DETERMINANTS OF QUALITY AND QUANTITY VALUES OF WATER FOR DOMESTIC USES IN THE STEELPOORT SUB-BASIN: A CONTINGENT VALUATION APPROACH

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Abstract

The value that domestic users attribute to reliability of water supply and to the quality of this water is a function of several determinants, such as the source of water, the socio-economic characteristics of households (per capita income, level of education, etc.), and other variables. Users that have private tap water at home may value less improved availability or more reliable source than households for which the only source of water is the closest river or a borehole. On the other hand, users connected to regular potable water supply are more interested in quality improvements compared to those who fetch water from surface source. This study analysed and measured the influence of such factors on domestic user's perception of the value of reliability and quality of water supply in rural and urban areas of the Steelpoort sub basin of South Africa. A stated preferences method (the Contingent Valuation Method - CVM) was adopted to quantify and analyse the relationship between willingness to pay (WTP) for improved availability and quality of water and such factors. Although WTP is not a measure of water price, and therefore cannot be used to construct water demand functions, the results of these analyses have important policy implications. The results inform decision-makers of the relative contribution of different socio-economic and spatial factors to the value of water. This study draws important lessons for the water demand management and allocation at catchment level.

Keywords:

Water Value, Contingent Valuation, Domestic Uses, Source of Water, Decision Support, Water Quality.

1. Introduction

Water resource allocation is an important issue in present day South Africa. The policy framework for water allocation and management includes the Water Services Act (108 of 1997) and the National Water Act (NWA, 36 of 1998), both of which place on government the responsibility for, and authority over, water resource management, including its efficient and equitable allocation and distribution.

The NWA provides the framework for a decentralized water resource management based on the nineteen Water Management Areas (WMA), where the establishing Catchment Management Agencies (CMAs) will be in charge of the local policies for water allocation to competing users.

The Steelpoort sub-basin (SPSB), situated in the Olifants WMA, is a good case study for the analysis of water demand management and allocation at catchment level. The sub-basin includes water users ranging from domestic households, to industries, mines and agricultural farms. It is expected that these users would place different values on quantity and quality of water depending on their socioeconomic characteristics and, for the economic sectors, their production functions.

There are important gains from water resource valuation for policymakers. First, placing values on water from various sources including surface water would allow policymakers decide whether costs can be recovered from investing in water resource development, including quality control. Second, the values placed on water can be used as input into a cost-benefit analysis to identify institutional and infrastructural changes that may improve water resource management. Third, failure to recognize the economic value of water has led to wasteful and environmentally damaging uses of the resource. Managing water as an economic good is an important way of achieving efficient and equitable use, and of encouraging conservation and protection of water resources (Dublin Statement on Water and Sustainable Development (1992): Principle No. 4). Lastly, many studies that attempt to value water recommend that charge and subsidy levels should be supported by empirical analysis (Halpern, et al., 1999).

A contingent valuation survey was realised in the SPSB to collect factual information necessary for conducting the intended analysis. Consistent with the new policies on water allocation, the study identifies Steelpoort as one of the strategic catchment areas already under stress from the increasing demand for water by different users. While the Department of Water Affairs and Forestry (DWAF) has a goal of using water pricing, limited-term allocations, and other administrative mechanisms to bring supply and demand into balance in a manner that is beneficial and in the public interest (Thompson, et al., 2001), the study models willingness to pay (WTP) for water not as a measure of price, but of values attached to the resource by users.

Goldblatt (1998) used WTP to assess the effective demand for improved water supplies in informal settlements in Johannesburg. The justification for estimating demand functions in most studies is that policy makers would like to have some efficiency criteria for investing in the public good, especially in the water sector which is judged by most as the least financially autonomous sector.

The South African experience is particularly remarkable in that there is a huge demand for new infrastructure given the inequality inherited from apartheid era. There is a big public pressure on government to redress the inequality from the national statistics of about 99.9% of white South Africans having access to formal water services opposed to 43.3% of Africans as of 1994. On the other hand, the public investment required to achieve equity in water access has no corresponding pricing mechanism to ensure efficiency since pricing water at the margin (equating prices to the marginal cost of water provision) would be regressive. In addition, South Africa is recovering from a “political game of passive resistance” that took the form of nonpayment of rents and services charges to government during the apartheid era (Goldblatt, 1998).

Regardless of these weaknesses, the WTP method can estimate the benefit that people attach to the provision of water. The estimation of WTP is based on Hicksian compensated demand function that, for all practical purposes assumes utility maximization and the related axioms about preferences of consumers are satisfied. This is justified since water is provided at a fee in the study area, although some sources of water are available at no fee.

This paper estimates the value that domestic users in the SPSB attribute to improved quantity and reliability of water supply and to improved quality of water. The main variables that influence these values include the source of water, family size, individual and family income, level of education, and household location.

The paper is organized in five sections. Section 2 sets the theoretical basis and specification of the empirical model; section 3 describes of the data used to calibrate the empirical model; section 4 presents and discusses the empirical results; conclusion and implications of the study are drawn in section 5.

2. The contingent valuation framework

Contingent valuation (CV) is an important survey-based procedure for eliciting the economic value of the quality and availability of nonmarket commodities (Nicklitschek et al., 1996). The method is particularly attractive because of its simplicity and flexibility, and it is commonly applied to cost-benefit analyses and environmental impact assessments.

The CV framework is based on maximizing utility from the consumption of market and non-market goods such as environmental quality Q[1]. Q is therefore used as an argument in the individual’s utility function,

$$U(X,Q) \qquad (1)$$

Where X is a vector of market goods. The individual’s problem is to maximize *U (.)* subject to the budget constraint,

$$PX = M \qquad (2)$$

Where P is a vector of market prices, and M is income. When Q is given, the solution of the utility maximization problem is a set of Marshallian Demand functions,

$$X_i(P,M,Q) \qquad (3)$$

The Contingent Valuation Methodology (CVM) builds on the above framework adopting indirect utility functions,

$$V_i(P,M;Q);\forall i \qquad (4)$$

Where $i = 1,...,N$ denote individuals.

