The pricing and allocation of water in Central America:

Analysis of metered and coping water demand

in 17 Central American cities

By

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December 2002

Introduction

This report deals with issues in demand for potable water, and distributional and allcational impacts of water pricing policies, departing from analyses of household data for water demand in 17 cities in Central America and Venezuela. The data have been collected by the consulting firm ESA Consultores in Tegucigalpa, Honduras, initially for purposes separate from this report. The ESA data files contain micro data on (both revealed and stated) household water demand for the following cities (with the years in which the studies were undertaken in parentheses):

- Tegucigalpa, Honduras (1995)
- San Pedro Sula, Honduras (1995)
- Santa Rosa de Copán, Honduras (1995)
- Choluteca, Honduras (1995)
- Comayagua, Hondruas (1995)
- Managua, Nicaragua (1996)
- Santa Ana, El Salvador (1996)
- Sonsonate, El Salvador (1996)
- San Miguel, El Salvador (1996)
- Caracas, Venezuela (whole) (1996)
- Barquisimeto, Venequela (1996)
- Merida, Venezuela (1996)
- Caracas, Venezuela (marg. Barrios) (1997)
- Guatemala City, Guatemala (1997)
- Villa Nueva, Guatemala (1997)
- Chinautla, Guatemala (1997)
- Mixco, Guatemala (1997)
- Panamá City, Panamá (1998)
- Colón, Panama (1998).

The data were collected in 11 different questionnaire studies, where households were interviewed on a range of issues, among these the issues of current water service and consumption, and on willingness to pay for proposed improvements in this service. The sample sizes in the individual surveys ranges from 750 to 2400. While there are 18 cities in the sample, the Caracas data is not utilized, as it contains no interesting information for our purposes.

The most interesting features of these data sets are for our purposes the following:

a) Their comparability. The questions posed in the different surveys were in most cases almost identical, making it possible e.g. to make calculations on the entire pooled data (or subsets of this). As such it is a rather unique data set with a range of possible applications, of which we will here only utilize a few.

b) The availability of revealed preference data on water consumption and prices. Two types of useful data are found in our material, namely data for households with regular metered consumption, and data for households with no regular water connection, who rely on coping sources, and where we have information on the amount of water consumed and prices paid for such water. Generally, different subsets of consumers face different (average and marginal) water prices, and consume different amounts of water. Households with and without regular water service face widely diverging water prices, and their water consumption differs greatly.

c) The availability of stated preference data, on willingness to pay for improvements of water services beyond current service levels. This concerns both connected customers whose service is currently substandard, and unconnected households who have the option of being connected. While this data can yield additional insights into water demand issues, it will not be utilized in this report.

We will now briefly outline the contents of this document. In chapter 1 below we sum up some key aspects of the data as utilized for our statistical analysis. Chapter 2 deals with estimation of water demand. Section 2.1 here considers data for metered tap households. Section 2.2 reports on estimations of water demand for "coping" households, defined as households without piped tap connections, who must rely on other sources for their water consumption. Section 2.3 describes attempts to merge the data for metered and coping households into one data set, and estimate water demand on this joint set.

Chapter 3 represents attempts to "transfer" water demand estimates from sets of households where we have such data, to sets where data is not available. For metered tap households (treated in section 3.2) and coping households (section 3.4) transferability is simply tested by successively estimating demand functions excluding one city, and subsequently imputing demand for the “missing” city, which is then compared to the actual demand levels for that city. For nonmetered tap households (treated in section 3.3) the procedure is somewhat more complex, and also far more uncertain. Here corrections are also made both for degree of rationing and for the lack or marginal pricing for these at the outset.

Chapter 4 deals with distributional and allocational effects of changes in water provision and prices. Section 4.2 considers values of water connections as derived from hedonic price relationships whereby house prices are affected by such connections. Section 4.3 attempts to derive similar values directly from the estimated water demand functions. Section 4.4 looks at effects of long-run average cost pricing for realized water demand among metered and nonmetered tap households, for the latter group assuming that metering is at the same time introduced.

Essential for all these calculations are our results with regard to water demand estimation, in chapter 2. We need to stress the complexity of the task of appropriately estimating water demand on micro data of the types available to us here. While a number of studies have been conducted on the basis of similar metered data alone, we are not aware of any similarly detailed study of coping water demand, nor of studies with the aim to integrate both types of data into one integrated analysis. This makes our work methodologically and conceptually challenging. As elaborated further below, each of these two main sets of data (for metered piped water, and for coping source water) presents its own specific set of problems. The data for metered households face problems of simultaneity and selection, both of which are discussed in detail by Bachrach and Vaughan (1994). In addition to the problem taken up by the latter authors we have in our case the possible problem that the set of households with meters may be self-selected. The main problems arising in the analysis of coping households are the variety of water sources used, and the costs related to hauling water, which can be treated in a variety of ways. A main additional problem is that the data for metered and coping households are likely to be incompatible in certain ways. This is partly due to simultaneity problems for one subset of the data (metered households), and that several water price variables may need to be used in the other subset (coping households).

Overall our data set covers approximately 11,500 households in 17 cities (when disregarding the data from Caracas, as noted above). However, around 8,000 of these are households with tap connections without meters, where water consumption cannot be observed. We have data for around 1,000 households with metered tap connections, and around 2,600 households who rely on coping sources only. These samples are sufficient for our main purpose of deriving common demand functions for the entire set of cities in our sample. However, individual city demand functions could not be meaningfully estimated, except for Managua in the case of metered households, and Tegucigalpa in the case of coping-source households.

Two other problems must be mentioned at the outset. The first is that our data set exists in two basic versions, one version where all individual country price and income variables are translated into USD at current nominal exchange rates (at the time the surveys were done), and another where the USD values are corrected using purchasing power parity (PPP) exchange rates published annually in the World Development Report. The differences between the nominal USD and PPP exchange rates are considerable, leading to important differences in the price-quantity relationships in the two data sets. As agreed at the planning seminar in Washington, all calculations to be presented in the following are based on the PPP data. We must however note that most of the estimations have also been run on the nominal USD data. Overall we have found that the PPP data perform much better, in terms of yielding proper fits and significance levels, than the nominal USD data. We have thus felt it appropriate to stick with the PPP data, which is used throughout except in a couple of cases where this is noted.[1]

The data being analysed were collected in diverse surveys at different times of the year. One possible adjustment to strengthen the analysis in this regard, which is not built into the current version of our report, might be the introduction of a seasonal dummy (rainy season / not rainy season) into the demand function.

Each study had its own sampling framework designed to permit inferences about the studied city’s population and sub-populations. The original datasets record the number of households that each observation represents (weights or expansion factors). These weights could easily be consolidated into the aggregate database. However, there are very large differences between the number of households represented by each observation in the different datasets, due to the fact that the ratio of the sample to the represented universe varied widely, depending on the availability of resources and other survey design considerations. Using the number of households represented by each observation to weight the analysis would lead to the observations from the large cities such as Panama and Managua swamping those from small towns such as Santa Ana and Sonsonate. For the purposes of our study, however, the behaviour observed in a household in Sonsonate is basically no less interesting or important than that of a household in Managua or Panamá. We have therefore decided that each of the observed households should be given equal weight in the consolidated dataset. This implies that they are treated as equally important descriptions of how a household

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[1] One should note some questions that can be raised about whether the PPP conversion factors for some of the countries are appropriate. In particular, the factor is very high (6.3) for Nicaragua, and quite high (3.16) also for Honduras, while it is 2.56 for Guatemala, 2.25 for Panama, 1.55 for El Salvador and 2.47 for Venezuela. These figures should be kept in mind in interpreting some of the results, among them the PPP converted household income figures presented in chapter 1 below. In particular, the figure for Nicaragua may seem implausibly high, at least when compared to that for similar countries such as Honduras and Guatemala. Note also that i one of our calculations, in section 4.5 dealing with effects of LRAC pricing, we use a lower factor (4) for Nicaragua.

might behave in the face of a given set of price and quality characteristics for different water supplies and given their own characteristics (number of persons, education, income, dwelling characteristics, geographical location, etc.). The material gives information on such characteristics, making it possible to correct for these in the various estimations, when needed. Nevertheless, in using and interpreting the data reported in this study, one must be aware that the samples taken from the various cities are not self-weighted, and the results are therefore not directly representative of the universe of households in each of the cities, nor is our entire sample statistically representative of the cities viewed as a whole.

1. Some key features of the data

Our data contain observations from 17 cities in 6 countries in Central America. The overall numbers of observations from each city varies, from a low of 201 in Chinautla to a high of 1714 in Managua. For our purposes the data will be grouped into three main categories, in the following called categories 1, 2 and 3. Category 1 observations contain information on actual (metered) consumption and (average and marginal) prices of water. Subjects are here asked to show their last monthly water bill, thus making it possible to precisely register both water consumption and expense in that period. Category 2 observations consist of connected households where consumption is not metered. Finally category 3 observations consist of unconnected households. Table 1a shows the distribution over the three categories of water consumers, across cities in our sample. Altogether there are 1035 connected households who have metered and registered water consumption and expense. These households are predominantly concentrated in 5 cities: Managua (Nicaragua), Santa Ana, Sonsonate and San Miguel (El Salvador) and Panama City (Panama). The number of connected households who do not have metered consumption is much larger, at almost 8000. The rest (almost 2700 households) are not connected. These rely on a variety of water sources, with greatly varying prices, and with varying costs in terms of fetching time, as will be documented more carefully below. An important subgroup among these consists of households who have a registered consumption of water sold from tank trucks. For most of these the price of such water provides a reasonable measure of marginal water cost. A little more than 700 households belong to this group.

Households with piped water access but no meters cannot be analysed, as we have no data for their quantities of water consumed. Substantial numbers of data points for metered consumption are available only for Managua, Santa Ana, Sonsonate, San Miguel and Panamá City, among these Managua stands out with 366 data points. A substantial number of observations on coping-source household demand are found in many more cities. Here Tegucigalpa stands out, with 839 data points. The sum of the observations in categories 1 and 3 is likely too small to be analysed at city level in Colon, Merida, Choluteca, Santa Rosa de Copan, Comayagua, and Chinautla. Observations from these cities are still included in pooled-sample calculations.

Table 1a. Distribution of main modes of water service for our data sample, across cities: 1=piped and metered service, 2=piped unmetered service, 3=no piped service

```
             City   |          1          2          3 |     Total
--------------------+----------------------------------+----------
            Managua |        366       1273         75 |      1714
         Santa Ana |        153        349        143 |       645
          Sonsonate |        143        302        225 |       670
         San Miguel |        111        239        195 |       545
      Ciudad Panamá |        218       1088         19 |      1325
              Colón |         37        270         10 |       317
       Barquisimeto |          0        715        282 |       997
             Mérida |          0        991          0 |       991
        Tegucigalpa |          0        434        839 |      1273
     San Pedro Sula |          0         55        181 |       236
          Choluteca |          0        324         28 |       352
Santa Rosa de Copán |          0         91         22 |       113
          Comayagua |          0        196         31 |       227
   Ciudad Guatemala |          5        125        233 |       363
        Villa Nueva |          1        739        206 |       946
          Chinautla |          0        133         68 |       201
              Mixco |          1        522        130 |       653
--------------------+----------------------------------+----------
              Total |       1035       7846       2687 |     11568
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Access to tap water does not guarantee that this water is safe for drinking. Table 1b gives an indication about the quality of tap water among households in our sample, by considering whether households deem tap water drinkable or not. We see that among households with metered piped connections an overwhelming majority (about 85 %) claim to drink their tap water untreated, while another 10 % drink it after treatment. Among households unmetered piped connections the overall fraction drinking tap water untreated is smaller, around 55 %, while another 35 % drink it after treatment. We see that there is considerable variation between cities: in Managua and the cities in El Salvador and Panama, water quality appears to be far higher (also for those with nonmetered service) than in the Venezuelan, Guatemalan and Honduran cities.

Table 1b. Distribution of all households served by tap water, according to main type of water service by whether or not tap water is drinkable

Metered households only

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             City   | Drinkable   Must be treated  no |     Total
--------------------+--------------------------------+----------
            managua |       317          44         5 |       366
          santa ana |       136          11         6 |       153
          sonsonate |       109          18        16 |       143
         san miguel |        85          11        15 |       111
      ciudad panamá |       202          16         0 |       218
              colón |        34           3         0 |        37
   ciudad guatemala |         0           4         1 |         5
        villa nueva |         1           0         0 |         1
              mixco |         1           0         0 |         1
--------------------+--------------------------------+----------
              Total |       885         107        43 |      1035
```

Nonmetered households only

```
             City   | Drinkable  Must be treated   No |     Total
--------------------+--------------------------------+----------
            managua |      1102         154        17 |      1273
          santa ana |       318          20        11 |       349
          sonsonate |       226          48        28 |       302
         san miguel |       159          28        52 |       239
      ciudad panamá |      1005          67        16 |      1088
              colón |       251          15         4 |       270
       barquisimeto |       192         486        37 |       715
             mérida |       192         793         6 |       991
        tegucigalpa |       230         148        56 |       434
     san pedro sula |        35          17         3 |        55
          choluteca |        93         126       105 |       324
santa rosa de copán |         9          63        19 |        91
          comayagua |        37         118        41 |       196
   ciudad guatemala |        36          76        13 |       125
        villa nueva |       276         372        91 |       739
          chinautla |        50          63        20 |       133
              mixco |        91         237       194 |       522
--------------------+--------------------------------+----------
              Total |      4302        2831       713 |      7846
```

A further problem of water service quality for many households with tap water is the fact that not all have continuous service and may thus to some extent be rationed. Tables 1c – 1e show the distribution of connected households in the different cities, by service frequencies.[2] For the entire set of connected households in our sample, table 1c shows that less than half have continuous service. Table 1d shows this distribution for households with meters. When service is not continuous for all households with tap water and meters, this may lead to a problem of water

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[2] Note that the table includes 315 observations from Tegucigalpa and 58 from San Pedro Sula where households have grouped themselves as unconnected, and still answered this question. Most of these are likely to be connected illegally

demand function estimation, since rationed consumers will not necessarily be on their demand curves but instead perhaps consume less than their (unrationed) demand. We see that about 60 % of households in this group have continuous service, and 80 % have service at least 8 hours per day. Most households with service frequencies in these ranges are likely not to be seriously rationed (in the sense of consuming less water than they would like to at the prevailing price). The problem of rationing may be viewed as not very serious when considering the metered group as a whole. This claim will be supported by the econometric analysis in chapter 2 below.

For the group of households with tap but not meters, average service frequencies are much lower, with less than 50 % having continuous service and about 25 % having service less than daily. Average service frequencies here vary greatly between cities, they are very high in Merida, and also high in Managua and Panama City, while they are particularly low in the Honduran cities, and somewhat less so the cities in Guatemala.

These observations indicate that there are two opposing forces that tend to make realized water consumption different, when we compare nonmetered and metered tap households. First, metered tap households face the direct price effect of increased water consumption at the margin, making it efficient for the households to limit their consumption. Nonmetered households face no such marginal price effects and have thus much less of an incentive to try to limit consumption. This effect works in the direction of higher water consumption among nonmetered as compared to metered households. On the other hand, many more nonmetered than metered households face direct quantity rationing as a result of water service not being continuously available. This effect works to make average water consumption higher for metered than for nonmetered households. In addition we must take into consideration the fact that average socio-economic characteristics are different between the two groups, where in particular average income is lower among those without meters. In chapter 3 below we will elaborate on these ideas, and present estimates of the two separate effects on overall water consumption.

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to the regular system, or have a private connection with very poor quality. The overwhelming majority of these households have service frequency of less than 8 hours per day.

Table 1c. Distribution of service frequencies by city, all connected households. Numbers of households in the respective groups.

City	Cont service	8 hrs or more	Less than 8 hrs	15-29 d/mo	10-14 d/mo	Less than 10	Total
Managua	1201	303	117	4	4	10	1639
Santa Ana	165	162	129	3	3	4	502
Sonsonate	281	65	47	13	18	21	445
San Miguel	71	89	174	9	0	7	350
Panama	750	111	136	148	43	118	1306
Colon	153	37	28	37	13	39	307
Barquisimeto	388	64	49	45	109	60	715
Merida	915	76	0	0	0	0	991
Tegucigalpa		124	177	170	43	235	749
San Pedro		65	20	27	1	0	113
Choluteca		96	106	77	45	0	324
Santa Rosa		3	6	39	43	0	91
Comayagua		137	24	19	16	0	196
Guatemala	21	0	14	40	39	16	130
Villa Nueva	269	11	44	214	180	22	740
Chinautla	33	15	82	0	1	2	133
Mixco	5	3	153	122	148	92	523
Total	4252	1361	1306	967	706	662	9254

Table 1d. Relative distribution of service frequencies by city, for metered households. Percentage shares of total numbers.

City	Continuous	More than 8 hrs/day	Less than 8 hrs/day	15-29 d/mo	10-14 d/mo	Less than 10 d/mo	Total number in smpl
Managua	83	12	5	0	0	0	366
Santa Ana	35	39	22	2	0	2	153
Sonsonate	68	14	17	1	0	0	143
San Miguel	9	34	56	1	0	0	111
Panama	74	9	6	7	1	3	218
Colon	46	14	22	16	0	2	37
Total average	62	18	15	3	1	1	1035

Table 1e. Relative distribution of service frequencies for nonmetered tap households, by city. Percentage shares of total numbers.

City	Cont service	More than 8 hr/d	Less than 8 hr/d	15-29 d/mo	10-14 d/mo	Less than 10 d/mo	Total
Managua	71	20	8	0	0	1	1273
Santa Ana	32	29	28	0	0	11	349
Sonsonate	61	15	7	4	6	7	302
San Miguel	26	21	47	3	0	3	239
Panama	54	8	11	12	4	10	1088
Colon	50	12	7	11	5	14	270
Barquisimeto	54	9	7	6	15	8	715
Merida	92	8	0	0	0	0	991
Tegucigalpa	0	24	29	3	4	40	434
San Pedro	0	69	22	8	1	0	55
Choluteca	0	30	33	24	14	0	324
Santa Rosa	0	3	7	43	47	0	91
Comayagua	0	70	12	10	8	0	196
Guatemala	17	0	11	30	30	13	125
Villa Nueva	36	1	6	29	24	3	739
Chinautla	25	11	62	0	1	1	133
Mixco	1	0	29	24	28	18	522
Total average	46	14	14	10	9	7	7846

Table 1f shows overall distributions of households in our sample according to property relation, for metered, nonmetered tap and nontap households, respectively. Overall, only about 50 % of all households claim to have property with title, about 25 % to be property owners but without title, and thus nearly 25 % to have no legal claims to their dwellings. The fraction with title is higher, almost 70 %, for metered tap households, while it is much lower, only about 30 %, for unconnected households. This indicates a strong relationship between the type of water connection, and the property relation. It also underlines another issue, namely that in several of the countries studied, a water connection may often serve as a proxy for a land title, by effectively formalizing the household’s relationship with the authorities, at its current place of residence.

Table 1f. Distribution of households by property relation, separately for metered, nonmetered tap, and nontap households. Percentage shares of different groups.

Group	Property w title	Property w/o title	Not legal Land	Squatter	Other	Total number
Metered tap	68	19	0	9	1	1035
Non-metered tap	56	25	4	12	3	7846
Nontap	31	31	24	9	6	2687
Total	51	26	8	11	4	11568

As noted in the introduction, our data comes in three different versions. One is the basic data set, where all price and income variables are denoted in local currencies. The second version is what we call the USD data, where all income and price variables are converted to (constant, 2001) US dollars. The third version is called the PPP data, where conversion of local currencies is done according to purchasing power parity indexes utilized by the World Bank, and published in the World Development Report, for the respective year of survey in the different cities, and finally translated back to 2001-equivalent figures. One here attempts to correct for differences in purchasing power of local currencies in terms of USD. In our discussion we will concentrate on the two last of these. We will put most emphasis on the PPP data, for two reasons. The first is the basic premise that the PPP conversions used are sensible, thus actually making the relative figures across countries more correct (e.g. in terms of "actual" prices of water, and real incomes).[3] The second reason will be emphasized further in chapter 2, namely that the overall estimations appear to yield far better fit when done on the PPP data than on the USD data.

Table's 1g – 1j describe distributions for household water consumption, prices and expenditures, according to the three main water service modes existing in our data set, namely households with metered, and nonmetered, tap water respectively, and unconnected households. Note that bottled drinking water is kept out of these tables.

Table 1g shows household water consumption across cities for metered and coping households respectively. The table shows that average water consumption is around 29 m^3 per household for metered tap households, and this average varies little among the 6 cities with substantial numbers in this category. By contrast, average consumption is only 4.8 m^3 for coping households, and varies considerably among cities. Disregarding about 360 households in Managua and Barquisimeto where water consumption is suspiciously low (and where we suspect a misclassification), average coping

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[3] Note however our comment on the conversion factor for Nicaragua, which is quite high and where we use a lower value for some of the calculations in chapter 4.

consumption among the rest is 5.5 m^3 per month, still only 19 % of average metered tap consumption.

