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Willingness to pay for the restoration of the Paraíba do Sul River: A contingent valuation study from Brazil

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ABSTRACT

Using a referendum-format contingent valuation survey, we investigated the residents' willingness to pay for restoring the water quality of the Paraíba do Sul river in the city of Campos dos Goytacazes, Brazil. We estimated values for an environmental improvement consistent with the Brazilian water legislation in order to facilitate the dialog among environmental scientists, water users, and policymakers, among other stakeholders. Over the years, residents have lost a great deal of water services due to residential, industrial, and agricultural pollution, and our contingent scenario proposes water quality improvements that will restore those services. Findings indicate that local residents are willing to pay from 0.81% to 1.25% of the average reported income above their current water bill for restoring the Paraíba do Sul river, depending on assumptions about response uncertainty.

1. Introduction

In many developing and developed countries, rivers have been considerably polluted due to unplanned, unprecedented agricultural, industrial, and urban growth. As a result, citizens have lost a valuable set of water services, including irrigation and recreational opportunities. In Brazil, the Paraíba do Sul (PDS) river basin provides an example of water resources that are continuously subject to a considerable amount of pollution. This catchment is an important resource for industrial irrigation systems, production of electricity, manufacturing, and other economic sectors in the states of Minas Gerais, São Paulo, and Rio de Janeiro. The livelihood of many households depends directly on the PDS river as they use it for drinking water systems, fishery, and irrigation of agricultural crops. Inappropriate agricultural practices, deforestation, residential wastewater disposal, and industrial discharge have polluted the PDS river with metals and organic contaminants (see Dittmar et al., 2012; Ovalle et al., 2013; Pereira et al., 2006; Silva et al., 2001). Consequently, surrounding populations, especially households located downstream, have lost several water services that the PDS river used to provide. Improving the river water quality may help mitigate health risks and restore water services that have been lost due to continuous pollution.

Restoring rivers is costly and developing nations face many pressing needs that compete for budget priority (e.g. poverty alleviation programs, education, health care, drinking water, and sanitation, among others). The lack of information regarding the economic value of river water quality improvements has been an impediment for making

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budget allocations to river restoration projects (Keeler et al., 2015). Economic valuation of river restoration projects has the potential to contribute to the determination of priorities by demonstrating the relative importance of rivers to surrounding populations. It can also identify alternative sources of funding for environmental programs by quantifying the benefits that different stakeholders would derive from water quality improvements. Unfortunately, few studies have investigated the economic value that local residents assign to potential improvements of the PDS river basin.

Among the exceptions, Rezende et al. (2015) designed a choice experiment to investigate local residents' willingness to pay for restoring the mangrove forest area in the PDS river estuary. Their experiment included three levels of restoration (minimal, moderate, and complete) with specific improvements in ecological services and esthetic characteristics of the mangrove forest, as well as different periods of time to achieve the proposed environmental improvements. Their results indicate that local residents' willingness to pay for the restoration program increases with the level of restoration and decreases with the time needed to restore the mangrove forest area. Kahn et al. (2017) also implemented a choice experiment to study local preferences for levels and time of restoration of the PDS river. The proposed restoration could take three levels: minimal, moderate, and full, which varied in terms of esthetic characteristics, exposure risk, ecological health, and compliance with heavy metal and sediment standards. They found that local residents have strong preferences for a rapid, full restoration of the PDS river. Rezende et al. (2015) and Kahn et al. (2017) designed scenarios to help respondents to understand and value the proposed environmental improvements. Yet, their studies do not describe the implications of the proposed improvements in terms of biological and chemical indicators. This makes it difficult to estimate the cost of river restoration projects and to monitor the effectives of those projects in improving the PDS river basin.

This study follows an alternative approach to define a river restoration program for the PDS river that is consistent with legislation-based water classifications. Our approach provides useful insights to design restoration programs for the PDS river because the Brazilian water legislation provides environmental benchmarks for scientists to monitor the progress of environmental programs and clearly identifies water services recovered with water quality improvements that residents can value. In addition, this study provides updated estimates of willingness to pay for restoring the PDS river given that Kahn et al. (2017) provided estimates for a sample of respondents surveyed in 2006. Specifically, we implemented a referendum-format contingent valuation survey to investigate residents' willingness to pay for water services recovered by restoring the PDS river up to a legislation-based Type II classification in the city of Campos dos Goytacazes, Brazil. Results indicates that the inhabitants of Campos dos Goytacazes are willing to pay a considerable increase in their water bill (at least 0.81% of the average household income) for water quality improvements of the PDS river.

The rest of this paper is organized as follows. Section 2 provides a description of our study site, the city of Campos dos Goytacazes and the Paraíba do Sul river. Section 3 describes the survey design including the CV question implemented to elicit respondents' willingness to pay for improved water quality of the PDS river. Section 4 presents the empirical strategy used to analyze the gathered data. Section 5 shows the survey results including willingness-to-pay estimates and determinants of local preferences for restoring the PDS river. Section 6 concludes the paper with a discussion of results and some policy implications.

