The value of water connections in Central American cities: A revealed preference study

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Abstract

We derive estimates of annualized values of access to home tap water, in 17 cities in Central America and Venezuela, using two different revealed preference methods. The first uses changes in capitalized home values from obtaining a connection (denoted HP). The second (denoted DF) derives changes in consumer surpluses on the basis of water demand functions estimated separately on the same data set. The average DF based value of water connections is larger than the HP based value by a factor of about two, when a "low" demand elasticity estimate is used, but smaller but only slightly so under an alternative "high" demand elasticity assumption. In either case the welfare effects of water connections at current water prices are large, and typically add 20-50 % to households' current real income in cities in Honduras, Guatemala and El Salvador. This eliminates 30-40 % of the initial average income difference between the group with and that without current water access.

1. Introduction

Water is an essential resource and commodity for humankind. Securing the full benefit of water for a household requires that it has access to (clean) tap water within the residence. Such access is far from universal in developing countries. Considering the Central American cities dealt with in this paper, tap water coverage is universal in some of the cities, notably Managua, Panama City and the Venezuelan cities, but much lower in the cities of Honduras, Guatemala and some in El Salvador. The main purpose of this paper is to derive values of obtaining tap water connections for hitherto unconnected households. A documentation of such values is of interest for several reasons. First, it may reveal the role of tap water access in alleviating urban poverty, as gaining tap water access contributes to increased real incomes. Equally important from a policy perspective, extending tap water service to additional households typically requires public investments whose returns need to be documented. If it can be demonstrated "beyond reasonable doubt" that the welfare effect of adding a new connection is greater than its costs, the connection ought to be added from a pure efficiency standpoint. Thus issues related both to distribution and allocation are important for motivating an analysis of the type undertaken here.

Estimating or calculating the value of tap water access can be done on the basis of either stated preference (SP) or revealed preference (RP) data. A typical SP approach is to survey a sample of unconnected households who are asked to state their maximum willingness to pay for a water connection. Alternatively, one may survey already connected households concerning the minimum monetary compensation necessary to give up their current connection. Among possible RP methods, two stand out. The first is "hedonic prices" (HP) whereby the value of water connections is inferred from differences in property values according to current connection status. The second can be coined the demand function (DF) approach and implies exploiting the property that the integral under a (known) water demand function of a given household in principle provides a measure of value (or consumer surplus) derived from that household's current water consumption.

SP approaches have become popular and widely applied in a range of valuation contexts, but mostly for "intangibles" such as environmental, health and aesthetic goods. Water is by contrast a more standard marketable commodity lending itself more readily to RP valuation. We will here focus on such approaches, and apply both the HP and DF approaches indicated above. Our basic data set contains survey data for more than 11500 households in 17 cities in Central America and Venezuela. It permits meaningful hedonic price relationships to be derived from 6 of the cities with less than full tap water coverage in this data set.[1] In addition we have available estimates of water demand functions on data for metered tap households in the region. These estimates permit the calculation of consumer surpluses from water consumption for metered tap households, and for non-metered tap households as well using a combination of imputation procedures and aggregate city water consumption figures.

A traditional view among many economists is that RP data are generally superior to SP data, as only the former are based on actual market behavior. This is however not to say that RP data are unproblematic in our applications. Many strong model assumptions lie behind each of our two methods, as will be discussed further in the following. We still stress the strength in being able to apply two alternative and radically different RP methods for one unified purpose. Typically, estimates of the economic value of such amenities are extremely uncertain. If two radically different methods provide valuation figures "in the same ballpark", or better, within a more narrow relative range, the figures can be argued to mutually reinforce each other, even though it provides no direct proof that the figures are correct.

Overall, our results indicate that currently connected households enjoy large welfare gains from their connections to the water system, given current water prices and service levels. Since unconnected households typically have far lower average incomes than connected ones, providing tap water access to more households then also reduces overall income inequalities substantially. One estimate, presented in table 10 below, indicates that the overall average of unconnected households' incomes as a fraction of those of connected ones (when income is defined to include the net welfare gain from a water connection), would rise from 62 to 75 % if tap water were provided to all. Part of this change is due to the fact that most unconnected households today pay far higher water prices than connected households do, but more is due to the fact that tap water as such provides a high level of net consumer surplus to households.

We must stress that our derived welfare measures are those for connected and not for unconnected households. This implies that our measures can most directly be interpreted as unconnected households' "willingness to accept" (WTA) a new

[1] For further descriptions and discussions of this data set see Strand and Walker (2003a, 2003b).

connection (or equivalent surplus measure). In most empirical studies the WTA measure is larger than the perhaps more widely accepted and applied "willingness to pay" (WTP) measure. We also stress that our calculations are "rough" in the sense that the different individual estimates are very uncertain, for a variety of reasons including sampling and specification errors, possible identification problems of the estimated relationships, and other methodological problems related to estimation methods and model formulation. We thus do not find it meaningful to speculate on the overall standard errors on the estimates provided; these estimates rather indicate orders of magnitude of the relevant numbers.