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[1] The household model is from Freeman (1993).

Since a market does not exist for the environmental good Q, its value is inferred from survey data reporting households' willingness to pay (WTP), or willingness to accept compensation (WTA) for a change in its quantity or quality (Kuriyama, 1998).

When a policy change is implemented so that quantity or quality of Q improves, i.e. from Q_0 to Q_1, the CVM survey measures the compensating surplus an individual is willing to pay to enjoy the improvement, i.e. remain at the same (compensated) utility level.

$$V_i(P, M, Q_0) = V_i(P, Q_1, M - WTP) \tag{5}$$

Where WTP is individual i's stated willingness to pay, P, M and Q as defined above.

The individual's willingness to pay for the change could formally be represented by:

$$WTP_i = m(P, Q_1, U_0) - m(P, Q_0, U_0) = P\left\{H(P, Q_1, U_0) - H(P, Q_0, U_0)\right\} \tag{6}$$

Where *m (.)* is the expenditure function, and *H (.)* is the Hicksian (compensated) demand function[2].

Until recently, stated preference data analysis focused mainly on WTP measures and their implication for environmental decision-making (Ryan, et al., 2000). The major advantage of the WTP approach is that anything of value to people can be translated into utilities in a framework that operates in financial terms (Anand, 2000). As illustrated above, underlying the WTP method is the assumption of utility maximization and the related axioms about preferences of consumers.

Questions have been raised in the literature on reliability and appropriateness of WTP measures for resolving social choice problems. Those include the reliability and validity of the survey instrument, the rationality of responses, and the sensitivity of the results to sequence, context and delivery of the questionnaire (Ryan, et al. 2000). WTP values are subjectively held valid to fill gaps caused by non-existent markets in situations in which we can only rely on responses to hypothetical questions. Assigning hypothetical or actual WTP to environmental options requires that the completeness axiom holds, yet the hypothetical nature of the CVM-WTP survey implies that preferences do not exist until the time an individual is invited to make a choice.

Anand (2000) further argues that WTP should not be used as criteria for social choice because incompleteness of preferences is fundamental to any social choice problem. In addition, a normative analysis of social choice problem is logically not constrained by the same axioms of completeness and transitivity of preferences as assumed by the WTP approach. Individual preferences will in general be relevant though decisions made on behalf of the citizenry are not the same as those made by the market, since among other things the relations between beneficiaries, providers and other stakeholders including the state are quite different in the two cases. To equate social and individual choice either misspecifies the decision problem, or uses wrong preferences to solve it.

Consumer theory gives a positive relationship between WTP and household income (Deffar, 1998). The households' socioeconomic characteristics such as household size, education, municipal location, and the resource characteristics such as the source of water and the distance to the source are then assumed to account for variations in WTP responses (Hokby and Soderqvist, 2001).

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[2] This WTP exercise is applicable when only one profile change is proposed to respondents.

2.1 The 2-Step Model

In implementing the CVM survey, a respondent is presented with questions on whether or not he or she is willing to pay either for improved availability or quality of the commodity in question. In the **first step**, one would be interested in the probability of an outcome of dichotomous choice problem (yes/no) measured by the latent response variable (*wi*), i.e.,

$$\left.\begin{array}{l} P(wi=1)=F(X,\beta) \\ P(wi=0)=1-F(X,\beta) \end{array}\right\} \qquad (7)$$

Where X is a vector of explanatory variables explaining the individual's choice of whether or not to pay, β is the set of parameters. The marginal effects on *P* (.) are derived from the cumulative density function. Assuming a logistic distribution, the standard logistic model is expressed as the odds, i.e.,

$$\frac{F(X,\beta)}{1-F(X,\beta)}=e^{Z_i} \qquad (8)$$

The log of odds is linear in Z_i, for all individuals in the sample,

Where $Zi=\beta' X$ (9)

The probability that an individual would be willing to pay is given by

$$P(wi=1)=\frac{e^{Z_i}}{1+e^{Z_i}} \qquad (10)$$

For simplicity it is usually assumed that the same variables that influence the value of the stated willingness to pay determine whether or not an individual would be willing or not willing to pay in the first place.

The regression model for equation (10) is found by taking the mathematical expectation of the latent variable, given the observed component X :

$$E(w\,|\,X)=0[1-F(\beta' X)]+1[F(\beta' X)]=F(\beta' X) \qquad (11)$$

The first order conditions are given by:

$$\frac{\partial E(w\,|\,X)}{\partial X}=\left(\frac{dF(\beta' X)}{d(\beta' X)}\right)\beta=f(\beta' X)\beta \qquad (12)$$

Where *f (.)* is the density function corresponding to the cdf *F (.).*

The second step consists of using the estimated models to calculate the expected mean WTP. The general formulation of the empirical Tobit model is given as:

$$WTP_i^*=\beta' X_i+\varepsilon_i \qquad (13)$$

$$WTP_i=\begin{cases} 0 \text{ if } WTP_i^*\le 0 \\ WTP_i^* \text{ if } WTP_i^*>0 \end{cases} \qquad (13')$$

Where X_i' is for individual i, a vector of explanatory factors in the regression, β is a vector of fitted coefficients, and WTP_i^* is the stated willingness to pay for individual i.

The vector $X_i^{'}$ referring to WTP for improved availability of water was assumed to include the following variables: frequency of availability of water, per capita water consumption, household monthly income, age of the household head, source of water and the maximized WTP probability for improved quantity of water from step 1. To estimate the WTP for improved quality of water, the vector $X_i^{'}$ was assumed to include the maximized WTP probability for improved quality from step 1, the household monthly income, the amount of water consumed, the water user's appreciation of quality, and the source of water.

The Tobit specification for estimating WTP for both improved quality and quantity was favored over the OLS (Tables 9 and 10). The OLS assumes that those who are not willing to pay for water in the logistic regression would not participate in the *market for improved availability of water* even if more water were to be provided to them. The Tobit regression assumes that the OLS is a misspecification, since an *a priori* filter for those with $WTP = 0$ amounts to sample selection bias, and the least squares estimators are as a result biased and inconsistent[3].