2. Characterization of the Paraiba do Sul River in Campos dos Goytacazes

This study was conducted in the city of Campos dos Goytacazes (hereafter referred to as Campos), located approximately 275 km northeast the city of Rio de Janeiro with a land area of 4026 km^2. The last census indicated that the municipality of Campos had a population of 463,731 inhabitants as of 2010 (48.1% males and 51.9% females), with more than 90% living in urban centers. The average household had 3.24 members and earned a monthly income of 2251 Reais (R$).[1] On average, urban households earned a higher income than households in rural areas (R$ 2372 vs. R$ 1105 per month).

The PDS river crosses the city almost at its center (see Fig. 1). This river is among the most important catchments in Brazil with an area of 57,000 km^2 and an extension of 1145 km (ANA, 2015). For Campos, the PDS river is its primary water source for human consumption and other economic activities. As many rivers in Brazil, the PDS river is continuously polluted by the discharge of untreated residential wastewater and other effluents. According to the 2015 National Sanitation Ranking, the southeast region of Brazil, where the PDS river is located, only treats 47% of the wastewater. On average, the 100 largest Brazilian cities only treat 50% of their effluents, and only 10 of those cities treat up to 80% of the wastewater (Instituto Trata Brasil, 2016). A number of prior studies have documented the hydro-ecological and biogeochemical characteristics of the PDS river (e.g. Almeida et al., 2007; Araujo et al., 2015; Carvalho et al., 1999; Carvalho et al., 2002; Marques et al., 2017; Ovalle et al., 2013). Those studies have reported high levels of organic and inorganic pollutants that put the health of surrounding populations at risk. The PDS river water quality is further jeopardized by the latent threat of environmental accidents. For instance, in April 2003, the PDS suffered one of the most notable environmental incidents in Brazil consisting of an uncontrolled paper mill effluent discharge (Hoag, 2013). As a result, approximately 600,000 inhabitants experienced water service interruptions for more than 10 days, biota was decimated, and the ecosystem disruption was incalculable.

The 184 municipalities located in the PDS river basin contribute to its pollution, and the city of Campos is not the exception. Table 1 shows measures of total and fecal

[1] The census information was retrieved from https://cidades.ibge.gov.br, last accessed on November 14, 2017.

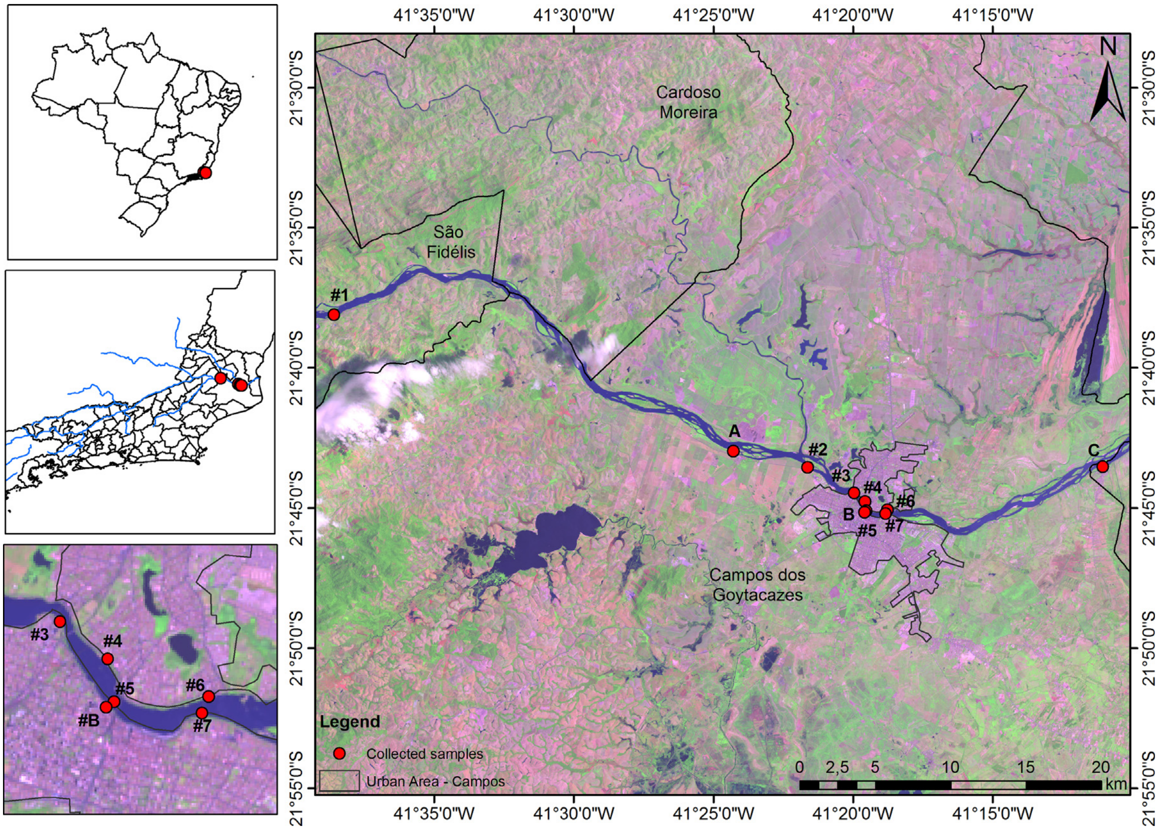

Fig. 1. Study sites in the Paraíba do Sul River.

