Estimating the Willingness-to-Pay for Water in Georgia

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Abstract: *In this paper, data from a 1992 telephone survey of Georgia residents were used to study people's willingness-to-pay (WTP) for water as a commodity. A dichotomous contingent valuation method was employed to estimate the marginal scarcity rent of water. Results indicated that the average WTP was $15.10 above the current monthly water cost, or about 81 percent of current bills. The aggregate WTP for all of Georgia was estimated to be nearly $393 million, suggesting that water is underpriced.*

Key Words and Phrases: *Dichotomous contingent valuation, Public water supply, Water pricing.*

In 1994, the Congress of the United States took up the reauthorization of both the Safe Drinking Water Act (SDWA) and the Clean Water Act. Throughout the debate over both acts, all agreed on one thing: The price of water will increase. The U.S. Environmental Protection Agency (EPA) recognizes that the SDWA has become a symbol of the debate over unfunded federal mandates. The EPA notes that while 89 percent of all U.S. households pay an average of $1 to $2 per month for SDWA compliance, costs for households served by some small systems can be more than tenfold higher. Thus, those living in rural areas of Georgia, as well as agribusinesses throughout the state, will be facing higher water costs in the future.

As state and local government officials debated the SDWA reauthorization, they often cited the reluctance of people and businesses to pay higher water bills. However, the pricing of water across the United States often does not provide an environmentally, economically or socially sound utilization of water resources (Postel). Throughout the United States, rates charged to public water users are generally based on the historic average costs of producing and distributing water. Although water is plentiful in the United States, many states, notably California and other western states, have experienced severe water shortages. Hence, there is uncertainty about the future supply of water. In determining the price charged to users, water is usually treated as an economically "free" commodity. Because water is viewed as a free good, local water suppliers often price water using a descending rate structure. Results from the American Water Works Association *Water Industry*

Data Base indicate that 40 percent of the utilities surveyed nationwide have declining block rates and 44 percent use a uniform rate structure. A recent study in Georgia showed that 51 percent of the sampled water utilities in the state were using a uniform rate structure— customers were charged the same per unit cost regardless of quantity. Six percent used a flat payment method whereby customers paid a constant dollar amount regardless of use. Of the rest, 33 percent used a decreasing rate structure, seven systems were unmetered and 7 percent used an increasing rate system (Jordan and Elnagheeb).

Charging declining, or even uniform rates, encourages high water consumption. In the face of long-term water supply problems and insufficient financing to improve the situation, water rates should better reflect true costs. To encourage wise water use and conservation, the full economic value of the commodity should be reflected in its price. Further, as researchers explore the economics of tradeable water permits, data on the full value of the commodity is required. Economists have routinely called on water systems to replace average cost pricing with a rate structure that includes the marginal cost of providing water (Goldstein; Mann; Mercer and Morgan; Raftelis). Marginal cost pricing would include the marginal scarcity rent of the resource.

Furthermore, as noted by Kucera, water rates need to, but rarely do, reflect the risk component of cost of service. Implementation of the SDWA and the Clean Water Act will require increased expenditures by water systems. Kucera also discussed the increased risk of higher capital costs due to changes in the financial markets. Due to the costs of developing new water supplies and assuring water quality, financial rating services such as Standard and Poor have revised their benchmarks to reflect escalated risk. Consequently, whether marginal scarcity rent is recognized or not, water prices do not ordinarily include these levels of risk. Accounting for these risks will require additional revenue to be recovered in rates. What then is the public's willingness-to-pay for water as a commodity or for its risk component?

Extensive literature exists on water demand (e.g., Agthe et al. 1986, 1988; Billings, 1982, 1987; Billings and Agthe; Charney and Woodward; Chicoine et al.; Foster and Beattie, 1979, 1981; Gibbons; Griffin and Chang; Hanke; Herrington; Hewitt and Hanemann; Kindler and Russell; Nieswiadomy and Molina, 1988, 1989, 1991; Opaluch; Schneider and Whitlach; Stevens, Miller and Willis; Thomas and Syme). Other researchers have considered the measurement of water quality benefits (Schutz and Lindsay; Smith and Desvousges). This paper takes a different approach by attempting to estimate the value of water as a commodity. This value is loosely defined as the maximum amount people are willing to pay every month above their current water costs for water as a commodity.