2. Some aspects of the current water situation in Central American cities

In this section we look briefly at some main aspects of the water situation in the cities in Central America included in our data set. Table 1 shows distributions of households by mode of water service in our sample. We distinguish between three main groups: metered and non-metered tap connected households, and unconnected households. Some of the major cities in the region, notably Managua, Panama City and the Venezuelan cities, have basically universal tap water coverage. In most of the other cities substantial fractions of households are not tap connected. The fraction of tap connections with meters is in most cases below (and in some cases much below) half. This is of some importance in the following, as having a meter appears to be associated with considerable economic value in many of these cities.

Table 2 shows average household water consumption by city, measured by our data for metered tap and unconnected households, or by imputed or estimated values for non-metered tap households.[2] An interesting feature of this table is the enormous difference between average water consumption levels of tap and non-tap households. Average monthly tap consumption is in the range 30-35 m^2 in most cases, similar across cities at least for metered households where data are most reliable. By contrast, average non-tap consumption is only 5-6 m^3, less than one fifth of average tap consumption, and much more variable, but in no case more than one third of the tap

[2] Our data population samples are reasonably close to random within each of the three main groups in question, such that the figures in the table are reasonable approximations to average population figures. Our data however do not in general give the correct distributions of households across the three categories.

level (for San Miguel). The differences between metered and non-metered tap households are by contrast rather small with slightly higher consumption levels in the latter group. This group faces a zero marginal water price, making them more wasteful in their water consumption than metered households are (who pay for water at the margin of consumption). The small differences in average consumption levels are however somewhat deceptive. Non-metered households typically have characteristics such as relatively low income and small residences, and are rationed more often and to a greater degree than metered tap household are. All these factors tend to reduce water consumption.[3] In other words, if these differences were eliminated, the differences in average consumption between the two groups would have been greater.

There are five main reasons why water consumption is lower for non-tap than for tap households. First, water prices are generally higher, at least at the margin. Secondly, getting access to water is less convenient, since it must often be hauled to the house. Thirdly, without tap many potential uses of water are often ruled out, such as using washers or even possibly taking showers. Fourthly, non-tap households tend to have certain characteristics (e.g. low income) correlated with low water consumption. Other characteristics of non-tap households (such as large family sizes and living in highly polluted neighbourhoods) however oppose these effects, and imply that the fourth argument is unimportant overall. Fifthly, water quality is most often higher and more homogeneous for tap water than for non-tap water.

Table 3 shows water prices paid by metered tap and non-tap households.[4] We see that average purchase prices for non-tap water are more than 10 times average prices for tap water. The difference is even more dramatic for some of the cities (such as Tegucigalpa) and for water from particular sources (such as water bought from tank trucks which is most convenient to households). Some non-tap water (from wells and public taps) is free; thus the rest (in particular tank truck water) is even more expensive than the table figures indicate.

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[3] In our main report, Strand and Walker (2003a), we estimate effects of these factors on realized water demand, and find that their overall effect is quite large, often in the range one third of actual water consumption or more.

[4] The figures in the table are local values at the times surveys were made (mostly over the period 1995-1997) and converted into current 2001 USD, multiplied by the PPP conversion factor given in the left-hand column. To find figures in current USD, the figures in table 3 must be divided by these conversion factors.

The right-hand column of table 3 shows average time spent on water hauling by non-tap households. The overall average is about 11 hours per household per week, and varies widely (from 3 to 24 hours) across cities. These figures indicate considerable inconvenience in obtaining water for non-tap households.

In all, water prices and inconvenience levels are far higher for non-tap than for tap households. Both factors serve to explain part of the differences in water consumption between these groups. In a separate econometric demand analysis conducted by the authors (Strand and Walker 2003b) (short-run) water demand functions are estimated jointly for tap and non-connected households. This however indicates that only about one third of the difference can be explained by such factors, leaving the rest unexplained. Possibly, the third factor suggested above (tap access facilitates and "creates" more uses of water) explains most of the rest.

These price and quantity differences indicate that providing tap water to a previously unconnected household may lead to enormous welfare gains. This is related both to the much higher pecuniary and hauling costs associated with non-tap water, and to the fact that taps make possible a range of water uses that are otherwise infeasible. The next section sets out to try to quantify these gains.

3 Deriving capitalized values of water connections from home price data

Home prices are likely to embed values of amenities supplied at or in the vicinity of the home.[5] Water service quality is one such amenity. In principle, when a house is purchased, the buyer also purchases the net (expected present) value of water services (as well as other relevant services) to be provided at the house, at all future dates.[6] Consider two houses differing only in the value of water services provided, in a competitive housing market where all households have the same demand for water services. Different prices of the two houses will then perfectly reflect differences in present values of water services provided. In practice the issue is more complicated, due to the housing market not being perfectly competitive, different household

[5] This corresponds to the theory of hedonic prices presented by Rosen (1974), with application to the housing market, see e.g. principal discussion in Freeman (1993) and Palmquist (1991), and recent applications by Lake et al (1998), Bateman et al (2000), Day (2001), and Strand and Vågnes (2001).