coliforms in the PDS river waters before, in, and after the city of Campos. Lamonica (2012) demonstrates that the amount of total and fecal coliforms increases as the river crosses Campos. Before entering the city (see site A in Fig. 1), the PDS river shows fecal coliform levels according to type II river waters ($<1.0 \times 10^3$ CFU/100 ml) as defined in the National Environmental Council's Resolution No. 357 (CONAMA, 2005).[2] Once the river enters the city, fecal coliforms increase up to levels that surpass the legal standards for type II river waters. Our own testing results, shown in the last panel of Table 1, are consistent with the findings of Lamonica (2012). The concentration of fecal coliforms in sites 1 and 2 (see Fig. 1) is of type II waters. However, fecal coliform levels surpass the maximum established for type II waters starting at site 3, which is an effluent of wastewater. In another effluent of wastewater that is directly discharged in the river (site 6), we found concentrations of fecal coliforms above 240×10^3 CFU/100 ml.

The effluents of wastewater (sites 3 and 6 in Fig. 1) also discharged chemical pollutants into the PDS river (see Table 2). Concentrations of organic carbon, nitrogen, and phosphorus in those sites are higher than the average registered since 1994 in a long-term testing site in the same city (site 5 in Fig. 1). Moreover, the levels of those pollutants surpass the legal standards for type II river waters. The chlorophyll concentrations in the long-term testing site also exceed the legal standard for type II waters, particularly in dry periods where blooms of cyanobacteria (*Anabaena* sp.) are commonly observed. As a result, water supply is often interrupted for several days at that time of the year. Based on comparisons of those results with legal standards (i.e. CONAMA's Resolution No. 357), the PDS river water can be classified as type III.

3. Survey design and sampling strategy

The survey-based contingent valuation (CV) method has proven to be a viable approach for eliciting households' willingness to pay for environmental improvements in developing and developed countries alike. For instance, Alam (2013) in Bangladesh, Bliem and Getzner (2012) in Austria, Lalika et al. (2017) in Tanzania, Lee (2012) in Korea, Shang et al. (2012) and Zhao et al. (2013) in China, as well as Brugnaro (2010) and Peixer et al. (2011) in Brazil provide recent examples of CV studies implemented to value different services that rivers can provide. The CV

[2] In its Resolution No. 357, The National Environmental Council (CONAMA, for its initials in Portuguese) provides a detailed guide to classify fresh and salt waters in Brazil. First, this resolution classifies water bodies by their salinity as fresh water (<0.5), brackish water (0.5–30) or marine water (>30). Then, the resolution recognizes five types of freshwater: Special and Types 1–4, in respective order of quality. The resolution provides a number of biological and chemical standards for each type of freshwater (see CONAMA, 2005), as well as a comprehensive list of services that each type of freshwater can provide (see Appendix A).

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Table 1
Total and fecal coliforms in the Paraíba do Sul River.

Period	Site	Latitude	Longitude	Total coliform (CFU/100 ml) *10³	Fecal coliform (CFU/100 ml) *10³
Dry	A	21° 42′58″	41° 24′17″	20.7 ± 3.9	0.6 ± 0.2
	B	21° 45′08″	41° 19′35″	43.3 ± 5.2	2.9 ± 1.6
	C	21° 43′31″	41° 11′03″	37.0 ± 13.8	1.4 ± 1.1
Wet	A	21° 42′58″	41° 24′17″	10.1 ± 3.2	0.8 ± 0.3
	B	21° 45′08″	41° 19′35″	17.0 ± 11.6	$1.5 \pm .8$
	C	21° 43′31″	41° 11′03″	12.8 ± 10.0	1.1 ± 0.6
Dry	1	21° 38′06″	41° 38′35″	10.5 ± 1.1	0.2 ± 0.1
	2	21° 43′33″	41° 21′37″	17.9 ± 2.2	<0.1
	3	21° 44′27″	41° 19′58″	16.9 ± 1.8	4.1 ± 0.8
	4	21° 45′06″	41° 19′35″	22.7 ± 2.0	22.7 ± 2.0
	7	21° 45′58″	41° 19′32″	5.4 ± 1.4	5.4 ± 1.4

Notes: The location of sites is shown in Fig. 1. Coliform indicators for sites A, B, and C come from Lamonica (2012), who gathered water samples in 2011 to 2012. In this study, water samples were collected from sites 1, 2, 3, 4 and 7 in August 2017. According to CONAMA (2005), the legal standards on fecal coliforms are a maximum of 1.0×10^3 CFU/100 ml for Type II waters and 2.5×10^3 CFU/100 ml for Type III waters.

Table 2
Selected chemical parameters in city effluents and Paraíba do Sul River.