The policy hypothesis of this paper is that water as an economic good is underpriced. Furthermore, if viewed as an economic and not a free good, people would be willing to pay more for water to account for its value as well as the future cost of risk. Thus, the underpricing of water is due to faulty assumptions by rate makers about consumer response to higher water prices.

As noted by Colby, in most regions of the United States, water is not bought or sold in competitive markets. Thus, data do not normally exist for standard demand analysis that would reveal the value of water. Even in the west, where there are emerging water markets, most are transfers of rights for agriculture or other uses. Lichty and Anderson surveyed a number of water valuation techniques designed to estimate the value of water. These usually infer the value of irrigation water from regression analysis of farmland prices. Young and Gray also estimated the value of irrigation water for lawns and some indoor residential use. Yet, outside of the agriculture sector, there are few examples of free market water transactions to observe water values.

Other valuation techniques noted by Lichty and Anderson include the estimation of demand functions that try to determine user response, in terms of consumption, to different prices in the agriculture sector. A cost-of-delivery technique is used mostly by water departments, while economists have also explored the alternative cost method. Input-output analysis has also been used to value water as a part of the final demand of an industrial sector. Finally, linear programming (Kulshreshtha and Tewari) and simulation analysis have been suggested. The contingent valuation method (CVM) has also been employed to value water. However, most such studies have used the CVM to value amenities such as upstream recreational opportunities.

Colby notes that many water studies on urban water demand focus on price elasticities, but not on the willingness-to-pay (WTP) for additional units of water. The vast majority of these marginal demand studies have focused on the responsiveness of quantity demand to changes in price and not on the marginal scarcity rent of water.

The purpose of this paper is to present the results of a 1992 WTP-for-water telephone survey conducted in Georgia. The WTP for water above the current price, was estimated using CVM (Mitchell and Carson)and a dichotomous-choice model.

Model

The maximum payment people make today to secure future supplies of a resource is called option price (Bishop; Freeman). The option price is the sum of expected consumer surplus and option value and is an appropriate measure of economic value of a resource when uncertainty prevails (Brookshire, Eubanks and Randall; Desvousges, Smith and Fisher). Our objective here is not to distinguish between the two components of the option price. Rather we want to estimate people's total WTP today to guarantee the same supply in the future.

We assume the individual wants to maximize his/her utility function subject to a budget constraint:

$$\max_{X,W} U(X,W;S)$$

$$\text{subject to} \quad P_x X + P_w W = I \tag{1}$$

where X is a set of all goods other than water, W is water, P_x and P_w are the prices of X and W, I is income and S is a set of socioeconomic and demographic characteristics.

Solving (1) will give the indirect utility function:

$$V_O = V(P_x, P_w, I; S) \tag{2}$$

Due to supply decrease, as we suggested in the survey, a shift in the supply curve will result in a price increase from P_w to (P_w+d) and the new utility function will be:

$$V_1 = V(P_x, P_w + d, I; S) \tag{3}$$

Now, if the consumer had to pay any amount (i.e., WTP) to get back to the old price (shift in supply by opening new sources, as suggested in our survey), then that amount should not make him/her worse than would the price increase. That is:

$$V_2 = V(P_x, P_w, I - WTP; S) >= V(P_x, P_w + d, I; S) = V_1 \tag{4}$$

The maximum amount of WTP will set equality in equation (4). Solving (4) (with equality) we obtain:

$$WTP = f\,(P_x, P_w, d, I; S) \tag{5}$$

The function $f(.)$ in (5) will depend on the function $V(.)$ (Hanemann 1984, 1985, 1989).

The value of d will depend on the shift in the supply curve (as expected by the respondent) due to the expansion of the population in Georgia. In our empirical model we use the variable *CONCERN* (see Table 2) to capture this effect. We assume P_x to be constant across respondents, while water price, P_w, is approximated by the monthly water bill (*COST* in Table 2). Gender, age and education were used for S. We also used a dummy variable (*OWNWELL*) to distinguish between those who get water from their own wells and those who get water from city/county systems. If water is a normal good, we expect the effect of income (I) to be positive and that of water price

(*COST* = P_w) to be negative. The effect of *d* (*CONCERN* in empirical model) is also expected to be positive because the higher the shift in supply, the more one needs to pay to get back to the old price. The effects of other variables (s) are to be determined empirically and compared to previous studies.