[6] In our data we do not identify in all cases whether the current occupant of the property is the owner or a renter. This should be of little consequence here as long as the correct purchase price of the property is given, and rent is not controlled.

preferences, and correlation of water access with other valuable house attributes. Different household preferences also tend to imply that households who value water services highly, have already chosen houses with such services, leaving households with lower values in houses without service. Positive correlations between attributes imply that a high house price tends to reflect high quality of other services than water, whereby the differences in water services only explain part of the house price difference. Moreover, house prices tend to embed expectations about future changes in amenity values (e.g., when an improved water service is expected to be provided at some future date, this should increase the house price for a given current service). The former two factors imply that house price differences tend to overestimate the value of water services, while the latter factor implies the opposite.

Our data set contains about 11500 households. Among these about 4000 individual residence values are recorded (where assessments are made by respondents at the time of interview), together with information on square-meter sizes of residential units and lots and type of ownership. Table 4 shows the percentage distributions across types of home ownership, for each of the three types of water service. The table shows ownership distributions both for the entire data set and for the subset for which we have property prices (in parentheses). The former of these data correspond most closely to true population distributions. The table shows that most metered tap households, and somewhat fewer non-metered tap households, live in residential units with titled ownership, while most of the rest live in units with untitled ownership. By contrast, less than a third of non-tap households have title, and more than a third live on land with no ownership claim whatsoever.

Home values vary considerably by city and category. They average about 13000 USD (PPP adjusted) for houses with no water connection, and about 29000 and 42000 USD for homes with non-metered and metered tap connections, respectively. Table 5 presents results from (linear and log-linear) regressions where house prices are explained by water service variables in addition to other important observed variables. Two water service variables are included, namely main service type, and a dummy taking the value of one only for connected households with daily water service. The cities for which we have data are Managua, Sonsonate, San Miguel, Santa Ana (reference city), Panama, Colon, Guatemala City, Villa Nueva, Chinautla and Mixco. Other variables include residence size in square meters, lot size in square meters, household income, and whether or not owner has title, electricity service, and fixed telephone service. One should here however be aware that several variables, potentially affecting house prices, are missing, such as overall neighborhood quality and house quality, which may be correlated with water access (assuming that the effects of these variables are not picked up by the electricity, telephone and title variables). If this is the case, our estimations will tend to give too high partial values to water access, in determining house prices.

The log-linear relationship gives far better fit to the data than the linear one, and is used in interpreting results.[7] A metered water connection here increases home value by 39 %, and a nonmetered one by 9 %, respectively, for given frequency of tap service. The variable "daily water service" shows the partial effect of daily tap service versus less frequent service (estimated commonly for metered and nonmetered tap households). This coefficient is about 0.17 (implying that the house price increases by 17 % when tap water service is daily instead of less frequent in the log-linear case) and highly significant. This implies that the home values of households with metered tap connection and daily service, are on the average 39 + 17 = 56 % higher than home values for households without tap water access, everything else equal. As already stressed, these calculations must be viewed with some scepticism as the stated differences may represent also other omitted variables in the relationship.

Table 6 provides city-wise results based on log-linear estimations. Here results are much less precise, largely due to the smaller numbers of observations for each city. We have now removed the dummy variable indicating daily service, and concentrate on effects of unconditional metered and non-metered tap service. In all relationships metered and non-metered tap coefficients are positive, and almost everywhere highly significant. Coefficient sizes vary, but are generally higher for metered than for non-metered tap connections. The other log coefficients are also in most cases stable and significant, and (at least when significant) with correct signs. Coefficients from linear relationships are generally less stable, and significant in fewer cases.

All relationships indicate a large partial effect of better water service on house prices. This indicates a large willingness to pay to obtain better water service, or for access to a house in districts with better water service (for given other amenities). It is a bit less clear what its implication is in terms of the value of better water service, since other residential amenities (such as house and neighborhood quality and other unidentified services) which are left out from our analysis could as noted be correlated with the quality of water services.

The estimations in tables 5-6 can be used to derive direct pecuniary effects on home prices of water connections by type of connected service, for previously unconnected households, based alternatively on general and city-specific functions. Only with general functions are we able to distinguish between daily or non-daily service (and then essentially only for non-metered tap households; almost all metered tap households have daily service). Average city-wise pecuniary effects for previously unconnected households are presented in table 7. The first two columns show effects of being connected with meter (using common and city-specific functions respectively), and the last three without meter (the first two columns are based on common estimated function with and without daily service, and the last on specific functions unconditional on service frequency).

4. Values of water connections derived from water demand functions

Values of tap water connections can in principle be derived also from estimated water demand functions. In this section we will derive measures of increases in consumer surplus when previously unconnected households are connected to the water system, based on log-linear water demand functions estimated by the authors and reported elsewhere (see Strand and Walker (2002)). The water demand function for a given household i in the non-stochastic case here takes the following form:

(1) $$\ln W(i) = A(i) - b \ln P(i).$$

W(i) is here water consumption and P(i) water price, and A(i) incorporates all other factors than the water price affecting household i's water consumption, both general factors and those specific to household i. (1) is expressed alternatively as

(2) $$W(i) = e^{A(i)} (P(i))^{-b} .$$

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[7] Semi-log relationships were also estimated, but they were also generally inferior to log-linear ones and are not commented on.

