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Residents' acceptability and response to the water-pricing policy to reduce marine pollution caused by domestic sewage

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Domestic sewage has huge negative impacts on the marine environment. This paper discusses whether residents can accept the water-pricing policy that collects funds to improve sewage treatment technologies to reduce marine pollutants by raising water prices. First, the contingent valuation method is used to elicit residents' acceptability of a water-price increase. Second, the contingent behavior method is applied to observe residents' responses to the pricing policy. The results show that residents can accept an increase of 0.90 CNY/m^3 in water price on average in Qingdao, China. We also find that people with low income show low acceptability of the water-pricing policy. Additionally, the water price plays a positive role in promoting residents' willingness to reduce water use. The information transmission will encourage people to adopt water-saving behavior and strengthen the impact of the water-pricing policy on water-saving behavior. This paper provides important implications to establish a water-pricing policy to reduce the negative impacts of domestic sewage on the marine environment.

KEYWORDS

domestic sewage, water-pricing policy, willingness to pay, water-use behavior, Qingdao

1 Introduction

With rapid growth of the economy in the coastal zone in China, marine pollution has led to many marine environmental problems and becomes an important issue (Fu et al., 2018; Shan et al., 2019; Wang et al., 2021). Suggested by previous studies, approximately 80% of marine pollutants come from land-based sources (Hildering et al., 2009), and domestic sewage is one of the most important land-based sources. According to the "Bulletin of Marine Ecology and Environment Status of China," China's domestic sewage discharge showed an overall upward trend from 733.85 million tons in 2017 to 806.02 million tons in 2021. Beyond that, it can be seen that pollutants discharged from domestic pollution sources contained a variety of nutrients and heavy metals, e.g., 61 domestic pollution sources tested emitted 23,004 tons of chemical oxygen demand and 8,363 tons of total nitrogen in 2019. That is, domestic sewage will be an important source of marine pollutants for a long time in China, and will eventually lead to a series of environmental problems, such as eutrophication of water bodies and heavy metal pollution. Therefore, it is critical to analyze the characteristics of domestic sewage and adopt feasible measures to manage the marine pollution problem caused by domestic sewage.

The characteristics of domestic sewage are reflected in two aspects: the large amount of domestic sewage discharge and low standard of sewage treatment. During the 13th Five Year Plan period in China, the newly built sewage treatment facilities are mainly small and medium sized, and they could not achieve economies of scale and, thus, cause low operation efficiency of sewage treatment plants (Zhou et al., 2020). More importantly, we found that, although the sewage disposal rate is relatively high, the quality of water discharged by urban sewage treatment plants is still inferior to the Class IV[1] of Environmental Quality Standards for Surface Water announced by the State Environmental Protection Administration of China in 2002. Take the chemical oxygen demand as an example: The most stringent discharge standard of a municipal wastewater treatment plant is 50 mg/L, whereas the required criteria for Class IV surface water quality is 40 mg/L. That is, water discharged after treatment will still cause damage to the environment. Therefore, the sewage treatment technologies need to be improved to reduce the negative impacts of domestic sewage on the marine environment. Additionally, it is worth noting that the government should take some measures to promote public involvement in sewage treatment (Tong et al., 2014). The sewage treatment charges paid by residents only cover the operation costs of sewage treatment plants in most areas of China, and the operation of sewage treatment plants still depends on the government's financial subsidies (Tan et al., 2015a), which causes financial pressure and low efficiency of technological upgrades. Based on the polluter-pays principle, residents have the responsibility to bear the costs of the treatment of domestic sewage. Therefore, making a water-pricing policy to collect funds for improving sewage treatment technologies is a possible solution for reducing the marine pollution caused by domestic sewage.

To sum up, this paper aims to explore whether residents are willing to participate in marine pollution management and accept a water-pricing policy that refers to the increase of water prices to raise funds for the technology upgrades of domestic sewage treatment plants to reduce the adverse impacts on the environment in the context of China. Our article contributes to the literature in the following three ways. First, this paper seeks to determine residents' acceptability to the water-pricing policy through investigating the public's willingness to pay (WTP) for upgrading sewage treatment technologies to improve water quality after treatment. Combined with water consumption, WTP is used to reflect the maximum acceptability of the water-pricing policy to manage pollution among residents in Qingdao, China. In addition, we make efforts to observe the differences of residents' acceptability of the pricing policy among different income groups. Furthermore, this paper explores the increase in water prices from the perspective of the cost of technology upgrades and compares it with residents' WTP to find a proper level of water-price increase to formulate the water-pricing policy. Second, the water-pricing policy may have a negative impact on residents' welfare through raising the cost of water use. The public may have psychological conflicts, which will reduce the effectiveness of the policy implementation. Therefore, it needs to investigate residents' opinions on the water-pricing policy. The change in residents' water consumption is used to represent residents' opinions in this paper. Furthermore, residents' reducing water consumption also can be considered as a water-saving behavior, which would help to reduce the amount of domestic sewage discharge and marine pollutants. Therefore, we use the contingent behavior (CB) method to construct six price-increase scenarios as different policy contexts and observe the effects of price increase on residents' water-use behavior in Qingdao, China. Third, respondents are divided into a treatment group that is presented with environmental improvement information and a control group that does not receive the message to examine the impact of information transmission on residents' water-use habits. Additionally, we pay attention to testing the moderating effects of information transmission on the impacts of the water-pricing policy, environmental perception, and media attention on water-conservation behavior.

The remainder of the paper is structured as follows. The following section presents a review of the existing literature related to the paper. Section 3 provides details about the survey and data. Sections 4 and 5 give the estimation strategy and empirical results. The last section draws conclusions and presents policy implications.