Survey

The analysis in this paper was based on a telephone survey of Georgia residents using a random dial approach (Dillman). The survey was conducted by the University of Georgia Survey Research Center in 1992. The survey covered only residential households. Out of 520 contacted eligible numbers, responses were received from 400, resulting in a response rate of about 77 percent. The 120 non-response numbers included business numbers, respondent unavailable, non-working numbers, no answer/busy, or strange noise. The 400 responses represent a statistically valid sample of the population of Georgia (Schaeffer, Mendenhall and Ott).

Respondents were given the following brief description of the water situation in Georgia:

> Although surface water and groundwater remain plentiful in Georgia, population pressures are beginning to affect the future outlook for water supplies. Population expansion has caused concern about the reliability of future water resources. Such concern has led the states of Alabama and Florida to question Georgia's water use in court.
>
> Currently most water systems in Georgia sell water to customers at the cost of production and distribution only. Water itself is treated as a free good or commodity. No doubt, such low prices have encouraged wasteful use of this precious resource.
>
> Conservation of existing water, exploration and opening of new water sources require substantial amounts of money. One way to collect such money is to stop treating water as a free good. That means that we, as customers, pay for the water costs of production and distribution, as well as for the water itself.

Then the following hypothetical situation was read:

> Now I would like to read a hypothetical situation to you. Imagine that the local water system will measure the amount of water you use every month even if the water is from a well that you own. Imagine also that the water system authority will charge you a fixed price for every 1,000 gallons of water you use. This price will be fixed for the next five years. This will increase your monthly water costs by the real value of water you use.

Following this, the WTP question was asked. The WTP question used the referendum format which has been recommended and used by several CVM researchers (e.g., Bishop and Heberlein; Hanemann 1984, 1985). The WTP question reads as follows:

> Now, suppose that the water authority would send you a monthly bill of $X for the water you use in addition to whatever amount you are now paying for water. Would you be willing to pay this amount?

The caller filled in the value of the bid, X. Different values of X were used for different respondents. These bid values were based on a pretest telephone survey of 40 Georgia households. The WTP question in the pretest survey used the open-ended format (Mitchell and Carson). A method suggested by Boyle, Welsh and Bishop was then used to determine and assign bids to respondents in the actual survey.

The survey also asked respondents where they obtained water (city/county or own well), its monthly cost, how concerned they were about possible water shortages in Georgia, and socioeconomic and demographic characteristics.

WTP Estimation

There are two approaches to estimate equation (5). One approach is to choose a function *V()* as in equation (2) and then solve the equality in (4) analytically for WTP (Hanemann 1984, 1985, 1989). Another direct approach is to assume a functional form for *f(.)* in equation (5) and then estimate it (Cameron 1988; Cameron and Huppert; Cameron and James). The two approaches can give the same results depending on the choice of *V(.)*. In this paper we follow the second approach. We also assume that WTP (equation 5) is a linear function of the explanatory variables:

$$WTP = XB + e \tag{6}$$

where e is an independently identically distributed (as normal) error term with zero mean and σ standard deviation.

In the dichotomous contingent valuation method, which was used in this study, each respondent was asked whether she\he would be willing to pay a certain amount, t_j. The variable h_j takes the value one if the j^{th} respondent says "yes" to a bid t_j, and zero otherwise. The probability of a "yes" response, $Pr[h_j = 1]$ is given by:

$$\begin{aligned} &Pr[h_j=1]=Pr[WTP_j \geq t_j] \\ &=Pr(X_jB + e_j >= t_j) \\ &=Pr(e_j/\sigma >= -W_j) = \Phi(W_j) \end{aligned} \tag{7}$$

where:

$$W_j = -t_j/\sigma + X_jB/\sigma \qquad (8)$$

and $\Phi(.)$ is the distribution function for the standard normal distribution.

The parameters of the above model can be estimated by the maximum likelihood (ML) method. The log-likelihood function, L, is given by:

$$L = \Sigma_j \; 1n(\Phi[(2h_j-1)W_j]) \qquad (9)$$

where the summation is from j=1 to j=n, and ln stands for the natural logarithm.