Table 1h shows average recorded water expenditures by city and main service mode, using the PPP data set (here bottled water is kept out, and coping households in Managua and Barquisimeto are kept out in accordance with comments in the previous paragraph). The table shows that average expenses on the purchase of water are approximately 14.6 USD and 13.7 USD (at PPP rates), for connected households with metered and unmetered consumption, respectively. For households without connections this average is 22.9 USD. The expenditure for metered piped households varies relatively little among the cities in the sample for which we have observations, from a low of about 6 USD in Guatemala City, to a high of about 20 USD in Managua (the latter figure may however be somewhat high due to the high PPP conversion factor used for Nicaragua). The monthly expenditure for coping households varies much more, from a low of 0.16 USD in Santa Rosa de Copan, to a high of more than 49 USD in Mixco. This variation reflects both a great variation across cities in the predominant sources of nontap water across the cities, but also differences in water price for a given source type, as becomes clear from tables 1i and 1j below.

Table 1g. Distribution of average household consumption of water across cities, for metered tap households, and for nontap households.

City	Metered tap households	Nontap households
Managua	26.7	
Santa Ana	30.5	8.57
Sonsonate	31.1	5.10
San Miguel	30.1	11.38
Panama City	31.1	
Colon	34.8	
Tegucigalpa		3.68
San Pedro Sula		4.84
Choluteca		3.85
Santa Rosa de Copan		1.87
Comayagua		2.83
Guatemala City		5.23
Villa Nueva		7.08
Chinautla		3.08
Mixco		8.32
Total	29.3	5.50

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Table 1h. Average monthly water expenditure, by city and main type of water service. PPP data.

City	Metered tap Households	Nonmetered tap households	Nontap households
Managua	20.2	22.9	
Santa Ana	8.8	10.1	16.1
Sonsonate	9.0	9.1	5.7
San Miguel	8.5	11.1	6.0
Panama	16.2	21.5	
Colon	16.8	24.8	
Barquisimeto		15.1	
Merida		9.8	
Tegucigalpa		5.4	27.5
San Pedro Sula		12.6	8.8
Choluteca		6.4	17.7
Santa Rosa de Copan		10.9	
Comayagua		5.4	
Guatemala	6.1	6.1	38.0
Villa Nueva	9.1	12.2	38.4
Chinautla		10.5	9.4
Mixco	8.7	8.6	49.2
Total	14.6	13.7	20.8

Table 1i gives the distribution of water prices facing different consumer groups, as averages for respective households in each city. We present four types of such data. First, we present average marginal water prices facing metered tap consumers, which in turn comes in two versions, in terms of both the USD and the PPP data, and presented in columns 1-2 of the table. These data show that the marginal (USD) prices paid for tap water by households with meters is around 0.14 USD, as an average across all metered households, while the corresponding average PPP converted figure is around 0.40 USD. The average marginal tap water price varies little across cities (with "substantial" numbers of households in the respective categories), from a low of 0.08 USD in Panama City, to a high of 0.21 USD in Sonsonate, when considering the nonconverted data. The variation is somewhat greater for the PPP data, with Managua at the high end with 0.62 USD (due to the noted high PPP conversion factor for Nicaragua).

All the other data in table 1i are presented in PPP converted versions only. Column 3 shows average water prices paid by metered tap households. We see that these are generally somewhat higher than the marginal prices paid (except for two cities in El Salvador where they are slightly lower), and significantly higher in Panama City and Colon. This is the case despite of the rising block rates (which in isolation should indicate that marginal prices are higher than average), and is due to fixed consumption-independent charges which in some cases are quite high.

The fourth column of table 1i gives assessed average tap prices for nonmetered households. Since we do not have individual consumption figures for these households, the numbers are here quite uncertain. They are calculated by dividing total water-related household expenditure (for which we have data) by imputed consumption values for nonmetered households, where the latter imputations are presented in chapter 3 below. On this basis we calculate average (PPP converted) at about 0.42 USD per m^3, i.e. slightly higher than marginal metered tap prices, but somewhat lower than average prices facing metered households.

Table 1i. Average and marginal water prices faced by households with metered tap connections, and unconnected households (excluding bottled water), across cities. USD pr. m^3 at PPP rates. Averaged across households in each group. Numbers of households in parentheses.

City	Marginal tap price for metered hh, USD data	Marginal tap price for metered hh, PPP data	Average tap price for metered hh, PPP data	Assessed aver. tap price for nonmetered hh, PPP data	Nontap,PPP data
Managua	0.108 (366)	0.625	0.784	0.481 (1022)	
Santa Ana	0.204 (153)	0.246	0.263	0.342 (219)	2.08 (141)
Sonsonate	0.213 (143)	0.331	0.257	0.311 (205)	2.76 (222)
San Miguel	0.209 (111)	0.325	0.260	0.357 (149)	0.61 (191)
Panama	0.080 (218)	0.179	0.534	0.767 (590)	0.12 (9)
Colón	0.118 (37)	0.266	0.526	0.917 (172)	0 (6)
Barquisimeto				0.358 (238)	
				0.317 (590)	
Tegucigalpa				0.254 (379)	8.43 (826)
San Pedro Sula				0.682 (32)	1.34 (175)
Choluteca				0.211 (323)	2.47 (24)
Santa Rosa				0.344 (91)	
Comayagua				0.180 (196)	
Guatemala				0.221 (97)	5.73 (206)
Villa Nueva				0.435 (670)	5.27 (192)
Chinautla				0.362 (100)	3.23 (55)
Mixco				0.281 (474)	5.68 (121)
Total	0.142 (1035)	0.397 (1035)	0.515	0.415 (5547)	5.12 (2217)

The last column of table 1i presents average water prices paid by nontap households. 5 USD (PPP converted), or about 10 times the average price paid by metered tap households (and 12 times those paid by nonmetered tap households), when taking the average across all households in our samples. Details on these data are presented in section 2.2 below. We will note that nontap water prices vary considerably, across city, household, and even across water source for a given household. In the table we find San Miguel at the low end with an average nontap water expenditure of 0.61 USD/m^3, and Tegucigalpa at the high end with 8.43 USD/m^3.

The differences in average water expense and prices across cities, for households relying on coping water sources, can be further accounted for through the more detailed patterns of consumption of coping water by source.

Data on average household income across cities and modes of water provision in our sample are presented in table 1j. We find a large difference in average incomes between tap and nontap households, with much lower incomes to the latter group. We also find that metered households have higher average incomes than nonmetered households (for all cities except San Pedro Sula), but here differences are smaller (and the relationship is opposite for Santa Ana and San Miguel). On average over all households in our data set, PPP adjusted monthly household incomes are more than 1100 USD for metered tap households, 950 USD for nonmetered tap households, and only about 500 USD for nontap households.

Distributions of average household sizes across cities and water service categories are given in table 1k. Here differences are small and unsystematic across water service modes. Households are on average somewhat smaller within the group with metered tap service, and somewhat larger for the group with nontap service. There is some variation across cities, as Managua, Tegucigalpa and Villa Nueva have larger than average household sizes, while Mérida and the cities in El Salvador have smaller sizes.

Table 1j. Distribution of average household incomes by city, for different categories of water consumers (1=metered tap, 2= nonmetered tap, 3=nontap), USD/month at PPP rates

City	Metered tap households	Nonmetered tap Households	Nontap households	Total average
Managua	1451	1162	726	1205
Santa Ana	505	537	380	495
Sonsonate	542	468	300	435
San Miguel	529	641	391	529
Panama City	1580	1209	846	1265
Colon	1534	1195	968	1227
Barquisimeto		1123	624	982
Merida		1163		1163
Tegucigalpa		564	469	501
San Pedro Sula		491	623	592
Choluteca		890	830	885
Santa Rosa de Copan		973	310	842
Comayagua		768	293	702
Guatemala City		737	540	611
Villa Nueva		750	711	742
Chinautla		545	508	533
Mixco		739	597	710
Total	1112	952	515	864

Table 1k. Distribution of average household sizes, by city and main water service mode.

City	Metered tap households	Nonmetered tap households	Nontap households	Total
Managua	5.56	5.33	5.02	5.37
Santa Ana	4.56	4.30	4.91	4.49
Sonsonate	4.07	4.17	4.40	4.22
San Miguel	3.86	4.06	4.48	4.16
Panama City	4.44	4.46	4.73	4.46
Colon	3.97	4.53	4.50	4.46
Barquisimeto		4.96	4.81	4.92
Merida		4.13		4.13
Tegucigalpa		5.52	5.33	5.39
San Pedro Sula		5.16	5.25	5.22
Choluteca		5.16	4.57	5.11
Santa Rosa de Copan		4.75	4.32	4.66
Comayagua		4.80	4.90	4.1
Guatemala City		5.56	4.77	5.03
Villa Nueva		5.51	4.89	5.37
Chinautla		5.12	4.80	5.01
Mixco		5.22	4.86	5.15
Total	4.72	4.86	4.95	4.87

2. Estimation of water demand from household data

We will now present our work in estimation of water demand, for metered tap and nontap households. The following methodological considerations are important in this work.

1. Only metered consumption can form a basis for such estimation. In principle households with no meters face a marginal water price of zero, and the level of consumption should thus be in accordance with a zero marginal price. However, their consumption is generally not observed (at best only at an aggregate level). Metered consumption (where meters function properly and are read without error) by contrast implies that the marginal water price motivating consumption is the actual water price, as set by the water utility.
2. There is an identification problem in the water demand function as a result of the block-rate structure of water pricing in each individual city, which implies that the real marginal and average prices are generally increasing functions of the consumer's demand. This problem is quite fundamental and will be discussed more carefully later in this section.
3. There may be problems with water demand estimation when consumers are rationed. Many of the households in our samples have water service, which is not continuous. This implies the possibility that their actual water consumption is less than their potential (unrationed) demand.
4. The water services received by households with piped connections are not homogenous. They vary in several dimensions, such as the numbers of hours per day served, water pressure, and whether or not the water is clean. We have reasonably good household data on numbers of hours served per day. We also generally have data on whether or not households drink tap water. Our survey data also contain other possibly relevant information, e.g. on the incidence of infectious diseases at the household level during the observation period. We come back to these issues in the subsections below.
5. Unconnected customers rely on a variety of sources, and the marginal water price generally differs by source (it is e.g. likely to be highest for supply by vendors), and more generally, the value of water to households may depend on the source (see Whittington and Swarna (1994) for a detailed discussion). In addition there are generally costs of hauling coping-source water, with must be added to the pecuniary cost.
6. A further question is whether water demand is motivated by the marginal price of water, and not e.g. by the average price. This will be taken up in our empirical analysis below.

7. Some households facing a zero marginal water price need not actually have a zero perceived marginal value of water, for at least two different reasons. First, they may be unaware or unsure of the technical properties of the block-rate schedule. Secondly, they may be unsure of their total aggregate consumption and thus the relevant block price.[4]

We here first note that bottled drinking water must be treated as a separate commodity, qualitatively different from water from other sources (tap or nontap). Bottled water is generally priced much higher than nonbottled water, indicating that it is a different commodity and one that ought to be kept out of the main estimations here.[5] Secondly, water not delivered to the house is in general not the same as water delivered (by tap or vendor). Nontap water not delivered to the house must generally be hauled by the household, which implies that hauling costs (i.e. the time and effort associated with water hauling) are incurred, and these must be assessed in addition to possible pecuniary costs. Thirdly, when considering water delivered to the house, it may matter greatly whether it is delivered by tap or by vendor. Tap water can be pressurized and distributed throughout the house, something that is generally more difficult for vended water. In practice for most households, tap water has a much wider range of uses than delivered nontap water, which speaks in favor of treating these also as two separate commodities.

A relevant additional issue for the analysis of effects of water prices on water demand is whether demand is actually determined by marginal prices, or (additionally or alternatively) by some other concept of prices, such as average water price or water bill. Possibly, many consumers, not being trained in economic analysis, might take the average water bill per consumed water unit as the relevant consumption-motivating price; see e.g. Opaluch (1984), Chicoine and Ramamurthy (1986), Nieswiadomy and Molina (1991) and Bachrach and Vaughan (1994). In order to utilize average water price as a variable in our estimations, and make it possible to test prior hypotheses about the validity of such an assumption, measures of average water prices for different consumer groups were constructed.

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[4] This point has been made to us by Julie Hewitt. The idea is that water demand may be stochastic due e.g. to climatic factors. To illustrate the idea, assume that the water price paid by a given household is calculated on the basis of total water consumption per month. When you are at the start of a given month, you may be uncertain about the temperature later in the month. If this is going to be high, your water demand will then turn out to be high, pushing your total monthly consumption up into a higher block, with a higher marginal water price. Therefore, today’s consumption decision should take into account a probability assessment that overall monthly consumption will be in the various brackets, with different marginal prices. However, most consumers are not likely to be able to compute this and as a result they may have an erroneous conception of the real marginal price applicable in the relevant period.

2.1 Estimation of water demand for households with metered taps

2.1.1 Introduction

Estimation of water demand functions on the basis of individual observations of households when the water price follows block rates is problematic, as manifested by many studies in the literature. Bachrach and Vaughan (1994) discuss these problems in detail, in particular as they relate to Latin American urban water systems, and with ample references. In our data we have for all cities included nondecreasing (and generally rising) block rate schedules. Bachrach and Vaughan point out two possible problems with such estimation, namely a) the problem of simultaneity of water prices and consumption levels, and b) the problem of sample selection of households. Problem a) follows because a rising block-rate system implies that higher consumption leads to a higher (or at least no lower) marginal water price. Thus trying to estimate water demand functions on the basis of just one city using block rates must by necessity fail, because such a procedure will identify a "supply function" for water and not a demand function. Having data for a number of different cities with different block rates can in principle circumvent this problem. There will then still in general be a problem of simultaneity, which will bias the estimates of the water demand relationship using e.g. OLS regression. This problem has been discussed by a number of authors, early contributors being Billings and Agthe (1980), Foster and Beattie (1981), Nieswadomy and Molina (1989) and Opaluch (1982). These authors pointed out that using the marginal price directly then will bias the relevant coefficients to be estimated, and that replacements must be used. One early approach was to use the average water price either alone or together with the marginal price; see also our analysis below where a variant of this procedure is used (albeit in an inappropriate way). A more appropriate procedure was however seen to apply instrumental variable techniques, the most straightforward of which is two-stage least squares (2SLS) regression, where the marginal water price is explained by instrumental variables. More recently, econometrically more advanced approaches have been utilized, e.g. by Hewitt and Hanemann (1995) and Hewitt (1998), who use a combined discrete-continuous approach to such estimation, and Nauges and Blundell (2002), who use nonparametric methods. Note also two other recent studies. Renwick and Green's (2000) study of water demand for Californian water districts, using a panel data set, but where individual households were not observed. Hajispyrou et al. (2002) consider household water demand in

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[5] From table 1j, the average bottled water price in our sample (at PPP rates) is 150 USD/m^3, while the corresponding average (nonbottled) coping water price is around 5 USD/m^3.

different districts of Cyprus, where households as here face rising block-rate pricing schemes. Their approach is quite similar to ours, namely instrumental variables using the 2SLS procedure.

Problem b) may be of consequence when the group of consumers with metered consumption and nonzero marginal water price in a given city is a self-selected, and unrepresentative, sample from the underlying population. In table 1b we found that while almost 9000 of the households in our sample have tap water service, only 1035 of these have metered consumption. For the 5 cities with substantial metering, our sample includes more than 4000 households with tap water, less than one fourth of which are metered. The sub-group with meters may conceivably be self-selected e.g. because some groups may have greater incentives to obtain meters than others. It could for instance be the case that those who end up with meters are those who have the most to gain by having meters installed, e.g. because they know they have a low consumption and else would have had to pay a higher standard rate. This data problem is somewhat different from but related to that discussed in Bachrach and Vaughan (1994) (who consider selection as to whether or not the observed marginal water price is positive), and may in principle bias our results. On the whole we have however not viewed this problem as overriding, as further discussed below.

In view of the above problems, our estimations of the relationship between household water demand and marginal water price for metered and connected households proceeds in three steps. First, we consider regular OLS regressions, mainly to check for systematic effects of other variables than water price on water demand. Secondly, we consider 2SLS regressions, where the marginal water price is explained, and predicted, by a set of instrumental variables. The third step is 2SLS estimations where instruments are used also for the so-called difference (or implicit subsidy) variable, or alternatively the average price variable.

We have carried out a large number of estimations for each of the USD and PPP data sets. Our presumption has however been that the PPP conversions are the more appropriate ones, and that the PPP conversions are appropriate when applied to the entire merged data set. A basic justification for such a viewpoint is that water is a necessary good that is consumed by all households, and in competition with other necessary goods and taking into account the real value of households' purchasing power. Thus what matters for water demand is the "burden" of water expense relative to the "burden" of other expenses and to incomes. For such a purpose an appropriate PPP conversion clearly appears to be superior to a simple USD based conversion of local currencies. This initial hypothesis seems to be confirmed by our data. Throughout, our calculations based on the PPP data are far more "sensible" than those based on the USD data, in the sense that they much more frequently yielding significant and sensible coefficients. All presented results in the following will thus be those derived from the PPP data.

2.1.2 OLS regressions accounting for factors behind water demand

We will start our analysis in this chapter with presenting estimates based on one-equation, linear and log-linear, demand relationships of the following type:

$$W = a + b P + c D + d Q + \varepsilon, \tag{2.1}$$

or alternatively

$$\log W = \alpha + \beta \log P + \gamma \log D + \delta \log Q + \mu, \tag{2.2}$$

where W is household water demand, P is the marginal water price facing the household, D a difference variable described below, and Q a set of background variables a, b, c, d, α, β, γ, and δ are vectors of parameters to be estimated, and ε and μ error terms. A presumption behind OLS as an appropriate estimation method is here that these error terms be uncorrelated with the left-hand side variables. The reason for concentrating on the linear and log-linear relationships is mainly its ease of interpretation (in particular, the coefficient β can be identified as the price elasticity of water demand). (2.2) Is here a standard logarithmic specification, which will yield demand elasticities with respect to the various background variables (e.g. b will be interpreted as the price elasticity of demand). (2.1) Is a linear specification where estimated coefficients can be interpreted as simple derivatives of the demand functions, and where the underlying assumption is that these derivatives are constants. This may be a reasonable approximation over the relevant range for the variables.

The difference variable D is constructed to measure the difference between the outlay that would have resulted if all water were charged according to marginal price P, and the actual outlay for water. Increasing block-rate schedules (which are found in most of the cities for which we have data) imply that D is positive or at least nonnegative (it will be zero at the lowest block). D is often called the Taylor-Nordin difference variable, based on the analysis of Taylor (1975) and Nordin (1976) of similar effects in the electricity market. It can then be viewed as an implicit subsidy following from the block-rate schedule. The coefficients c and γ should then in principle correspond to coefficients for a regular income variable (denoted I and entering into the background variable vector Q). A common observation in many applications is that these are different, often in such a way that c and γ are greater than the corresponding coefficients to I, implying that average water price has an influence on water demand which is separate from income and the marginal water price; see the discussion and examples in Bachrach and Vaughan (1994).

We have also found it relevant to conduct somewhat more elaborate testing of the marginal price versus average price model, according to the model developed by Opaluch (1984) and Chicoine and Ramamurthy (1986).

An interesting and policy-relevant issue could here have been to estimate separate demand relationships for ”high-income” and ”low-income” households. A common presumption as well as finding in the related literature is that low-income households have more elastic water demand then high-income households, partly because the budget share to water is higher for the former (see e.g. the discussion in Renwick and Green (2000)).

Table 2a shows results from linear and log-linear OLS regressions whereby water demand among households with metered tap-water consumption is a function of various background variables. The overall explanatory power of the included variables is quite high, with a corrected multiple R-squared between 0.5 and 0.6 in both cases. We note that marginal water price (as expected) has a positive (“wrong”) sign in the relationship (representing the property that water pricing schedules generally are upward sloping in amount consumed), and this effect is in addition is quite strong. These relationships are however as noted not reliable due to simultaneity, and are mainly of interest for comparative purposes. Note that in the regressions we include an implicit subsidy variable D defined above, as the amount of “subsidy” in terms of marginal minus average water price, which has a rather strong positive effect on water demand (which however is significant only in the linear case); in the log-linear relationship water demand is raised by 8 % when the amount of implicit subsidy is doubled. Such a result is to expected from previous research (Chicoine and Ramamurthy (1986), Bachrach and Vauaghan (1994), Taylor (1975), Nordin (1976), Griffin and Martin (1981)). A further problem of simultaneity, discussed below, is however that the subsidy variable also generally is endogenous; see below.

Numbers of children and adults in the households have quite weak (but significant) influence on water demand. In the log-linear relationships the elasticities with respect to household income and number of persons in household are around 0.02-0.04. In the linear relationship one additional child in the household raises overall water demand by about 0.5 m3 per month, and one additional adult by somewhat more. Considering individual cities’ demands, the linear relationship show that in particular Managua, but also the cities in El Salvador, have considerably (and significantly) lower water consumption than Panama and Colon, which serve as reference cities.

Table 2a. Results from OLS regressions of metered household water demand as a function of marginal water price (t statistics in parentheses).