The Tobit model was estimated using maximum likelihood to generate estimators that are consistent and asymptotically normal, although these properties are highly sensitive to specification errors (Amemiya, 1973; Judge, et al., 1987). The Tobit model is also less useful for predicting fitted WTP. The standard Tobit may give predictions that fall outside the domain of permissible values. Inclusion of observations for which the $WTP = 0$ causes the function to swivel towards negative values, although the WTP function has a lower limit of zero. Values falling below the lower limit would not make any economic sense although the underlying model is statistically valid.

The complication with predicted values from a Tobit also arises because there are three possible regressions depending on the nature of the study. The first regression is similar to the ordinary least squares (OLS) when the dependent variable is largely uncensored.

$$E(WTP_i^*) = X_i'\beta \qquad (14)$$

The second and third, and their corresponding marginal effects are given below.

$$\left.\begin{aligned} E(WTP_i \mid WTP > 0) &= X_i'\beta + \sigma\frac{f_i}{F_i} \\ \frac{\partial E(WTP_i \mid WTP > 0)}{\partial x_j} &= F_i\beta_j \end{aligned}\right\} \qquad (15)$$

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[3] About 38% of the sampled households were not willing to pay for more quantity, while about 59% of the sampled households were not willing to pay for improved quality.

$$\left.\begin{aligned} &E[WTP_i] = F_i E\left[WTP_i \mid WTP > 0\right] \\ &\frac{\partial E[WTP_i \mid WTP > 0]}{\partial x_j} = \beta_j \left[1 - (f_i X_i{}'\beta)/(\sigma F_i) - (f_i / F_i)^2\right] \end{aligned}\right\} \qquad (16)$$

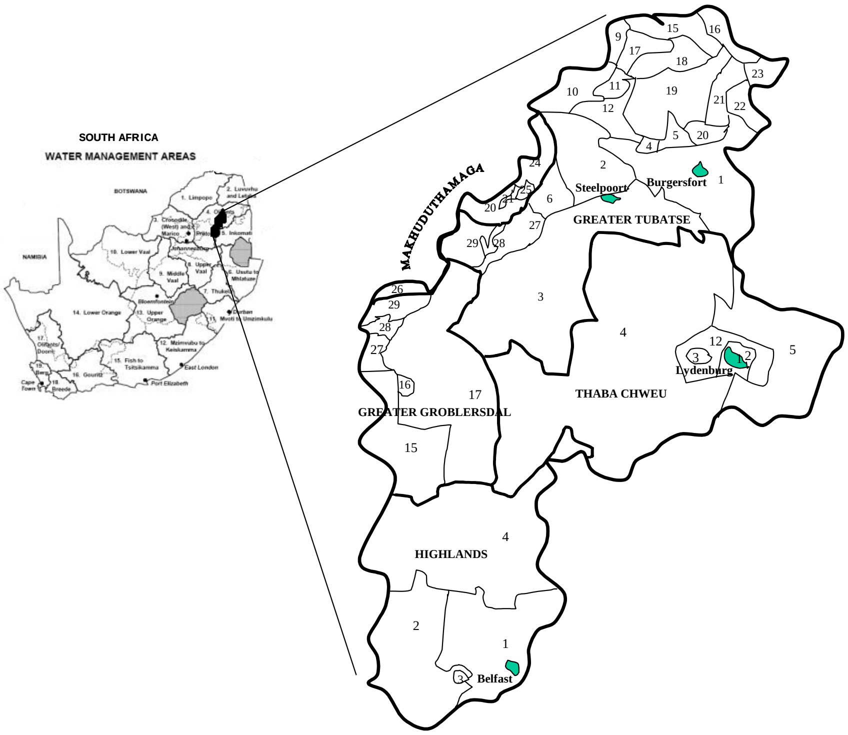
Where f_i and F_i are respectively the probability distribution function and cumulative distribution function of a standard normal distribution evaluated at $Z_i = \frac{X_i{}'\beta}{\sigma}$, and σ is the standard deviation of the regression error term.

3. Sources of the data

This study adopted the CVM described above to analyse determinants of quality and quantity value of water in the SPSB.

To implement the intended analysis, a CV survey was carried out among rural and urban households in the SPSB. As argued earlier, the SPSB was chosen as a case study due to its representativity of a catchment under water stress and for its diversity of water users potentially in conflict.

The target population for the study was defined as the households in the SPSB using water for domestic purposes. This population is distributed in 43 wards of five municipalities, namely: Greater Groblersdal (GG), Greater Tubatse (GT), Highlands (HL), Makuduthamaga (MK), and Thaba Chweu (TC) (map 1).



Map 1 – The Steelpoort sub-basin: Municipalities, administrative wards and main urban centers

Using the South Africa Explorer software (Jhagoroo et al. 2000), and the 1996 Stats SA Census data, the total population in the sub basin was estimated at 249,066 habitants (47,892 households). This population was calculated by overlapping maps of the sub-basin by the Department of Water Affairs and Forestry (DWAF) and those by SA Explorer. The latter indicate the administrative units (wards and municipalities) to which Census data refer. This procedure allowed including in the target population (with a certain degree of precision) only those households falling within the sub-basin borders.

Following one of the key questions of the study, consisting in the investigation of the different domestic water uses and consumption patterns observable in rural and urban areas, a stratified sample of rural and urban households was chosen from the target population. The survey aimed at providing a description based on factual data of the current differences in terms of water supply and distribution in the two mentioned areas. The CVM was then adopted to elicit the WTP of rural and urban households for improved availability and quality of water, and the relation between their respective WTP and their current situation.

It was assumed that “urban areas” were the wards including the four major centers in the sub-basin, namely Lydenburg (2 wards), Belfast, Steelpoort, and Burgersfort. According to this assumption, out of the 47,892 households in Steelpoort, 41,079 live in rural areas while 6,813 live in urban areas. The number of respondents to be selected from each stratum was found by multiplying the uniform sampling fraction (0.0055) by the size of the population in each stratum. This resulted in 226 rural households and 37 urban households. Because of the limited number of urban households resulting from this technique, the survey team decided to bring this sub-sample to 60 households. Rural households to be interviewed were also increased to 270. During the survey it was also possible to interview an additional group of 45 rural households. This brought the total sample size to 375 households (315 rural and 60 urban).