Parameters	City effluents		Long-term testing site (Site 5)			Legal standards	
	Site 3	Site 6	Mean	Minimum	Maximum	Type II	Type III
Dissolved organic carbon (mg/L)	24.20	7.97	3.22	0.68	6.30	–	–
Total dissolved nitrogen (mg/L)	26.61	70.10	1.37	0.42	2.40	<2.18	–
Total dissolved phosphorus (mg/L)	8.33	3.58	0.06	0.01	0.24	<0.10	<0.15
Chlorophyll (μg/L)	–	–	3.4	1.3	35.5	<10.0	<60.0

Notes: Water was collected in the city effluents on June 2014. In the long-term testing site, water samples were collected every two weeks since 1994. The legal standards are reported in CONAMA (2005).

method consists of two parts: (1) a hypothetical scenario that introduces an environmental change, and (2) a follow up question that elicits respondents' maximum willingness to pay (or minimum willingness to accept) for that environmental change (Birol et al., 2006).

Eliciting respondents' willingness to pay through the CV method requires careful survey design, choice of survey mode, and selection of the random sample (Bateman et al., 2002; Whittington, 2002). In this study, a collaborative team from Fairfield University (in USA) and Universidade Estadual do Norte Fluminense (in Brazil) designed and implemented an in-person CV survey instrument. The survey instrument included a number of sequential questions designed to clearly define the environmental change to be valued (i.e. water quality improvements in the PDS river). First, respondents were provided with information regarding the actual water quality of the river and were asked how credible they found that assessment. The (translated) question read as follows:

> Recent studies conducted by researchers at UENF have shown that the PDS river can be classified as "Type III" water according to Brazilian legal standards. This implies that the PDS river can be used for human consumption only after conventional or advanced treatment; irrigation for tree, cereal and fodder crops; recreational fishery; indirect-contact recreation; and watering livestock. Using a scale of 1 to 5, where 1 means "not credible" and 5 means "very credible", how credible do you think the results of those studies are?

Subsequently, the valuation component of the survey was introduced. Following best practices, the CV question was framed as a referendum where the respondent could vote for or against an environmental project that would improve the water quality of the PDS river. To fund the proposed project, a monthly fee would be added to the water bill in the next 10 years. This payment vehicle was chosen due to its practicality. The project fee was randomly varied across respondents from R$ 5 to R$ 30, in increments of R$ 5. This exogenous variation in the project fee allows for estimating the household's willingness to pay.

The referendum-format CV scenario initiated with a reminder about the current water quality of the PDS river. Next, the proposed project was presented with a detailed list of services that individuals would receive as a result of improving water quality up to a Type II classification (according to the Brazilian legislation). The CV scenario also included a split-sample treatment, with variations in the time it would take to restore the river if the project was approved: (a) 10 years and (b) 15 years. These periods of time were chosen based on expectations of local scientists regarding the time it would take to restore the PDS river, with 10 years being an optimistic (yet realistic) scenario and 15 years being a more plausible case. The CV scenario ended with a reminder that money spent on this additional fee will not be available for other household expenses. The (translated) referendum voting question is as follows:

> For the next question, please assume that the population will have the opportunity to vote against or in favor of a

> restoration project for the Paraíba do Sul river. Currently, that river cannot be safely used for swimming, skiing, diving, irrigation of vegetables, direct-contact recreation, or direct human consumption. With the restoration project, the PDS river water quality will improve, and the river will be safely used for swimming, skiing, diving, irrigation of vegetables, and direct-contact recreation. However, it would not be recommended to drink water directly from the river. Studies conducted by UENF show that, given the ecosystem's structure and uses, it would take **[10 / 15]** years to reach the water quality improvements mentioned above. To fund the project, a monthly additional fee of R$ **[5 / 10 / 15 / 20 / 25 / 30]** would be introduced in the water bill of every household in Campos for the next 10 years, which would result in a total of 120 payments (one per month). Keep in mind your household budget. Any amount of money given for the project will not be available for household expenses such as groceries, cloth, etc. Would you Vote For or Against the project?

The precision of CV estimates is often in question because respondents can exaggerate their willingness to pay in a hypothetical scenario. While there is some evidence that the referendum format applied here may reduce hypothetical bias (Carson and Groves, 2007), it is not clear that this format alone can eliminate hypothetical bias (Little and Berrens, 2004; Murphy et al., 2005). Blumenschein et al. (2008) argue that WTP for a non-market good can be precisely estimated by including a follow-up question about the certainty of responses and argue that this approach is more effective in reducing the hypothetical bias than other approaches. Hence, a follow-up question about the certainty level of the referendum response was included. Respondents were asked about the certainty of their voting responses on the referendum question using a scale from one to five, where one meant completely uncertain and five completely certain. This follow-up (un)certainty question was worded as follows:

> In relation to the last question, and based on a scale of 1 to 5, where 1 means completely uncertain and 5 means completely certain, how certain are you of your response?

In-person interviews are the most practical survey mode in developing countries. Yet, some challenges were faced to conduct in-person interviews because gated communities and apartment buildings with restricted access have proliferated in the city of Campos in the last years. Those residents hardly grant access to unexpected visitors, making it difficult for interviewers to reach them. In addition, other areas were inaccessible for interviewers due to safety concerns. Under these circumstances, which are commonly observed in Brazil, prior valuation studies have conducted in-person interviews at what Brazilians refer to as "democratic locations" (e.g. Brugnaro, 2010; Rezende et al., 2015). Democratic locations are those points of interest that are frequented by all socio-economic strata such as the central plazas, malls, and produce markets. Following this approach, a total of 274 completed questionnaires were obtained.