Variable	Linear	Log-linear
Marginal water price	18.0 (6.3)	0.208 (13.8)
Household income	0.001 (3.0)	0.022 (2.35)
Implicit water subsidy	0.71 (7.4)	0.082 (1.65)
Children	0.54 (2.28)	0.021 (2.57)
Adults	0.65 (2.95)	0.038 (5.13)
Managua dummy	-15.1 (-8.0)	-0.70 (-11.4)
Santa Ana dummy	-7.37 (-3.15)	-0.39 (-4.96)
Sonsonate dummy	-6.35 (-2.78)	-0.37 (-4.87)
San Miguel dummy	-8.23 (-3.4)	-0.40 (-4.90)
Have other water service	-4.3 (-2.76)	-0.21 (-3.97)
Have cistern	17.4 (2.9)	0.34 (1.69)
Constant	28.3 (4.58)	3.48 (12.77)
Adjusted R-squared	0.566	0.528

2.1.3 2SLS regressions correcting for simultaneity of prices and quantities of water demand

We will now extend the simple OLS estimations presented above, to take into account the simultaneity of marginal price and quantity determination implied by the block rates. The most straightforward procedure is to use 2SLS estimation, involving two steps. In the first step, a separate relationship is estimated for the marginal price; in the linear case one uses a specification of the type

$$P = a_1 + b_1 V + \eta \tag{2.3}$$

where V is a vector of exogenous instruments, a_1 and b_1 are parameters to be estimated, and η is an error term. The instruments should here be chosen such that they are uncorrelated with the error term in the original equation (2.1). This relationship is in the next step used to calculate predicted values of the marginal price, thereby potentially purging the marginal price variable of its correlation with the error term in the original OLS relationship. This original relationship can then be estimated, using the predicted marginal price variable in the right-hand side.

Note that the 2SLS procedure serves to replace the "correct" marginal (and possibly also average) price variable (i.e. the one calculated according to the actual block-rate schedule) with an "incorrect" variable (i.e. an imputed value whereby the marginal price is "explained" by purely exogenous variables). This may appear to impose biases, or at least additional uncertainty, on the estimated relationships. It is clear that the imputation procedure by necessity imposes additional uncertainty. As long as this uncertainty is not systematic, however, this is no major problem as long as the data set is sufficiently large, and the instruments are chosen to be uncorrelated with (orthogonal to) the regression equation error term.[6] As for the actual instruments used, somewhat different sets turned out to work most efficiently in the different estimations.[7]

Another problem with this type of estimation, which has been noted in the literature, is that when the tariff structure is governed by block rates households need to solve two separate problems in one: first, which part of the block structure in which to adapt, and secondly, how much water to actually consume within the chosen block. An econometrically correct solution of this problem requires discrete estimation techniques to solve the first problem, and continuous techniques to solve the second; for applications see Hewitt and Hanemann (1995), Corralll et.al. (1998) and Pint (1999). Our approach here will be simpler; we assume that both choices can be modelled as one, which is likely not to lead to great loss of information when households are either will inside a given block and certain about the block rate, or else uncertain about which block is actually valid.

An additional consideration is that the "difference variable", representing the implicit subsidy implied by the tariff schedule (i.e. the difference between marginal and average water price multiplied by realized consumption) has an important influence on water demand, and is itself generally endogenous. A number of studies in the literature, among them Billings (1982), Nieswiadomy and Molina (1989), Nieswiadomy and Cobb (1993), Hanke and Maré (1982), Höglund (1999), Nauges and Thomas (2000), Renwick and Archibald (1998), Renwick and Green

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[6] More intuitively, we are here in effect trying to remove the influence on the real marginal price paid of the other aspects of the demand function (such as household size, income etc) due to the stepped tariff function. We do this in the first step by seeking a marginal price which is not influenced by the other independent variables in the the demand function. This has the statistical characteristic that it is not corrleated with any of the other independent variables in the model, and nor is it correlated with the error term (which might be picking up variables excluded from our model). Subject to this constraint, this procedure seeks to establish maximum correlation with the real marignal price observed in the dataset. We then, in the second step, take the corrected price, impute it back into the dataset and model the demand using our imputed price and the other factors all together.

[7] In most of the 2SLS regressions presented, instruments were different combinations of the following: numbers of household members; dummy variable related to whether interviewee can read or write; city dummies; dummies related to whether household has water tank or cistern; property lot size.

(2000), and Martinez-Espiñeira (2002). We will here mainly refer to the Renwick and Green (2000) study of Californian water demand, which is representative and state-of-the-art. They correct for such endogenieity by regressing it on a set of instruments, and using the predicted values from such a regression instead of the actual values. In a set of estimations to be reported below we follow this procedure, thus instrumenting both for the marginal price and the implicit subsidy variable, or alternatively for the average price variable; see below.

A further consideration in this section is the testing of marginal versus average price as the "most important" determinant of water demand. More generally, we want to consider a variant of our model whereby water demand is specified as a function both of marginal and average water price. We come back to this issue below.

We concentrate on 2SLS estimations, where instruments are used both for the marginal water price, and also for a socalled difference (or implicit subsidy) variable, as will be explained below.[8] The basic, linear or log-linear, demand relationships can still be assumed to have the forms (2.1)-(2.2). A presumption behind OLS as an appropriate estimation method is here that error terms are uncorrelated with the left-hand side variables. The reason for concentrating on the linear and log-linear relationships is mainly its ease of interpretation (in particular, the coefficient β can be identified as the price elasticity of water demand).

Separate relationships for P and D must be estimated, using instrumental variables that are uncorrelated with the error terms ε or μ. In the linear case, this implies estimating (2.3) and in addition

$$D = a_2 + b_2 W + \kappa, \tag{2.4}$$

where κ is an error term, W a set of instrumental variables, and, a_2 and b_2 coefficients determined by the relationship, and where equivalent relationships are estimated in the log-linear cases. Under the presumption that the instruments V and W are uncorrelated with the respective error terms, (2.3) and (2.4) can then be used to construct a set of predicted values for P and D, which will generally be uncorrelated with the errors ε and μ. These sets of values can then in turn be used as explanatory variables in the original relationships (2.1) and (2.2), resulting in unbiased estimates of these relationships.

A "difference variable" D, or similar variable having similar qualitative effects for the estimated relation, can be constructed in various ways. One such construction is to take the difference between the outlay that would have resulted if all water had been charged according to marginal price P, and the actual outlay for water. Increasing block-rate schedules (found in most of the cities for which we have data) imply that D takes nonnegative values at least for “relatively high” consumption levels, although it may be negative for low levels whenever there is a fixed initial charge independent of consumption. D is often called the Taylor-Nordin difference variable, based on early work by Taylor (1975) and Nordin (1976) for the electricity market. It can then be viewed as an implicit subsidy following from the block-rate schedule. The coefficients c and γ should here in principle correspond to coefficients for a regular income variable (denoted I and entering into the background variable vector Q). Typically, however, these are different, often such that c and γ are greater than the corresponding coefficients to I, implying that average water price has an influence on water demand separately from income and the marginal water price; see the discussion and examples in Bachrach and Vaughan (1994). Our formulation makes it possible to test for such effects.

It may also be of interest to study the effects of margial and average water prices separately. Consider the following specification for the linear case:[9]

$$W = a_1 + b_1 P - b_2 D/W + d_1 Q + \varepsilon_1, \qquad (2.5)$$

where (P - D/W) now is the average water price. Opaluch (1984) and Chicoine and Ramaurthy (1986) have used such a specification to construct a test for effects of the marginal versus average price on water demand; see Bachrach and Vaughan (1994). The following models can here be tested:

1. Marginal price model: Null hypothesis implies $b_1 < 0$, $b_2 = 0$
2. Average price model: Null hypothesis implies $b_1 = b_2 < 0$.

In addition one may test the two coefficients b_1 and b_2 separately. In particular, if the average price has a separate effect on water demand (apart from that of marginal price, and not necessarily the same), one would expect $b_2 < 0$. We have attempted to test one such specification, and have in addition included a log-linear specification with both marginal and average price included.

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[8] For another recent related analysis, which however is not based on household data but on (panel-type) data for regions in California, see Renwick and Green (2000).

[9] In Bachrach and Vaughan (1994) a similar specification is used, which however includes an income variable where income is corrected for the implicit subsidy. Since the estimated coefficient on income is much smaller than that on the difference variable, it matters little which of these two alternative specifications is used.

Table 2b sums up our main estimations on this data set. The first four columns of the table include one linear and three log-linear estimations on the pooled set of metered household data. All of these include the marginal water price as one explanatory variable. In the third column, a difference variable D is included; in the first and fourth column we include an average price variable; while the second column includes only the marginal water price. In the second estimation we have corrected for city by introducing city dummies, while in the other we do not (in the second using city dummes increases the explanatory power of the regression, while in the two last cases the parameters become unstable in this case). We find no strong systematic relative differences in fit between the linear and log-linear relationships, in terms of overall fit in terms of R-squared, and significance of the water price variables (only one linear case is presented; other linear cases give far less precise fit to the data). Note that estimated income effects on water demand are very small in all regressions, and not significant in the two regressions using the difference variable. The effect of household size is now however greater than in previous estimations.

The regression presented in the third column is designed to correct for average price endogeneity. Note also that the estimation in the first column implies a direct test of the marginal versus average price model. We find that marginal and average price each has a standard negative effect on water demand, but that only the average price has an independent significant effect, which in addition is much greater in absolute value than the partial of the marginal price under this specification. We are able to reject hypothesis 1. This conclusion indicates that average price has a separate effect on water demand apart from marginal price. We are not able to reject hypothesis 2 (which is seen by noting that the standard deviations of the two relevant coefficients are respectively 3.1 and 2.9, making a difference test inconclusive).

Quantitatively, this linear estimation implies that, at average consumption values (approximately 29 m^3/month), the partial elasticity of the marginal water price is only about -0.05, while the partial elasticity of the average price is approximately -0.14. This implies that when marginal and average water price are increased simultaneously by one percent, demand is estimated to fall by about 0.2 % under the linear model, at average consumption levels.

A very similar result is found in the corresponding log-linear specification, in column 4. Only the average water price has a partial significant effect, and this effect is considerably greater in absolute value than the partial effect of marginal price (-0.22 versus –0.085). The elasticity of water demand with respect to a simultaneous increase in average and marginal prices is here (in absolute value) approximately –0.3, and thus somewhat greater in absolute value than that calculated from the estimated linear relationship.

Consider next the estimation where only marginal price is included, in the second column of table 2b. Here we find a partial elasticity of –0.17, higher than the marginal price elasticity but lower than the sums of marginal and average price elasticities, both in column 4.

Income elasticities are all positive but quite small (below 0.1), and significant only in two out of 5 cases. Family size has greater effects, on additional child or adult in the household adds from 1.5 to 2 m^3 to the household's water consumption under the linear specifications, and about 5 % and 8% respectively in the log-linear cases (corresponding to between 1.4 and 2.3 m^3 at average consumption levels).

Another very interesting result, from columns 3-4, is that rationing is found to have a significant effect on water consumption, but only for households who are not served every day. For those serviced daily, average consumption is about 30-40 % higher than for those served less frequently. Strikingly, we however find no measurable effect on water consumption on the average daily time of water availability, for those served every day. This may appear surprising, and perhaps contrary to common knowledge and wisdom about water demand in the region. We hypothesize that it may be due to the presence of private water tanks, which are filled up when water is available for use during the rest of the day. Our result in this regard has a very important policy implication, if it turns out to hold up under closer scrutiny. It namely indicates that attempts to ration household water consumption, by making it available only during part of the day, is generally ineffective. The main effect of such a policy appears to be that it imposes costs on households, by making them install expensive water tank systems.

As for other variables we attempted several but ended up with a small number which were found to be significant in several cases and which increased multiple R-squared sizably. These were a dummy presence of telephone in the house, and house value, which both tend to increase water consumption, and dummies for the three El Salvador cities (which were significantly positive in the log-linear case of column 3).

One might here perhaps worry that the somewhat questionable values of the PPP conversion factors impact on the quality and validity of our estimation results. Note however that in the case of estimated log-linear functions, and with correction for city, the magnitude of the PPP conversion factors will only affect the estimated coefficients on the respective city dummies, and not the other coefficients. Since we mainly emphasize log-linear relationships with correction for city, our main point of view is that the PPP issue is not overridingly important.

Table 2b. 2SLS regressions where instruments are used both for marginal price and difference variable/average price (t statistics in parentheses).

Variable	Linear including average price variable	Log-linear with only marg. price variable	Log-lin, incl. diff. var and rationing dummies	Log-linear incl. aver. price and rationing dummies	Log-linear incl. difference variable, Managua
Marginal water price	-4.3 (-1.10)	-0.172 (-2.22)	-0.201 (-3.35)	-0.085 (-1.56)	-0.268 (-1.45)
Difference variable			0.34 (3.93)		0.36 (3.64)
Average water Price	-10.42 (-3.55)			-0.221 (-3.26)	
Household Income	0.0016 (3.28)	0.024 (2.94	0.017 (0.85)	0.022 (1.57)	
Children	1.48 (4.02)	0.065 (5.09)	0.053 (4.67)	0.053 (4.15)	0.053 (1.2)
Adults	1.85 (5.39)	0.088 (7.28)	0.083 (6.63)	0.085 (7.13)	0.100 (2.55)
Have telephone	2.94 (2.86)	0.099 (2.98)	0.134 (2.59)	0.109 (2.93)	0.069 (0.96)
Value of house	0.000036 (2.67)	1.11e-06 (1.39)	8.10e-07 (1.13)	6.93e-07 (1.39)	5.32 e-07 (0.47)
Santa Ana dummy		0.123 (2.00)			
Sonsonate dummy		0.187 (3.19)			
San Miguel dummy		0.164 (2.62)			
Cont service dummy			0.425 (2.78)	0.319 (3.24)	
Service > 8 h/d dummy			0.430 (2.76)	0.307 (3.07)	
Service < 8 h/d dummy			0.493 (3.11)	0.345 (3.35)	
Constant	23.7 (13.5)	2.48 (26.4)	1.09 (2.50)	2.16 (13.81)	
Adjusted r-squared	0.184	0.177	0.170	0.162	0.184

As already noted, our useable data sample is not large nor rich enough to yield good individual demand estimates at the city level. One possible exception is Managua, where we have the largest number of households in this category (366). In table 2b we consequently also include, in the right-hand column, estimation results from one 2SLS regression for Managua, with instrumentation for both the marginal price and the difference variable, which in turn are based on Managua data only. We here find a somewhat larger absolute value of the marginal price elasticity of demand, -0.27 (versus –0.2 in the corresponding case using the whole data set). The elasticity with respect to simultaneous increases in marginal and average water prices is from these estimations even greater (but cannot be read directly out of the figures).[10]

Our results indicate that for metered households the effect of price increases on realized demand are not particularly large, but still large enough to count for price increases in realistic ranges. The reason is that initial (average and marginal) prices for most households in this group are quite low. E.g., a doubling of the marginal price, and at the same time a 50 % increase in average price (a combination of price changes which is practically implementable in most of the cities involved) would then lead to a reduction in realized demand in the range 20-33 %, which is quite considerable.

2.1.4 Possible sample-selection problems

An econometric problem arises when there are common variables responsible for explaining the sample selection process (here, deciding which households belong to the sample of metered households) and the water demand itself. Such a problem may arise in our context if households with small water consumption desire to have their consumption metered, and conversely, when households with high consumption desire not to have it metered. This would in case result in an adverse selection problem (analogous to those analysed by e.g. Akerlof (1970) and Greenwald (1986), for the used car market and the labor market), whereby overall household water consumption in a given city would be underestimated by basing it on metered consumption only. An approach to this problem would be to use Heckman’s two-step procedure (see Heckman (1979, 1990), Lee, Maddala and Trost (1980), Maddala (1983), Greene (1993)). In the first step of this procedure, a binary variable explaining the probability of including a given observation in our sample is estimated as a probit relationship against a set of exogenous variables treated as instruments. This provides point estimates of inverse Mills ratios that can be inserted into the original OLS equation, thereby yielding unbiased estimators for the “true” coefficients in the OLS relationship as applied to the underlying population, given that proper instruments have been chosen. Note that this procedure does not have the potential to eliminate the simultaneity problem created by the block-rate structures for water prices, at least not completely. This prediction itself involves two steps, as follows: 1. Imputing a set of values for the marginal water price, for those connected households for whom this price is not actually observed, and possibly also for the

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[10] The difference variable is here constructed to be always positive, and a one percent increase in the difference variable as used is here equivalent to less than a one percent drop in average price. Thus the elasticity with respect to marginal

difference variable as defined above. 2. Using this set of imputed values, together with the actual values for which the marginal water price (and difference variable) is observed, as a common left-hand side variable in a regression against a set of exogenous instruments. Such a regression is used to form a predictor for the marginal price, for households where the marginal price is observed. In this way we obtain a set of (imputed and predicted) values of the marginal water price, in principle for all households, which can be used as explanatory variable to yield unbiased estimates of the price effect on demand.

A question is however whether sample selection problems are sufficiently serious in our case, to warrant econometric treatment as indicated above. An obvious alternative to using the Heckman procedure is to simply correct for observable household characteristics when attempting to compare households with and without metered consumption. Such a simpler procedure may be sufficient when metering of water consumption is largely exogenous for the individual household, e.g. because metering is prevalent in some cities/neighbourhoods but not in others. Another point is that households may desire to have water meters for reasons unrelated to their individual water consumption, e.g. because a water meter may serve to formalize their place of residence. Such factors would also generally render Heckman-type procedures unnecessary in our case.

We have carried out Heckman-type estimations on our data, but these turn out to yield rather imprecise and unstable results. Whatever apparently more reliable results (in terms of significance of coefficients and explanatory power of relations) are obtained generally yield somewhat higher estimated effects of water price on consumption. Our main view is that the application of the Heckman procedures are not called for in our case, for reasons just given above. In particular, our view is that the issue of obtaining meters is not severely affected by self selection at the individual household level (within the group that has access to tap water), since it is almost completely determined by the city, and region within the city, in which the household resides, and that choice of residence is only marginally affected by this factor alone. Remember that our data shows that average water costs are basically the same for households with and without meters, average service (proxied by average service frequency, and whether or not tap water can be consumed) is only slightly lower for nonmetered versus metered households, and there is generally a cost of obtaining a meter (relative to household income) These factors imply that there is probably little net gain, in terms of overall reduction in water costs, from having a meter even for households that know they consume less water than average, which in turn should imply that the metering issue in most cases

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and average price simultaneously, to be calculated for Managua on the basis of our estimation in table 2c, generally lies somewhere between –0.3 and –0.6

will not affect the household's place of residence. We have consequently decided not to include any such estimations in the report.

2.2 Calculations on coping-source data

2.2.1 General description of the coping-source data

We now turn to the analysis of data for households that are not connected to piped water and instead rely fully on "coping" sources, above classified as category 3 households. A variety of coping sources are used by households in our sample. Note initially that many households with tap connections also utilize coping sources for part of their consumption. This is evident from the following tables 2c-d. Table 2c shows the distribution of households with positive money expenses for coping-source water. Naturally, almost all of these belong to group 3 who rely on coping sources. Note however that there are also some (372 out of a total of about 9000) households who have piped water connections and in addition spend money on coping sources.

Table 2d shows the corresponding distribution of households by average consumption of coping-source water. This table complements table 1f (which showed average total water consumption according to main service modes 1 and 3). The table also shows coping-source water consumption for households in groups 1-2 who rely on such additional sources. As expected this consumption is generally small, and particularly small for households with meters. For households without meters the average is somewhat higher, about 0.55 m^3 per month, but this is still a very small share of average water consumption among households with piped connections. Coping-source water consumption for households with piped connections varies considerably among cities, and is by far highest in San Miguel where it is almost 4 m^3 per month on the average. As is reasonable, the amount of coping-source water consumed by households is increased substantially higher when the quality and frequency of tap water service is lowered. A more detailed analysis shows that most of these are heavily rationed and thus do not satisfy their demand from their tap connection. In particular, our data show that among the about 600 households that have tap water service at most 10 days a month, average coping water consumption is about 2 m^3, while it is essentially zero for households with continuous piped water service. These data are not reproduced here, but can be obtained from the authors upon request. Since total water demand for these households is not observed, they cannot be included in the statistical analyses presented in this section.

Table 2c. Distribution of cases with positive money expense for coping sources, according to main mode or water service (1=metered tap, 2= nonmetered tap, 3= nontap).

```
                              Main service mode

            ciudad |         1          2          3 |     Total
-------------------+---------------------------------+----------
           managua |         1         13         24 |        38
        santa ana |         5         38        109 |       152
         sonsonate |         0          6        143 |       149
        san miguel |         2          8         75 |        85
     ciudad panamá |         2         10          1 |        13
             colón |         0          4          0 |         4
      barquisimeto |         0         15        137 |       152
            mérida |         0          2          0 |         2
       tegucigalpa |         0         84        779 |       863
    san pedro sula |         0          0         49 |        49
         choluteca |         0         53         10 |        63
santa rosa de copán |         0          4          1 |         5
         comayagua |         0          7         21 |        28
  ciudad guatemala |         0         10        159 |       169
       villa nueva |         0          9        171 |       180
         chinautla |         0          1         25 |        26
             mixco |         0         98        116 |       214
-------------------+---------------------------------+----------
             Total |        10        362       1820 |      2192
```

In table 2e, we have split up total consumption of coping-source water among household reyling solely on such sources, into 8 different categories, namely bottled water, private tap water, public tap water, water vended from tank trucks, water from private wells, water from other wells, water from rivers and lakes, and water from other unspecified sources. Considering only cities with substantial numbers of households in the coping category in our sample (at least 100), average total coping water consumption varies substantially among the cities, from a low of 3.7 m^3/month in Tegucigalpa, to a high of 11.4 m^3/month in San Miguel, and with an overall (unweighted) average of 5.5 m^3.[11] The overall average household water consumption within this group is thus only 19 % of the average consumption among all metered tap households (29.3 m^3), or less than one fifth. The types of coping sources used vary widely across cities. Overall, vended truck water is the most important single source for the sample as a whole (and this is a particularly important source in Tegucigalpa, Guatemala City, Villa Nueva and Mixco), followed by water from public taps, private wells and private taps respectively.