The elasticity parameter -b is considered common for all households. In the CS calculations below we use two alternative values for b. b = 1/3 is considered our "best" point estimate given that changes in P represent simultaneous short-run changes in both marginal and average water price, as found by Strand and Walker (2003b) using an instrumental variable (IV) approach. This estimate is however uncertain, for several reasons. First, different estimation methods tend to yield different values of the demand elasticity under block-rate pricing. The two relevant alternative methods are the Hanemann-Hewitt discrete-continuous choice approach (DCC; Hewitt and Hanemann (1995), Cavanagh, Hanemann and Stavins (2002)), and the nonparametric methods (NM) used by Nauges and Blundell (2002). Cavanagh, Hanemann and Stavins (2002) estimate -b for U.S. households at about 0.3 using the DCC approach, and at about 0.6 using our IV approach. Nauges and Blundell (2002) find similar estimates (from Cyprus) of about 0.45 using IV, and about 0.68 using NM. Both these IV estimates on b are greater than that found by us for Central American cities, while alternative estimates are either higher or lower than the IV estimate. Thus, clearly, the IV estimates (in our case as well) are uncertain, but not obviously too high or too low. Secondly, all our estimates referred to above might be interpreted as "short-run" elasticities, while "long-run" elasticities (perhaps equally relevant) may be higher; see e.g. Hewitt and Hanemann (1995) who find b values in excess of unity using the DCC approach (albeit on data for a rather small set of households). We here thus also consider a higher value of b, namely 2/3.[8]

If b is assumed to be common for all households, $e^{A(i)}$ in (2) can be viewed as determined independently by household. To assess its value for a given household we may consider it determined from (2) for the given water price and quantity facing that household (in the metered case; in nonmetered tap cases we here use imputed values of W, while P is represented by average price). Thus

$$e^{A(i)} = W(i)(P(i))^b . \qquad (3)$$

Inverting (2) we derive the following solution in terms of P:

[8] One might speculate whether even higher values of b are relevant, in view of the Hewitt-Hanemann result. Extending a demand function with absolute values of b in excess of unity however leads to contradictions with our data. It would in case imply that the overall expense on water is lower at high water prices than at low, which is the opposite of what we find. We are thus confident that the absolute value of b cannot be much greater than 2/3.

$$(3) \qquad P(i) = e^{\frac{A(i)}{b}} W(i)^{-\frac{1}{b}} \equiv a(i)W(i)^{-\frac{1}{b}}.$$

(3) defines an individual-specific parameter a(i). Define now the consumer surplus from a water connection for household i, CS(i), in the following way:

$$(4) \qquad CS(i) = \int_{W=W(0)}^{W(i)} a(i)W^{-\frac{1}{b}} dW + P(0)W(0) - P(i)W(i).$$

Again P(0) and W(0) should be interpreted as "backstop" (high) price and (low) quantity (the water price above which the tap price presumably could not rise), taken in the empirical analysis to equal the average of nontap prices and consumed quantities by city. Under log-linear demand functions this is a "conservative" assumption in the sense that the calculated marginal water price at low quantities, along the water demand function, easily can be higher than the nontap price (and the real willingness to pay for tap water may greatly exceed the willingness to pay for nontap water, as indicated by the analysis in section 2.3 above). Calculating the integral in (4), CS(i) may be written as

$$(5) \qquad CS(i) = \frac{a(i)}{1-b}\left((W(0))^{-\frac{1-b}{b}} - (W(i))^{-\frac{1-b}{b}} \right).$$

Since a(i) is household specific, it is more convenient to substitute for a(i) from (4), yielding the following expression:

$$(6) \qquad CS(i) = \frac{1}{1-b} P(i)\left((W(0))^{-\frac{1-b}{b}} (W(i))^{\frac{1}{b}} - W(i) \right).$$

We may alternatively express CS(2) in terms of P(0), the assessed "backstop" coping-water (truck) price. We then arrive at our final expression for household CS:

(7) $$CS(i) = \frac{1}{1-b} P(i)W(i)\left(\left(\frac{P(0)}{P(i)}\right)^{1-b} - 1\right).$$

Using the two alternative estimates for b, of 1/3 and 2/3 respectively, we calculate CS for individual households with tap using actual water outlays for P(i)W(i), average water price (actual or imputed) for P(i), and an assessed average truck price (8 USD, PPP adjusted) for P(0). These CS measures are defined relative to that occurring under a "stipulated maximum" water price level P(0).

In order to compare tap and coping households in a common framework, we need similar measures of consumer surpluses from current water consumption for coping households. This is more problematic as there is less precise information on the marginal value of water at individual current consumption for coping households. Moreover, attempting to measure marginal utilities of water consumption much below the minimum needed to sustain human existence is questionable. In the following we take a simplified approach to this issue by first (in accordance with the above) assuming that households who consume 5 m^3/month of water and use some truck water at the stipulated price of 8 USD/m^3, have a consumer surplus normalized to zero. Secondly, if the truck price facing an unconnected household, P_t, is higher or lower than this level, we assume that the household experiences a "net loss" or "saving" of (8-P(t))*W(c), where W(c) is their overall coping consumption. For households with no truck water consumption we replace P(t) with an imputed price variable, whose value is calculated on the basis of the general truck price in the respective city. Table 8 presents average household CS values by city and type of water service, based on formula (7), separately for metered and non-metered households, where we take the difference between the CS values of the respective tap and non-tap household categories. Overall, there is little difference between metered and non-metered households in a given city and for a given type of calculation, and relatively small variation across cities, reflecting similar city tap water consumption averages for registered metered households and non-metered households. The CS calculations for non-metered households in cities with no metered consumption (essentially all the last 11 cities in the table) are here particularly uncertain, as their consumption must typically be imputed (although we have figures for average household water consumption, from water utilities, for most of the cities).