4. Analytical framework and modeling approach

This section provides a utility-theoretic framework to analyze individuals' responses to improvements in water quality of the PDS river. This framework assumes that the individual i's utility is a function of goods and services she consumes, as well as personal characteristics (hereafter denoted with the subscript i). Let $V_i(Y_i, W, P, Z_i)$ represent the utility function of individual i. Utility levels increase with individual i's income (Y_i) and water services that the PDS river provides (W), and decreases with prices of other goods (P). The individual utility is also affected by relevant personal attitudes and perceptions (Z_i). Keeping everything else constant, a water quality improvement of the PDS river will increase the individual's utility because the amount of water services is expected to increase from its current level W_0 to a higher level W_1. Given that utility decreases with income reductions (i.e. payments), the individual will be willing to pay for water quality improvements up to the extent that this payment does not decrease her utility below the original utility level. Thus, an individual's maximum WTP for an improvement in water quality ($W_0 \rightarrow W_1$) can be stated as follows.

$$V_i(Y_i, P, W_0, Z_i) = V_i(Y_i - \mathrm{WTP}_i, P, W_1, Z_i) \tag{1}$$

This implies that an individual's WTP for water services is a function of multidimensional water attributes, income, prices of other goods, and her personal attitudes and perceptions.

In the referendum format, an individual's willingness to pay for the proposed water quality improvements is not directly observed. It is expected that response to the referendum question will be favorable (i.e., response is Yes) only if WTP is greater than or equal to the program fee (FEE) presented to the respondent. Otherwise, the respondent is expected to vote against the project. This can be represented by an indicator variable R:

$$\begin{array}{ll} R = 1 & \text{if WTP} > \text{FEE} \\ R = 0 & \text{otherwise} \end{array} \tag{2}$$

Hence, the probability of favorable responses is equal to the probability that WTP is greater than the project fee presented to respondents in the CV question [i.e., $P(\text{Yes}) = P(\text{WTP} > \text{FEE})$]. This equivalence allows for deriving WTP estimates from econometric models of binary responses to the CV question. Thus, under the assumption that the error term (e) in Eq. (1) follows a logistic distribution, responses to the CV question are investigated through logit models with the following specification:

$$LN\left(\frac{P_Y}{1-P_Y}\right) = \delta\,\text{FEE} + X\alpha + e \tag{3}$$

where P_Y is the probability of a positive response (i.e. Yes) and X is a vector of covariates including a treatment indicator of restoration time (10 vs 15 years), household income, and control variables for attitudes and perceptions (i.e. $Y, Z \subset X$). The term e is a stochastic error that follows a logistic distribution. δ and α are coefficients to be determined using a maximum likelihood estimation approach. Note that prices of other goods and services

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(P) are excluded from the empirical estimation because they are assumed to be constant across respondents.

The average WTP can be computed from coefficients in Eq. (3) as follows:

$$\bar{WTP} = -\bar{X}\hat{\alpha}/\hat{\delta} \quad (4)$$

where $\bar{X}$ represents the vector of averages of independent variables, $\hat{\alpha}$ represents the estimated coefficients of independent variables other than FEE, and $\hat{\delta}$ is the coefficient of FEE. WTP estimates could be upwardly biased due to the hypothetical nature of the CV question. Blumenschein et al. (2008) and Vossler et al. (2003), among others, propose correcting for response uncertainty to obtain more conservative and presumably realistic WTP estimates. That approach is followed here in considering responses to the CV question as favorable only if the respondent answered Yes to the referendum question ($R = 1$) and indicate a certainty level (c) of her voting response that is greater than (or equal to) a threshold value of certainty ($\bar{c}$). That is, a respondent's WTP is inferred through the recoding indicator R' as follows:

$$R' = 1 \text{ if } R = 1 \quad \text{and} \quad c \geq \bar{c}; R' = 0 \text{ otherwise}. \quad (5)$$

Eqs. (3) and (4) are estimated using the recoded responses in order to provide WTP estimates that are presumably unbiased.

Table 3 presents the variables used to estimate logit models of voting responses. According to the experimental design, the variable FEE depicts the individual's responsiveness to project fees and allows for eliciting the willingness to pay (WTP) for the proposed water quality improvement of the PDS river (i.e. $W_0 \rightarrow W_1$). Given that those fees reduce household budget for other goods and services, FEE is expected to have a negative effect on the likelihood of voting in favor of the project. The binary indicator RESTORE is used to estimate effects of the length of restoration time (15 years relative to 10 years). It can be hypothesized that RESTORE will have a negative impact on the likelihood of voting in favor of the project because respondents may prefer to observe water quality improvements in the PDS river sooner rather than later (see Meyer, 2013). Economic theory also indicates that household income (Y_i) is a relevant variable in consumption choices. The variable INCOME is expected to have a positive impact on the likelihood of voting in favor of the proposed project because the water services to be provided by improving the quality of the PDS river would be beneficial for the household.