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[11] Note that the data on coping-source households for Managua and Barquisimeto here have been taken out, since these seem not to be meaningful.

Table 2d. Distribution of average consumption of coping-source water, by city and main service mode, m^3 in month registered

City	Metered tap	Nonmetered tap	Nontap
Santa Ana	0.17	1.00	8.51
Sonsonate	0	0.36	5.09
San Miguel	0.34	3.94	11.36
Panama	0.07	0.19	
Colon	0.05	0.12	
Tegucigalpa		0.70	3.67
San Pedro Sula		0.08	4.80
Choluteca		0.49	3.84
Santa Rosa		0.35	1.86
Comayagua		0.13	2.83
Guatemala City		0.29	5.20
Villa Nueva		0.11	7.05
Chianutla		0.06	3.08
Mixco		0.87	8.30
Total		0.56	5.48

Table 2e. Distribution of coping-source water use, as averages for unconnected households in each city. m^3 per month.

City	Bottle	Priv tap	Public tap	Truck	Priv well	Other well	Lakes, Rvrs	Other Srcs	Total	Nbr in smpl
Santa Ana	0.06	0.98	0.34	2.35	0.90	1.60	0	2.34	8.51	143
Sonsonate	0.00	0.78	2.43	0	1.04	0.07	0.13	0.65	5.09	225
San Miguel	0.02	1.00	0.69	0.17	8.08	1.30	0.02	0.10	11.4	195
Panama	0	1.00	0	0	0	0	0.14	0	1.14	19
Colón	0.25	2.21	0.17	0	0	1.04	0	0.21	3.63	10
Tegucigalpa	0.01	0.69	1.26	1.62	0.01	0.07	0.02	0.13	3.67	839
San Pedro Sula	0.04	1.07	1.77	0.34	0.73	0,79	0.02	0.09	4.80	181
Choluteca	0.00	0.78	0	0.83	0.44	1.78	0.01	0	3.84	28
Santa Rosa	0	0.76	0	0	0.94	0.07	0	0.11	1.87	22
Comayagua	0	2.76	0	0	0	0.02	0.05	0	2.83	31
Guatemala City	0.03	0.73	0.64	3.64	0.06	0.10	0.03	0	5.20	233
Villa Nueva	0.03	0.88	1.54	4.47	0.01	0.01	0	0.13	7.05	206
Chinautla	0.01	2.30	0.60	0.13	0	0	0.02	0.04	3.08	68
Mixco	0.02	0.71	0	7.32	0.00	0.24	0	0.03	8.30	130
Average	0.02	0.88	1.12	1.69	0.91	0.35	0.03	0.24	5.48	2230

Table 2f shows average costs per m^3 of coping water for the different water sources across cities in our sample. Prices are seen to vary widely, across cities and sources. These prices reflect both the degree to which markets for the respective water deliveries are developed in the different cities, and the general availability of coping-source water. As expected, water vended from trucks is generally the most expensive mode of coping water delivery (with an average price of about 9.50 USD/m^3), followed by private tap water, and then water from public taps and external wells. Naturally also, water from private wells (in most cases belonging to the household), and water hauled from lakes and rivers, bear very low monetary costs to the households.

Table 2f Distribution of average water prices for coping households, by water source. USD per m^3 at PPP rates. Numbers of households in different categories in parentheses.

City	Bottled water	Priv tap	Publ tap	Trck	Priv well	Othr well	Lks, Rvrs	Other	Average (exc. btl)
Santa Ana	103.7 (5)	3.00 (45)	0.59 (16)	3.83 (39)	0 (12)	2.03 (33)		0 (46)	2.08 (141)
Sonsonate	131.0 (1)	3.74 (74)	3.29 (134)		0 (33)	2.34 (4)	0 (9)	0 (34)	2.76 (222)
San Miguel	119.5 (19)	2.49 (47)	0.76 (38)	0.74 (2)	0 (128)	1.48 (20)	0 (1)	0.85 (4)	0.61 (191)
Panama		0.14 (8)					0 (1)		0.12 (9)
Colón	119.1 (1)	0 (3)	0 (1)			0 (2)		0 (1)	0 (6)
Tegucigalpa	93.0 (15)	10.1 (301)	4.63 (337)	12.69 (329)	5.83 (2)	4.50 (24)	0.73 (12)	14.3 (12)	8.43 (826)
San Pedro Sula	83.0 (9)	1.56 (90)	0.79 (82)	9.53 (9)	0 (22)	1.44 (29)	0 (6)	3.89 (3)	1.34 (175)
Choluteca	232.1 (1)	1.08 (11)		33.88 (3)	0 (2)	1.45 (8)	0 (1)		2.47 (24)
Santa Rosa		0.65 (14)			0 (4)	0 (1)		0 (3)	0.48 (19)
Comayagua		0.94 (29)				3.67 (1)	0 (1)		0.89 (30)
Guatemala City	182.2 (27)	6.60 (62)	0.99 (45)	8.00 (126)	3.01 (8)	2.29 (10)	1.00 (4)		5.73 (206)
Villa Nueva	193.8 (27)	7.58 (45)	2.20 (53)	6.15 (105)	5.48 (2)	1.10 (1)		0 (3)	5.27 (192)
Chinautla	186.4 (2)	3.82 (43)	0.76 (9)	2.99 (3)			0 (1)	0 (1)	3.23 (55)
Mixco	160.6 (11)	4.87 (22)		6.24 (106)	7.68 (1)	10.5 (18)		0 (1)	5.68 (121)
Average	150.1 (118)	6.01 (794)	3.18 (715)	9.47 (722)	0.25 (214)	3.20 (151)	0.35 (36)	1.73 (108)	5.12 (2217)

Another main difference between water obtained from tap and from coping sources, is that while the former source permits water to be provided "automatically" and thus without time or effort cost for the household, water from coping sources generally needs to be hauled by household members. This imposes time and effort costs on the households. The direct time expense is here generally measured in our data, since households have been asked to provide estimates of hauling times during the observation period, for the different categories of coping water hauled. The effort cost however cannot be measured directly.

Table 2g provides the data on average household time costs of hauling water during the month for which we have data, where we distinguish between time used in hauling water delivered by trucks, and water from other sources, in the first two columns of the table. The third column gives data on total hauling costs. We find that overall time used in hauling coping-source water was quite substantial, on average almost 11 hours per household per month. We find, not surprisingly, that water delivered by trucks generally is associated with lower average hauling costs than water from other sources. For truck water, the average hauling time per m^3 consumed is about 1 hour 20 minutes, while for other water the same average is about 2 hours 15 minutes.

Table 2g. Distribution of hauling times for coping households, hours per household per month

City	Truck water	Water from other coping sources	Total coping water use	Number of households affected
Santa Ana	0.02	2.93	2.95	143
Sonsonate	0	8.15	8.15	225
San Miguel	0	3.72	3.72	195
Panama	0	7.57	7.57	19
Colon	0	16.58	16.58	10
Tegucigalpa	0.95	7.21	8.16	839
San Pedro Sula	0.04	18.53	18.57	181
Choluteca	0	3.01	3.01	28
Santa Rosa	0	4.71	4.71	22
Comayagua	0	4.31	4.331	31
Guatemala City	10.83	13.39	24.22	233
Villa Nueva	4.96	10.13	15.09	206
Chinautla	0.10	8.39	8.48	68
Mixco	8.03	3.55	11.59	130
Average	2h 20min	8h 16min	10h 40min	2330
Average hauling time per m^3	1h 20min	2h 15min	1h 55min	2330

Consuming water from nontap sources imposes at least three different types of hardship on a household, relative to consuming water directly from the tap. Two of these are clearly documented in our data. First, the pecuniary cost of nontap water is substantially higher than that of tap water. Secondly, nontap water is associated with substantial hauling costs. A third type of "hardship" cannot directly be measured from our data, namely the inconvenience of not having access to water delivered by tap.

2.2.2 Estimation of demand functions on the basis of coping-source data

We now proceed to the estimation of water demand functions based on data for households relying solely on coping sources. This poses a number of challenges. First, we need to properly identify the water price or prices, relevant for inclusion into the estimated demand relationship(s). Secondly, we need to define the proper measure of coping-source water consumption, which is no trivial task since there are various such sources, as documented above. Thirdly, we need to specify a correct measure of hauling cost, in terms of time and effort expended to haul water to the household.

For assigning prices to nontap water the following two approaches were initially viewed as relevant:

1. To calculate an average water price for all water delivered directly to the household (except bottled drinking water). This will then be taken as the price of all nontap water (also that which is actually hauled).
2. To use the prices for all different deliveries of water to the household as independent observations (together with the associated magnitudes), in cases where these differ. One would then need to impute water prices to hauled quantities, e.g. in proportion to prices of nonhauled quantities.

An alternative which we did not try, but which may in principle be feasible and is of some interest, is to estimate a simultaneous equations system where coping water from each individual source is considered as a specific commodity, and where, in general, all types of water consumption can be affected by all prices. This implies implementing the socalled discrete-continuous model of water demand (see Heckman (1978), Hanemann (1984)) in a rather advance application, with several types of water demand simultaneously, that may or may not be used by a given household. The usefulness of such a procedure is indicated by Whittington and Swarna (1994), who (in section III of their report) discuss the discrete-continuous model at some length, and also point out that the model has never been implemented on data from developing countries, and that such implementation is difficult. We will not proceed in this direction here, but leave it to future research. Possibly, our data is suitable for such analysis, in a better way than any earlier material ever obtained.

In our empirical analysis we settled for simpler and more summary estimation procedures, which yield more robust results. We considered the following estimation alternatives:

a. Use only the price of water delivered by trucks, as indicating the marginal price of water from all sources. This requires that only those households that have some truck purchased water are included in the calculations.
b. Use both the truck price as the marginal price for those with positive truck purchases, and the average coping water price for those without truck purchases, and use only one water consumption variable, namely overall coping water use. This permits all households with some purchases of coping water to be included, but the marginal price will have a different interpretation for those with and without truck purchases.
c. Use the truck price and the average price of other coping water as two independent explanatory variables, and use one aggregate variable for coping-source water consumption.
d. Use the truck price and the different prices of coping-source water, by source, as simultaneous independent explanatory variables, for overall coping water consumption.

Out of these only a and b were found to give meaningful and useful results. When attempting alternative c, only the truck price turned out significant and with the right sign, while the alternative price either had a wrong-signed or very small (and insignificant) coefficient. Alternative d was found to yield both unstable and in some cases unsensible results, in particular, often positive estimated price effects on water consumption. These problems likely stem from data problems whereby the identification of the sought independent effects is made difficult by measurement errors both in individual consumed quantities and hauling times, and great variations across households in the sources of nontap water utilized.

From the above discussion most the empirical analysis presented here is based on alternative a above, where we identify the marginal coping-source price with the average price paid by each household for water bought from pickup trucks. Generally, bottled water is kept out of these estimations. The price of water bought from trucks can in most cases be considered to represent an estimate of the marginal water price facing the household, in the sense that it is usually the most expensive water bought, and its supply is usually not rationed (such that whatever additional water necessary after supply from other available sources can be provided by additional supplies from tank trucks, in neighborhoods where such service is at all available).[12] Given such a perspective, the ratio of average marginal metered tap price to coping-source price, across all households in the sample, is, astonishingly, almost 24 to one.

We have however as noted also made some stimations based on variants of cases b-c above, where we use the average price of all coping-source water purchased, and the average prices of vended water from trucks and from other sources as separate price variables.

A further issue in this context is how to treat econometrically the time costs of hauling water in the estimated relationships, which is a cost item for coping households, alongside with pecuniary costs of water purchases. It is not obvious how this cost item should be included, since no direct measure of hauling cost is available in money terms, in our data nor in other relevant material. Our approach here has been to use the time cost of hauling water per unit of water consumed, from trucks and other sources separately, as independent explanatory variables in the coping water demand functions. Time cost is then specified either in terms of the total time of hauling water from the respective source, or the time per cubic meter hauled. The latter may be the more reasonable in terms of interpretation, in particular in a log-linear model where this time cost would be very similar to a monetary cost.

We now turn to the econometric analysis of demand for coping-source water. In principle such demand estimations might face problems of simultaneity and selection, in much the same way as for metered tap water discussed above. Simultaneity problems could arise e.g. if those households who need a lot of coping-source water on average have to pay either higher water prices than others (because they may need to rely on more remote and expensive sources at the margin when demand is high), or lower prices (because high-consumption households have better supplies of such water, e.g. own wells or get rebates from vendors).[13] We have tested our data for such simultaneity, and found none. We have also run 2SLS regressions using instruments for the coping water price, but find that the slope on the demand-price schedule is essentially the same as with OLS, so we have stuck to the latter.

The issue of sample selection must be considered here in the same way as for metered tap consumption in section 2.1 above. There are at least two types of selection problems to take into account. First and perhaps most importantly, there may be self selection to the category of coping

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[12] This may not necessarily or always be a good assumption, since it generally requires households to have a certain water storage capacity to even out consumption between times when tank trucks come along, which may not always be available.

[13] Note that there are also simultaneity problems associated with the discrete-continuous model and its implementation, as pointed out by Whittington and Swarna (1994). This follows because the choices with respect to what coping water source(s) to utilize, and the amount of water to consume from each of the used source(s), in principle are independent,

source reliance as such. Note then, first, that in the short run it is reasonable to take the group of households belonging to category 3 (without tap water access) as exogenous and not interacting with endogenous variables in our study. In the longer run households however relocate, also across groups with and without tap water access. It is then natural to assume that those households who have the most to gain by such access (in particular, those with the greatest innate water needs), have the most incentive to move from the nontap to the tap category, and thus be most inclined to make such a move. Such a process of relocation will lead to a distribution of households across service modes, where households with high innate water consumption are underrepresented among coping-source consumers, and overrepresented among tap consumers. This type of selection problem may be more severe than the similar problem discussed for selection from the nonmetered to the metered tap category, since there is obviously a lot more to gain, in welfare terms, in the current case.

We have attempted in our preliminary analysis to correct for possible self selection by using Heckman’s two-step procedure, but with no apparent success (coefficients are generally unstable, insignificant and often with wrong signs). This approach was consequently dropped, and no results based on this method are reported. It may still be useful to have this problem in mind when interpreting the results from the model.

The selection-type problems just indicated may possibly be played down for the reason that moving from one neighborhood without water access, to another one with water access, often at the same time implies gaining access to many other goods such as sewerage, electricity, telephone connections, overall safety, and better local schools and social services. Overall, gaining access to all these goods is associated with considerable cost increases, in terms of higher property prices faced by purchasers of property.[14] The ability to bear such costs is then likely to be a far more important factor for moving, than differences in preferences for water access as such.

A further selection-type problem that ought to be considered is that there may be selection to the use of tank truck water among coping sources, which may be relevant when one concentrates on tank truck customers. Note however that in many of our calculations we include all households

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and equations specifying each of these choices should in principle be estimated appropriately, to consider this problem. This issue together with the general simultaneous equations problem, we must also leave to future research.

[14] We find in our material, that when correcting for city and measurable house characteristics, houses with metered tap access are about 20 % more valuable than houses with nonmetered tap access, and more than twice as valuable as houses with only nontap water supply. Moreover, when controlling also for access to telephone connections, electricity and sewerage, one finds that these three variables (which are strongly correlated with tap water access) by themselves explain almost the entire difference in house price; water access is left with a small independent effect. This indicates that many and complex factors are behind a possible decision to move, from a “bad” neighbourhood to a better one, and that water access by itself is likely not to play an overwhelming role in this decision. These calculations are presented and further elaborated in section 4.2 below.

using coping sources (and thus do not confine ourselves to only the tank truck users). In such case, we will argue, this selection problem can safely be ignored.

Table 2h shows results from one linear and three different log-linear OLS estimations explaining total coping water demand for coping households. We have tested a large number of specifications, and ended up with a set of specifications where, in each case, only one water price variable is included. The first three columns describe results from calculations where we include only those households who purchase at least some water from tank trucks, with the average tank truck price used as the relevant water price. The two last of these both describe log-linear relationships, denoted (1) and (2). These differ only in the way time hauling costs are included. In the first (as well as in the linear relationship) time hauling cost is defined as hauling time per m^3 of water provided for each of the two categories of water (truck water and other water). In the second (as well as in the calculation in the right-hand column) total hauling time is used as the relevant hauling cost variable. Note again that the estimation presented in the right-hand column includes also households that purchase no truck water but fully rely on other sources. For such households, the average price paid for water from other sources is used as the relevant water price variable. The set of households included is then increased considerably, from 722 to 2248.

Overall, the log-linear relationships give much better general fit to these data, than the one linear relationship included in the table (which in turn is the best of all the linear ones attempted). The log-linear relationships give quite good overall fits, with multiple R-squared close to 0.4 or exceeding 0.4 (by contrast, our “best” linear relationship gives an R-squared of only about 0.15). We also find many more (and more highly) significant coefficients from the log-linear relationships. These factors speak strongly in favor of putting most emphasis on the log-linear relationships, in interpreting our results.

Our results show that the tank truck price has a significantly negative, but not very large, effect on total coping water demand. To take the linear relationship first, there an increase in the truck water price by one (PPP) USD reduces overall coping demand by about 110 liters per month. This does not seem like a large effect (but remember here that the average truck price was about 8 USD/m^3, PPP adjusted; at the average coping consumption of 5.5 m^3/month, this is equivalent to a price elasticity of approximately –0.16). From the log-linear relationships, we find price elasticities in the range –0.10 - –0.18. This elasticity seems to be slightly higher when only the truck price is included, as compared to the case where other water prices are included. This is in our opinion a reasonable result. Truck demand is here in most cases likely not to be rationed for any given household (i.e., the particular household is likely to be able to purchase as much water as it wishes from any given truck, at the going truck price). Non-truck demand may be rationed or constrained in more cases. E.g., some households may obtain limited amounts of cheap water from neighbours, or have wells or other sources with low access costs but limited capacity (which perhaps must be supplemented with more expensive truck water). Overall water demand will then be less responsive to price increases for these other sources. Such effects will manifest themselves in our estimations in the form of relatively low demand elasticities with respect to increases in prices of water from other coping sources than trucks.

Table 2h. Regressions of coping household water consumption against different background variables. In linear relationship, effects in m^3/month, prices/incomes in USD at PPP rates. T statistics in parentheses.

Variable	Linear, marginal truck price only	Log-linear, marg. truck price only (1)	Log-linear, marg. truck price only (2)	Log-linear, all water prices included
Water price	-0.11 (-2.76)	-0.12 (-2.40)	-0.18 (-3.41)	-0.10 (-7.17)
Truck water time Hauling cost	-0.19 (-2.13)	-0.22 (-8.52)	-0.20 (-6.25)	-0.097 (-27.9)
Other water time Hauling cost	-0.06 (-1.71)	-0.093 (–2.67)	-0.18 (-2.51)	-0.36 (-3.70)
Household size	0.40 (3.36)	0.056 (5.88)	0.055 (5.61)	0.063 (10.1)
Household income	0.0029 (4.81)	0.077 (4.84)	0.084 (5.18)	0.041 (3.80)
Tegucigalpa dummy	-3.10 (-4.02)	-0.59 (-8.69)	-0.56 (-8.07)	-0.268 (-7.72)
Guatemala dummy	-2.50 (-2..55)	0.015 (0.18)	-0.11 (-1.36)	0.23 (4.09)
Villa Nueva dummy	-2.03 (-2.01)	-0.021 (-0.26)	-0.05 (-0.62)	0.25 (4.65)
Owner w. title	1.58 (1.86)	0.19 (2.78)	0.18 (2.58)	0.12 (3.53)
Owner wo. title	1.81 (1.95)	0.096 (1.29)	0.10 (1.33)	0.034 (0.90)
Constant	5.74	1.72	1.72 (11.0)	1.55
Multiple r squared	0.156	0.411	0.383	0.371
Number of obs	722	722	722	2248

Both of our included hauling cost variables are significant in all the log-linear relations. Overall, hauling costs seem have a substantial impact on coping water demand. Our estimates indicate that a doubling of both hauling cost variables reduces overall coping water demand by 30-40 %. All hauling cost coefficients are significant, the truck hauling cost variable highly so in all alternatives. This in fact implies that the estimated effect on total coping water demand of a given relative increase in all hauling costs is greater than the effect of all money costs. One should approach these figures with some caution, in particular since the hauling cost variable, in the way it is included here, may be prone to misspecification.

We have included dummies for three major coping-source cities in our material, namely Tegucigalpa, Guatemala City and Villa Nueva. The first of these is found to have a clear and significant, and strongly negative, effect (water consumption in Tegucigalpa is lower than in the average of the reference cities by about exp(0.55), or by a factor of about 1.7, holding water price and other control variables constant).