Since W_j is linear in parameters (where $1/\sigma$ and β/σ considered parameters), packaged commands, such as PROBIT in LIMDEP (Greene), can be used to estimate these parameters. Because of the invariance property of the maximum likelihood estimates, estimates of σ and β can then be obtained from the estimates of $1/\sigma$ and β/σ. The expected WTP from equation (6) is, therefore, given by:

$$E(WTP) = XB \qquad (10)$$

The model in (6) was estimated by "weighted" maximum likelihood using the software LIMDEP (Greene). To restore population representativeness, appropriate weights were used in the estimation (Sonquist and Dunkelberg). The weights were based on cross-tabulations of race by sex and education from the sample and census data (Bachtel; Wetrogan). These weights help mitigate the sample bias when calculating the aggregate WTP for the state (Loomis). Separate WTP regression models for the city/county and private-well-water users were first estimated. However, pooling the data gave better statistical results.

Nonparametric Estimator of WTP. The previous (parametric) approach of estimating the average WTP required a (normal) distribution assumption. The danger of the distribution assumption is that parameter estimates will be inconsistent if the assumption is not correct (Yatchew and Griliches). The non-parametric approach, which is distribution-free, relaxes this assumption (Duffield and Patterson; Kriström). For more details, see Appendix A.

Empirical Results

Table 1 presents the offered bids and the distribution of responses to these bids. Table 2 presents definitions and descriptive statistics for the explanatory variables, (X) of equation 6.

Table 1.
Distributions of Responses to Offered Bids

			Wholesale		City/County		Own well	
Bid	Assignees[a]	n_1[b]	n_2[c]	P(yes)[d]	n_2[c]	P(yes)[d]	n_2[c]	P(yes)[d]
1	64	62	59	0.618	48	0.672	11	0.377
3	54	52	45	0.688	36	0.628	9	0.922
5	52	49	43	0.612	37	0.628	6	0.500
7	38	34	32	0.422	22	0.520	10	0.213
10	68	64	58	0.447	48	0.398	10	0.683
15	38	36	29	0.387	23	0.480	6	0.114
20	24	23	20	0.587	17	0.493	3	1.000
25	24	22	21	0.249	19	0.277	2	0
30	13	13	12	0.121	9	0.170	3	0
35	11	11	11	0.645	10	0.614	1	0.744
45	5	5	4	0	1	0	3	0
70	6	6	6	0	5	0	1	0
100	3	2	1[e]	0	1[e]	0	0	0
Total	400	379	341		276		65	

[a] The number of individuals assigned to bid (whole sample).
[b] The number of individuals who responded with "yes" or "no" to the bid. The difference between columns 2 and 3 is the number of missing observations.
[c] Number of individuals who responded "yes" or "no" after dropping protest responses and outliers.
[d] Weighted proportions of "yes" responses.
[e] One response identified as outlier.

As for checking for outliers, it has been done in CVM studies based on an open-ended valuation question format (Smith and Desvousges). No previous research that we are aware of has attempted to test for outliers in CVM studies based on referendum valuation question formats. In this study we used the "simulated residuals" approach suggested by Gourieroux et al. to detect outliers in censored regression models. Following this approach, only one observation was detected as an outlier. The outlier

Table 2.
Definitions and Descriptive Statistics of Explanatory Variables

		Average[a]		
Variable	Definition	City/Count	Ownwell	All[b]
INCOME	Household's total annual income before taxes for 1992 in dollars.	31,861 (16,915)[c]	33,012 (17,383)	32,095 (16,988)
MALE	1 if male, zero otherwise	0.460 (0.499)	0.453 (0.502)	0.459 0.499)
AGE	Age in years	44 (17)	47 (18)	45 (17)
CONCERN[d]	Zero if not concerned, 1 if somewhat concerned, 2 if very concerned in response to statement in footnote d.	1.04 (0.72)	1.13 (0.64)	1.06 (0.70)
COST	Cost of water per month: water bill and well maintenance and pumping costs	20.84 (16.27)	10.22 (11.02)	18.68 (15.92)
EDUCATION	1 if had college or higher level of edcation, zero if otherwise	0.534 (0.500)	0.525 (0.504)	0.532 (0.500)
OWNWELL	1 if obtained water from own well, zero otherwise	0 (0)	1 (0)	0.203 (0.403)
Sample size		243	61	304

[a] These are weighted averages.
[b] Averages for city/county water users, own well water users, and whole sample.
[c] Numbers in parentheses are sample standard deviations.
[d] Some states, like California, have water shortage problems. Are you very concerned, somewhat concerned, or not at all concerned that a similar problem may happen in Georgia."

respondent had an income of $55,000 and responded "yes" to a bid of $100.00. Respondents with similar incomes responded "no" to lower bids ($70.00 and $45.00 bids). Inspection of Table 1 also indicates that this observation was an outlier.