2 Literature review

2.1 WTP for marine water quality improvement

Marine water pollution control receives the wide attention of people from all walks of life. Many articles provide estimates of the values of marine water-quality changes from the perspective of cost and benefit (Barton, 2002; Vesterinen et al., 2010; Czajkowski et al., 2017; Peng and Oleson, 2017) and indicate that water pollution control could generate substantial nonmarket benefits (Machado and Mourato, 2002). Some focus on the assessments of the values of marine water quality improvement. For example, Jones et al. (2008) estimate that residents were willing to pay 16.84 euro every 4 months over a period of 4 years for the project of constructing a sewage treatment plant in Mitilini, Greece. Tuhkanen et al. (2016) find that the average WTP for improving the marine water quality to achieve good environmental status was around 65 euro per household per year in Estonia. The studies report that a large number of respondents were willing to pay for the hypothetical water quality improvement projects proposed in the surveys (Wang et al., 2013a; Wang et al., 2013b). Furthermore, the factors that affect WTP were also studied for understanding respondents' preference heterogeneity (Martin-Ortega et al., 2012). Early articles paid attention to analyzing the impacts of socioeconomic characteristics (Larue et al., 2017; Pakalniete et al., 2017). Subsequently, papers began to test the influences of the psychological factors (Aguilar et al., 2018), multiple substitutes, and distance decay (Bateman et al., 2006; Jørgensen et al., 2013; Choi and Ready, 2021). For example, Šebo et al. (2019) find that respondents' knowledge about the environmental problems concerning the lake demonstrated a positive impact on WTP. In summary, the existing

1 Class IV surface water quality: The water is applicable for the areas of general industrial protection and the entertainment areas where the water does not contact with human body directly.

articles about people's WTP for improving marine water mainly focus on the total amount of payment. Different from previous studies, this article combines the WTP for improving marine water quality with household water consumption to explore people's acceptability of the water-pricing policy.

2.2 Factors influencing water-use behavior

The huge amount of water consumption and inefficient sewage treatment technologies pose a serious threat to the marine environment. Therefore, it is necessary to analyze the factors affecting water consumption to ensure efficient use and provide implications for promoting water-saving behavior, which could eventually reduce the amount of domestic sewage discharge. First of all, price is an important factor to determine residential water consumption (Renwick and Green, 2000; Marzano et al., 2020). Although some previous studies argue that water demand is price inelastic (Arbués et al., 2003; Jiang et al., 2016), the investigations clearly demonstrate that price played an important role in residents' water-use behavior. High prices could let residents reduce water consumption significantly (El-Khattabi et al., 2021). Some studies further find that short-term price shocks can induce long-term behavioral changes (Zetland, 2021). Therefore, water-pricing strategy is an effective tool for policymakers to manage water consumption (Zhao et al., 2016; Du et al., 2021). Furthermore, research also shows that residents' water-use behavior is a mixed function of many factors (Kenney et al., 2008). Both demographic characteristics (Schleich and Hillenbrand, 2009; Tong et al., 2017; Araya et al., 2020) and behavioral and psychological variables (Dolnicar et al., 2012; Fielding et al., 2012; Beal et al., 2013) were found to affect water consumption. For example, Russell and Knoeri (2020) find that attitudes, subjective norms, and personal normative beliefs had positive impacts on water-conservation behavior. In addition, some environmental factors, such as climate and geography, were also found to have influences on water-use behavior (Abu-Bakar et al., 2021). For example, humid and rainy weather increased household water consumption by increasing the frequency of body cleaning and clothes changing (Fan et al., 2017).

In conclusion, the determinants of domestic water use are highly complex and diverse. However, it is difficult to evaluate the potential welfare of residents caused by future water price policy based on existing literature. Therefore, this paper evaluates the impact of water-pricing policy on residents' water-use behavior and controls the effects of residents' perception of the marine environment, attention to the relevant reports, and socioeconomic characteristics. Meanwhile, a treatment group in which respondents are shown information that the water-pricing policy will lead to the improvement of marine water quality eventually and a control group in which respondents do not receive the message of environmental quality improvement are constructed to observe the impact of the transmission of positive information on residents' environmentally friendly behaviors.

3 Methods

3.1 Survey instrument

The data for this study were compiled from respondents' responses to two types of questionnaires, which were designed to explore residents' water-use behaviors and the acceptability of the water-pricing policy. We carried out three pretests around the Ocean University of China from November 2019 to April 2020 and then revised and improved the questionnaire according to feedback. Subsequently, we commissioned a professional questionnaire distribution platform to deliver the online questionnaires randomly to its sample database in Qingdao, China, June to July 2020.

The final questionnaire of the treatment group consisted of five sections. The structure of the questionnaire is shown in Figure 1. The first section gave a brief introduction to the background and purpose of the investigation to ensure that the respondents answered the questions as truthfully as possible. In the second section, respondents were asked about their attitudes toward the marine environment, the perception of the impact of marine environmental damages, and the attention to relevant reports. The third section started with residents' attitude to the following question: Do you think domestic sewage will cause damage to the marine environment and investigated residential water consumption and water charges. Then, it elicited respondents' WTP for improving domestic sewage treatment technologies to let the water quality meet Class IV of the Environmental Quality Standards for Surface Water (EQSSW, GB3838-2002). The fourth section constructed six pricing-policy scenarios to inquire about the changes of residents' water-use behavior. The final section investigated respondents' socioeconomic characteristics concerning gender, age, education, family members, personal gross income, family gross income, etc.

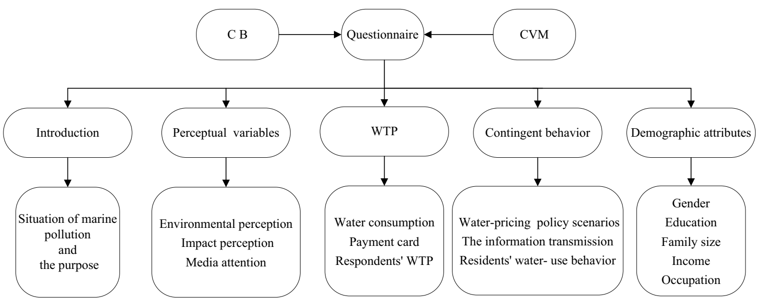

FIGURE 1
The structure of the questionnaire.

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Different from the questionnaire for the treatment group, the purpose of the water-price increase was not mentioned in the control group. In other words, it only presented the scenarios of the increase in water price in the fourth section.