Six rural wards were identified due to their representativity of their respective municipalities. Two wards were from GT (a third was added during the survey), one in GG, HL and TC respectively. All the five wards of the sub basin including towns of certain relevance were selected as urban areas for the survey.

To obtain the list of the households, a multistage selection was implemented consisting of the following steps. In rural areas: 1) A list of the villages comprised in each rural ward was obtained by the ward’s councilor; 2) Two villages were randomly selected in each ward; 3) A list of households living in the village was obtained by the chief of the selected villages; 4) A random method was adopted to identify the households to be interviewed. In urban areas, to obtain the households lists in each town the team made use of the telephone directory or contacted the councilors in each selected ward.

Once the survey was conducted, we realized that the characteristics of the 45 households interviewed in TC (3) were those of an urban area, and not rural as we thought when designing the sample. Furthermore, one of the rural questionnaires was not properly filled and was discarded. The final composition of our sample was therefore: 374 households, of which 269 rural and 105 urban. After these adjustments, the urban stratum represented 28% of the sample, whereas in the mother population it accounts for only 14.3%.

To collect the necessary factual data, a CV survey questionnaire was developed and tested. The survey questionnaire was designed to capture four types of data, namely location of the household by municipality and ward, its socio-economic characteristics, water availability and use, and willingness to pay for improved water availability and quality.

Households were asked whether or not they were willing to pay, first for an improved availability of, and a more reliable access to water, then for an improved quality of water (and the amount they were willing to pay).

4. Discussion of the empirical results

4.1 Socio-economic characteristics of the sample

An average household income of R1,632/month characterizes the surveyed sample (Table 1), with a relatively high level of dispersion. This result is consistent with the data from the 2001 Census (Statistics SA, 2003), from which the average household income for the Steelpoort sub-basin is R1,787/month.

Tab. 1 – Monthly income (ZAR) per household and per capita in Steelpoort

Location	***Mean household monthly income***	***St. dev. monthly income***	***Mean monthly income per capita***	***St. dev. monthly income per capita***
Rural	1109.7	1095.1	188.7	241.6
Urban	2972.5	4410.8	784.5	1539.1
Steelpoort	1632.7	2643.6	356.3	880.8

The average income for the surveyed rural households corresponds to one third of the urban households' one (one fourth in terms of per capita income).

These considerations regarding income distribution among the surveyed households are important for analyzing the uses of and willingness to pay for water, as income is an important determinant.

33.7% of the heads of the surveyed households declared to be unemployed (almost 40% in rural areas) (Table 2) compared with 80% of real unemployment (declared unemployed + not economically active) in the sub basin according to Statistics SA. 26.5% of the interviewed heads of households receive a state pension, whilst 20% of the household heads are employed either in the public or in the private sectors. Another 9.4% is self-employed running small trade businesses.

Tab 2 - Occupation of household head (%)

Occupation	***Rural***	***Urban***	***Steelpoort***
Farm Worker	6.3	1.9	5.1
Pensioner	28.6	21	26.5
Domestic	1.1	1.9	1.3
Public Sector	4.8	21.9	9.6
Mining Worker	4.1	1.9	3.5
Industrial	6.7	14.3	8.8
Self-Employed	8.6	11.4	9.4
Unemployed	37.9	22.9	33.7
Other	1.9	2.9	2.1
Total	100	100	100

As it was observable for the monthly income, the level of education attainment is very different in rural and urban areas (Table 3). Rural households' heads declared an average level of education corresponding to primary school compared to the secondary school level of the urban ones.

Tab. 3 – Level of education of the household head

Location	***Education attainment****
Rural	0.9
Urban	1.8
Steelpoort	1.1

* : 0=none, 1=primary, 2=secondary, 3=diploma, 4=degree

4.2 Patterns of water use

Four different sources of domestic water were identified in the SPSB: private tap, collective tap, river water and vending water. Private tap water users were mainly found in urban areas, while collective tap, river water and vending water are mostly in rural areas.

The distribution of water sources for the whole sample indicates that most households get their water supply from collective taps (Figure 1). Private tap water represents the second most important source, followed by river water, while use of water supplied by vendors is marginal.

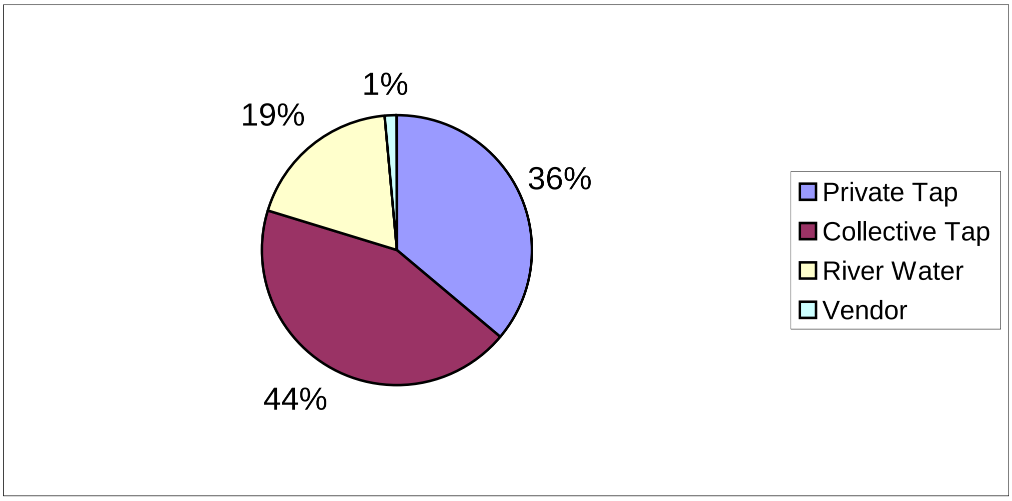


Fig. 1 – Sources of water in the SPSB (2003)

These results are consistent with the Stat SA data from the Census 2001 that provide the following distribution of sources in the sub-basin: tap in dwelling and inside yard 29.7%, collective tap 35%, river + stream 24.8%, vendor 0.9%, other 9.6%.