Household size and income also have the expected direction of impact on water demand. One additional household member increases demand by 400 liters per month in the linear relationship, and about 6 % (or about 330 liters at average consumption) in the log-linear ones . 100 USD of additional monthly income in the household increases water consumption by 290 liters per month. The corresponding income elasticity in table 2h is about 0.08, which at the average coping household (PPP corrected) income, of 515 USD, and average water consumption, corresponds to only about half of this, around 140 liters of increased water consumption per 100 USD increase in household income.

We have also attempted to estimate water demand relationships for individual cities. Tegucigalpa turns out to be the only relevant case here. First, note that almost half of all observations of positive truck demand are from this city. Secondly, our attempts to derive individual functions for other cities have turned out fruitless. Table 2i shows results from linear and log-linear regressions similar to those in table 2i. We here first note that the log-linear relationships now are relatively even better compared to the linear one, in terms of relative overall fit (with R-squared of more than 0.3 in the former cases, and only 0.075 in the latter). This speaks in favor of emphasizing the log-linear relationships also here. A difference from the estimations in table 2i is that we now, in one of the log-linear relationships, have included two different water price variables, namely both the truck price and the average price of other water, as independent explanatory variables.

In the first log-linear relationship (where only the truck price is considered), we now find a quite high absolute value of the price elasticity of demand, -0.47, much higher than for the pooled sample. In the second log-linear case (where both price variables are included) this elasticity is somewhat smaller, but still large in absolute value (-0.35, and approximately –0.4 when considering simultaneous increases in both specified water prices). When considering estimated elasticities with respect to hauling time variables, there is now a particularly strong effect of hauling cost for truck water for estimations when concentrating on those households where some truck water is used (-0.25 and highly significant); and strong effects of both hauling cost variables in estimations utilizing the full set of households (also those who rely fully on other sources than truck water). The elasticity with respect to other water prices in the latter case is low and not significant. Note also that the household size effect on water demand for Tegucigalpa is very similar to that for the pooled data set, while the household income effect in the more reliable log-linear relationships is somewhat greater for Tegucigalpa than for the pooled sample.

Overall, our results for Tegucigalpa indicate a stable and substantial, negative, price elasticity of water demand for coping-source water, which appears larger in absolute value than that for the pooled sample. It is difficult from our data to identify any particular reasons for this higher value for Tegucigalpa. It might indicate that the pooled model is misspecified, something that may follow from different and unobservable individual characteristics of water demand in the different cities included in this sample. It could then happen that the true price elasticity for the entire set of cities included is closer to that estimated for Tegucigalpa, but our data are not able to uncover this conclusively. Another possibility is that the Tegucigalpa data set is by itself too small to yield reliable estimates, and that a replication of this data set would have yielded different results. Such observations can however at this point, before other and perhaps better data is obtained, only be speculation.

Table 2i. Regressions of coping source water demand, Tegucigalpa. m^3 per month, USD at PPP rates in linear relationship. t statistics in partentheses.

Variable	Linear, truck price only	Log-linear, truck price only	Log-linear, all prices
Truck price	-0.129 (-3.33)	-0.475 (-5.61)	-0.353 (-5.20)
Other price			-0.033 (-1.97)
Truck hauling time cost	-0.062 (-1.80)	-0.254 (–7.58)	-0.248 (-7.45)
Other hauling time cost	-0.059 (-3.54)	-0.018 (-0.39)	-0.217 (-11.96)
Household size	0.344 (3.77)	0.058 (4.52)	0.068 (7.93)
Household income	0.0018 (3.56)	0.125 (4.27)	0.075 (4.33)
Constant	3.04	1.77	1.70
Muliple r-squared	0.075	0.341	0.313
Number of observations	839	375	836

In summing up this section, barring possible misspecification of the aggregate model, our estimations on the coping households on the whole indicate a negative price elasticity of demand for the pooled sample of coping households, in the range –0.1 - –0.2. This is a lower value range than that found for metered tap consumption (where our most reliable estimates seemed to lie in the range –0.3 - –0.4). On second thought this is perhaps not surprising. Most coping households have very low water consumption, on average less than one fifth of the consumption of households with metered tap connections. For coping households a further increase in the water price, beyond that already experienced, should then perhaps not be expected to reduce consumption by much, since their consumption is already close to the minimum volume necessary for basic survival. Nor does a reduction in the price increase consumption much unless the household gets a tap connection, since few extra uses become worthwhile in this case (the price is still very high compared to the utility to be derived from its use and the logistical problems of procuring and storing the water remain important), so that the household prefers to assign the real income gains from reduced water prices to other forms of consumption. In addition we have found that the income effect on water demand is small. When a household does not have a piped connection (unless it has a cistern and pump) there are few potential uses of water within the household, beyond the pure necessities related to cooking and cleaning, regardless of income. It is also noticeable that an increase in household size by one person seems to increase household water consumption by not much less in coping households than in households with metered tap connections, despite the overall level of water demand being much higher in the latter types of households. This indicates strongly that the level of water demand among coping households is largely driven by basic needs and to only a small degree by income and price variables. Again, however, the Tegucigalpa data (in particular the price elasticity estimate obtained from this data set) questions this view, and leaves the final answer somewhat less clear at this point.

2.3 Water demand calculations based on combined data for metered tap and coping households

Our final results presented in this chapter are based on calculations where we have merged data for metered tap households and coping-source households, using a common variable representing water price. For metered households we here use the marginal water price, constructing imputed values of this after regressing it on the same set of instruments that was used in section 2.1. For coping households we use the truck price where this is observed, and else the average coping water price. The overall data set is thus something of a hybrid: one part of it is replaced by imputed values, and in the part, the definition of water price varies between types of consumption.

Results from five different estimations are presented in table 2j. These can be grouped in three different ways. First, column one presents results from a linear estimation, while columns 2-5 present log-linear estimations. Secondly, the estimations in the three first columns relate to the entire material, i.e., all the data on metered and coping-source households are included. The estimations in the last two columns are done on a subset of the data, for the cities in El Salvador only. Thirdly, the estimations in columns 1, 2 and 4 include a full set of background variables, while the estimations in columns 3 and 5 include a very limited set of variables: only household size and household income in addition to the water price variable.

We will first comment on the estimations done on the entire data set and including the full set of background variables, i.e., the two first columns of table 2j. The figures in these columns show results from one linear and one log-linear OLS regression on such a data set. We here include dummies for all cities, for two categories of house ownership (owner with title, and owner without title, with nonowners as the reference group), and four categories of degrees of rationing among the subset of households with metered tap connections (nonrationed, service 8-16 h/day, service less than 8 h/day, and service 15-29 days/month, where service less than 15 days/month are reference group).

We see that the log-linear relationship here gives a particularly good fit to this data set (with R-squared of almost 0.67). The fit is also good but somewhat less so (with R-squared of 0.58) for the linear relationship. One should however be aware that this seemingly extraordinary fit to individual data is strongly related to the extremely high explanatory power of the binary variable representing whether or not the household belongs to the metered tap or the coping category (in the table, the variable “have a connection”). To take the linear relationship, the water connection itself here in fact explains more than 20 m^3 of water consumption, i.e., more than 2/3 of average total water consumption for connected households. This result indicates that providing a water access to a household raises its water consumption tremendously, regardless of the prices charged for water before or after the access change. In the log-linear relationship the corresponding coefficient is 1.27, which implies that connecting the household, holding everything else equal, multiplies water consumption by a factor of about 3.5.

The estimated price elasticity on the merged data is rather small in absolute value, only around –0.04 (but significant), and thus smaller than the individual elasticities estimated on the two separate (now merged) data sets. This may indicate the possibility of specification error due to lack of common structure of the two separate data sets, and to the problems in constructing a common water price variable. (We will see below that estimated price elasticities tend to be much higher under the alternative specification with much fewer variables, in column 3.) When considering the other variables included, we find moderate elasticities with respect to income and family size, in the range 0.06-0.07, which are very similar to those found on the individual data sets for metered and coping households. The effects of property relationship are small and insignificant.

In the same way as for estimations on the metered data alone, we find significant effects of rationing on overall water demand among metered tap households. Having as reference group those households with tap water access fewer than 15 days a month, unrationed consumption is now on average 28 % higher in the log-linear relationship, and the difference is highly significant in the log-linear relationship (but smaller, and not significant, in the here much less suitable linear relationship). Also in the same way as for the metered data alone, we in addition find no discernable difference in water consumption between those who have continuous water service, and those who have water access every day but then less than 8 hours. This confirms our earlier finding that there seems to be no effect on household water consumption in our data, from water rationing as long as the household has daily water access. Overall, the measured effects of rationed versus nonrationed water demand are however somewhat smaller than those found when doing the estimation on the metered data alone, as reported in table 2b.

The estimations done on the entire data set here also include estimated dummy variables for all cities in the sample; these are not reproduced in the table. Many of these dummies are large and highly significant and are largely in line with city dummies estimated for each of the two separate data sets in previous sections.

We will next comment on the estimation presented in the fourth column of table 2j, for a log-linear estimation on a subset of the data where we include only the three cities in El Salvador, Santa Ana, Sonsonate and San Miguel, and where we use the same set of explanatory variables as those used in the two first columns (except the dummies for other cities). From table 1a, these are the only three cities with “substantial” numbers of observations (more than 100) in each of the categories metered tap and coping households. It would appear a priori reasonable that the water demand situation in these three cities is more homogeneous than for the entire set of cities. This hopefully makes for a more meaningful derivation of a common demand function. Encouragingly, the overall price demand elasticity is now higher in absolute value, about –0.2 (and much more highly significant), and more in line with estimated elasticities for the two data sets separately, for the entire data set. The overall fit of the relationship is also in this case high, but somewhat less so than for that estimated on the entire data set. This is probably related to the fact that the coefficient on water connection is not quite as high for the El Salvadorean cities, as for the entire data (and, although significant, less highly so). It is still high, about 0.85, implying that having a water connection increases water consumption by a factor of about 2.4 in these three cities. The effect on water consumption of degree of rationing is greater in these cities than for the entire sample of cities, with a coefficient of 0.6 on nonrationing (where reference group as before is households without daily access). Otherwise results are similar to those for the entire data set.

We have also, mainly for reference and comparison, included results from two log-linear estimations (on the entire data set, and on the set from El Salvador) where the model is stripped of all explanatory variables except water price, household income, and household size. In effect we here postulate a much stronger version of a common water demand function, where the connection and rationing mode play no direct role for water demand, and only the water price (together with income and family characteristics) affects water consumption. A motivation for such an exercise is that a number of previous analyses of water demand have either applied, or recommended, such a model. As noted above, the estimation results presented in columns 2 and 4 of table 2j show a very large effect on water consumption of the connection itself (and in addition a large effect of rationing among those connected). Since connected households face much lower water prices and consume much more water than unconnected ones (and in addition nonrationed connected households have larger water consumption than rationed ones), one should expect much larger estimated effects of water prices on water consumption within a relationship where only water price is included, as compared to one where corrections are made for piped water connection and rationing.

This is exactly what is found. The coefficients on water price in columns 3 and 5 are far greater in absolute value than the coefficients in columns 2 and 4 (the column 3 coefficient is here in fact more than one order of magnitude greater than the corresponding coefficient in column 2). Both of the “stripped down” coefficients in columns 3 and 5 have values between -0.4 and -0.5. These coefficients are also much greater than (largely between 2 and 3 times as high as) the individual coefficients on marginal water price, estimated on the metered and coping household separately, and reported in sections 2.1 and 2.2 above. These results point to the possibility of a serious misspecification when attempting to estimate common water demand functions on data for connected and unconnected (and for rationed and unrationed) consumers. Such functions will have demand coefficients on water price, that are far too high in absolute value.

Another important feature of the results reported in columns 3 and 5 is that the household income variable has a much greater (and more significant) effect on water demand, than the effects in columns 2 and 4. The main reason for this is that household income is correlated with other (here, excluded) variables with important effects on water demand. In particular, there is a tendency for high-income households to be connected and unrationed, and for low-income households to be unconnected. This will lead to household income coefficients in columns 3 and 5 that are biased in the upward direction.

One should be aware of several objections to merging the two data sets in the way done here. One possible objection follows from the seemingly basic property of water demand, that being connected in itself is associated with an enormous increase in water consumption, and thus in all aspects of this consumption. The basic water consumption structure is then obviously quite different for connected than for unconnected households. Trying to estimate common coefficients on a data set where two such very different consumer groups are pooled may then not make sense and lead to serious biases, the nature and magnitude of which are difficult to predict. A second set of problems arising in this context is due to the rather separate problems with the two separate sets of estimations, on the data sets for the metered tap and coping households. Remember first that there was a serious identification problem in the metered data analysis, which required instrumental-variable methods to be applied to that subset (and actual observations to be replaced with imputed values based on regressions against a set of instruments). The coping data set is by contrast used directly without any imputation procedure, but there may be problems with this set as well, in particular with constructing the proper water price variable (since several coping water sources are generally used by a given household, each with a different pecuniary price and hauling cost; in fact hauling costs are not at all considered in this section). Merging one imputed data subset with one subset of actual observations (and where there may in addition be serious errors-in-variables problems) in the same estimation may be questionable. It is also difficult to take properly into consideration all problems with both sets in the same statistical operation, and the variables representing income, household size etc. may have very different effects in the two separate sets. Finally, possible sample selection problems could imply that households relying on coping sources are a self-selected group with lower basic water demand, and that there are self-selection problems among the metered households as well. The estimates presented here should thus be read and interpreted with caution.

We will still claim that our estimates are of independent interest. In particular, our analysis is (at least to our knowledge) the first in the literature conducted on such merged data sets, making it rather explorative and interesting in its own right.

One implication of our findings is that analysts should take care with the use of elasticity estimates derived from data sets containing observations for piped demand and for coping source demand. Our findings suggest that such an approach leads to a conflation of two distinct demand curves. The estimated elasticity for the conflated curve will tend to be much higher than the real elasticity for each of the real curves. This obviously limits the usefulness of such estimates, and could give rise to serious errors. For example, if system planners were to use such a conflated curve to estimate the elasticity of demand for the expected reaction of piped consumers’ demand in the face of a price increase, they would be likely to seriously over-estimate the reduction in consumption.

Conflated demand curves have also been used by some writers (including one of the authors of the present paper) for estimating social benefits from increased water access.. In their presentation of methods of calculating benefits of increased water supply and access, Whittington and Swarna (1994) propose as a main practical approach to benefit calculation on revealed-preference data where observations are available for both metered tap and coping households, to fit a common (preferably log-linear) water demand function, to observed water consumption and prices for both the metered and coping households.[15] Our results demonstrate that such a procedure is likely to lead to serious misspecification, due to the fact that tap and nontap water demand functions are (at least in our case) radically different. In particular, the price elasticity of water demand thus estimated (corresponding to our elasticities reported in columns 3 and 5 of table 2j) will be way too high in absolute value. Note that our material includes observations of coping households who face water prices as low as, or lower than, those prices that metered tap households face. Still, the consumption of such coping households is only a fraction of that for the respective metered tap households. Clearly, using a common water demand function for both groups makes little sense.

This finding is consistent with economic common-sense, because there is obviously a great difference in the use-value of a tank of water that can only be redistributed within a household hauling it in buckets, compared with water under pressure in a piped system connected to faucets. A moment's reflection would lead one to expect that at any give price, consumption is going to be greater when the water is pressured.

However, this conclusion does not mean that the procedure recommended by Whittington is unacceptable as a simple approach to a lower-bound estimate for the economic benefit stream associated with installing piped water, where previously no service existed. If there are really two separate demand curves and if the true demand curve for piped water lies above and to the right of both the true coping water demand curve and the conflated demand curve, it is immediately clear that the estimate of average willingness to pay derived from analysis of the conflated curve will underestimate true willingness to pay. Whittington's procedure may therefore be an acceptable rough-and-ready approach to benefit calculation, as it will understate the real benefit of projects for installing piped water connections.

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[15] Such an analysis was attempted by Walker et.al. (1999) for Tegucigalpa, as an initial approach using part of the data material available here. It is unfortunately not possible to MISSIING TEXT HERE……

Indeed, we believe that our study adds further evidence to the documentation of the enormous positive effects on water consumption from having a connection to a piped water system. We have also shown that rationing has a clear negative effect on water consumption when daily access is denied. These effects are independent of other explanatory variables such as water price, income and family characteristics. These are interesting conclusions, for analytical and policy purposes.

Table 2j. Estimation of water demand relationships on pooled data for metered tap and coping households. t statistics in parentheses.

Variable	Linear, all obs.	Log-linear, all obs.	Log-linear, all obs, no dummies	Log-linear, El Salvador cities only	Log-linear, El Salvador, no dummes
Water price	-0.036 (-2.42)	-0.040 (-2.64)	-0.417 (-26.6)	-0.198 (-5.84)	-0.478 (-10.2)
Household size	0.739 (8.95)	0.069 (13.42)	0.029 (3.84)	0.060 (3.70)	0.016 (1.11)
Household income	0.0022 (8.51)	0.061 (6.83)	0.187 (14.8)	0.055 (3.15)	0.176 (7.1)
Have water connection	20.38 (19.4)	1.27 (19.5)		0.857 (2.67)	
Owner with Title	0.59 (1.23)	0.042 (1.42)		0.122 (2.44)	
Owner without Title	-0.079 (-0.14)	-0.0083 (-0.24)		-0.009 (-0.16)	
No water Rationing	1.99 (1.90)	0.284 (4.35)		0.605 (2.67)	
Service daily 8-16 h	0.83 (0.82)	0.173 (2.73)		0.444 (1.87)	
Service daily > 8 h	1.90 (1.91)	0.188 (3.00)		0.475 (1.45)	
Constant	3.48	1.48	1.29	1.42	1.67
Multiple R-Squared	0.581	0.667	0.238	0.592	0.140
Number of observations	3282	3282	3283	963	963

2.4 Overall conclusions on water demand estimation in Central American cities

We will here sum up a few main overall conclusions from sections 2.1-2.3 above. We focus on the following 9 points.

1. For both metered and coping-source data, when using the data sets for all available cities simultaneously, we find negative price elasticities of demand, which are all relatively low in absolute value. In the case of metered tap consumption, the “most reasonable” estimate of the price elasticity seems to be around –0.2 for marginal price alone, but higher in absolute value, around –0.4, with respect to a simultaneous change in marginal and average water prices. In the case of coping consumption, the corresponding figure seems to be closer to –0.1. Price elasticities of demand thus generally seem lower in absolute value for coping than for metered tap consumers. (Storage limits may be a major constraint for coping source consumers).
2. We also have reliable estimates of price elasticities for individual cities, namely Managua in the case of metered tap consumption, and Tegucigalpa in the case of coping consumption. In the Managua case we find a price elasticity of about -0.25 for marginal price alone, and closer to –0.6 when considering simultaneous changes in both marginal and average price. For Tegucigalpa we find a corresponding elasticity close to -0.4. These results might indicate that the “true” common elasticities are higher in absolute value than those found from the data for all cities simultaneously, but results cannot be considered conclusive. More data, from other cities and data sources, are however required to confirm such a conclusion.
3. For coping-source consumers we find substantial effects of hauling costs on demand, as expected, with demand elasticities with respect to all relevant hauling cost variables appear close to -0.3 - -0.4.
4. Water consumption of connected (and metered) households is on average more than five times that of unconnected ones. Moreover, the effect on water demand of the water connection itself completely overwhelms the effects of other explanatory variables, such as water prices, income and socio-economic variables, and explains around 2/3 of the total water demand for connected households.
5. Income effects on water demand are small, with elasticities mostly below 0.1. Effects of household size are rather stable; in most cases one additional household member increases water demand by 5-10 % (effects are somewhat larger for adults than for children). The percentagewise effect on water demand due to additional family members is not very different between the metered tap from the coping data set.
6. We find notable effects on water consumption of rationing, but only for households with piped water access less than every day (average water consumption seems to be about 40 % higher for those with daily access, than for those who do not have access every day). The consumption of those who are rationed only within a given day (but consequently have some access on all days)

seems not to be affected by this rationing, which may be due to the presence of sufficient storage facilities in such households.

7. It is imperative for sensible estimation on metered data to make corrections for simultaneity of consumption and price of water, due to the block rates in individual cities. This is here done using 2SLS, instrumented for both the marginal price and the "difference variable" (or alternatively, a variable representing average price). For the coping-source data OLS appears to give consistent estimates.
8. We have conducted estimations on a merged data set consisting of both metered tap demand and coping demand. Such estimations, done on the entire data set, show that having a connection explains a large fraction (possibly, more than 2/3) of the overall consumption of connected households. One may argue that such merging of data sets is problematic, due to the great difference both in the data generation process, and in the demand structure for these two types of data. We here find much lower demand elasticities in absolute values, on the merged data set when compared to each of the two merged sets separately. A separate calculation, done for the cities in El Salvador, however indicates a price elasticity close to those found in previous estimations, on the separate data.
9. As related to point 8 above, we have demonstrated the possibility of serious misspecification of a model where data for both metered tap and coping households are merged, without proper correction for connection, and for rationing among connected households. In estimating such a (misspecified) model we found price elasticities of water demand that were far higher (in absolute value) than the "correct" elasticities found from either the separate data sets or from the merged set where the proper corrections have been made. Therefore, such estimates should not be used for predicting the likely response of piped water customers to price changes, as they will over-estimate the reaction of consumption.