3.2 Measures

3.2.1 WTP for improving marine water quality

Respondents' WTP for improving domestic sewage treatment technologies to let the water quality meet Class IV of the Environmental Quality Standards for Surface Water (EQSSW, GB3838-2002) were elicited by the contingent valuation method. The WTP was elicited by a payment card because it can increase response rates compared with open-ended formats and is easy to carry out compared with dichotomy formats (Xu and Shan, 2018). The payment card was divided into 14 levels, which ranged from 0 CNY/a to more than 500 CNY/a (the WTP of each level is shown in Appendix A), and the gaps between smaller levels of WTP were designed to be smaller according to the results of our pretest survey. We mitigate hypothetical bias in four ways. First, we gave a brief introduction about the background of the sewage treatment technologies and the benefits of technology improvements for the marine environment prior to asking questions to ensure that respondents were informed about the situation. Second, we presented pictures of the marine environment before and after sewage technology upgrades. Third, we emphasized that the hypothetical scenario will be achieved after 5 years of efforts. Finally, we used water charges as a payment vehicle because sewage treatment charges are included in the water price in China.

3.2.2 Contingent behavior

The changes of residents' water consumption when people face different pricing-policy scenarios are learned by using the contingent behavior method, which elicits information about behavior under hypothetical scenarios (Rolfe and Gregg, 2012). The pricing-policy scenarios are divided into six levels, i.e., the water price would increase by 0.2, 0.5, 0.8, 1.0, 1.5, and 2.0 CNY/m^3. For each price increase level, a five-point Likert scale ranged from "1 = no change" to "5 = enormous reduction" was given to explore respondents' changes in water consumption. Additionally, the questionnaires were divided into two categories. In the treatment group, we emphasized that the funds collected by the water-pricing policy will eventually be applied to the upgrading of sewage treatment technologies and improve the marine environment, whereas in the control group, we only presented the scenarios of the water policy. The two types of questionnaires were randomly assigned to respondents.

3.2.3 Other measures

We asked about respondents' attitudes toward the marine environment, perception of the impact of marine environmental damages, and attention to relevant reports. These items were measured using five-point Likert scales. The details and summary statistics are presented in Table 1. Confirmatory factor analysis is an important analysis tool to investigate the causal relations among latent and observed variables, so we applied it to test the three latent variables, including marine environmental perception, impact perception, and media attention. In general, all the constructs demonstrated adequate internal consistency (Cronbach's alpha: above 0.75, regression weight: above 0.75, composite reliability: above 0.85, and average variance extracted value: above 0.60). In addition, principal component analysis was used to generate proxy variables of the three latent variables for the subsequent analysis.

3.3 Sample

A total of 865 samples of the questionnaires were collected through an online survey during June to July 2020. However, some

TABLE 1 Measurement items.

Variables	Description	Mean (S.D.)	Options (1 to 5)	β
Marine environmental perception (α=0.76, AVE=0.68, CR=0.86)	Rate how serious, you think the seawater pollution in Qingdao	3.06(0.91)	(not serious, very serious)	0.86
	Rate how clear, you think the seawater in Qingdao	2.85(0.86)	(very clear, very turbid)	0.81
	Rate how serious, you think *U. prolifera* bloom in Qingdao	3.02(1.00)	(not serious, very serious)	0.79
Impact perception (α=0.82, AVE=0.73, CR=0.89)	Please rate, in terms of the extent of economic development, the severity from marine environmental damages	2.80(1.05)	(very serious, no serious)	0.85
	Please rate, in terms of the extent of the quality of residents' life, the severity from marine environmental damages	2.72(1.06)	(very serious, no serious)	0.86
	Please rate, in terms of the extent of the lives of other organisms, the severity from marine environmental damages	2.29(1.06)	(very serious, no serious)	0.86
Media attention (α=0.84, AVE=0.75, CR=0.90)	Attention to related televised coverage of marine environment	3.10(1.05)	(no concern at all, very concerned)	0.86
	Attention to WeChat Official Accounts coverage of marine environment	3.11(1.08)	(no concern at all, very concerned)	0.87
	Attention to Internet coverage of marine environment	3.28(1.03)	(no concern at all, very concerned)	0.87

S.D, Standard deviation; β: Regression weight; α reliability: Cronbach's α; CR: Composite reliability; AVE: Average variance extracted value.

respondents did not answer the questions completely or spent too long or too short a time to answer the questionnaires, which may cause errors in the results. Finally, 418 samples were identified as valid samples. The percentage of valid questionnaires is comparatively lower than that in other articles, focusing on nonmarket valuation in China (Zhang et al., 2019; Xu et al., 2020; Xu et al., 2021). It may be that, because the application of the contingent behavior method is limited in China, some respondents could not exactly understand the scenarios. The details of respondents' socioeconomic characteristics are shown in Table 2.

The final samples comprise 35.9% men and 64.1% women; 51.9% of respondents fell in the age group of under 30 years; 20.1% of respondents indicated a low personal income, less than 20,000 CNY/a; 41.1% of respondents belonged to the income group of 50,000–120,000 CNY/a; 64.4% claimed that they had received a bachelor's degree. The survey sample was not a perfect representation of Qingdao residents. The sample education level was noticeably higher than the Qingdao average level. Respondents were characterized as having a low age and a high education. There are two possible reasons for this result. On the one hand, it is because we adopted an online questionnaire, a format that is more acceptable to younger and more educated respondents. On the other hand, it is presumably because young people are keen to engage in social affairs, and they have more energy and resources to participate in marine environmental governance. It should also be noted that young people are generally the main target groups of researchers with regards to the exploration of individuals' willingness to participate in or pay for marine environmental governance. Therefore, more attention should be allocated to the young, who might be more active and more likely to express their opinions on environmental management, which is also in line with the purpose of the study.

Specifically, among them, 235 people were given the environmental improvement information in the survey, and they were defined as the treatment group. It accounted for 43.8% of the total samples. In the treatment group, 62.1% of respondents held a bachelor's degree or above, and 63.4% indicated that their personal income was more than 50,000 CNY per year. Other respondents, which were considered as the control group, were not presented with the environmental improvement message. Comparing the socioeconomic characteristics of the treatment group with control group, we found that the statistical characteristics of respondents were very similar, which indicated that there were no significant differences between the two groups.