Calculations of the type executed here are likely to give incorrect individual CS values for coping households. For one thing, the true cost of non-truck water (including hauling costs etc.) is often lower than the truck water cost, in which case CS for unconnected households are higher than the values in table 8. The CS values for tap households may however also as noted be too low, as the marginal value of tap water is capped at 8 USD/m^3 also for these. This may be too low, as the predicted consumption for tap households at 8 USD/m^3 is in general well above average non-tap consumption (5 m^3), while we are in effect only valuing consumption levels in excess of W(8). Thus, clearly, we cannot in general say whether the average CS increase due to a water connection is over- or underestimated in our calculations.

5. Comparing hedonic-price and demand-function derived values of water connections, and some implications

The HP calculations in section 3 and the DF calculations in section 4 can all be used to value water system connections, by city, degree of rationing, and metering. This section seeks to compare the two sets of calculations in a common framework. Note that while the HP calculations are too imprecise to yield meaningful differential information across cities, the DF calculations yield values at the city or even household level, but less information by rationing and metering.

A natural common denominator for the two calculations is average monthly surplus from having a water connection. The surpluses derived from hedonic-price calculations are then found from table 7. A key issue is what discount rate to use when deriving annualised values from the hedonic price estimations. We will base our following calculations on a (seemingly high) discount rate of 15 %.[9] On this basis we calculate the monthly CS values (as 1/12 of the respective annualised values) derived from the HP relationships, for metered and non-metered households with continuous service, presented in the two right-hand columns of table 9. The two left-hand columns are the monthly figures found from the demand function estimations, given in table 8.

[9] While this is a high real rate of discount, households in this part of the world typically face at least similarly high credit (such as home mortgage) interest rates, even for dollar loans where these are available. Note that a high discount rate here is relevant for calculating annualised benefits also when the effect of water service on house price is short-lasting, as it would be when alternative, currently unconnected, home areas can be expected to receive water service at some (not too distant) future date.

The DF-based figures are generally larger for cities where we also have HP data, roughly by a factor of two, when based on a low demand elasticity estimate (b=1/3). Under the alternative assumption (b=2/3), differences between the two types of calculations are by and large smaller, and the HP figures greater on average, more so for metered than for non-metered households.

We also find greater effects of both metering and non-rationing on CS in the HP relationship than in the DF relationship (the latter effect can however not be identified directly from our figures). Our DF relationships are not able to capture all the specific beneficial effects of non-rationing and metering. Note that metering allows households to optimise their individual water consumption in ways that cannot fully be measured here. Metering may also imply other (and not necessarily water-related) benefits such as formalizing the relationship with the authorities. For rationing we have similar differences. Our DF estimations do not capture all inconveniences and extra costs resulting from water rationing, such as necessary instalment of tanks and inconvenient timing of water use over the day or week. In contrast, HP relationships may reflect such inconveniences, as households implicitly express willingness to pay to avoid them through acquiring a home with desirable service characteristics. A problem here is, as already noted, that the HP relationship is likely to capture only expected future service levels. Thus future expected water service improvements at currently unconnected (or poorly serviced) locations tend to reduce the relative current capitalized value of properties with connections. This may partly explain the lower measured values from the hedonic price calculations, as compared to the demand function calculations.

There exist not many studies with which our derived figures for the value of water access can be directly compared. The study that perhaps comes closest is Estache, Foster and Wodon (2002) valuing water services in Honduras from HP studies of differential house rents. Arguably, both the analytical and empirical basis for that study is weaker than for the current study; in particular, the house rent data utilized is likely to be biased due to widespread rent control. Their assessed monthly value of a water connection (almost certainly non-metered) is in the range 30-40 Lempiras per household, equivalent to about 8-10 USD (using the exchange rate of 13 Lempiras per USD for 1997, and adjusting by our PPP factor of 3.16). The benchmark for comparison with that study should here probably be our results for Guatemala City and Villa Nueva (in Guatemala), where our corresponding figures are 30-40 USD, i.e.

nearly four times as high. This indicates either that our figures are too high, or the Estache-Foster-Wodon figures too low (or a combination). We find the latter to be more likely, in particular in view of our much better data and the fact that we have two independent means of benefit derivation, while they only use one single approach.

An important public policy issue is the income distribution effects of connecting additional households to the tap water system. Such effects can be found for each set of CS calculations presented in tables 8-9. The initial distribution of income across different water service groups is then of course important. Table 10 sums up some such average income data, by type of water service, for cities where we have data for both tap and non-tap households. The table gives both income distributions prior to changes in service, and distributions that would prevail in the case where all currently unconnected households are provided with (non-metered) service.

