WTP (99 CNY/year), exceeding both villagers (67.5) and migrants (59.5), highlighting the role of non-economic drivers in volunteer participation.
3. On the relationship between environmental concern and WTP, random forest analysis quantified this linkage, identifying WTP (importance = 0.318) and income (0.195) as dominant predictors, collectively explaining 51.3% of variance. Environmental concern, as captured through the behavioral typology, emerged as a primary driver, while socio-demographic factors (education, age, policy evaluation) played secondary moderating roles. Gender and help-seeking propensity showed negligible effects, refining our understanding of the determinants of environmental payments.

These results highlight that effective DPCM strategies should incorporate economic capacity, policy trust, and varied stakeholder motivations. We therefore propose: tiered contribution systems based on income; targeted subsidies for low-income groups; and participatory monitoring involving locals in oversight to improve transparency and credibility. Future work should prioritize not only long-term behavioral studies but also practical collaborations with policymakers to co-design and pilot these mechanisms—especially subsidies and co-management frameworks—assessing their real-world impact to enable scalable, sustainable pollution governance in comparable regions.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The requirement of ethical approval was waived by the College of Resources and Tourism, Capital Normal University for the studies involving humans because the research involved anonymous surveys that posed minimal risk to participants. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

YD: Conceptualization, Data curation, Methodology, Writing – original draft, Writing – review and editing. XW: Conceptualization, Funding acquisition, Project administration, Supervision, Writing – review and editing. TL: Formal Analysis, Investigation, Writing – review and editing. KL: Software, Validation, Writing – review and editing. ZN: Formal Analysis, Methodology, Software, Writing – review and editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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