4 Estimate strategy

4.1 Determinants of the WTP for improving marine water quality

First, we use the CVM to investigate the respondents' WTP for upgrading technologies to reduce marine pollutants and make efforts to test the effects of social and attitudinal factors on the WTP. The model is constructed as follows:

$$ln(WTP_i + 1) = \beta_0 + \boldsymbol{\beta_1 A_i} + \boldsymbol{\beta_2 S_i} + \epsilon_i \quad (1)$$

where WTP_i is respondent i's WTP for technology upgrades. $\boldsymbol{A_i}$ is a matrix of respondent i's understanding and attitude variables toward the marine environment and domestic sewage, including attitude toward whether respondents think that domestic sewage causes damage to the marine environment, marine environmental perception, impact perception, and media attention. $\boldsymbol{S_i}$ is a matrix of respondent i's socioeconomic characteristics, including annual water consumption, gender, age, education level, family size, and personal gross income. ε_i is a random error term. An ordinary least squares (OLS) model was used to analyze influence factors on the decision of residents' WTP.

4.2 The influence factors on residents' water consumption

Subsequently, we apply the CB to examine the impact of the water-pricing policy on residents' water-use behavior. The water-pricing policy, environmental improvement information, annual

TABLE 2 The respondents' demographic characteristics.

Variable	Definition	Mean (S.D.)		
		Whole	Treatment group	Control group
Observations		418	235	183
Permanent resident of Qingdao	Yes=0, No=1	0.28(0.45)	0.25(0.43)	0.32(0.47)
Gender	Male=0, Female=1	0.64(0.48)	0.63(0.48)	0.66(0.48)
Age	Below 18=1, 18-25=2, 26-30=3, 31-40=4, 41-50=5, 51-60=6, Above 61=7	3.31(1.22)	3.31(1.19)	3.31(1.27)
Education	Junior middle school or below=1, High school or vocational high school=2, Junior college=3, Bachelor degree =4, Postgraduate or above=5	3.80(0.81)	3.82(0.82)	3.76(0.81)
Family size	Family population	3.59(1.64)	3.65(2.04)	3.50(0.89)
Personal gross income (unit: 1000CNY/a)	Below 20=1, 20-50=2, 50-120=3, 120-240=4, Above 240=5	2.69(1.09)	2.75(1.12)	2.61(1.05)
Family gross income (unit: 1000CNY/a)	Below 20=1, 20-50=2, 50-120=3, 120-240=4, 240-360=5, 360-500=6, Above500=7	3.95(1.23)	3.98(1.22)	3.91(1.26)

water consumption, environmental perception, and media attention are selected as the main explanatory variables. The specific formula is constructed as follows:

$$Y_{ij} = \alpha + \beta_0 P_{ij} + \beta_1 EI_i + \boldsymbol{\beta Z_i} + \boldsymbol{\beta' X_i} + \gamma_{ij} + \epsilon_{ij} \quad (2)$$

where Y_{ij} represents the change in respondent i's water consumption when faced with the scenario of pricing policy j. P_{ij} represents pricing policy scenario j that respondent i faces. There are six scenarios, including 0.2, 0.5, 0.8, 1.0, 1.5, and 2.0 CNY/m^3. We test the effect of information dissemination by creating a dummy variable, EI_i. EI_i is coded as one if respondent i is in the treatment group and is equal to zero if respondent i is in the control group. $\boldsymbol{Z_i}$ is a matrix of other main explanatory variables, including annual water consumption, environmental perception, and media attention. $\boldsymbol{X_i}$ is a matrix of control variables, including awareness toward whether you think that domestic sewage causes damage to marine environment, whether respondent i often goes to the seaside, whether respondent i is a permanent resident of Qingdao, impact perception, age, gender, education level, family size, personal gross income, and family gross income. γ_{ij} controls the individual fixed effect, and ε_{ij} is a random error term. Two models including OLS, and ordered logit model are applied to analyze the formula.

4.3 The role of information transmission

Finally, we attempt to examine if there are heterogeneities in the impacts of water-pricing policy, environmental perception, and media attention on residents' water-use behavior between the treatment and control groups. In other words, we wonder whether the environmental information transmission may have some indirect effects on residents' environmentally friendly behaviors. If the respondents are informed that the benefits obtained by the water-pricing policy will be applied to the technical progress of sewage treatment plants to reduce the negative impacts on the offshore marine environment, people may be aware of the importance of the environment and show a high intention of water saving. Furthermore, the higher pricing-policy scenario indicates a more serious water quality problem at present and a bigger demand for the improvement of water quality. Therefore, the willingness to conserve water may increase with increasing price; the water-pricing policy will give more incentives for residents to reduce water consumption and adopt environmentally friendly behaviors under the information transmission.

Besides this, respondents with high environmental perception have a good knowledge of environmental information, so the transmission of information has few impacts on them. However, people who think that environmental pollution is not serious at the beginning will perceive the status of the marine environment after receiving information and indicate stronger willingness to conserve water than before.

In addition, people with higher media attention usually have a stronger environmental consciousness and have more motivation to participate in environmental protection than those with lower media attention. Therefore, people with higher media attention may be more easily affected by the environmental improvement information and perceive higher responsibility to protect the environment than those with lower media attention.

We test the moderating effects by introducing the interaction between the transmission of the message and the three variables, including water-pricing policy, environmental perception, and media attention, into formula 2. The model is as follows.

$$Y_{ij} = \alpha + \beta_0 P_{ij} + \beta_1 EI_i + \boldsymbol{\beta_2 W_i} + \boldsymbol{\beta Z_i} + \boldsymbol{\beta' X_i} + \boldsymbol{\beta''} EI_i \times \boldsymbol{W_i} + \gamma_{ij} + \epsilon_{ij} \quad (3)$$

where $\boldsymbol{W_i}$ represents a matrix of three variables, including water-pricing policy scenario, environmental perception, and media attention. The OLS model is used to analyze the formula.