The most important result from this part of the study is probably that household water demand in Central American cities is, on the whole, relatively insensitive to price changes, and less sensitive for nontap households than for metered tap households. We have also documented that water prices for nontap households are at least an order of magnitude higher, and their consumption is less than one fifth, when compared with tap households. This indicates that extending connections to unconnected households may be associated with very large welfare gains, an issue that will be further explored in chapter 4 below. Increases in connection rates can in many cases be implemented in practice e.g. by charging somewhat higher water prices from connected households (who today generally only pay one third of the long-run marginal cost of water provision), and using the revenues to subsidize the construction of new connections.[16]

Another important, and seemingly new, result from our demand analysis is that household water consumption appears to be independent of rationing which occurs within a given day. Such rationing then has no effect on overall water consumption, and is largely meaningless if its purpose is to reduce overall such consumption (it is difficult to picture what would be other objectives of such a restriction).[17] Households seem to fill up their water tanks during hours when tap water is available, and use stored water during the rest of the day so as to leave overall consumption unaffected. There is a larger systematic effect on consumption due to denying households daily access. This of course does not imply that water rationing of this sort is an advisable policy choice. A much better policy choice would be to raise water prices and instead limit rationing.

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[16] One may here of course fear that connected households who today pay very low water prices, will strongly oppose such price increases and thus make them politically infeasible. Note however that many of the surveys included here asked respondents about their attitudes toward such changes. A clear majority of respondents stated that payments for water should be determined according to actual water consumption and cost of provision and not other criteria (such as income or custom).

[17] A separate possible objective could be to relieve pressure on the water system during peak-load periods, during the day or week. However, an at least equally good policy is then likely to be to let households use their taps freely, and let them adjust according to realized pressure as customarily experienced, over the day or week.

3. Transfer of water demand estimates from sample to out-of-sample observations

3.1 Introduction

The purpose of this chapter is twofold. First, we wish to evaluate the ability of the demand functions, estimated from our data, to predict water demand “out of the sample”, i.e., for sets of households for which we do not have direct information on water consumption or demand functions. This procedure is as follows. First, one removes one of the cities, for which one has data on water demand and prices, from the sample, and estimates water demand relationships on the remaining sample. Secondly, one imputes water demand for each household in the “missing” (removed) city, on the basis of the estimated relationship for the other cities. Thirdly, one compares this imputation with the actual water demand for each household in the “missing” city. This comparison may involve statistical tests of similarity of the imputed and actual water demand levels, at individual and aggregate levels. The purpose of such exercises is mainly to test some “transfer” properties of our estimated water demand relationships; that is, their usefulness for predicting individual household water demand in cities for which have no such data. This may be of interest for situations were such data are difficult or costly to collect, and imputing such values the data one has available may be a “cheaper” alternative.

However, the scope offered by our dataset for testing benefit transfer functions (or in this case, actual water demand functions) is limited. In particular, our data set does not have enough observations to allow us to estimate city-level demand functions[18]. This implies that we cannot test “transferability” of water demand functions themselves. We can still address a more limited problem, namely to test “transferability” of estimated water demand at the household level. As we will see below, even this procedure involves some methodological problems.

For metered tap households, the procedure indicated above should in principle allow us to impute individual household consumption as a function of marginal and average water price and relevant sets of background variables. Note however that for such households, whenever individual price and expenditure data are available, water consumption can immediately be inferred at the household level, since the individual city water tariff functions will be known. Then water

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[18] Except possibly for metered tap households in Managua, and non-tap households in Tegucigalpa. The most relevant set here is the former, which however is based on less than 400 observations, a relatively small number considering the demanding estimation procedure (where water price data cannot be used directly).

expenditure data are sufficient to infer household water consumption, and imputations of consumption are unnecessary.

Strictly speaking, the ability to carry out such imputations for households with tap and meters is of consequence only when one lacks data for both water consumption and water expenditure for these households. In such cases, however, observations from these very households cannot be used for estimating the "matching" water demand functions which are to be compared to that derived on the basis of data for the other cities.

This has two main ramifications. First, such procedures are of interest for imputing household water consumption only for households where one has access to data sets that includes neither water consumption nor water prices or expenditures. This could be the case when one, say, has survey data of a random population sample of metered households, including other variables than those concerning water consumption. Secondly, the imputation procedure must be based on other variables than (marginal and average) water prices. In other words, ordinary water demand relationships cannot be used to impute water demand.

The second main purpose of this chapter is to develop a procedure for imputing water demand for households with non-metered tap consumption. This is a quite different and perhaps more interesting problem. For these one may have observations on individual household water expenditure but not for individual household water consumption, and this consumption cannot be inferred from the water expenditure. This is the situation for households belonging to group 2, comprising almost 8000 out of our total of about 11 500 households. The development of reliable methods for "transferring" household water consumption levels to the households belonging to group 2 is of great practical interest. We will below, in section 3.3, try to impute such demands on the basis of water demand relationships estimated as functions of water expenditure and background variables, from data for metered tap households. This in turn involves three main problems. The first is econometric: for metered tap households water expenditure is endogenous. Here instrumentation might solve the problem, in the same way as for endogeneity of the water price as dealt with in section 2.1 above. The second problem is that demand functions for those with metered and those with nonmetered consumption may in principle be quite different, without us as researchers or observers being able to detect the difference. Possibly, having ones consumption metered may alter ones consumption considerably, and in ways that are difficult to predict without controlling for the effects directly. The third problem is that we have sparse and rather indirect data for actual water demand in these groups (and only in the aggregate when they exist), with which the imputed demand levels can be compared, at least not at the household level. This makes it difficult to test transferability for this group. Some information can here be obtained from engineers' estimates of average water consumption within nonmetered household groups, which are calculated on the basis of overall water supply and assessments of water losses. Such estimates will be considered later in the chapter.

A third type of data is available to us, namely for nontap households. Here individual household data on water prices and expenditures may be available, possibly also on hauling times, even when household data on water consumption are lacking. For this group the exercise of imputing individual household water consumption, for individual cities taken out of the main sample, is meaningful. Imputed demand quantities can be compared to actual quantities, and tests of “transferability” developed. There are still clearly problems also with these data, such that the diversity of water sources and real prices of water from the different sources among coping households, the fact that much of the water is hauled at costs that may vary substantially, and the fact that some sources are likely to be rationed without this being specified. Note also that when household water consumption data are missing, hauling time data are also typically missing, and possibly also data on average and marginal water prices (often only total water expenditure is recorded).

3.2 Transfer of estimated consumption values for groups of metered tap households

Consider here first a “simplistic” procedure for transferring consumption levels for metered tap households. In the first step, we here estimate a “water demand function” on the basis of all metered data except the data for one particular city. In this “demand function” we only include explanatory variables not related to water prices (which must be presumed missing for the city excluded; thus it would not “help” in predicting water demand for the missing city, to include such a variable). The cities considered for exclusion are, in turn, Managua (Nicaragua), Santa Ana, Sonsonate and San Miguel (El Salvador) and Panamá City (Panamá). These are the only cities for which the number of observations on metered tap households is sufficient to make a value transfer procedure meaningful. Note that only for El Salvador are there multiple cities (three) within one country. These cities give basis for “within country” demand transfers. The Managua and Panamá City data can only be used for “across country” transfers. When conducting such “across country” transfers it is not obviously sensible to introduce city (or country) dummies in the estimated common demand relationship, since it is unclear what value such a dummy should take for the “missing” city. (Intuitively, we have no prior basis for knowing whether the demand structure of, say, Managua is more similar to that of Panamá City, than to that of either of the El Salvadoran cities). A better procedure may then be to estimate the common “baseline” demand relationship without city and country dummies. There is then probably greater reason to believe that the demand structure is more similar between cities within a given country. This speaks in favor of including a country dummy for the two remaining El Salvadoran cities (but not individual dummies for these two), when using the “baseline” sample which excludes one of these cities.

The procedure followed in this section implies the following three steps:

1. For each of the 5 cities, we delete the data for this city from the data set for metered tap households, and estimate individual “water demand functions” on the basis of the remaining data set. This is done in the linear and log-linear cases. Variables representing water prices or expenditures are omitted, but otherwise we include the “best” set of variables available in our data set.
2. Impute values to individual household water demand, to each household in the omitted city, on the basis of the estimated function under step 1.
3. Compare the imputed values under step 2, to the actual water demand values found for the same set of households in the data set.

In step 1, linear functions of the form

$$W = a_1 + a_2R + a_3F + \Sigma\, a_iV_i, \quad i = 4, \dots, n, \tag{3.1}$$

or alternatively

$$W = b_1 + b_2R + b_3F + b_4E + \Sigma\, b_iV_i, \quad i = 5, \dots, n, \tag{3.2}$$

are estimated on the set of all metered households except those in the particular city for which we wish to do the imputation. Here W is household water demand, R, F and E household income, size and water expenditure, and V a vector of other explanatory variables. This vector may or may not include city or country dummies. The difference between (3.1) and (3.2) is that E enters into (3.2) but not into (3.1). Equivalent specifications are used for the log-linear case (where we instead use logs of W, F and E (and explanatory variables V if necessary).

As also argued above, it can be argued that only (3.1) is “interesting” for the analysis of “benefit transfer” to population groups with metered tap coverage. (3.2) should not be “interesting” since, as explained above, information on E cannot be available for the households in “need” of transfer.

(3.2) may however still be useful, but mainly for the purpose of imputing water consumption levels to tap households without meters. This issue is pursued in the following section 3.3.

Say that we have estimated (3.1), by OLS, on the set of all metered households except those in Managua. Managua is the only city in Nicaragua for which we have observations of metered tap households. Assume that we have no prior hypothesis that water demand in Nicaragua is more similar to water demand in, say, El Salvador than to that in Panama. It then makes no sense to use city or country dummies in estimating (3.1). We instead need to fit the best possible relationship to the remaining sample of metered tap households absent such corrections. We now in step 2 conduct the imputation whereby individual water demand levels are predicted for households in the "missing" city, taking into account the characteristics of these households with respect to the variables included in (3.1). For (3.2) the procedure is the same, with the only difference that now also water expenditure is used to predict water consumption.

The imputation under step 2 here ought to correspond to the "best" estimation of individual water demand for a set of households in the missing city with socio-economic characteristics corresponding to those of households in our sample. If the functional relationship between water demand and socio-economic characteristics is the same in the sample as in the population, the average error made in such a calculation should correspond to the average error made in predicting average population water demand.

Tables 3.1 and 3.2 describe results from linear and log-linear estimations under step 1 above, in each of the 5 cases considered (where data for Managua, Panamá City, Santa Ana, Sonsonate and San Miguel are removed in the different cases), and where no variables representing water pricing or expenditures are included. The most striking feature of these estimations is that the overall degree of explanatory power of the relationship is very small, in all cases, with an adjusted R-squared of about 0.1, and even lower for Managua and Panama City. A difference between the two former relationships relative to those for the three El Salvadoran cities included in that only in the latter could we include dummies for cities (outside of El Salvador) in these estimations. For El Salvador, we have relevant data from three different cities. Assuming a common structure of demand for the cities in El Salvador then makes it possible to include dummies for the cities outside of El Salvador, thus potentially increasing the precision of the estimates and the explanatory power of the relation. We see that precision is then increased, in particular when measured by the R-squared which is higher for the El Salvador cities, and as the Managua dummies in the three last relationships in table 3.1 (as well as in the following table 3.2) are large and significant negative. This issue has bearing on the question of whether water demand levels can be transferred across cities, within a given country and across countries, in the region in question (Central America). Our preliminary indications are that this may be difficult to do across countries, but perhaps more promising within a country or at least when demand data are available for the country of the city for which imputations are sought.

Except for this there is little to be said about the coefficients in table 3.1. They all generally have correct signs and are comparable (in terms of signs and significance levels) to coefficients estimated in chapter 2.

Table 3.2 present similar log-linear estimations. Most interestingly, explanatory power now is somewhat higher than in table 3.1, and the coefficients on income and household size on the whole more highly significant. This indicates slightly better fits of log-linear relationships in this case.

Table 3.1. Summary of linear regressions explaining metered water consumption as function of background variables where water price variables are left out, and where one city is left out of each regression (t statistics in partentheses).

Variable	Managua	Panama C.	Santa Ana	Sonsonate	San Miguel
Income	0.002 (2.7)	0.0005 (0.9)	0.0016 (3.4)	0.0018 (3.7)	0.0017 (3.3)
Children	1.43 (2.8)	0.93 (2.55)	1.34 (4.1)	1.29 (3.7)	1.32 (3.6)
Adults	1.40 (3.2)	1.91 (5.5)	2.03 (6.0)	1.78 (5.6)	1.89 (5.8)
Telephone	3.03 (2.3)	5.75 (5.2)	2.88 (2.6)	3.10 (2.8)	3.55 (3.2)
Electricity	-1.94 (-0.3)	9.29 (1.4)	0.52 (1.3)	0.53 (0.1)	0.81 (0.7)
Owner w. title	-1.02 (-0.6)	-3.23 (-2.1)	-0.05 (-0.03)	-1.10 (-0.7)	-1.61 (-1.0)
Owner wo. Title	-1.90 (-0.9)	-2.30 (-1.2)	-0.04 (-0.02)	-3.29 (-1.8)	-2.51 (-1.3)
Reg nonowner	-12.9 (-0.8)	-13.1 (-0.9)	-9.3 (-0.9)	-10.8 (-1.1)	-10.6 (-1.0)
Cont. water service	7.89 (2.1)	7.60 (1.6)	5.67 (1.5)	6.73 (2.1)	6.95 (2.1)
Service > 8 h/day	7.67 (1.9)	8.62 (1.8)	4.11 (1.1)	7.01 (2.1)	6.94 (2.0)
Service < 8 h/day	9.67 (2.4)	10.7 (2.2)	7.62 (2.0)	7.57 (2.2)	7.73 (2.1)
Service 15 + days1	7.77 (1.6)	3.80 (0.6)	6.21 (1.4)	6.54 (1.6)	6.15 (1.4)
Panama Dummy			-1.51 (-1.0)	-0.50 (-0.3)	-1.08 (-0.7)
Colon Dummy			2.64 (1.0)	3.81 (1.47)	3.19 (1.2)
Managua dummy			-6.21 (-4.2)	-5.58 (-3.7)	-5.92 (-4.2)
Constant	15.0 (1.9)	1.88 (0.2)	11.1 (1.8)	12.4 (2.2)	12.4 (2.1)
Adj R squared	0.053	0.081	0.115	0.113	0.105
N of obs.	669	817	882	892	924

Table 3.2. Summary of log-linear regressions explaining metered water consumption as function of background variables where water price variables are left out, and where the indicated city is left out of the respective regression (t statistics in parentheses).

Variable	Managua	Panama C.	Santa Ana	Sonsonate	San Miguel
Income	0.022 (1.5)	-0.003 (-0.2)	0.20 (1-4)	0.015 (1.1)	0.013 (0.9)
Children	0.048 (3.3)	0.036 (3.0)	0.050 (4.3)	0.051 (4.3)	0.049 (4.2)
Adults	0.058 (4.6)	0.080 (7.0)	0.087 (7.9)	0.077 (7.2)	0.081 (7.8)
Telephone	0.105 (2.7)	0.21 (5.7)	0.10 (2.8)	0.12 (3.3)	0.12 (3.4)
Electricity	-0.027 (-0.2)	0.43 (1.9)	0.14 (1.0)	0.12 (0.9)	0.13 (0.9)
Owner w. title	-0.031 (-0.6)	-0.12 (-2.5)	-0.02 (-0.4)	-0.07 (-1.3)	-0.07 (-1.3)
Owner wo. Title	-0.078 (-1.4)	-0.13 (-2.1)	-0.06 (-0.9)	-0.15 (-2.3)	-0.13 (-2.1)
Nonowner	-0.39 (-0.8)	-0.52 (-1.1)	-0.30 (-0.9)	-0.36 (-1.0)	-0.35 (-1.0)
Cont. water service	0.32 (2.9)	0.43 (2.8)	0.27 (2.3)	0.29 (2.6)	0.31 (2.8)
Service > 8 h/day	0.28 (2.4)	0.48 (3.0)	0.24 (1.9)	0.31 (2.7)	0.31 (2.7)
Service < 8 h/day	0.33 (2.9)	0.53 (3.4)	0.32 (2.5)	0.34 (2.9)	0.32 (2.7)
Service 15 + days1	0.18 (1.3)	0.21 (1.0)	0.13 (0.9)	0.13 (0.9)	0.11 (0.8)
Panama dummy			0.01 (0.2)	0.08 (1.5)	0.05 (1.0)
Colon dummy			0.19 (2.3)	0.26 (2.9)	0.23 (2.7)
Managua dummy			-0.22 (-4.6)	-0.16 (-3.0)	-0.19 (4.2)
Constant	2.6 (11.5)	2.0 (7.4)	2.3 (11.0)	2.4 (12.1)	2.4 (12.2)
Adj R squared	0.075	0.117	0.145	0.135	0.137
N of obs.	669	817	882	892	924

Table 3.3 show results from steps 2 and 3 of the three-step procedure sketched above. The first line in table 3.3 shows actual average water demand levels for metered tap households in our sample, from the 5 cities studied. Lines 3 and 6 of the table show corresponding averages of imputed water demand levels for the same household groups, where respectively the linear and the log-linear relationships are used in this imputation. We find a strikingly good correspondence between actual and imputed averages, in particular for the linear relationships. The only reasonably large difference, 5.8, is found for Managua, which is not surprising considering the large negative dummy coefficients on Managua in the three last columns of table 3.1 (indicating that the actual metered water consumption in Managua is considerably lower than in the other cities included, for households with given household characteristics). For the log-linear relationships the average error is larger, and imputed averages generally lower, than under the linear specification. Only for Managua is the average for imputed demand levels here greater than average actual levels.

The degrees of correlation between imputed and actual individual water consumption values, are here all quite small, in all cases below 0.2, except (perhaps surprisingly) for Managua where they are close to 0.4. This indicates great heterogeneity in individual water demand (and that water demand is more homogeneous in Managua than in the other cities). The ability of the estimated relationships to predict individual water consumption levels are thus not very high, in spite of average consumption being predicted quite well.

Table 3.3. Actual versus imputed average water demand levels for metered tap households, where imputations are done on the basis of the relationships from tables 3.1 – 3.2. m^3 per household per month. Standard deviations in parentheses.

Variable	Managua	Panama C.	Santa Ana	Sonsonate	San Miguel
Average metered demand	26.7 (13.5)	31.1 (15.4)	30.5 (16.9)	31.1 (18.1)	30.1 (14.7)
Range for metered demand	3.8 – 83.3	10 – 90.8	9 – 109	9 – 150	9 – 95
Average imputation from linear function	32.5 (4.9)	28.8 (5.4)	30.0 (4.8)	29.8 (3.4)	30.4 (3.7)
Difference from actual av. demand	5.8	-2.3	-0.5	-1.3	0.3
Range for linear imputation	19.0 – 49.0	6.9 – 44.2	17.7 – 52.5	22.0 – 43.4	22.2 – 39.6
Average imputation from log-linear funct.	29.5 (4.5)	25.3 (5.3)	26.1 (5.3)	25.9 (3.6)	26.8 (3.9)
Difference from actual av. demand	2.8	-5.8	-4.4	-5.2	-3.3
Range for log-linear imputation	18.4 – 50.8	10.3 – 41.6	15.3 – 55.3	17.8 – 39.3	18.9 – 36.3
Correlation, linear vs. actual	0.389	0.215	0.153	0.176	0.193
Correlation, log-linear vs. actual	0.381	0.199	0.189	0.198	0.180

Another feature of table 3.3 is that the ranges of individual variation for imputed values are much smaller than for the actual values. This follows from the property that there is probably great individual variation in water demand that cannot be picked up in our systematic variables. Such individual variation is likely due both to random factors for the individual household (making demand variable over time), and to systematic differences in preferences and water supply relationships that cannot be identified here. This is however no fundamental objection to our approach here. The main aim of imputation procedures if such types is to predict average and not individual demand. For average demand, our imputations appear to be quite good.

We have also carried out one set of calculations where imputations are made for each of the cities in El Salvador, on the basis of estimated relationships for the two remaining cities in the same country. These calculations are thus based on data for one single country only. This reduces our effective number of individual observations from about 1000 to only about 400, thus leading to more uncertainty in the estimation procedure. On the other hand, one might think that basing imputations for a given city only on data for other cities in the same country, and not on cities in other countries, leads to more common structure between the data set to be imputed and that from which the imputation is conduced. This might in turn reduce the error made in the imputation.

Table 3.4. Imputations for cities in El Salvador, made in each case on the basis of data for the other two El Salvador cities alone.