It is a common practice in contingent valuation studies to examine data for protest "no" responses and outliers. Out of the 400 questionnaires, 379 were complete responses to the WTP question: 179 responded "yes" and 200 responded "no" to the offered bids. Individuals who responded "no" to the WTP question were asked "Why?" Responses such as "I object to having to pay for water itself" or "Water should remain free" were considered protest responses. About 19 percent (37) of the 200 "no" responses were considered protest responses and were dropped from the analysis (Loomis et al.). This reduced the sample size to 342. Missing observations on other (explanatory) variables further reduced the sample size to 305. Dropping the outlying observation reduced the sample size to 304.

Table 3 presents the ML estimates of the parameters and their asymptotic t-ratios as well as the chi-square values for the WTP model of equation (6). When considering the statistical significance of the parameter estimates, the proportion of correct predictions, and the overall significance of all explanatory variables as indicated by chi-squared, Table 3 reveals that the model fitted the data well. Table 3 shows that the model had a high $\chi^2(8)$ statistic of 70.947 and proportion of correct prediction of 0.71. All coefficients were significantly different from zero at the five percent or ten percent level of significance.

WTP for water increased with the level of income indicating that water was a normal good. Table 3 also shows that male respondents were willing to pay less than female respondents. Our results also indicated that WTP decreased as age increased. Previous research has indicated that older respondents were less supportive of environmental problems than younger respondents (Hamilton).

As expected, WTP increased as the individual became more concerned about the possibility of a water shortage, as indicated by the positive coefficient on CONCERN. However, WTP decreased as water cost (water bill or costs of maintenance of well and water pumping) increased. Table 3 also shows that respondents with a college education or higher were willing to pay less than those who had a lower level of education. The negative education coefficient means that, with all other variables held constant, the more education one has, the less is the WTP. For example, a 60-year-old with higher education would be willing to pay less than a 60-year-old with less education, all other characteristics the same. The same can be said about a 30-year-old. While no theory exists about the sign of the education coefficient, one interpretation may be that more educated people may have different information which might lead them to believe that a water shortage is not likely. However, more research is needed on this empirical issue.

The OWNWELL variable differentiates between those who obtained water from their "own well" and those who obtained water from a city/county or community water system. Table 3 shows that the former group was willing to pay less than the latter group. A reason for such a result could be related to a question of property rights. Well owners might have considered water private property, having already paid for it by digging their wells.

Inspection of Table 4 shows that the WTP estimates from the model were close to the non-parametric estimates, especially for the whole sample and city/county. The average respondent on a city/county or community water system was willing to pay

Table 3.
Maximum Likelihood Parameter Estimates and their Asymptotic t-Ratios for the WTP Model of Equation 6

Variable Name[a]	Coeff [b]	Asym t
CONSTANT	19.680*	1.807
MALE	-16.012**	-2.600
AGE	-0.505**	-2.596
CONCERN	9.171**	2.055
COST	-0.395**	-2.024
EDUCATION	-14.035*	-1.953
OWNWELL	-12.646*	-1.740
INCOME	0.001**	3.243
BID (*t-variable*)	32.965**	3.924
$\chi^2(8)$[c]		70.947**
R[d]		0.71

[a] For variable names and definitions see Table 2.
[b] Coefficient estimates for the original parameters, (β, σ).
[c] 8 = degrees of freedom for chi-squared.
[d] Proportion of correct predictions from the probit estimation (Maddala).
*, ** Indicate statistical significance at the 10 percent and 5 percent level, respectively.

Table 4.
WTP Estimates (in dollars)

Whole Sample	City/County	Own Well
Parametric WTP estimates for Equation 6		
$15.10	$16.59	$9.28
(2.86)[a]	(3.31)	(5.64)
Non-parametric WTP Estimates		
16.99	17.45	12.98
(1.60)	(1.75)	(3.65)

[a] Numbers in parentheses are the standard deviations

about $16.59 above their current monthly bill (or $199.08 per year). This represented about 80 percent of the current average water bill. The average private-well-water user was willing to pay about $9.28 per month (or $111.36 per year) which represented about 90 percent of the average water cost to well owners. Previous research indicated that the latter group comprised about 22 percent of Georgia residents (Bachte), which is close to the estimate from this survey (20 percent). The overall average WTP was $15.10 per month ($181.20 per year). With a population of about 6.5 million and an average household of three members, the total number of households in Georgia was about 2.17 million in 1992. Thus, the aggregate WTP for the whole state was $32.767 million per month (or $393.204 million per year).