The three first columns of table 10 give average current household income figures, where income includes net consumer surplus from water services as derived from the DF (b=1/3) based calculations, in table 8. The fourth column gives similar figures when all currently unconnected households are given (non-metered) tap service. On average across all cities in our sample, the real income (including net benefits from water service) of unconnected households is only about 62 % of the average for connected non-metered households. This fraction increases to more than 74 % in the case where (non-metered) tap water service is provided to all at average current standards (in terms of prices and rationing frequencies). These calculations make it clear that providing universal tap water coverage can significantly improve the income distribution among current residents in the cities in question.

6. Concluding remarks

We have in this paper attempted to derive economic values of tap water services in Central American cities, and the role of such services in affecting real income levels, based on an extensive data set for households in 17 cities in this region. A significant fraction of these households are currently without tap service. We find wide disparities in average household water consumption and price levels between households with tap water access and those without. We then derive estimates of average consumer surplus from current tap water access for each of the cities, in two alternative ways. The first is based on econometric analysis of housing prices and their relationship with water access (the HP approach). The second departs from water demand functions directly, estimated by the authors commonly for all the cities, and calculates consumer surpluses as integrals under these functions (the DF approach). We show that the value of housing property is significantly affected by whether or not the house is connected to the water system, by whether the tap connection has a meter, and whether or not water is rationed. When correcting for a number of other factors as well, metered and non-rationed water connections respectively add on average as much as 56 % to the sales value of the house, everything else equal. Assuming an annual discount rate of 15 %, the average addition to a household's welfare from having a non-metered water connection is for most cities in the range 30-100 (PPP adjusted) USD per month. Since the underlying water demand elasticity is uncertain, we use two different alternatives for this elasticity when deriving welfare gain from calculations. Average gains are in most cases near 100 USD under a "low" demand elasticity (1/3, corresponding to our best IV estimate), and closer to 60 USD with a "high" elasticity (2/3). Overall, the HP- and DF-based calculations of the value of water access are quite close.

Letting the income concept include net benefits from water consumption, average incomes are higher by about 60 % among households with tap water relative to those without, in our (largely representative) data set. We show that when initially unconnected households gain tap water access (with quality and terms as for connected households), their real incomes thereby rise by as much as 15 % or more, thus eliminating about one third of the initial difference in average real incomes between the groups. Tap water access thus appears to be an important instrument for eliminating welfare differences between major groups, in Central American cities.

We need to emphasize that our water CS estimates are generally derived for connected and not for unconnected households. In the HP case, we find the values of current connection for connected households, in terms of additional house prices paid when living in a connected instead of an unconnected residence. In the DF case we rather derive the income reduction for an initially connected household, equivalent to losing its water connection. These measures may yield a too high value of water access for currently unconnected households, for at least three reasons. First, such households typically have characteristics (such as low income) correlated with low value of water, from both types of calculations. Secondly, the fact that these households are not currently connected is likely to reveal a relatively low value of a connection (they have not already been willing to pay the additional cost of being connected whenever possible, or buy a residence in a connected neighborhood). Thirdly, a more appropriate surplus measure may be the household's WTP to obtain a connection (and not the WTA to accept not obtaining it, as would be the more reasonable interpretation of the actually used measure), since financial limitations often will require unconnected households to pay for their new connection. These points indicate that our values most likely must be treated as an upper bound on the "true" value.

It also needs further stressing that our figures are extremely uncertain, and must more be viewed as numerical examples than as "hard" data. In particular, it is not very meaningful to try to derive confidence intervals for the variables, as several types of uncertainty are compounded some of which we have little control of. This said, our calculations are probably as good as any existing in the literature; we have at our disposal two rather distinct RP valuation methods, which yield similar results, something that might prompt one to have some confidence in the derived results.

Accepting our estimates, these have important implications for efficient resource allocation. In most of the region, the long-run marginal cost of additional water provision is close to 0.50 (current) USD per m^3, or 1-1.50 (PPP) USD in most cases. At current consumption rates for tap households in the region (around 25 m^3 per month higher than that of nontap households), provision of one additional connection would be worthwhile if its addition to social surplus is worth around 25-40 (PPP) USD per month. From our calculations, this appears to hold overwhelmingly, in most cases considered.

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Appendix: Tables

Table 1. Distributions of city populations by type of water supply at the time of survey

City	% share metered tap households	% share non-metered tap households	% share nontap households
Managua, Nicaragua	38.2	58.3	3.5
SantaAna, El Salvador	39.4	55.4	5.2
Sonsonate, El Salvador	36.5	47.1	16.4
SanMiguel, El Salvador	31.8	37.7	30.5
Panama City, Panama	32.7	65.7	1.6
Colon, Panama	27.0	71.0	2.0
Barquisimeto, Venezuela	72.1	27.9	0
Merida, Venezuela	31.1	68.9	0
Tegucigalpa, Honduras	20	48	42
San Pedro Sula, Honduras	25	55	20
Guatemala City, Guatemala	20	50	30

Note: For Tegucigalpa, San Pedro Sula and Guatemala City, figures are rough estimates. For other cities than those in the table we have no city-wide estimates.