Several variables are also included in the logit models to control for heterogeneous attitudes and perceptions among respondents (Z_i). For instance, the binary indicators CREDIBLE and CONSEQUENTIAL are included to control for the perceived credibility of information provided regarding the current water quality of the PDS river and the perceived consequentiality of this study. CREDIBLE is expected to have a positive impact on the likelihood of voting for the project because individuals who believe that the PDS river is contaminated would be more likely to pay for services that are currently considered lost. CONSEQUENTIAL identifies respondents who believe that survey results can influence local authorities to implement the proposed project. According to experimental and empirical evidence (see Carson et al., 2014; Herriges et al., 2010; Vásquez et al., 2009), CONSEQUENTIAL is expected to have a positive impact on the likelihood of voting in favor of the project. Additionally, socio-demographic characteristics (i.e. sex, age, education, household size, and time living in the study site) are used to control for unobserved respondents' attitudes and perceptions. No prior expectations are held for those characteristics because they can be related to pertinent attitudes and perceptions in different forms.

5. Econometric results

Table 3 shows some descriptive statistics that provide a profile of the average respondent. A majority of the respondents were females with an average age of 38 years. More than 40% of respondents completed high school, 28% had a college degree, and 13% had some graduate education. The average respondent has a household with at least three members, a household income of R$ 3760 (US$ 1100) per month, and has lived in Campos for more than 27 years. Females seem to be slightly overrepresented in our sample. Yet, some sample characteristics are comparable to population attributes reported in the 2010 census (see Section 2). For instance, the average number of household members is almost identical (3.19 vs. 3.24). The average income of sampled households is also similar to the average monthly household income reported in the 2010 census adjusted by annual inflation, which would be equivalent to R$ 3545 (US$ 1037) as of 2016.

Table 4 presents marginal effects from two logit models estimated to identify factors underlying the decision to support the proposed water project. Those marginal effects can be interpreted as changes in the probability of voting in favor of the proposed project resulting from marginal changes in corresponding covariates. Model 1 is a more parsimonious model where treatment and respondents' socio-demographic characteristics are included. Model 2 is an extended specification that assumes that the perceived credibility of the water quality assessment and the perceived consequentiality of this study may also affect the individual's decision to vote in favor of the project. The Pseudo R^2 statistics and the Akaike Information Criterion (AIC) indicate that Model 2 performs better than Model 1.[3] In contrast, the Bayesian Information Criterion (BIC) favors Model 1 over Model 2. It is worth noting that estimation results are robust across the model specifications, and that those models yield similar WTP estimates.

As expected, estimated coefficients on FEE are negative and statistically significant (at 10% level). This result indicates that the likelihood of voting in favor of the proposed project decreases with additional fees to be charged for improved water quality of the PDS river. This finding is consistent with economic theory and yields

[3] Several pseudo R^2 statistics have been developed for logit models. Table 4 presents two of the most commonly used ones: McFadden's and the Count Pseudo R^2.

Table 3
Variables definition and descriptive statistics ($n = 274$).

Variables	Definition	Mean	S.D.
FEE	Additional fee to be charge for water improvement	16.77	8.28
RESTORE	Restoration time (1 = 15 years; 0 = 10 years)	0.478	0.500
FEMALE	If the respondent is female (1 = Yes; 0 = otherwise)	0.602	0.490
HIGHSCHOOL	If the respondent has high school education (1 = Yes; 0 = otherwise)	0.405	0.492
COLLEGE	If the respondent has college education (1 = Yes; 0 = otherwise)	0.281	0.450
GRADUATE	If the respondent has graduate education (1 = Yes; 0 = otherwise)	0.131	0.338
AGE	Age of respondent (in years)	38	15.085
INCOME	Households' monthly income in the month prior to survey implementation measured in intervals of 1000 Reais[a]	4.255	2.985
HHSIZE	The respondent's household size	3.190	1.712
LIVING	Number of years that the respondent has lived in the city of Camposdos Goytacazes	27.409	19.984
CREDIBLE	If the respondent believed that the water quality of Paraiba do Sul river is type III (1 = Yes; 0 = otherwise)	0.555	0.498
CONSEQUENTIAL	If the respondent believed that the survey results can influence local authorities (1 = Yes; 0 = otherwise)	0.712	0.454

[a] Income intervals are: 0 = no income; 1 = less than 1000 Reais; 2 = 1000–2000 Reais; .... 10 = 9000–10,000 Reais; and 11 = more than 10,000 Reais.

Table 4
Logit models of voting responses (Marginal effects).