We also calculated the elasticities of WTP with respect to INCOME and water COST. Evaluated at the averages of income and WTP, the income elasticity of WTP was 2.19. This elasticity was significantly different from zero at the ten percent level. Hence, if the average annual income increased by one percent (about $320.95 per year), average WTP would increase by about 2.19 percent (about $3.97 per year). This increase in average WTP represented only about one percent of the increase in the average annual income ((3.97/320.95)X100).

Evaluated at the averages of COST and WTP, the COST (or own price) elasticity of WTP was about 0.5 (in absolute terms). Hence, as water cost increases by one percent, WTP will decrease by about 0.5 percent. Previous research has shown the demand for water to be price inelastic (Billings and Agthe).

Conclusions

In this paper, data from a 1992 telephone survey of Georgia residents were used to study people's willingness-to-pay (WTP) for water above its current price. The model developed in this paper was based on the concept of option price. A dichotomous contingent valuation method was used to determine the price people would be willing to pay for water above their current water bills. A model that expressed WTP as a linear function of the explanatory variables (income, gender, age, etc.) was found to fit the data well. Results from this model indicated that the average water user was willing to pay $15.10 per month or about 81 percent of the average current bill for water. This amount added up to $393 million per year for the whole state. These results give policymakers some indication of the revenues available to meet the expected costs of water due to the expected population expansion in Georgia.

The study found that WTP for water increased with income and that male respondents were willing to pay less than females. WTP decreased as age increased and also decreased as education level increased. As concern about water shortages increased, so did WTP. WTP decreased as the level of water costs increased. The model estimated here could be used to predict WTP for other states or results from similar models could be compared to these results.

Notes

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Appendix A
Non-Parametric Estimator of WTP

To develop the non-parametric estimator of WTP let t_i denote the ith bid and $\pi(t_i)$ the probability of a "yes" response to the bid t_i; $i=1,...,K$. Further, let M be the maximum an individual (in the population) is believed to be willing to pay. Duffield and Patterson provide the following non-parametric WTP estimator, NWTP:

$$NWTP = \sum_{i=1}^{k} \Delta t_i \, P_i \tag{A.1}$$

where:

$$\Delta t_i = t_i + (t_2 - t_1)/2$$

$$\Delta t_i = (t_{i+1} - t_{i-1})/2 \qquad i=2, \ldots, K-1 \tag{A.2}$$

$$\Delta t_K = (t_K - t_{K-1})/2 + (M - t_K)$$

n_i is the number of individuals assigned the bid t_i, a_i is the number of individuals who respond "yes" to the bid t_i, and $P_i = a_i/n_i$ is the proportion of "yes" responses to bid t_i. The probability $\pi(t)$ is thus approximated by a piecewise linear function through the points $(0, P_1)$, (t_1, P_1), ..., (t_K, P_K), (M, P_K). The WTP estimator in (A.1) is the area under the piecewise linear function and it is like a trapezoidal approximation of the integral of $\pi(t)$, over the range zero to M.

We expect $\pi(t_1) > \pi(t_2) > ... > \pi(t_K)$. However, the observed P_i may not be non-increasing. Therefore, Duffield and Patterson suggest the use of isotonic regression (Robertson, Wright and Dykstra). Kriströn has used this approach making use of the pool-adjacent-violators algorithm for smoothing the P_i's (Ayer et al.). For $P_i < P_{i+1}$, Ayer et al. proposed the use of $\bar{P}_i = \bar{P}_{i+1}$, where $\bar{P}_i$ and P_{i+1} are the maximum likelihood estimates and are given by:

$$\bar{P}_i = \bar{P}_{i+1} = (a_i + a_{i+1})/(n_i + n_{i+1}) \tag{A.3}$$

$\bar{P}_i$ and $\bar{P}_{i+1}$ replace P_i and P_{i+1} in the sequence P_i, ..., P_K. This replacement process continues until the sequence is monotonic (non-increasing in i.)

An estimate of the variance of the non-parametric WTP estimator is given by (Duffield and Patterson):

$$V(NWTP) = \sum_{i=1}^{K} (\Delta t_i)^2 \; P_i \; (1 - P_i)/n_i \qquad \text{(A.4)}$$