Variable	Santa Ana	Sonsonate	San Miguel
Average metered demand	30.5 (16.9)	31.1 (18.1)	30.1 (14.7)
Range for metered demand	9 – 109	9 – 150	9 – 95
Average imputation from linear function	30.5 (5.5)	29.8 (3.5)	31.4 (3.7)
Difference from actual av. demand	0	-1.3	1.3
Range for linear imputation	16.8 – 50.4	17.9 –39.8	17.1 – 39.0
Average imputation from log-linear funct.	28.0 (5.3)	26.6 (3.1)	27.5 (3.1)
Difference from actual av. demand	-2.5	-4.5	-2.6
Range for log-linear imputation	15.8 – 59.9	17.6 – 36.5	16.7 – 34.4
Correlation, linear vs. actual	0.049	0.107	0.158
Correlation, log-linear vs. actual	0.099	0.137	0.162

Table 3.4 show main results from these imputations. Comparing the results in table 3.4 to those in table 3.3 yields a mixed set of conclusions. First, in predicting average water demand results are quite similar to those found in table 3.3 for the linear estimations, while errors are a bit smaller here for the log-linear estimations (but such that the linear relationships still do best). On the other hand,

correlations between individual imputed and actual consumption values are, perhaps surprisingly, even smaller here (and far smaller for Santa Ana and Sonsonate).

We conclude from this exercise that there is not much to gain by basing imputations for a given city, on data for only other cities in the same country as that to which this city belongs. At least in our examples studied here, precision is then lost in terms of predicting individual consumption levels.

Overall, it seems difficult to predict individual household water demand for household with meters in a given city, on the basis of relationships estimated for other cities for which one has individual water consumption and price data, and where these relationships cannot include variables directly related to water consumption (such as water expenditure or price). This conclusion holds even when a substantial number of other observed variables, such as household income, family size and composition, and various other household characteristics, are used in determining a water demand function for other cities where individual water demand is observable, and which is to form the basis for the imputations.

In contrast, city averages for household water consumption levels are predicted quite well. In our examples, imputations based on linear estimated functions were particularly good for all the included cities except Managua. Thus if the objective is to obtain an estimate of average water consumption for such households, our procedure here may work well. One must however be aware that this may to a large extent be a consequence of the property of our data set, that average water consumption levels among registered metered tap households are very similar in the cities involved. A generalization to cases with more variation in averages is here not immediate, and needs to be studied in new data samples.

We were as noted not “allowed” to base imputations on variables related to water demand, prices or expenditure. One may still consider alternative cases. One case implies assuming (counterfactually) that water expenditure but not demand volume nor prices, is known at the household level for a set of households with meters and tap service. A set of imputations, similar to those in tables 3.3 – 3.4, have been done with results given in tables 3.5 – 3.6. We now do not report the underlying estimated functions, only note that their explanatory power increases dramatically with inclusion of water expenditure as explanatory variable. This is reasonable since, in a given city, those water expenditure and consumption are in general highly correlated.

Table 3.5. Actual versus imputed average water demand levels for metered tap households, where imputations are done on the basis of the relationships including water expenditures. m^3 per household per month. Standard deviations in parentheses.

Variable	Managua	Panama C.	Santa Ana	Sonsonate	San Miguel
Average metered demand	26.7 (13.5)	31.1 (15.4)	30.5 (16.9)	31.1 (18.1)	30.1 (14.7)
Range for metered demand	3.8 – 83.3	10 – 90.8	9 – 109	9 – 150	9 – 95
Average imputation from linear function	41.9 (17.4)	29.5 (12.3)	30.3 (11.6)	30.2 (14.1)	29.7 (9.8)
Difference from actual av. demand	15.2	-2.6	-0.2	-0.9	-0.4
Range for linear imputation	10.2 – 167.7	13.2 – 83.1	20.4 – 97.6	20.6 – 134.4	21.5 – 83.8
Average imputation from log-linear funct.	42.7 (15.2)	28.8 (9.7)	32.3 (26.0)	31.7 (29.0)	30.3 (20.7)
Difference from actual av. demand	16.0	-2.3	1.8	0.6	0.2
Range for log-linear imputation	21.5 – 134.7	11.9 – 72.6	11.9 – 186.1	11.7 – 231.6	11.5 - 137.8
Correlation, linear vs. actual	0.927	0.837	0.950	0.970	0.956
Correlation, log-linear vs. actual	0.923	0.757	0.960	0.980	0.970

The imputations in table 3.5 imply a serious overestimation of average water demand for Managua, but much more correct figures for the other four cities, both in the linear and the log-linear cases. This mainly indicates that the water tariff schedule (PPP adjusted) is quite different (water is more expensive, PPP adjusted) in Managua than in the other four cities, while costs are much more similar in the remaining cities. The correlations between imputed and actual individual consumption levels are now extremely high, and for the El Salvadoran cities almost perfect. This is unsurprising as water expenditure here is an extremely good (almost perfect) predictor of individual water demand, along a common estimated tariff function.

The imputations reported in table 3.5-3.6 may perhaps be argued to be not very useful. For metered tap households in general, they are not really necessary in the sense that individual consumption data will always be available for such households. We will still argue that it may be of some independent interest to explore similarities or dissimilarities of water demand for metered tap households across cities in the Central American region, and how various background variables impact on these demand levels. Ultimately, this may tell us something about similar relationships also for nonmetered tap households, which is a more important concern in our study.

Table 3.6 shows a set of imputations similar to that in table 3.4, for metered tap household in the three cities in El Salvador only, where now water expenditure is used in imputing individual water demand. As expected, average imputed values are here extremely close to actual averages, and this holds also at the individual level.

Table 3.6. Imputations for cities in El Salvador, made in each case on the basis of data for the other two El Salvador cities alone, and using data on water expenditures.

Variable	Santa Ana	Sonsonate	San Miguel
Average metered demand	30.5 (16.9)	31.1 (18.1)	30.1 (14.7)
Range for metered demand	9 – 109	9 – 150	9 – 95
Average imputation from linear function	30.8 (15.3)	31.0 (19.6)	29.6 (12.6)
Difference from actual av. demand	0.3	-0.2	-0.5
Range for linear imputation	17.8 – 120.1	17.9 – 175.5	18.4 – 98.5
Average imputation from log-linear funct.	30.9 (19.7)	31.3 (23.9)	30.0 (17.4)
Difference from actual av. demand	0.4	0.2	-0.1
Range for log-linear imputation	12.9 – 139.7	13.2 – 194.5	17.4 – 116.5
Correlation, linear vs. actual	0.947	0.971	0.957
Correlation, log-linear vs. actual	0.971	0.986	0.979

3.3. Imputation of water demand to tap households without meters

We will now discuss calculations where our aim is to impute (or predict) water demand of households for whom we have no actual water consumption data. This is an important issue since it concerns most of the households in our total sample, almost 8000 out of 11500 households. A proper analysis of the implications of policy measures such as changes in water prices, rationing and coverage would need to address the issue of water demand within this group, both overall city demand and how it varies among households. Here we move to more “shaky” ground than with the analysis above. First, we have no the data with which to directly compare possible imputations, making direct checks of our calculations impossible in most cases. Secondly, households without meters are likely to behave in different ways than households with meters. We should here recall that the main purpose of the analysis in section 2.1 was to derive the effects of marginal and average water prices, and changes in these, on realized water demand within the group of metered tap households. We have no guarantee nor direct proof that nonmetered households behave in ways similar to metered households.

The demand functions estimated in chapter 2 above may, arguably, still be taken to indicate that the behavior of the two groups could be similar. Our main result from chapter 2 was that when estimating water demand functions where both marginal and average water prices were included, we found a partial elasticity with respect to marginal price of about –0.1, and a partial elasticity with respect to average price of about –0.2. The partial linear coefficient with respect to marginal price (when average price was also included) was about –4, while the related linear coefficient with respect to both marginal and average price was about -15. The latter result indicates that when we consider two different households who both face the same average water price, among them one (nonmetered) household facing a zero marginal water price, and one (metered) household facing a marginal water price of 0.40 USD, PPP adjusted, the former should on average have a water consumption which is about 1.4 m^3 higher than the latter. A marginal water price of 0.40 USD, PPP adjusted, is the average for all metered tap households in our sample (from table 1h, the city averages vary from 0.07 USD in Guatemala City to 0,62 USD in Managua; for most cities the average is between 0.2 and 0.4). This is a rather small demand difference between the two households, and requires that the water demand of both metered and nonmetered household react similarly to changes in average water prices. Possibly, metered households are more sensitive to average water price changes simply because they are aware that their consumption is metered and thus, potentially, subject to higher pricing. We come back to this line of argument below.

Tables 3.7 and 3.8 show (preliminary) results from imputations of average household water consumption levels for tap households without meters, for the full set of cities in our sample. The imputations are done in four ways corresponding to the typology of cases used for metered households above: using linear and log-linear imputation functions, and basing imputations on data without and including water expenditure data respectively.[19] Corrections are made for calculated effects of rationing, but not for effects of water pricing variables. In this sense the results are

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[19] As an example of the procedures followed, the imputations in the first column of table 3.7 (representing “linear without expenditure”) are based on an estimated linear functional relationship between water demand and a number of observable individual variables, but excluding water expenditure, and including city dummies.

"preliminary"; more "complete" imputations are done in table 3.10 below where corrections for water pricing are embedded. Corrections for price generally increase imputed water demand for nonmetered households. The figures in table 3.7-3.8 are thus biased downward, as will be discussed further in connection with table 3.10.

Table 3.7 here only considers cities where there are data on both metered and nonmetered households, and includes city dummies. This table indicates that, when not correcting for marginal price effects, average imputed water demand levels to nonmetered households differ little from metered households' demand levels. When considering averages of the four imputations, imputed nonmetered demand levels are higher only in San Miguel and Panama City. There are however substantial differences between the four. One pattern is that imputed average water demand levels are higher when basing imputations on observed water-related expenditure, than when ignoring this type of information. This in turn indicates that average water-related expenditure (after correcting for relevant other background variables) is higher in the group of nonmetered than in the group of metered households, which in turn indicates that the average water price paid by those without meters is higher than for those with meters. The main reason for this conclusion is that in the imputation functions which include water expenditure, there is a very strong relationship between water expenditure and imputed water demand. A nonmetered household with a high water-related expenditure is then likely to be assigned a higher water consumption than another household with a lower expenditure.

Table 3.7. Summary values for imputed water consumption levels where imputations are based on common functions for the whole sample of tap households, and including city dummies. Averages

City	Metered households	Linear wo. expenditure	Linear w expenditure	Log-linear wo. exp	Log-linear w exp	Average for imputed values
Managua	26.7 (13.5)	24.8 (5.8)	29.1 (41.6)	22.4 (4.6)	26.1 (25.5)	25.6
Santa Ana	30.5 (16.9)	29.1 (4.8)	30.1 (10.0)	25.8 (4.4)	31.1 (19.1)	29.0
Sonsonate	31.3 (18.1)	30.3 (5.9)	30.4 (8.3)	27.8 (6.2)	31.5 (16.3)	30.0
San Miguel	30.1 (14.7)	30.9 (7.1)	32.7 (12.6)	28.4 (7.3)	35.0 (23.6)	31.8
Panama C.	31.1 (15.4)	30.2 (5.8))	34.6 (18.1)	28.2 (5.8)	33.9 (19.6)	31.7
Colon	34.8 (12.0)	29.6 (5.9))	37.8 (19.8)	27.7 (5.8)	37.9 (20.6)	33.3
Average	29.3 (15.4)	28.1 (6.3)	31.9 (28.2)	25.8 (6.0)	31.0 (22.3)	29.2

Table 3.8 includes all cities but no city dummies, on the presumption that we have no basis for correcting for city considering cities for which no actual individual household water demand data can be obtained. The table shows that imputed water consumption levels for nonmetered households (where corrections as noted have not yet been made for different marginal pricing) are rather similar to levels for metered households, in cities for which we have data on both. In all cities except Managua and San Miguel, average imputed nonmetered consumption is lower than metered consumption, when taking averages over the four calculation. Among cities with only nonmetered households, average imputed consumption levels are generally somewhat lower than for the rest, and the difference is particularly great for Tegucigalpa, San Pedro Sula and Guatemala City. There are several main reason for these lower values. One is relatively low levels of income and other "unfavourable" social characteristics in these cities. Another is relatively high degrees of rationing among nonmetered households, which is likely to depress demand, as will be exposed in more detail below.

A key water policy issue is the effect of water rationing on realized water consumption. Our data set embeds no direct data on rationing but rather on the relative amount of time during which water is available to the individual household. In chapter 2 above we found no evidence that households who are served every day, but not continuously, have lower water consumption than households with continuous service. By contrast, households who are served less than 15 days a month were found to have substantially lower water consumption on the average. The functions used for imputing water consumption to nonmetered households embed such relationships between degrees of rationing and water consumption among metered households. They provide a basis for calculating what these imputations would have been in the (hypothetical) case where all nonmetered households were provided continuous service, and assuming that they are reacting in the same way as metered households to changes in rationing regime.

Table 3.8. Summary values for imputed water consumption levels where imputations are based on common functions for the whole sample of tap households (and not including city dummies). Averages

City	Metered households	Linear wo expenditure	Linear w expenditure	Log-linear wo. Exp	Log-linear w exp	Average for imputed values
Managua	26.7 (13.5)	26.7 (5.6)	32.5 (39.2)	24.4 (4.8)	29.1 (22.2)	28.2
Santa Ana	30.5 (16.9)	28.4 (5.0)	28.6 (10.1)	25.9 (4.5)	28.6 (14.8)	27.9
Sonsonate	31.3 (18.1)	28.4 (6.2)	27.9 (8.5)	25.7 (6.0)	27.1 (12.2)	27.3
San Miguel	30.1 (14.7)	31.5 (7.1)	32.4 (12.3)	28.5 (7.4)	32.5 (18.2)	31.2
Panama C.	31.1 (15.4)	27.7 (5.8)	31.1 (17.2)	24.5 (5.1)	28.8 (14.7)	28.0
Colon	34.8 (12.0)	26.9 (5.9)	33.9 (18.8)	24.1 (5.1)	31.4 (14.9)	29.1
Barquisimeto		35.4 (16.3)	32.2 (36.1)	31.9 (15.0)	28.0 (25.8)	31.9
Merida		25.2 (13.5)	27.5 (22.4)	31.6 (12.0)	23.9 (17.7)	27.1
Tegucigalpa		24.3 (7.7)	22.5 (7.4)	22.7 (6.0)	19.6 (10.8)	22.3
San Pedro Sula		24.0 (6.5)	24.6 (7.9)	21.2 (5.3)	24.6 (10.6)	23.6
Choluteca		32.5 (11.1)	25.7 (8.4)	28.6 (11.8)	23.1 (12.4)	25.2
Santa Rosa		32.9 (13.2)	30.8 (16.8)	27.1 (12.8)	31.4 (24.1)	30.6
Comayagua		30.3 (7.9)	23.3 (8.3)	26.9 (7.4)	20.2 (111.3)	25.2
Guatemala City	11.4 (13.4)	27.6 (5.5)	24.1 (7.9)	23.1 (5.0)	21.0 (12.3)	24.0
Villa Nueva		28.4 (4.5)	30.8 (12.6)	23.8 (4.3)	32.4 (17.3)	28.9
Chinautla		29.3 (4.1)	30.5 (9.1)	25.4 (3.8)	30.8 (15.3)	29.0
Mixco	15 (0)	32.8 (11.4)	28.6 (16.9)	28.1 (10.9)	26.8 (22.1)	29.1
Average	29.3 (15.4)	30.0 (9.9)	29.5 (23.5)	26.6 (9.1)	27.4 (18.6)	28.5

Table 3.9 presents a set of such calculations, based on the first presented imputations in table 3.8, from a linear water demand function without water cost variable included. The figures in table 3.9 represent increases in water consumption, for given frequencies of service, relative to water consumption levels in the group with service less than 15 days a month. The table reconfirms our previous conclusion, that water demand is likely to drop noticeably only when water is available less than 15 days a month. For the latter group the calculated reduction in water consumption is substantial, on the order 6-9 m^3 on the average.

Table 3.9. Calculated effects of rationing on water demand for nonmetered tap households, by city and degree of rationing, using imputed consumption values (imputations from linear function without water cost variable). Excessive water demand relative to reference group = water supply less than 10 days per month.

City	Cont supply	> 8 h/day	< 8 h/day	15-29 days/mo.	10-14 days/mo.
Managua	6.3	5.5	8.0	7.8	2.3
Santa Ana	9.3	9.4	9.8	6.4	3.3
Sonsonate	8.5	8.9	11.4	8.9	2.0
San Miguel	8.9	5.6	8.9	5.2	
Panama City	7.2	6.7	8.8	7.6	1.6
Colon	7.0	6.9	7.6	5.9	0.9
Barquisimeto	15.7	9.6	9.8	8.5	0.5
Tegucigalpa		2.4	6.1	6.2	5.1
San Pedro Sula		9.1	12.9	10.7	
Guatemala City	6.3		8.2	8.7	2.4
Villa Nueva	6.8	6.0	9.4	8.6	2.9
Chinautla	4.1	3.9	6.2		-0.1
Mixco	3.3	1.5	8.1	9.4	4.5
Average	8.3	6.9	8.9	8.8	2.7

Table 3.10 gives perhaps the most important set of calculations in this chapter. We here present our corrected estimates of individual-household water consumption among nonmetered households, where implicit calculations for demand responses to metering are built in and added to the calculations in table 3.8. Such a calculation can be viewed to consist of three steps. The first step is the imputation procedure behind the figures in table 3.8. In the second step one uses demand responses estimated from demand functions in section 2.1, to predict water consumption for households who face a zero marginal water price. The third step consists of estimating the effect on water demand due to the elimination or reduction of water rationing within the group of nonmetered households. This last step is relevant since the reduction in water demand which comes about as a result of metering is likely to at the same time reduce the degree of effective rationing, for the individual household and at the macro level, and thus also permit a supply regime with less overall rationing.

The figures in the second and third columns of table 3.10 embed price corrections of the types indicated. The correction in the second column of table 3.10 is calculated as follows. First, we base the calculation on the estimated relationship between marginal water price and metered water consumption on the figures presented in the second column of table 2c (linear relationship including average price variable), using a coefficient on marginal price of –4.3. Secondly, for each observation we derive a prima facie estimate of average water price by dividing total water expenditure on initially imputed water consumption (from the imputations in table 3.8). Thirdly, we take this as the estimate also of the marginal water price that would have been facing these households. Denoting this estimate by M, the estimated upward correction (corresponding to the increase in consumption resulting from these households not being metered) equals 4.3*M m^3/month , where M is measured in (PPP adjusted) USD. This yields assessed values of individual (rationed) household water consumption for nonmetered tap households, as they would have been realized under a zero marginal water price, and an average water price equal to actual calculated averages. The city averages for these corrections are given in the second column of table 3.10. These averages vary from a low of 0.9 m^3/month in San Pedro Sula, to a high of 5.8 in Guatemala City, and the overall average is 2.5.

The third column of table 3.10 makes this calculation in a somewhat different way. We here assume that nonmetered and metered households respond in different ways to changes in average water prices. Nonmetered households are now assumed <u>not to respond at all</u> in their water demand to changes in average water price. Intuitively, metered households may respond to changes in average water prices, possibly due to their cognitive difficulty in distinguishing between average and marginal price (but assuming that they are aware that the amount of money they need to pay for water is related to their consumption). For nonmetered households, it may instead be more reasonable to assume that these do not take the water bill into consideration when choosing their water consumption, simply because they know that there is no relationship between the two when their individual water demand cannot be metered.

Under the latter set of assumptions the upward demand correction is larger, namely 14.7*M m^3/month (corresponding to the sum of coefficients before marginal and average price in the second column of table 2c). When deriving hypothetical demand responses to marginal price increases for nonmetered households we must now however be more careful to define the average water price for nonmetered households in a consistent way. A problem in this respect is that the average water price for nonmetered households will be endogenous in our formulation, since the assessed demand volume is endogenous and this demand volume is in turn used for deriving an estimate of average water price. We must now calculate our estimates of average water price and consumption for nonmetered households from the following set of simultaneous equations:

$$CW = CW(0) + 14.7 * WP \tag{3.3}$$

$$WP = \frac{WB}{CW}, \tag{3.4}$$

where CW is the water consumption of the household, CW(0) is the estimated (or rather imputed) water consumption had the household faced water metering, WP is the actual average water price facing the household, and WB its water bill. (3.3)-(3.4) solve for CW and WP, and we are here basically interested in the solution values for WP. These are solved for, with city averages given in the third column of table 3.10. Here, naturally, figures are higher than in column 2. Nonmetered households' assessed water consumption levels are now on average 7.5 m^3/month higher than the levels the same households would have had, if they had been metered (under the same water pricing schemes as those currently existing in their respective cities), for a given degree of rationing.

The figures in the second and third column of table 3.10, together with those in the right-hand column, indicate the potential for reducing water demand through proper water pricing among households that today do not have their water consumption metered and consequently face a zero marginal water price. These figures are however extremely uncertain, for several separate reasons. First, the estimated relationships in table 2b are by themselves uncertain, may in particular not be good for extrapolation to marginal prices outside of the range of average marginal prices for metered households. Secondly, the calculations require assumptions about common features of the water demand structure among metered and nonmetered households, in particular, that the two groups react to average water prices (when considered separately from marginal prices) in identical ways.