	Model 1	Model 2
FEE	−0.006 (0.003)*	−0.006 (0.003)*
RESTORE	0.040 (0.055)	0.047 (0.055)
FEMALE	0.010 (0.058)	0.004 (0.057)
HIGHSCHOOL	−0.085 (0.085)	−0.088 (0.084)
COLLEGE	0.020 (0.096)	0.024 (0.094)
GRADUATE	−0.106 (0.128)	−0.114 (0.129)
AGE	−0.009 (0.003)***	−0.009 (0.002)***
INCOME	0.001 (0.011)	0.0004 (0.010)
HHSIZE	0.029 (0.020)	0.030 (0.020)
LIVING	0.002 (0.002)	0.002 (0.002)
CREDIBLE	–	0.071 (0.056)
CONSEQUENTIAL	–	0.107 (0.061)*
Observations	274	274
McFadden's pseudo R^2	0.076	0.092
Count pseudo R^2	0.679	0.682
AIC	337.11	335.59
BIC	376.85	382.56

Notes: Numbers in parentheses are corresponding standard errors.
* Significance at 10% level.
*** Significance at 1% level.

support to the construct validity of our referendum CV scenario to value water quality improvements. The split-sample treatment indicator, RESTORE is statistically insignificant suggesting that respondents are indifferent between 10 and 15 years to achieve a Type II classification for the PDS river. Prior studies have found that respondents are somewhat impatient in achieving river restorations (Kahn et al., 2017; Meyer, 2013). In this study, we did not find statistical evidence on local residents' impatience to restore the PDS river, at least not for the window of time included in the CV scenario (10 vs. 15 years).

Results also indicate that the probability of a favorable vote decreases with respondent's age. Compared to younger individuals, older people may believe that they will benefit from the proposed project during a shorter period of time. Therefore, when discounting future benefits, older people may find that those (discounted) benefits do not surpass the present value of project fees and, consequently, they are less likely to vote for the PDS river restoration. Consistent with prior studies that indicate that perceived consequentiality of CV surveys have an effect on individuals' willingness to pay (e.g. Carson et al., 2014; Herriges et al., 2010; Vásquez et al., 2009), the estimated coefficient on CONSEQUENTIAL is positive and statistically significant at 10% level (see Model 2). This result suggests that respondents who believe that this study may influence policymakers to restore the PDS river are more likely to vote for the proposed project than those respondents who do not believe so. Other covariates were found to be statistically insignificant.

Table 5 shows the average WTP for water quality improvements with corresponding 95% confidence intervals calculated using Krinsky and Robb's (1986) bootstrapping procedure (with 5000 simulations). Model 1 indicates that the average individual would pay R$ 47.05 more in their monthly water bill for improving the water quality of the PDS river up to a type II classification. Model 2 yields a similar estimate of R$ 44.34. WTP estimates can be compared to the average monthly household income to explore the household's ability to pay a project fee. The WTP estimate derived from Model 1 is equivalent to 1.25% of the reported average monthly household income, and the WTP estimate from Model 2 is equivalent to 1.18% of that average income. These estimates represent a small share of the household income, which suggests that households would be able to afford paying a project fee of R$ 44 to R$ 47.

As discussed above, there is a persistent concern that WTP estimates derived using the CV method can be biased due to its hypothetical nature. Following Blumenschein et al. (2008) and Vossler et al. (2003), among others, we estimated more conservative WTP estimates by recoding favorable responses to take the value of zero (i.e. voting against the project) if the respondent reported a (low) certainty level of one or two (out of five) regarding her vote response. This certainty threshold is consistent with the median certainty level of three and the average level of 3.36.[4] Based on this criterion, a total of 26 positive

[4] It is worth noting that average certainty levels remain between 3.1 and 3.6 across proposed project fees. We found reported certainty levels to be disassociated from the proposed project fee ($\chi^2 = 20.66$, p-value = 0.417).

Table 5
Estimates of average willingness to pay.

	Model 1	Model 2
Mean	47.05**	44.34**
Upper bound	278.41	195.20
Lower bound	−113.22	−90.38

** Significance at 5% level.

Table 6
Estimates of average willingness to pay with certainty correction.

	Model 1	Model 2
Mean	34.32*	30.48**
Upper bound	198.06	106.90
Lower bound	−108.65	−36.04

* Significance at 10% level.
** Significance at 5% level.

responses were recoded as zero. Table 6 shows those WTP estimates. The average respondent would pay between R$ 30.48 and R$ 34.32 for water quality improvements, depending on the model used to estimate those values. Those estimates are equivalent to 0.81% and 0.91% of the average household income respectively.[5]

6. Discussion and conclusions

This study investigated the willingness to pay for restoring the Paraíba do Sul river, one of the most important catchments in Brazil. The proposed environmental improvement was based on the water classification defined in the Brazilian water legislation. Our water testing results suggest that the PDS river can be currently classified as Type III. The contingent valuation scenario consists of improving the river water quality up to a Type II classification. With this definition of the proposed environmental improvement, this study will facilitate the dialog among different stakeholders given that the Brazilian legislation clearly define biological and chemical benchmarks and water services for each water classification. Moreover, willingness-to-pay estimates provided in this study demonstrate the relative importance of the PDS river to local residents. Hence, this study is policy relevant and a contribution to the growing literature on contingent valuation of environmental improvements in developing countries.