Table 2. Average household water consumption, metered tap households (in sample), nonmetered tap households (imputed) and nontap households (in sample).

City	Metered tap Households	Nonmetered tap households, imputed (1)	Nonmetered tap households, imputed (2)	Calculated overall average from utility data	Nontap households
Managua	26.7	30.7	37.8	24.6	
Santa Ana	30.5	31.2	34.2	40.6	8.57
Sonsonate	31.1	31.1	33.8		5.10
San Miguel	30.1	33.2	36.3	28.4	11.38
Panama City	31.1	31.4	38.1	32.4	
Colon	34.8	31.5	39.5	68.5	
Barquisimeto		39.8	42.9	73.4	
Tegucigalpa		25.4	27.6		3.68
San Pedro Sula		24.9	30.8		4.84
Choluteca					3.85
Santa Rosa de Copan					1.87
Comayagua					2.83
Guatemala City		28.9	30.8		5.23
Villa Nueva		30.4	34.1		7.08
Chinautla		31.0	34.1		3.08
Mixco		34.2	36.7		8.32
Total	29.3	31.8	35.9		5.50

Table 3. Pecuniary and time costs of water service facing households with different types of service, across cities. Pecuniary costs in USD pr. m^3 at PPP rates. Averages across households in each cell.

City	PPP conversion factor	Marginal tap price, Metered house-holds	Average tap price, metered households	Imputed average tap price, non-metered households	Average water price, nontap households	Average truck price, nontap househ.	Hauling times, h/mo, non-tap house-holds
Managua	6.3	0.625	0.784	0.481			
Santa Ana	1.55	0.246	0.263	0.342	2.08	3.83	2.95
Sonsonate	1.55	0.331	0.257	0.311	2.76		8.15
San Miguel	1.55	0.325	0.260	0.357	0.61		3.72
Panama	2.25	0.179	0.534	0.767	0.12		7.57
Colón	2.25	0.266	0.526	0.917	0		16.58
Barquisimeto	2.47			0.358			
Merida	2.47			0.317			
Tegucigalpa	3.16			0.254	8.43	12.69	8.16
San Pedro Sula	3.16			0.682	1.34	9.53	18.57
Choluteca	3.16			0.211	2.47		3.01
Santa Rosa	3.16			0.344	0.48		4.71
Comayagua	3.16			0.180	0.89		4.31
Guatemala	2.56			0.221	5.73	8.00	24.33
Villa Nueva	2.56			0.435	5.27	6.15	15.09
Chinautla	2.56			0.362	3.23		8.48
Mixco	2.56			0.281	5.68	6.24	11.59
Total		0.397	0.515	0.415	5.12	9.47	10.67

Table 4. Distributions of percentage shares of households by property relation in our overall data set (without parentheses), and in our data on home values (in parentheses), separately for metered, non-metered tap, and non-tap households.

Group	Property w title	Property w/o title	Not legal Land	Other	Total number
Metered tap	68 (67)	19 (23)	9 (7)	1 (3)	1035
Non-metered tap	56 (48)	25 (40)	16 (10)	3 (2)	7846
Nontap	31 (26)	31 (60)	33 (11)	6 ((3)	2687
Total	51 (47)	26 (41)	19 (10)	4 (2)	11568

Table 5. Relationships between property prices and water availability and background variables.
Regressions covering entire sample (3424 obs.), t statistics in parentheses.

Variable	Linear regression	Log-linear regression
Size of residence	89.2 (10.9)	0.359 (14.3)
Size of lot	31.2 (2.54)	0.163 (5.59)
Income	2.66 (8.04)	0.063 (5.35)
Metered connection	3376 (1.09)	0.387 (4.98)
Nonmetered conn.	415 (0.17)	0.193 (3.17)
Daily water service	5283 (2.51)	0.172 (3.30)
Owner with title	3517 (2.39)	0.206 (5.63)
Electricity dummy	811 (0.26)	0.229 (2.90)
Telephone dummy	17099 (9.91)	0.474 (11.2)
Managua dummy	7842 (2.98)	-0.145 (-2.18)
Sonsonate dummy	7605 (2.59)	0.184 (2.53)
San Miguel dummy	14410 (4.80)	0.578 (7.78)
Panama dummy	8552 (2.79)	0.190 (2.52)
Colon dummy	15891 (2.91)	0.313 (2.34)
Guatemala city dummy	-9592 (2.81)	-0.302 (-3.53)
Villa Nueva dummy	-8557 (3.17)	-0.080 (-1.19)
Chinautla dummy	-6942 (1.71)	-0.442 (-4.53)
Mixco dummy	18500 (6.34)	0.624 (8.66)
Av monthly income	865	
Multiple r squared (adjusted)	0.189	0.412

Table 6. Results for individual cities, log-linear relationships (significance at 5 % (**) and 10 % levels (*) indicated).