5 Results

5.1 Descriptive statistics

5.1.1 Public awareness and attitude toward marine environmental protection

The results show that most residents perceive the serious marine environmental quality in Qingdao, China: 95.0% of respondents think that oceanic pollution is a critical problem in Qingdao, China. Only 39.2% and 1.9% believe that the water is clear and very clear, respectively, and 6.7% think the *Ulva prolifera* bloom is not a serious problem. In the aspect of perception about the impact of marine environmental damages, almost all respondents believe that

TABLE 3 Statistics of willingness to pay frequency.

Payment level	Frequency	Ratio (%)	Cumulative ration (%)	Payment level	Frequency	Ratio (%)	Cumulative ration (%)
0	9	2.15	2.15	101-150	62	14.83	79.90
0.1-5	44	10.53	12.68	151-200	27	6.46	86.36
5.1-15	22	5.26	17.94	201-250	32	7.66	94.02
15.1-30	43	10.29	28.23	251-300	11	2.63	96.65
30.1-50	45	10.77	39.00	301-400	9	2.15	98.80
50.1-80	41	9.81	48.81	401-500	5	1.20	100.00
80.1-100	68	16.27	65.07	Above 500	0	0	100.00

the destruction of the marine environment has many adverse effects. Only 2.2% of respondents believe that environmental damages do not have negative effects on economic development, and 96.2% and 98.1% agree that marine environmental damages have negative impacts on the lives of people and other organisms. Furthermore, the majority of respondents show high attention to the related reports on the marine environment in daily life through different ways. Compared with the WeChat public account (92.3%), TV (97.1%) and Internet (97.6%) are the preferred ways to pick up information.

5.1.2 Annual water consumption

We set up the option "unclear" in exploring household water consumption and water charges in the process of designing the questionnaire according to the feedback that some respondents do not know their water consumption and charges. The results show that 45 and 64 respondents indicate that they do not know their water charges and water consumption, respectively. Therefore, we use water charge to represent water consumption because of fewer missing values. The results show that only 9.8% of respondents report that they pay less than 135 CNY/a for water use, and 57.7% claim that their annual water charges range from 135 to 525 CNY/a, and seven people indicate high water charges that are more than 1100 CNY/a. Excluding those who do not know their water charge, the average water charge is 300.1 CNY/a. In addition, using the sample of 373 respondents who provided a clear answer to their water charge, we apply an OLS model to estimate the water charge function with respect to the socioeconomic variables, including gender, age, education level, family size, and personal gross income. The regression results are shown in Appendix B.1. Subsequently, the missing data on water charges are replaced according to the regression results. Finally, the average household water charge is about 378 CNY per year. In Qingdao, a ladder water price system, in which residents should bear different water prices according to their amount of water consumption, has already been adopted to encourage residents to save water. The charging standards for household water consumption per year are divided into three levels: no more than 144 m^3, 144–204 m^3, and more than 204 m^3, respectively. The corresponding water prices are 3.50, 4.65, and 8.00 CNY/m^3. According to the existing water-pricing policy, the average household water consumption is about 108 m^3/a.

5.2 Residents' acceptability of the water-pricing policy

5.2.1 Statistics of WTP

The investigation shows that 80.14% of respondents definitely agree that domestic sewage leads to some damage to the marine environment, and 97.8% of respondents report a positive attitude and indicate that they are willing to take the responsibility for environmental protection. The frequency of WTP is shown in Table 3; 31.1% of respondents indicate that they are willing to bear the extra water charge of 80.1–150 CNY/a for technical progress of sewage treatment plants; 1.2% of respondents report their WTP above 400 CNY/a. The median of WTP for technology upgrades is 90 CNY/a. The average WTP is calculated through the mathematical expectation formula of discrete variable WTP:

$$E(WTP) = \sum_{h=1}^{n} A_h P_h = 97.15CNY/(household{\star}a) \quad (4)$$

where $E(WTP)$ is the average WTP for technology upgrades of the sewage treatment plants. A_h is the WTP of option h (we replace the payment level value with the median of each option, and the payment level above 500 CNY/a is replaced by 600 CNY/a). P_h is the probability of choosing option h. n is the number of options.

The result shows that the average WTP for environmental improvement is 97.15 CNY per household per year in Qingdao, China. Additionally, the average annual water charge paid by a household is 378 CNY; thus, the resulting increase in the household water bill would be 25.7% in Qingdao, China. The average WTP accounts for 0.04% of the family gross income.

Furthermore, we use the estimated average water consumption and the average WTP to calculate the average water-price increase P_{mean}.

$$\begin{aligned} P_{mean} &= E(WTP)/TWC = 97.15CNY/(household{\star}a)/108\left(m^3/household{\star}a\right) \\ &= 0.90CNY/m^3 \end{aligned} \quad (5)$$

In general, residents can accept an increase of 0.90 CNY/m^3 in water price to improve the sewage treatment technologies to reduce the negative effects on the marine environment.

5.2.2 Influence factors of the WTP

Equation (1) is analyzed, and the estimation results are listed in Appendix B.2. The results show that personal gross income is a statistically significant variable in explaining WTP. It is a widely accepted fact that the demand for good environmental quality tends to increase with income (Sebo et al., 2019). People with higher income could have energy and time for living and health issues. There is a significant difference in the payment decisions between males and females. The result indicates that females have stronger environmental consciousness and higher WTP than males, which is consistent with previous studies (Dardanoni and Guerriero, 2021). The coefficient on the education level variable is positive and significant, which means that highly educated people are more likely to pay for environmental protection than less educated ones. The improvement of sewage treatment plant technology can not only reduce the environmental pollution, but also reduce the threat to the health of coastal residents and bring a series of social and economic benefits (Birol and Das, 2010). Higher education experience may raise people's concern about environmental protection, which is in accord with previous findings (Piriyapada and Wang, 2014; Cicatiello et al., 2020; Jin and Li, 2020). Additionally, the coefficient of family size is significant at the 1% level, which indicates a negative correlation between family size and WTP. It means that households with large populations are less willing to pay than those with small populations, which is close to the results of Jones et al. (2008). Annual water consumption shows a significantly positive impact on the WTP, indicating that households with a higher water bill present higher WTP for upgrading technologies to improve marine quality.