Under the current classification, the PDS river waters cannot be safely used for swimming, skiing, diving, irrigation of vegetables, direct-contact recreation, or direct human consumption. With the exception of direct human consumption, those services would be restored if the PDS river waters were improved up to a Type II classification. Using the contingent valuation method, this study has estimated the value that Campos' residents would assign to water services regained through a restoration project for the PDS river. Conservative estimates indicate that residents are willing to pay at least R$ 30 in a month for improving the PDS river up to a type II classification. This estimate is equivalent to 0.81% of the average household income. Respondents were informed that those payments would occur monthly for the next 10 years (i.e. 120 payments). Using a monthly discount rate of 2% (as used in Rezende et al., 2015), the present value of those payments would be R$ 1382.43. If those estimates are aggregated over the number of households in Campos (estimated at 144,596 connections to the potable water system), the (discounted) total benefits would be approximately R$ 199.9 million. This estimate can be compared to total costs of the proposed project to assess its feasibility and prioritization among other environmental and social programs.

This study also tested some practical hypotheses. For instance, we investigated effects of the perceived consequentiality of our study on willingness-to-pay estimates (Carson et al., 2014; Herriges et al., 2010). Results indicate that respondents who believe that this study could have policy consequences are willing to pay a higher amount for restoring the PDS river than respondents who do not believe so. In addition, we tested the hypothesis that willingness-to-pay estimates are responsive to the perceived credibility of water quality information provided in the CV survey. No evidence was found to support this hypothesis. Finally, a split-sample treatment was designed to test the hypothesis that individuals are impatient in achieving environmental improvements (Kahn et al., 2017). Findings indicate that respondents are indifferent between achieving river restoration in 10 or 15 years. It could be that the average respondent has an impatience threshold outside of that window of time. For instance, Meyer (2013) found a rapid decay in perceived benefits from river improvements over time, with a loss of half of the benefits when the proposed improvements take 5 years to occur. Investigating local time preferences over different periods of time to achieve river restoration would be a logical extension to this study.

Conflict of interest

None declared.

Ethical statement

Authors state that the research was conducted according to ethical standards.

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[5] Higher thresholds of certainty were investigated. With a certainty threshold of four, 91 responses were recoded as zero. When the certainty threshold was increased to five, 137 responses were changed to zero. The high number of responses changed due to uncertainty suggests that certainty thresholds of four and five are too demanding for the voting behavior of our respondents. Therefore, it is not surprising that WTP estimates are statistically insignificant when favorable voting responses are recorded using those certainty thresholds.

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Appendix A. Water services as defined by CONAMA's Resolution No. 357

Source: CONAMA (2005).

Type	Services
Special	Water supply for human consumption with disinfection; preservation of natural equilibrium of aquatic communities; preservation of aquatic environments in units of conservation of integral protection.
Type I	Water supply for human consumption after simplified treatment; protection of aquatic communities; direct-contact recreation such as swimming, skiing, and diving; irrigation of vegetables for raw consumption and fruits that grow close to the ground and that are consumed without peeling it; protection of aquatic communities in indigenous lands.
Type II	Water supply for human consumption after conventional treatment; protection of aquatic communities; direct-contact recreation such as swimming, skiing, and diving; irrigation of vegetables, fruit trees, parks, gardens, and sport fields; aquaculture and fishing.
Type III	Water supply for human consumption after conventional or advanced treatment; irrigation of trees and forage; amateur fishing; secondary-contact recreation; animal watering.
Type IV	Navigation; landscape harmony

Appendix B. Methods used to test the water quality of the Paraíba do Sul River

We applied a chromogenic substrate method (Colilert®) to quantify total and fecal coliform levels in the PDS river. This method confirms the presence of total coliforms when the color of water samples change from colorless to yellow. Fecal coliform is identified using the enzymatic action of β-glucuronidase, which is produced by *Escherichia coli*.

For fecal coliform quantification, we used the Quanti-Tray® with 49 large cavities and 48 small cavities. After passing through a sealer, the pack was incubated in an oven at a temperature of 35 °C for a period of 24 h. Then, large and small cavities with total and fecal coliforms were counted. The counts for fecal coliform are performed under UV light (365 nm) and the data was entered into the program IDEXX MPN Generator 3.2, which provides 95% confidence intervals of the total and fecal coliform in CFU/100 ml.

Since 1994, The Laboratory of Environmental Sciences at Universidade Estadual do Norte Fluminense has monitored nutrients and chlorophyll a levels in the PDS river (Ovalle et al., 2013). Water samples (~2 L) are collected every two weeks in the same site (Site 5 in Fig. 1). For this study, we also collected water samples in two city effluents (Sites 3 and 6 in Fig. 1). Each water sample is initially filtered in fiber glass membranes (GF/F; Ø 0.7 μm), and all filters are used for determination of chlorophyll a. A sub-sample of water (~200 ml) is immediately acidified with 10% H_3PO_4 until pH 1 for dissolved organic carbon and total dissolved nitrogen (DOC/TDN) analysis. Water samples are acidified again (2 M HCl) and sparged with ultra-pure air. DOC/TDN levels are identified using high temperature catalytic oxidation (TOC/TN Shimadzu). The level of total phosphorus is determined according to the phosphomolybdic acid method (i.e. measured spectrophotometrically as reactive orthophosphate). Chlorophyll a is extracted using alkaline acetone (90%) and then its level is determined spectrophotometrically.

See the following sources for a detailed description of water testing methods applied here:

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