Important geographical differences were observable when data were analysed by municipality (Figure 2). Households surveyed in Thaba Chewu live in the urban area of Lydemburg and their source of water is exclusively private tap. Conversely, households in the rural Makhuduthamaga in the areas once occupied by Bantustans rely almost exclusively on collective tap water. Households interviewed in Greater Tubatse and Greater Groblersdal live either in peri-urban or in rural areas, and their source of water is mainly collective taps or river. Greater Tubatse households having private taps live in the urban areas of Steelpoort and Burgensfort. Finally, households surveyed in Highlands have a good access to private tap water. They live either in the urban area of Belfast or in the relatively rich rural area represented by ward 3 where large commercial farms are located.

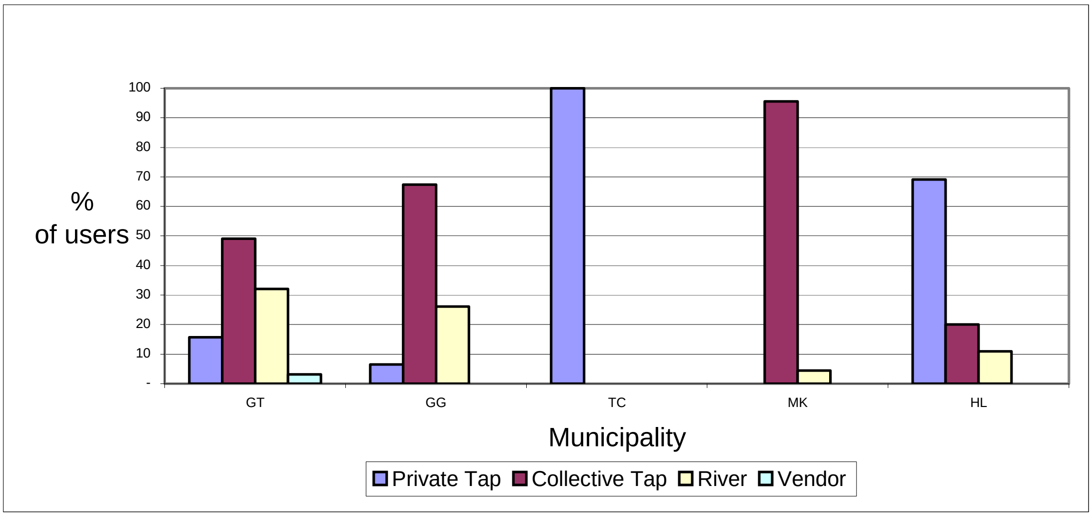


Fig. 2 – Water source distribution per municipality in Steelpoort

A clear dichotomy is observable between rural and urban water consumption patterns. Urban households consume three times more water than rural ones, and per capita consumption in urban areas is five times higher than in rural areas (Table 4).

Tab. 4 - Monthly water consumption per household and per capita

Location	***Household water consumption (m^3/month)***	***Per capita water consumption (m^3/month)***
Rural	4.8	0.8
Urban	14.8	4.6
Steelpoort	7.6	1.8

A wide range of variation exists among urban areas, whereas water consumption in rural areas seems to be more uniform. A household typology was identified for both rural and urban units (tab. 5). From the surveyed sample, three types of urban households and two types of rural ones were determined. *Urban 1* is formed by households living in TC (1), GT (1) and GT (3). This group has the highest level of income, employment, and literacy. *Urban 2* is formed by households living in TC (2) and TC (3) and has an intermediate level of education, a low per capita income and a very high unemployment rate. *Urban 3* is formed by households living in HL (1) and it is characterized by the lowest urban per capita income and educational level. The high percentage of pensioners in this group keeps the figure of unemployment at a reasonable level. Households living in former Bansustans (GT (4, 17, and 29), GG (27), and MK (26)) form *Rural 1*. This group has rates of employment, literacy, and per capita income among the lowest of the whole surveyed sample. Households living in HL (2) constitute *Rural 2.* This group has a per capita income comparable with the one of the *Urban 2* group and is mainly composed by farm workers (30%) and families receiving state pensions (30%).

Tab. 5 - Monthly per capita income, unemployment rate, and education attained by the head of the household in urban and rural groups

Group	*Monthly per capita income (ZAR)*	*Unemployment rate (%)*	*Education Attainment**
Urban 1	1733.1	0	2.6
Urban 2	303.4	40	1.5
Urban 3	128.9	20	0.8
Rural 1	164.7	40	0.9
Rural 2	311.4	10	0.7

* : 0=none, 1=primary, 2=secondary, 3=diploma, 4=degree

Table 6 indicates that *Urban 1* group has far higher water consumption than the other two urban groups. The source of water influences heavily the consumption pattern. In fact in urban areas households with private taps consume as an average three times more water than collective tap users and twice more than river water users. On the other hand, in rural areas the water source does not seem to influence significantly water consumption.