Environmental perception, impact perception, and media attention play positive roles in residents' WTP as expected. People's understanding of things and attention to a certain event reveal the importance people attach to the thing and their attitude toward it, which will have a critical impact on their behavioral decision, consistent with previous studies (Shin et al., 2017; Yadav and Pathak, 2017). People who perceive severe environmental quality, perceive serious impacts of environmental pollution, or pay attention to the environmental issues, will be more likely to pay for the project of environmental quality improvement.

5.2.3 The heterogeneity of acceptability of water-pricing policy

The implementation of policy should not only consider economic efficiency, but also its acceptability among the public. Previous studies have found that price-control mechanisms impose inequitable burdens on low-income households (Clark and Finley, 2008; Olmstead and Stavins, 2009). Therefore, we make efforts to observe whether there are significant differences in the acceptability of pricing policy among different income groups to analyze the acceptability of the policy of price increase. We calculate the maximum acceptability of an increase in the unit price of water as the water policy using the following formula.

$$P_{imax} = WTP_i / WC_i \tag{6}$$

where P_{imax} is respondent i's maximum acceptability of an increase in the unit price of water. WTP_i is respondent i's WTP for improving marine quality. WC_i is respondent i's water consumption.

The distribution of P_{imax} grouped by personal income is shown in Figure 2. There are some differences in acceptance of pricing policy among different income groupings. Specifically, the upper and lower quantiles of the five income groups are quite different. The two groups with higher income show higher levels in the lower quartile of WTP than the three lower income groups. The median of the groups with the lowest income level is much smaller than the other groups. People in the low-income group express low acceptability of the water-pricing policy. Furthermore, the interaction between water price, income, and water-use behavior is also complicated. The increase in water price could lead to a strong impact on the household budget when income is lower (García-López et al., 2020). Therefore, it is necessary to consider the welfare of the low-income group when forming the water-pricing policy (Ruijs et al., 2008).

5.2.4 Cost of sewage treatment technology upgrades

A comparison of benefits and costs can be used to analyze the feasibility of the water-pricing policy as a tool to let technology upgrade. The previous section analyzes residents' acceptability of the pricing policy through investigating their WTP for the technology upgrades, which can be considered as the benefit of it. Therefore, we try to explore the increase in water price from the perspective of the cost of technology upgrades in the following.

Tan et al. (2015b) constructed a cost–benefit model to analyze the differences in the regional operating costs using data from 227 sewage treatment plants, covering eastern, central, and western regions of China. The total costs were estimated to be 1.38 CNY/m^3 on average. Different from the previous article, this paper investigates 129 sewage treatment plants in the eastern region of China and selects their operation costs, construction costs, and main pollutant concentration after treatment. Then, we gather the information about the standard of Class IV surface water quality in Environmental quality standard for surface water (GB3838-2002) and the sewage treatment standard in Discharge standard of pollutants for municipal wastewater treatment plant. Assuming the function is linear, the total cost of achieving Class IV surface water quality is estimated by OLS after selecting important indicators, such as ammonia nitrogen and biological oxygen demand. It is estimated that the total cost is 1.37 CNY/m^3. It should be noted that this function ignores the nonlinear relationship between the cost and technology upgrades. Furthermore, this cost does not include the depreciation of the pipe network facilities and the cost of sludge treatment, so the cost is underestimated. The current standard sewage treatment charge is 1 CNY/m^3 in Qingdao, which means that the water price should be increased by at least 0.37 CNY/m^3 to meet the cost of upgrading the technologies of sewage treatment plants. Combined with residents' acceptability of the water-pricing policy for collecting funds to improve the marine environment, it is found that raising water prices by 0.37 CNY/m^3 to cover the costs of upgrading technologies and reduce the adverse influences of domestic sewage on marine quality is feasible.

5.3 Residents' response of water-use behavior to the water-pricing policy

5.3.1 The water-pricing policy and changes in residents' water-use behavior

Most residents are willing to pay for the technology upgrades through the analysis of residents' WTP. Therefore, we further analyze the effect of the water-pricing policy on residents' welfare. CB is used to observe the changes in residents' water-use behavior in different

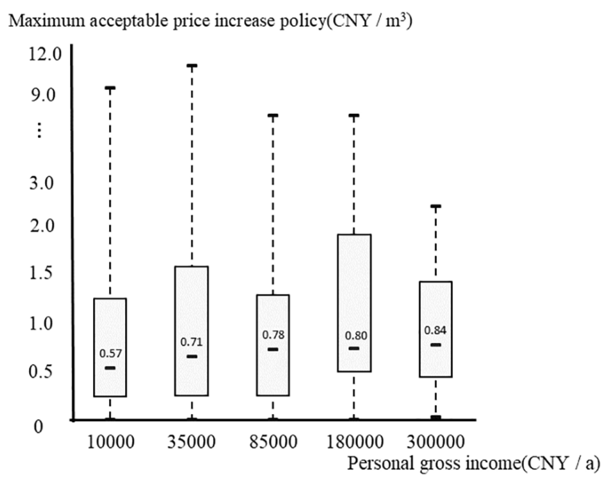

FIGURE 2
Residents' maximum acceptable pricing policy under different income levels. Note: The bottom of the box is the lower quantile, the bar in the middle of the box is the median, and the top of the box is the upper quantile. The bar at each end is the minimum and maximum acceptable price increase policy of the income group.

scenarios of the pricing policy. We include some statistics of residents' water-use behavior according to different water-pricing policy contexts before analyzing formulas 2 and 3.

As shown in Figure 3, when the water-pricing policy scenario shows that the water price increases by 0.2 CNY/m^3, respondents are not sensitive to the policy: 63.64% of respondents choose the option "no change." When the water price increase policy is 0.5 CNY/m^3, many respondents indicate that they will reduce their water consumption slightly. When the policy's increase degree is 0.8 and 1.0 CNY/m^3, only 11.00% and 3.59% of respondents still indicate that they will not change their water-use behavior. Furthermore, when the pricing policy increases by 2.0 CNY/m^3, people have a strong reaction to the policy: 98.80% of people reduce their water usage, among which 80.39% choose to reduce their water consumption significantly. The proportion of people who choose the option "enormous reduction" reaches the highest in all pricing policy scenarios. It may be because, no matter whether respondents were told what the water-pricing policy was for or not, the extra price outweighs the benefits people could get. In conclusion, the water-pricing policy will have a negative influence on residents' utilities as expected.