Variable	Ma	SA	Son	SM	GC	VN	Mi
Size	0.54**	0.36**	0.29**	0.28**	0.38**	0.27**	0.29**
Lot	-0.09	0.18*	0.26**	0.15**	0.12	0.50**	0.21**
Income	0.13**	0.11*	0.13**	0.05	0.03	0.00	0.04*
Metered tap	0.71**	0.33*	0.69**	0.28*			
Non-metered tap	0.31*	0.27	0.63**	0.31**	0.35**	0.28**	0.50**
Title	0.28**	-0.10	0.21**	0.07	0.50	0.29**	0.06
Electricity	-0.25	0.51	0.23	1.09**	-0.17	0.72**	0.18
Telephone	0.83**	0.50**	0.29**	0.27**	0.21	0.78**	0.25**
Number of obs	652	308	318	295	218	672	399
R squared	0.4122	0.2225	0.5597	0.2278	0.0895	0.1657	0.2157

Explanations to table 3.2
Ma = Managua, SA = Santa Ana, Son = Sonsonate, SM = San Miguel, PC Panama City, Co = Colon, GC = Guatemala City, VN = Villa Nueva, Mi = Mixco
Metered tap, non-m. tap, title, electr, tel = dummy variables associated with presence of indicators
Average = average house price in sample, in 1000 USD, PPP adjusted.
Av. inc. = average monthly income by city in USD, PPP adjusted, for households in our sample.

Table 7. Average estimated effects on home prices of being connected, for previously unconnected households, by city and type of connection, using common and city-specific log-linear hedonic price functions. Capitalized values in USD, PPP adjusted. Standard deviations on individual values in parentheses.

City	Metered, daily service, common function	Metered service, specific functions	Non-m. daily service, common function	Non-m not daily service, common function	Non-m service, Specific functions
Managua	4152 (4729)	6028 (6866)	3099 (3530)	1639 (1866)	2632 (2998)
Santa Ana	6568 (7341)	4433 (4954)	4903 (5479)	2592 (2897)	3627 (4053)
Sonsonate	4985 (4449)	7034 (6278)	3721 (3320)	1968 (1756)	6423 (5732)
San Miguel	13560 (8934)	7764 (5115)	10121 (6668)	5352 (3526)	5896 (5663)
Guatemala City	3166 (3859)		2363 (2881)	1449 (1523)	2266 (2762)
Villa Nueva	3835 (4556)		2863 (3401)	1514 (1798)	2196 (2609)
Mixco	11038 (9033)		8239 (6743)	4357 (3565)	11287 (9237)

Table 8. Net consumer surplus from a water connection calculated from log-linear demand functions, by current mode of tap water service, for two different demand functions. Averages by city. USD per month, PPP adjusted.

City	Metered households, price el = -1/3	Non-metered households, Price el = -1/3	Metered households, price el = -2/3	Non-metered Households, price el = -2/3
Managua	115.2	108.6	98.7	91.6
Santa Ana	104.7	101.9	46.0	50.5
Sonsonate	118.9	112.8	57.7	61.1
San Miguel	153.1	158.4	94.0	104.1
Panama	132.0	123.5	112.9	78.4
Colon	152.2	131.8	95.7	89.2
Barquisimeto		116.6		54.8
Merida		103.1		47.2
Tegucigalpa		90.2		48.9
San Pedro		96.1		60.6
Choluteca		112.8		58.7
Santa Rosa		118.8		62.3
Comayagua		99.1		48.0
Guatemala		100.3		43.4
Villa Nueva		107.0		58.8
Chinautla		98.9		49.0
Mixco		98.7		43.1
Total	127.2	117.0		

Table 9. Average CS by city and type of tap water service, calculated from demand functions and hedonic price relationships.
Monthly values in USD, PPP adjusted.

City	Metered hh, HP based for ind cities	Non-metered hh, HP based for ind cities
Santa Ana	85	61
Sonsonate	62	47
San Miguel	170	127
Guatemala	40	30
Villa Nueva	48	36
Mixco	138	103
Unweighted average of HP estimates	90	67
Average, cities with common obs (3 first only)	105	67
Average, same cities, from demand funct with b = 1/3	126	113
Average, same cities, from demand funct with b = 2/3	66	60

Table 10. Average income in different groups, including assessed net consumer surplus from water consumption calculated from water demand functions (1) and hedonic price functions (2). USD per month per household, PPP adjusted.

City	Metered tap house-holds	Non-metered tap households	Non-tap hh in current state	Current non-tap, non-metered service provided	Average rel. total income, non-tap vs. tap, % Current service	Same average rel. total income when all have tap, %
Santa Ana	612	713	383	492	56.9	72.0
Sonsonate	651	659	290	403	44.3	62.9
San Miguel	634	753	343	501	45.6	66.5
Panama City	1705	1491	839	962	56.2	64.5
Colon	1670	1417	953	1085	65.2	74.1
Tegucigalpa		638	454	545	71.2	85.4
San Pedro		551	610	706	110.9	130.9
Choluteca		990	817	930	82.5	94.2
Santa Rosa		1086	304	423	28.1	39.5
Comayagua		858	284	383	33.1	45.7
Guatemala C.		832	527	627	63.4	75.2
Villa Nueva		873	709	816	81.2	92.7
Chinautla		645	513	620	79.5	93.2
Mixco		854	602	711	70.6	81.0
Total average (unweighted)		882	545	657	61.8	74.5