Tab. 6 - Per capita monthly water consumption (m^3) by source of water in urban and rural groups

Group	*Private Tap*	*Collective Tap*	*River Water*	*Vendor*	*Total*
Urban 1	9.2	5.4	-	-	9.1
Urban 2	2.5		-	-	2.5
Urban 3	1.3	0.4	2.2	-	1.3
Urban	**4.8**	**1.4**	**2.2**	**-**	**4.6**
Rural 1	0.4	0.8	0.7	0.4	0.8
Rural 2	0.8	0.8	0.2	-	0.8
Rural	**0.7**	**0.8**	**0.7**	**0.4**	**0.8**

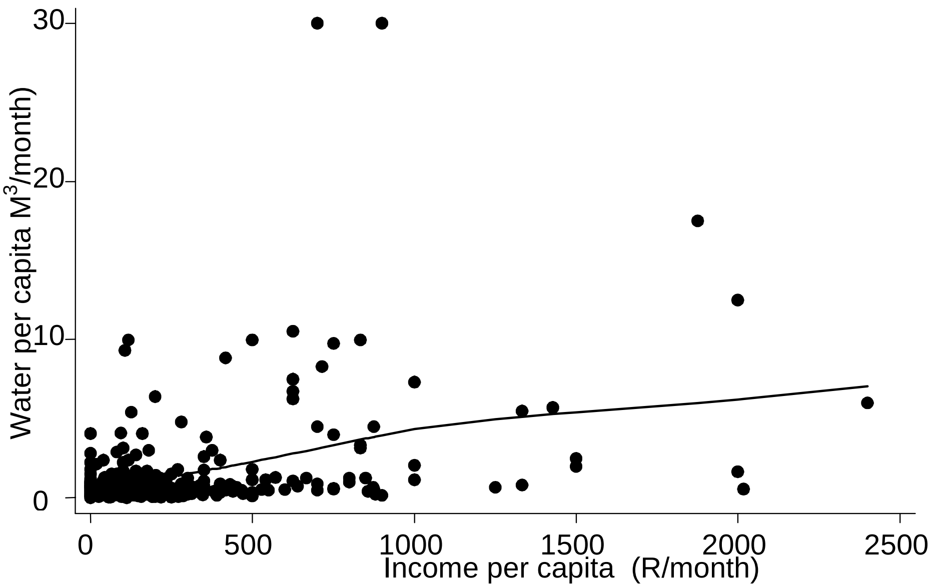


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Fig. 3 – Water consumption and income in Steelpoort

Water consumption is clearly correlated with some of the observed socio-economic variables. Figure 3 shows the correlation between per capita income and per capita water consumption.

Another factor influencing water consumption is the frequency of water availability. This variable is highly correlated with the source of water, as indicated in table 7. Almost all households with private tap water have access to the resource all day every day, whereas most of collective tap and river water users cannot afford more than one or two trips per day to fetch water. The distance to the closest source and the time needed to perform the task were important limiting factors. On the other hand, very few households in rural areas fetch water with a frequency lower than daily.

Tab. 7 - Frequency of using/fetching water by source (%)

Frequency	***Private***	***Collective***	***River Water***	***Vendor***	***Total***
Less than once everyday	3.7	8	0	50	5.1
Once everyday	1.5	27.6	11.3	50	15.1
2X everyday	1.5	31.3	35.2	0	21
3X everyday or more	93.3	33.1	53.6	0	58.6

Water quality perception is also heavily influenced by the source of water. Table 8 indicates that 87% of households with private tap consider the quality of water “good” or “very good”, while only 57.1% of collective tap users and 7.1% of households fetching water from the river rank “good” or “very good” the quality of the resource. The proportions are reversed for households considering the quality of their water bad. In fact 88.5% of households fetching water from the river consider the quality of the resource “poor” or “very poor”, while 32.5% of collective tap users and only 9.6% of private tap users rank the quality of their water “poor” or “very poor”.

Tab. 8 – Perception of water quality by source (%)

Water quality	***Private tap***	***Collective tap***	***River Water***	***Vendor***	***Total***
Very poor	4.4	6.1	41.4	0	12.1
Poor	5.2	26.4	47.1	20	22.5
Just OK	3.7	10.4	4.3	0	6.7
Good	11.1	8.6	7.1	0	9.1
Very good	75.6	48.5	0	80	49.6

4.3 Willingness to pay for improved water quality and quantity

Of the total sampled households, 61.9% were willing to pay for improved availability of water, while only 40.6% were willing to pay for improved quality of water.

The distribution of households’ binary decision to pay (or not to pay) for improved availability is statistically strikingly different between rural and urban households. 82% of interviewed rural households are willing to pay for a more regular and reliable source of water, compared with only 11% of urban households. On the other hand, 48.3% of rural households were willing to pay for improved quality compared to only 21% in urban areas.

This confirms the importance of connecting rural households to regular supplies of clean water whereas urban households place higher priority on quality as they are already connected to regular supplies. It is clear that rural households have very high demand for both quantity and quality attributes.

The application of the two-step model to the collected data allowed revealing the *incidence* (probability) and the *intensity* (quantification) of WTP for improved quantity and quality of available water. The logistic analysis (first step) providing the incidence of WTP can be found in the appendix 2. The results of the second step are illustrated in the following sections.

4.3.1 Willingness to pay for improved availability of water

The maximized probability from the logistic regression has a positive and significant influence on the willingness to pay for improved availability of water. A bootstrap of the standard error of the coefficient revealed however the maximized probability was biased[4]. The bias is not peculiar, since we are dealing with a predicted value from a probability model designed as far as possible to attach high probability values to extreme values (0 and 1). The resulting distribution of the predicted probabilities has a peak at each extreme value.

The [frequency of] availability of water is significant and negative. This suggests a negative relationship between the availability of water, which is a measure of the reliability of water supply from the source, and willingness to pay for more water. The more reliable the water supply is to a household, the less the household would be willing to pay for more regular water supply. Private tap and collective tap water users have a more regular supply of water, and so have an eroding impact on the mean willingness to pay. The tap water dummy in both regressions also confirms the latter.