5.3.2 Regression results

The estimation results of Equation (2) are listed in Table 4. Because of the six scenarios that every respondent faced, we get 2508 observations in total. Column (1) only investigates the impacts of the pricing policy, information, and annual water consumption on the changes in residents' water-use behavior, whereas Column (2) further analyzes the environmental perception and media attention and considers the impact of control variables. Column (3) introduces the individual fixed effect and the control variables simultaneously. Column (4), the ordered logit model, is used to analyze the model to make a robustness test.

The impacts of water-pricing policy on the change in residents' water-use behavior are in line with our expectations and are positive and significant at the 1% level in all columns. The greater the water-pricing policy increase, the more obvious the reduction in residential water consumption. It suggests that consumers would respond to the water-pricing policy by lowering consumption. This is consistent with previous studies indicating that a careful manipulation of price can be an important contributor to water conservation (Martínez-Espiñeira and Nauges, 2004; Zetland, 2021). It may be because the water-pricing policy leads to the increase in the cost of living, thus promoting residents' water-saving behavior (Savenije and van der Zaag, 2002). In summary, it reveals that most residents change their behavior when the price increase policy is high, indicating that their utilities may have been influenced. Thus, we need to think carefully about the formulation of the water-pricing policy.

The coefficients of the environmental improvement information are also significantly positive in all columns. Especially when the control variables and individual fixed effect are controlled, the coefficient of environmental improvement information changes significantly, increasing from approximately 0.07 to 11.62. It means that the transmission of environmental improvement information has a significantly positive impact on residents' water-use behavior. In other words, residents who are presented with environmental improvement information tend to change their water-use habits and adopt water-saving behavior. It is consistent with previous studies that suggest the role of information is a critical tool to increase the willingness of residents to save energy (Ek and Söderholm, 2010; Sun et al., 2018). The environmental improvement information strengthens people's awareness of environmental protection; thus, people will voluntarily choose to conserve water for protecting the environment.

The negative effect of annual water consumption on water-saving behavior reveals that people who use more water per year are less likely to change their water habits than those who use less water. It may be because people who use more water in their daily life have a weaker awareness of water saving, thus indicating less willingness to conserve water than those who use less water.

In addition, environmental perception and media attention are positively correlated with residents' willingness to reduce water consumption as expected. It shows that people who perceive the status of marine environmental damages or pay attention to marine environmental issues will be inclined to change their water-use habits and protect the environment.

Finally, in column (4), the direction and significance of all variables are in line with columns (1), (2), and (3). It demonstrates good coherence between the results obtained by the two approaches, which suggests that our results are robust.

5.3.3 Regression results of moderating effects

The estimation results of model 3 are reported in Table 5. Specifically, all columns consider the impacts of individual fixed effect and control variables. The result, as given in column (1), indicates that the interaction of environmental improvement information with the pricing policy is found to be positive and significant at the 5% level. The marginal effect of the water-pricing policy on reducing water consumption depends on information transmission. In the face of the same policy scenario, people who know the environmental improvement information show a higher willingness to reduce water consumption than those who don't know. It implies that the water-pricing policy has a stronger effect on promoting residents' water-saving behavior when respondents are informed of environmental improvement information.

The interaction between information transmission and environmental perception shows a negative role in reducing water consumption. Meanwhile, the coefficient of environmental perception

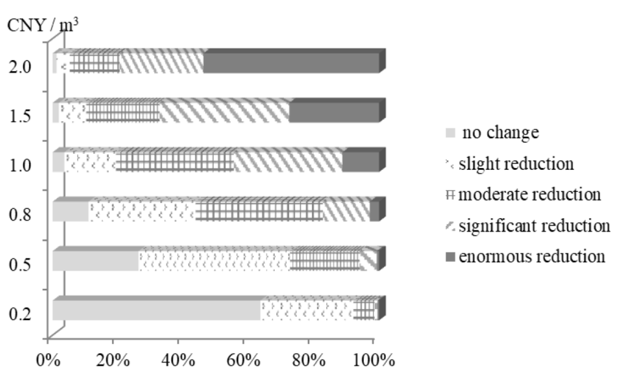

FIGURE 3
The water-pricing policy and the changes in residents' water-use behavior.

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TABLE 4 Regression results of residential water consumption.

Variables	(1)	(2)	(3)	(4)
Pricing policy	1.579*** (0.031)	1.579*** (0.030)	1.579*** (0.019)	7.790*** (0.212)
Environmental improvement	0.072* (0.039)	0.074* (0.038)	11.622** (4.568)	55.140*** (18.057)
Ln(Water charge)	-0.111*** (0.028)	-0.083*** (0.030)	-1.516** (0.681)	-7.146*** (2.693)
Environmental perception	/	0.053*** (0.020)	0.419* (0.220)	1.970** (0.871)
Media attention	/	0.083*** (0.021)	14.237** (5.565)	67.700*** (22.023)
Controls	NO	YES	YES	YES
Individual Fixed effect	NO	NO	YES	YES
Observations	2508	2508	2508	2508
R-squared/Pseudo R^2	0.511	0.529	0.848	0.617
Log likelihood	/	/	/	-1538.795

(1) Controls: awareness of the hazards of domestic sewage, impact perception, whether the respondents often go to the seaside, whether they are the permanent residents of Qingdao, age, gender, education level, family size, family gross income, and personal gross income.
(2) *** p<.01, ** p<.05, * p<.1.

TABLE 5 Regression results of moderating effects.

Variables	(1)	(2)	(3)	(4)
Pricing policy	1.537*** (0.027)	1.579*** (0.019)	1.579*** (0.019)	1.537*** (0.029)
Environmental improvement	11.546** (4.565)	0.312* (0.171)	0.181 (0.187)	0.231 (0.196)
Ln (Water charge)	-1.516** (0.681)	0.103 (0.150)	-0.363 (0.247)	0.081 (0.216)
Environmental perception	0.419* (0.220)	0.728** (0.328)	-0.362* (0.199)	0.679* (0.263)
Media attention	14.237** (5.561)	1.352*** (0.387)	-0.248 (0.379)	1.279*** (0.357)
Environmental improvement * Pricing policy	0.076** (0.038)	/	/	0.076** (0.038)
Environmental improvement * Environmental perception	/	-1.458** (0.592)	/	-1.392*** (0.534)
Environmental improvement *Media attention	/	/	1.041** (0.423)	0.047 (0.334)
Controls	YES	YES	YES	YES
Individual Fixed effect	YES	YES	YES	YES
Observations	2508	2508	2508	2508
R-squared	0.848	0.848	0.848	0.848

(1) Controls: awareness of the hazards of domestic sewage, impact perception, whether the respondents often go to the seaside, whether they are the permanent residents of Qingdao, age, gender, education level, family size, family gross income, and personal gross income.
(2) *** p<0.01, ** p<0.05, * p<0.1.

is still significantly positive, which suggests that the transmission of the environmental improvement information negatively moderates the effect of environmental perception on water-saving behavior. The information would let people who did not recognize the environmental damages at the beginning realize their behavior's negative impacts on environment and then increase their willingness to reduce water consumption. That is, the differences in the incentives to protect the environment between people with high environmental perception and those with low environmental perception are reduced in the context of environmental improvement information transmission.

In addition, the result in column (3) indicates that information transmission positively moderates the effect of media attention on the change in water-use behavior. It implies that media attention has stronger effects on reducing water consumption when the information is presented. People with higher media attention may more easily receive the environmental improvement information and be affected by it than those with lower media attention. Therefore, they may be more likely to perceive a high responsibility to protect the environment under the information transmission.

To control for correlations between the variables interacting with information transmission, we further include three interactions within the same model. The results are shown in column (4). The directions and significance of critical variables are almost consistent with that in the former columns, which demonstrates that the moderating effects of information transmission exist.

6 Conclusions

Improving the quality of water after treatment is an important step to reduce the huge negative impacts of domestic sewage on the ocean and coastal environment and to further improve marine water quality. This study attempts to provide a useful reference for the government to consummate a management policy through exploring a proper increase in the water price to collect funds for upgrading technologies of sewage treatment plants. First, this paper investigates public preferences for the improvement of marine water quality and reveals that the mean of household WTP is 97.15 CNY per year for the scenario, which assumes that water quality after improving domestic sewage treatment technologies meet level IV of the Environmental Quality Standards for Surface Water (EQSSW, GB3838-2002) in Qingdao, China. The average water-pricing policy that residents can accept is 0.90 CNY/m^3. Additionally, people in the low-income group are willing to accept a lower water-pricing policy. Furthermore, we estimate that water prices should increase 0.37 CNY/m^3 from the viewpoint of the cost of technology upgrades. It suggests that residents' WTP could cover the cost of upgrading technologies for reducing the negative impacts caused by wastewater, which could give some policy implications for developing water-pricing policies.

Second, we apply contingent behavior to investigate the changes in residents' utilities in the face of the water-pricing policy and explore the determinants of residents' water-conservation behavior. According to the results, a high individual's willingness to conserve water is found if a respondent faces the scenario of a high water-pricing policy. People with high environmental perception, high media attention, or low water consumption intend to save water. The transmission of environmental improvement information that raising water prices is used for technical progress in sewage treatment plants to weaken the negative impacts of wastewater will encourage people to adopt pro-environmental behaviors. In addition, we examine the moderating effects of the information transmission. The results show that the dissemination of information on environmental improvement will positively moderate the influence between the pricing policy and residents' water-saving behavior. The results of this study could help policymakers to better understand how to guide people's behavior in policy-enforcement environment segments with different characteristics.

This paper discusses the acceptability of water-pricing policy to manage marine pollution and explores the effects of policy scenarios and information transmission on residents' water-conservation behavior, which has important policy implications for the government to establish an effective mechanism to manage the negative impacts of domestic sewage. From the perspective of management practice, the government needs to publish a pricing policy to collect funds for reducing the impacts of domestic sewage. First, raising funds may need the participation of all residents. Combining residents' acceptability of water-pricing policy with the estimated cost required by the upgrading technologies of the sewage treatment plants, it can provide a useful reference for the decision making of the water-pricing policy to collect funds. Second, the implementation of the policy needs to take an individual's utility into account, which means that an appropriate pricing policy should not be too high. Furthermore, the low-income group can only accept a low level of pricing policy due to income constraints, so the government should take the opinions of lower income groups into account before making the policy. Meanwhile, our findings also highlight the importance of information transmission in promoting public participation in marine pollution management. The transmission of environmental improvement information not only promotes the residents' water-saving behavior, but also increases the transparency of the government and strengthens the effectiveness of policy implementation. Therefore, the government should attach importance to establish an information publishing platform to release authoritative information. Otherwise, not only does the nondisclosure of information induce the suppression of residents' environmentally friendly behaviors, it also weakens the positive effect of a price increase policy on residents' water-saving behavior. Besides this, the government should mobilize residents to build a good social environment to actively participate in water saving. Although the local government in China has thought highly of the adverse impacts of wastewater on marine environment, it remains a major challenge for the government's future work to reduce its negative impacts.

Data availability statement

The datasets presented in this article are not readily available because the data that has been used is confidential. Requests to access the datasets should be directed to ZX, xuzhihua2016@126.com.

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent from the participants was not required to participate in this study in accordance with the national legislation and the institutional requirements.

Author contributions

ZX: Conceptualization, Methodology, Writing - Original Draft, Writing - Review and Editing. CW: Investigation, Data Curation, Writing - Original Draft. SL: Investigation. JS: Investigation, Writing - Review and Editing. All authors contributed to the article and approved the submitted version.

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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.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fmars.2023.1105837/full#supplementary-material

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