Tab. 9 - WTP regression for improved availability of water

	TOBIT		
Wtpq=WTP amount for quantity*			
	Coefficient	*t*	*P>t*
Constant	10.27	0.74	0.46
Pqty=(predicted probability from logistic regression)	66.17	8.48	0.00
Availability of water (frequency)	-9.11	-4.84	0.00
Income (square root of)	0.10	0.97	0.33
Water per capita	4.59	2.19	0.03
Tap= dummy for tap water	-24.41	-5.12	0.00
Age	-0.03	-0.18	0.86
_Se (Ancillary parameter)	*32.11*		
Number of observations	354[#]		
F (7, 215)			
Prob > F			
R-squared			
Root MSE			
Pseudo R^2	0.08		
LR chi2 (6)	187.21		
Prob > chi2	0.00		
Log likelihood	-1123.62		

#: Observations summary: 131 left-censored observations at wtpq ≤ 0, 223 uncensored observations

** The stated WTP amount (R/month) per household*

Level of significance: 10%

The per capita monthly consumption of water is significant and positive. This result is consistent with the theoretical expectations that, at low levels of water consumption, the

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[4] A bootstrap procedure is a re-sampling technique from a sample from either an unknown or known population. In the case where the population is unknown, an empirical cumulative distribution function can be estimated after re-sampling with replacement from the sample.

more the positively valued good is consumed, the more a household is willing to pay a marginally higher amount to improve water availability. It can be noted though that some rural households using collective taps or river water, and therefore willing to pay for an improved and more reliable water quantity, have a relatively high water consumption. Income is also positive, but insignificant. Bootstrapping the standard error rejects the assumption of inconsistency in the income coefficient. The age of the respondent was found to be negative but insignificant.

4.3.2 Willingness to pay for improved quality of water

The maximized probability from the logistic regression has a negative but significant influence on the WTP for improved quality. This result would at first glance be peculiar. However, this perception disappears as soon as the distribution of willingness to pay responses for the logistic model is interposed with the households' location, source of water, and income. In fact, the large majority of bids for improved quality come from rural households having access to river or collective taps, whereas only 14% of private tap users, mainly in urban areas, were willing to pay for improved water quality. Because of the income effect, individual urban household's WTP is higher than rural household's one. This fact affects the coefficient of the maximized probability from the logistic regression in the WTP function for water quality because urban households willing to pay individually more are few, and rural households willing to pay individually less are numerous. In line with the above interpretation, income has a positive and significant marginal impact on households' willingness to pay for quality. The household current consumption of water is also positive and significant factor explaining the willingness to pay for improved quality of water. A household with abundant water would be more concerned with improving quality of water than if it had access to less water.

Tab. 10 - WTP regression for improved quality of water

	TOBIT		
Wtpl = WTP amount for quality*			
	Coefficient	t	P>t
Constant	59.85	6.07	0.00
Pqlty =(predicted probability from logistic regression)	-28.50	-3.63	0.00
Income	0.001	2.74	0.01
Water = amount of water used per month (log of)	2.09	1.78	0.08
Wuaql = water user's quality ranking (0= poor,…, 5=very good)	-18.49	-8.68	0.00
_Se (Ancillary parameter)	18.32		
Number of observations	364[#]		
F (6, 142)			
Prob > F			
R-squared			
Root MSE			
Pseudo R2	0.13		
LR chi^2 (4)	212.51		
Prob > chi2	0.00		
Log likelihood	-693.23		

#: Observations summary: 215 left-censored observations at wtpl $\leq$ 0, 149 uncensored observations
** The stated WTP amount (R/month) per household*
Level of significance: 10%

Water users' appreciation of quality is negative and significant. This means that as an individual's appreciation of quality increases, their marginal contribution to WTP declines. The quality of water was highly correlated with the dummy for tap water. The dummy variable for tap water was found to be negative but insignificant, and was subsequently eliminated from the regression.

4.3.3 Expected WTP and discussion

Equation 16 was used to estimate the predicted values (Table 11) for those households who were willing to pay a positive WTP amount.

Rural households consistently placed more value on improving availability and quality of water. Urban households were only marginally willing to pay for additional quantity and improved quality since as indicated in the regression results, they are typically tap water users with an almost sure access to water.

Tab. 11 - Predicted willingness to pay (R/household/month) for improved quantity and quality of water

Location	**Median WTP for Quantity**	**Mean WTP for Quantity**		**Median WTP for Quality**	**Mean WTP for Quality**
Rural	22.3	21.6		4.4	6.3
Urban	0.8	3		0.5	4.5
Steelpoort	17.8	16.4		1.8	5.8

It has to be noted that WTP* for improved water availability as a proportion of the household's monthly income corresponds to 2.7% and to 0.5% in rural and urban areas respectively. On the other hand, WTP* as a proportion of the actual monthly cost of water (estimated opportunity cost for river water users) corresponds to 107.5% and 2.9% in rural and urban areas respectively.

An immediate implication of the results is that rural households value improved availability of water more than the urban households. The welfare implication is therefore that improving water quantity and quality has a higher marginal benefit to rural households[5]. There is sufficient evidence that the rural households could actually support some of the investment that would be necessary to improve availability and quality of water.

The creation or improvement of infrastructure and services that may improve water services and distribution will significantly improve the welfare of both the rural poor and the middle-income urban households. Such infrastructure would increase access to clean water, and improve the living standards of rural households. Equity would also be enhanced as rural households enjoy the same level of water services as the urban households.

Improving water provision in rural areas could affect negatively the revenue of the water-vending sector. But in Steelpoort, vending water users account for only 1% of the sample compared to about 19% of river water users who stand to benefit from infrastructure development. The socioeconomic gain would therefore be positive in the case of improved water provision.

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[5] Urban households with revealed WTP*>0 for quantity were willing to pay a higher amount averaging R24.45 per month compared to rural mean WTP for quantity of R22.03 per month. Similarly, urban households with WTP*>0 for quality were willing to pay a higher amount averaging R21.52 per month compared to rural mean WTP for quality of R9.62 per month. The predicted WTP for urban households was lower because of the high number of zero respondents who were included in the Tobit regressions. The total sample average WTP for households willing to pay a positive amount was R22.14/month for quantity and R11.35/month for quality respectively. The predicted WTP for urban households was lower because of the high number of zero respondents who were included in the Tobit regression.

Public investment in water facilities is the key to unlocking development in water services in rural areas. Where the main source of water is the river, the government may come in to provide collective taps. The results also show that households with collective taps would wish to graduate to private taps, a development that may allow households to improve other sanitation requirements such as flush toilets and safe convenient water. The predicted WTP for both quantity and quality indicate that provision of collective taps or private taps where they were inexistent would improve household welfare with the possibility of recouping some of the investment through charges.

Where public investment is unattainable, enhancing the participation of private water-providers such as vendors would be an alternative to be explored. As indicated above, the success of the vending sector in Steelpoort is limited, probably because of its informal nature. Government may intervene to introduce some standards, or at least provide a regulatory framework that would enhance the success of the sector.

5. Conclusion

This paper set out to estimate willingness to pay for improved availability and quality of water in Steelpoort river basin. Two broad conclusions are drawn as follows.

First, rural households stand to benefit from improved availability of water more than urban households. The local government responsible for providing water would be maximizing social welfare if investments were carried out to extend allocation of private tap water to those currently using collective tap water. In addition where budgetary considerations limit such investments, extending collective tap water to those using river water and vending water would be *Pareto* efficient[6].

Second, there are cost-recovery avenues that may provide budgetary relief. Internally, there are many households having access to private tap and collective taps at zero cost, or at a cost not corresponding to the quantity used. This anomaly should alert the relevant authorities of inefficient billing and tariff collection by their agents. Externally, the household valuation of water would to some extend provide a basis for investing in water resource improvement since some of these values could eventually be recouped in the form of tariffs.

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[6] There is scope for improving the availability of water for collective tap users and river water users without having to raise the tariffs for private tap water users.

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Appendix 1: Probability functions for the CVM model

Since we are assuming a logistic distribution function,

$$\left.\begin{aligned} f(.) &= \frac{e^{Zi}}{(1+e^{Zi})^2} = \Lambda(Zi)[1-\Lambda(Zi)] \\ \frac{\partial f(.)}{\partial X} &= \Lambda(Zi)[1-\Lambda(Zi)]\beta \end{aligned}\right\} \qquad \text{(A.1)}$$

Since each observation is a single draw from a Bernoulli distribution (binary with one draw) and all observations are independent, the probabilities can be modeled as,

$$P(wj = ij) = \prod_{ij=0}[1-F(\beta' X_j)]\prod_{ij=1}F(\beta' X) \qquad \text{(A.2)}$$

Hence the likelihood (and log likelihood) function to be maximized is:

$$\left.\begin{aligned} L &= \prod_{j=1}^{n}[F(\beta' X_j)]^{wj}[1-F(\beta' X_j)]^{1-wj} \\ LogL &= \sum_{j=1}^{n}[wj \log F(\beta' X)] + (1-wj)\log[1-F(\beta' X)]] \end{aligned}\right\} \qquad \text{(A.3)}$$

Once the probability of a respondent is observed, the underlying value of the WTP is a function of the maximized probability:

$$WTP_i^* = \max(wi^*, 0) \qquad \text{(A.4)}$$

Equation (A.4) is estimated using the standard censored Tobit model. It is assumed that the error term in equation (A.4) is normally distributed. Although the underlying population is assumed normal, survey data are rarely normally distributed. A bootstrap procedure is employed to assess the consistency of the results.

Appendix 2: Estimating probability of WTP

The decision whether or not to pay for improved availability of water is mainly influenced by the source of water (table A2.1). The odds of willing to pay for improved availability increase for collective tap water users and river water users, but declines for private tap water users. It is therefore more likely for collective tap and river water users to be willing to pay for improved availability of water compared to private tap users. As demonstrated in the text, private tap users typically have easier and more reliable access to water, hence are unlikely to be in favor of paying for a better supply.

	Logistic for willingness to pay for quantity				Logistic for willingness to pay for quality			
	Wtpqt (1= Yes, 0= No)				*Wtpql (1=Yes, 0 =No)*			
Explanatory Variables	***Coefficient***	***Std. Err.***	***Z***	***P>|z|***	***Coefficient***	***Std. Err.***	***Z***	***P>|z|***
Location: 1= urban, 0 = rural	-1.43	0.46	-3.12	0.002				
Source of water dummies								
private tap#	-9.57				-3.01			
collective tap	5.08	0.56	9.07	0.000	1.48	0.34	4.41	0.000
river	4.49	0.62	7.25	0.000	1.52	0.58	2.64	0.008
Education dummies								
none	0.22	0.46	0.49	0.627				
primary	1.02	0.56	1.81	0.071				
secondary	0.78	0.47	1.67	0.095				
tertiary#	-2.02							
Income					0.02	0.01	2.48	0.013
Water Quality (1= Poor, 0= otherwise)					3.29	0.37	8.88	0.000
Constant	-2.44	0.45	-5.43	0.000	-3.13	0.42	-7.53	0.000
Number of observations	373.00				372.00			
Wald chi2 (6)	156.53				131.05			
Prob > chi2	0.00				0.00			
Log pseudo-likelihood	-81.00				-148.07			
Pseudo R2	0.67				0.41			

Level of significance: 10%

#: Calculated after the regression as the negative of the sum of the coefficients of the other categories

Tab. A2.1 - Probability models for willingness to pay for quantity and quality of water

Location of a household is another significant explanatory variable in the quantity logistic regression. Urban respondents are less likely to be willing to pay for improved quantity of water. This is consistent with the finding of the descriptive analysis that urban water users have higher per capita water consumption (about three times the sample mean).

The level of education is also a significant factor explaining the binary choice to pay or not to pay for more water. Respondents with qualifications below tertiary school are more likely to be willing to pay for more water because most of them live in rural areas and have access only to collective taps or river water. In contrast, tertiary qualifications holders live mainly in urban areas, have access to regular private tap water, and would be less likely to be willing to pay for an improved access to water.

The odds for respondents with primary education are higher compared to those with secondary qualifications. This is because only 27% of the respondents with primary qualifications compared to 53% of the respondents with secondary education have access to more regular water from private taps. Respondents with no education would be less likely to pay for more water because they have low or no income.

Water quality perception is the main determinant for the decision whether or not to pay for improved quality of water. The source of water is also an important determinant of the binary choice to pay or not for improved quality of water.

Private tap water users typically have better quality water and so the odds of paying for improved quality declines. Collective tap and river water users are inclined to wish for better water quality, due to their negative perception of the resource quality.

Income is another statistically significant explanatory variable for those willing to pay for improved quality. Income has a positive influence on the probability of a household to pay for improved quality of water although the marginal odds for income are only 0.02.