Table 3.10. Average estimated water consumption for nonmetered tap households, calculated under zero price and actual under two different demand-response alternatives, and estimated average increase in water demand with no rationing, by city, based on linear demand functions

City	Calculated cons. at marg price	Estimated actual cons., small response	Estimated actual cons., large response	Cons. incr. under no rationing
Managua	26.7	30.7	37.8	0.3
Santa Ana	28.4	31.2	34.2	0.6
Sonsonate	28.4	31.1	33.8	1.0
San Miguel	31.5	33.2	36.3	1.5
Panama City	27.7	31.4	38.1	2.2
Colon	26.9	31.5	39.5	2.5
Barquisimeto	35.4	39.8	42.9	4.6
Tegucigalpa	24.3	25.4	27.6	3.8
San Pedro Sula	24.0	24.9	30.8	1.5
Guatemala City	27.6	28.9	30.8	5.0
Villa Nueva	28.4	30.4	34.1	3.1
Chinautla	29.3	31.0	34.1	1.1
Mixco	32.8	34.2	36.7	1.9
Average	29.3	31.8	35.9	1.9

The right-hand column of table 3.10 gives overall city estimates of average demand increases among nonmetered tap households under a (hypothetical) case of no water rationing among these. The numbers in table 3.9 are here combined with the frequencies of service among nonmetered households, from table 1e. We there found that about 15 % of all nonmetered tap households are served less than 15 days a month, but to varying degrees in different cities. These calculations indicate that the effective average degree of rationing varies from a low of 0.3 m^3 per household per month in Managua (where almost all households are served daily), to 5 m^3 per household per month in Guatemala City (where service levels for nonmetered tap households are very poor). As an average for all nonmetered tap households this increase is 3.5 m^3/month. One should be aware that these figures embed corrections for a number of socio-economic characteristics such as income and family size, and that the nonmetered households have e.g. lower average incomes than metered ones (which works to lower the relative water consumption of nonmetered households).

An independent check of the effects of our calculations here can be found from observations of behavioural changes after the introduction of metering, where such data exist. The best available case is probably one from Panama. Walker et.al. (2000, table 20) provide data on effects for Panama City and smaller towns in Panama. They find that for residential areas in Panama City, water consumption had dropped by 22 % 4 months after the introduction of metering (from an average of 55 to 43 m^3 per household per month in the particular sample considered). These figures can be compared to the calculated responses to metering found for the same city, in table 3.10. Such responses consist of two parts, first, the effect of metering (which reduces water demand, prima facie), and secondly, the effect of changes in rationing when effective demand drops.

Consider first the calculation in column 2 of table 3.10. The prima facie effect of the changed marginal water price is here a drop in demand by 3.7 m^3, from 31.4 to 27.7 m^3. With no change in rationing this will be the total demand effect, which amounts to about 12 % of the initial consumption level, i.e. smaller than the relative effect found from the Panama City observations.

Take next the calculation in the third column of table 3.10. Here the prima facie drop in water demand is much larger, 10.4 m^3 (from 38.1 to 27.7). In such a case the degree of rationing is bound to be affected at the same time. Assume then that the degree of rationing would be reduced to only 1/3 of its initial effect. The partial demand effect of this would be an increase in water consumption of about 1.5 m^3 per household per month, for a net overall drop in water demand of (10.4 – 1.5 = 8.9) m^3 per household per month. This corresponds to an overall average demand drop of about 23 % from the initial demand level 38.1, or almost exactly the same drop as was actually found for Panama City, upon introduction of metering.

Note that in the actual Panama case, for marginal barrios in Panama City and for smaller towns in Panama overall water consumption in fact increased after the introduction of water metering, by respectively 6 % (from 27 to 29 m^3 per household per month) and 12 % (from 36 to 40 m^3 per household per month). The latter figures indicate that there might also at the same time have been supply responses that led to more water being supplied, in addition to the groups in question being rationed less severely than before.

When deriving the effects of rationing on water consumption in tables 3.9 and 3.10, these effects were derived individually for each household, using imputation functions by which rationing effects, for different degrees of rationing, are implicitly derived. A different method for estimating degrees of rationing is to depart directly from the estimated functions in chapter 2, between water consumption and rationing degree. We there found no discernable effect of rationing for households with water supply at least 15 days a month, in neither the linear nor the log-linear estimated demand functions. Relative to this group, the group of households with supply 10-14 days a month, and less than 10 days a month respectively, enter with negative coefficients of approximately –6 m^3/month and –8 m^3/month in the linear relationship, and –0.3 and –0.4 in the log-linear relationship. An alternative option is here to simply assume that such effects are common also for the whole set of nonmetered households. Table 3.11 calculates average effects of rationing among nonmetered households in the different cities, under this set of assumptions. We here find the calculated effects of rationing to be somewhat smaller than those appearing from tables 3.9 – 3.10. While not conclusive, these calculations indicate that, on average, the quantitative effects of water rationing (in the sense that water is not continuously provided) could be modest, even for the nonmetered group of tap households.

Table 3.11. Calculated effects of rationing on water consumption, for metered and nonmetered tap households, using linear and log-linear rationing functions, and assuming fixed effects of degree of rationing. Averages by city

City	Metered cons, linear	Metered cons, Log-linear	Nonmetered, Linear	Nonmetered, Log-linear
Managua	0.04	0.03	0.07	0.06
Santa Ana	0.20	0.14	0.88	0.74
Sonsonate	0	0	0.92	0.55
San Miguel	0	0	0.23	0.16
Panama City	0.34	0.36	1.04	0.83
Colon	0.22	0.27	1.41	1.26
Barquisimeto			1.59	1.51
Merida			0	0
Tegucigalpa			3.41	3.06
San Pedro			0.11	0.07
Choluteca			0.83	1.00
Santa Rosa			2.84	3.74
Comayagua			0.50	0.45
Guatemala City	3.6	2.33	2.75	2.72
Villa Nueva	0	0	1.70	1.79
Chinautla			0.17	0.16
Mixco			3.11	3.82
Average	0.14	0.13	1.11	1.12

Table 3.12 represents an attempt to compare our data for average observed metered and imputed nonmetered water consumption, to citywide estimates of overall average water consumption, during approximately the same time periods, provided by city water administrations. There is relatively good correspondence between these data except in the cases of Sonsonate, where the average citywide water consumption data show much lower values than those derived from our data, and Barquisimeto and Colon, where the average citywide data show much higher values. Note however that the citywide data are very uncertain; we really do not know much about the average amounts actually consumed. None of the cities namely has a system for adequately measuring physical water losses, and city administrators do not really know what fraction of total water is lost in leakages. System losses are usually assessed as a residual, once assumptions are made about final consumption. All cities really know is 1. What comes out of the production systems; 2. The metered consumption of a proportion of their users, and 3. What is charged to nonmetered consumers. One therefore needs to bear in mind the possibility that true water consumption of nonmetered consumers might be higher than the estimated billing assumes, in some cities - and lower, in others.

Table 3.12. Registered water consumption levels in cities for which we have citywide data, compared to sample and imputed levels from our data set.

City	Tap water hhs (1000)	% nontap hhs	% metered tap	% non-metered tap	Total water cons (mill m^3)	Calc. monthly water cons/hh	Sample aver., metered hhs	Imputed aver., non-metered hhs (1)	Imputed Aver., Non-metered hhs (2)
Managua	158.4	3.5	38.2	58.3	46.7	24.6	26.7	30.7	38.7
SantaAna	25.6	5.2	39.4	55.4	12.5	40.6	30.5	31.2	36.8
Sonsonate	9.8	16.4	36.5	47.1	1.3	11.1	31.1	31.1	37.1
SanMiguel	17.0	30.5	31.8	37.7	5.8	28.4	30.0	33.2	36.6
Panama	138.5	1.6	32.7	65.7	53.9	32.4	31.1	31.4	38.8
Colon	16.9	2.0	27.0	71.0	13.9	68.5	34.8	31.5	40.7
Baruiqis	82.0	0	72.1	27.9	73.2	73.4		39.8	48.6
Merida	38.4	0	31.1	68.9	18.7	40.6		30.1	

3.4.Imputing water consumption for nontap households

In the final section of this chapter we turn to imputation of water demand among households with no tap water service. We proceed in basically the same way as for metered tap households. First, we delete data for one city from the entire data material covering nontap households. Secondly, we impute water demand levels to households in the deleted city, according to the specified imputation function (which is specified in alternative ways). Thirdly, we compare the imputed values to the actually observed (and initially deleted) values, individually and as averages.

This procedure is much more prone to error and uncertainty, than the similar procedure for metered tap households. The reason is that (individual and city-wide) water demand levels vary much more for nontap than for metered tap households, are much more affected by supply variables, and the relationship between water price and demand is much more vague since a variety of different water sources, with different costs in terms of hauling time and convenience, are utilized. The number and quality of supply variables, that one will have available at any given time for these, may vary considerably. Whenever individual and city averages for coping water demand are not available, one is neither likely to know precisely the distribution of coping water use across sources, hauling times, water expenditures and prices for the different sources, all variables which in practice are necessary to control for when imputing coping water demand.

Imputations for this group of households are given in table 3.13. Calculations are made for the 8 main cities for which we have coping household data, namely Santa Ana, Sonsonate and San Miguel (El Salvador), Tegucigapla and San Pedro Sula (Honduras), and Guatemala City, Villa

Nueva and Mixco (Guatemala). Favorably, there are at least two cities in each country for which we have data. This makes it possible to investigate possible differential effects, when correcting or not correcting for country effects, in the imputations.

Imputations are done in four different ways. In all cases they are based on log-linear functions, building on chapter 2 where we showed that log-linear water demand relationships are far superior to linear ones for coping households. The first, presented in the second column of table 3.13, imputes household water consumption on the basis only of standard background variables (such as income, household size, type of housing property, and other characteristics of the home and its location). Such imputations must necessarily be very imprecise, due to the great heterogeneity of water supply modes and costs, across cities, city regions and individual households. The imputation functions here have multiple R-squared coefficients of around 0.2. The average error in predicting average coping water consumption at the city level is here rather great. Overall, the city averages are underestimated, in all cities in the sample, on average by 2.9 m^3 per household per month, corresponding to an error of about 40 %. Errors are particularly large for San Miguel and Santa Ana (El Salvador) and Mixco (Guatemala). Errors at the individual household level are naturally greater than this; here we find partial coefficients of correlation of only about 0.1.

The next set of imputations, given in the third column of table 3.13, are based on imputation equations containing information on average water prices for coping water. Such imputations are relevant when data for the average coping water price but not for average consumption are available at the individual or city level. We see that the average imputed water demand level now is raised somewhat, and is closer to the “correct” average (1.6 m^3 per household per month lower), and the average error is now also smaller. For three cities (Sonsonate, Tegucigalpa and Guatemala City) imputed average water consumption is now greater than the actual average.

The third set of imputations is done including country dummies in imputation functions for the whole set of data except the excluded city. The use of country dummies will here improve precision of the imputations if there tend is some common structure among cities in a given country. We find that the imputed averages are now raised further, and made closer to the “true” averages, and the average error is reduced even further (and is now slightly below 2).

Finally, we have conducted imputations based only on own-country observations. By this we mean that the deleted observations from a given city are imputed from an estimated relationship based on data for the remaining cities in only that country (for El Salvador and Guatemala this function will then be estimated on the basis of two cities, and for Honduras only one city). We see that this pushes up the average further and reduces the error, to about 1.8.

On the whole, in predicting average water consumption levels for coping households, errors are quite large, on the order 30 –40 % of the true levels (and here in most cases be downwardly biased). Errors are successively reduced when predictions are based on information on average prices paid for coping-source water, and country dummies respectively. They are further reduced when one may impute consumption levels directly on the basis of data for cities in the same country only. This appears reasonable and indicates that it is more meaningful to attempt to transfer water consumption levels from one city to another within a given country, than it is to transfer similar values to cities in other countries.

Table 3.13. Actual and imputed average water consumption levels for coping households. Standard deviations in parentheses.

City	Average coping consumption	Imputation equation without water price or city dummies	Imputation equation incl water price	Imputation equation incl water price and country dummies	Imputation equation incl only own country obs
Santa Ana	8.57 (9.50)	4.27 (1.75)	5.66 (1.65)	6.33 (1.59)	6.22 (2.2)
Sonsonate	5.09 (4.04)	4.10 (1.67)	5.56 (1.71)	6.89 (1.78)	7.67 (2.2)
San Miguel	11.38 (9.01)	3.68 (1.54)	5.34 (1.73)	6.03 (1.80)	7.21 (2.8)
Tegucigalpa	3.68 (5.60)	2.74 (1.33)	5.06 (1.48)	4.43 (1.26)	3.94 (1.4)
San Pedro	4.84 (5.25)	3.45 (1.35)	4.30 (2.32)	4.03 (1.74)	4.21 (1.6)
Guatemala	5.23 (4.07)	4.91 (0.82)	5.68 (1.24)	6.61 (1.44)	6.56 (1.7)
Villa Nueva	7.08 (4.41)	4.34 (0.82)	5.46 (1.06)	6.31 (1.17)	6.06 (1.1)
Mixco	8.32 (5.07)	3.29 (1.19)	4.28 (1.24)	5.67 (10.9)	5.98 (1.5)
Average (arithmetic)	6.77	3.86	5.17	5.79	5.98
Average error		2.91	2.17	1.95	1.79

4. Distributional and allocational effects of changes in water provision and prices

4.1 Introduction

Important elements of the political economy of water provision are the impacts of changes in the numbers of households provided with tap water service, and in water prices and metering for households with such service. Three key issues are here as follows:

1. What is the real income effect, and distributional impact, of a change in water service mode for a given household, most importantly, a change from a situation without tap water in the home (a “coping” service), to one with tap water service?
2. What is the impact on realized water demand for households with tap service, when prices are changed for metered households, and when metering is introduced for previously nonmetered households?
3. What are income and distributional effects of changes in water provision and/or prices, for given distribution of service modes across households?

These three questions can all in principle be addressed on the basis of data obtained in our study. Question 1 can be studied from at least three different angles. First, since household water service is tied to residences, we may consider how capitalized home values vary across households with different types of water service. Secondly, our estimated water demand functions in chapter 2, and imputed functions and demand levels in chapter 3, may be used for deriving measures of consumer surplus from water service, which in turn can be used to find consumer surplus changes associated with service mode changes. A third approach is to use our stated preference data, on WTP for a water connection among currently unconnected households. In the analysis below we only consider the first two of these approaches, dealt with in sections 4.2 and 4.3 respectively.

The second question has already in part been addressed in chapter 3 above, where we attempted to impute water consumption levels, and responses of water consumption to marginal and average water pricing, to currently nonmetered households. Here we will go a bit further in this direction, by imputing water demand to both metered and currently nonmetered households, when both long-run average cost (LRAC) pricing, and full metering, are simultaneously introduced. This is dealt with in section 4.5.

The third main question will not be dealt with directly in this chapter. It can be addressed most directly for households with metered tap connections, using derived water demand functions in combination with data on individual household income. From individual demand responses to changes in marginal and average water prices, changes in household water budgets can be calculated, taking into consideration macro demand and supply interactions e.g. via reduced necessary rationing when water demand is instead rationed through higher prices. The analysis in chapter 3, where demand and demand responses for these groups were imputed, may at least in part provide a foundation for such an analysis.

4.2 Deriving capitalized values of water connections from house price data

House prices are likely to embed values of amenities supplied at or in the vicinity of the house.[20] The quality of water service is such an amenity. In principle, when a house is purchased, the buyer at the same time purchases the net (expected present) value of water services to be provided at the house, at all future dates. For two houses which differ only in the value of water services provided, given that the housing market is competitive and that all households have the same demand for water services, differences in present discounted values of the respective water services will be perfectly reflected through different prices of the two houses. In practice the issue is more complicated, due to lack of competition, differences in household preferences, and variation among houses in terms of other valuable attributes. House prices are also likely 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). Still, houses with better water service will tend to fetch higher market prices, everything else equal. The relationship between the two will be more reliable, the more precisely one is able to isolate the partial effect of the water service house price, i.e., to appropriately correct for other variables that also influence on house prices.

In our data set we have about 4000 observations of assessed market values of individual residences (where assessments are made by respondents at the time of interview), together with information on square-meter sizes of residential units and lots, and information on the type of

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[20] This corresponds to the theory of hedonic prices presented by Rosen (1974), and studied with particular reference to the housing market by e.g. Freeman (1993) and Palmquist (1991).

ownership. These data can be combined with our individual information on other variables likely to influence on house prices, both related and unrelated to water service.

Table 4.1 gives an overview of average home values for the cities where such data are available, and split up by main category of water service (1 = metered tap, 2 = nonmetered tap, and 3 = nontap supply). The bottom line of the table indicates that average house prices vary considerably by category, from a low of about 13000 USD (PPP adjusted) for houses with no water connection, to a high of about 42000 USD for houses with metered tap connections, while houses with nonmetered tap connections are in an intermediate range (29000 USD).

Table 4.2 presents some statistics on the overall significance of average values of residential units, for households in the different cities and grouped by water service mode. In short, the table states numbers of annual household salaries that are necessary to purchase each household’s current residential unit on the average. Such ratios are seen to vary considerably by city. They are high (7-11) for San Miguel, Sonsonate and Mixco, and low (1.3-2) for Guatemala City, Chinautla and Villa Nueva. They are generally highest for houses (and households) with metered tap service, and lowest for households without tap service, as apparent from the bottom line of the table. Barring systematic misrepresentation, these ratios are on the whole surprisingly high.[21] House prices are on average almost 6 times annual incomes for households with metered tap service, and on average more than 3.5 times annual incomes for households with no direct tap service. These ratios are generally as high or higher, when compared to similar rations in most rich countries.

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[21] There is of course a danger that household incomes are underreported in the survey, perhaps for the fear that stated amounts are to be used for tax purposes in some cases. We however have no direct indication of such underreporting. Such an error would also in case be counteracted by underreporting of house prices, for the same basic purpose.

Table 4.1 Average home values, by water service mode and city in the sample. USD, PPP converted. (Second line shows numbers in respective samples.)

City	Metered tap	Nonmetered tap	Nontap	Overall average in sample
Managua	39100	23500	8500	26300
Santa Ana	27000	25700	13400	23100
Sonsonate	41600	41300	10200	30500
San Miguel	50700	50500	27800	42300
Panama City	46400	40800	28900	41800
Colon	65300	42700	12400	45000
Guatemala City	16600	12100	6500	8600
Villa Nueva	16600	12200	7800	11400
Chinautla		6800	6200	6700
Mixco		36500	22600	34000
Total	42000	29500	13200	28300

Table 4.2. Average ratios of home value to annual household income, by water service mode and city (1=metered tap, 2=nonmetered tap, 3=nontap)

City	Metered tap	Nonmetered tap	Nontap	Overall average in sample
Managua	3,34	2.62	1.49	2.73
Santa Ana	4.75	5.36	4.17	4.95
Sonsonate	8.50	9.41	4.32	7.41
San Miguel	16.82	10.34	9.24	11.24
Panama City	4.27	5.10	3.20	4.91
Colon	3.09	4.44	0.86	4.18
Guatemala City	1.26	1.87	1.41	1.58
Villa Nueva	2.59	2.19	1.29	2.01
Chinautla		1.25	1.27	1.26
Mixco		8.09	5.07	7.53
Total	5.93	4.66	3.65	4.66

The figures in table 4.1 are “gross” in reflecting effects of other background variables that may differ systematically by service mode. Table 4.3 presents results from (linear and log-linear) regressions where house prices are explained by main water service variables together with other important variables for which we have data. Two water service variables are included, namely main service type, and a dummy variable which takes the value of one for connected household with daily water service (this variable thus takes the value of zero, both for connected households that have water service less frequently than every day, and for all unconnected households). The cities included in this estimation are Managua, Sonsonate, San Miguel, Santa Ana (reference city), Panama, Colon, Guatemala City, Villa Nueva, Chinautla and Mixco. Other variables included in the calculations are residence size in square meters, lot size in square meters, household income, whether or not the owner has title to the property; whether or not the property has electricity service; and whether or not the property has fixed telephone service.

In interpreting the results from figure 4.3 it is useful to first consider the effect of "daily water service", which compares average values of homes with daily tap service on the one hand, and homes with less frequent tap service on the other, and holding all other variables constant. We see that the coefficient here is greater than 5000 USD in the linear case, and about 17 % in the log-linear case, and in both cases it is clearly significant. We next go to the coefficients for "metered connection" and "nonmetered connection". These show the effect of having a metered and nonmetered tap connection respectively, with service less frequently than daily, when compared to not having a tap connection at all. Here only the log-linear relationship yields significant effects. (Overall, however, the log-linear relationship gives much better fit to the data than the linear one, and should be preferred in interpreting results.) These effects are large: having a metered connection increases house value by 39 %, and having a nonmetered connection increases it by 19 %, respectively, in both cases conditional on current tap service being less frequently than daily. The comparison between a household with metered tap connection and daily service, and one without tap connection, is then even more dramatic. This effect is found in the log-linear case by adding the two separate coefficients for "metered connection" (39 %) and "daily service" (17 %), resulting in an overall increase in house price of about 56 %.

One needs to be careful in interpreting these coefficients. It is far from clear that they are "clean", i.e. representing only the indicated variable. Still, these results are clearly interesting and stimulating for further analysis.

A "byproduct" from this analysis is certain additional results regarding effects of other variables on house prices. First, we find a positive partial income effect on house price (with elasticity about 6 %). This could be a selection effect in the sense that households with higher incomes select "better" neighborhoods with higher house prices (for given values of the registered variables), or have more money available for house maintenance. Secondly, we find moderate effects of increases in floor and lot sizes on house prices (a doubling of these increases the price by 36 and 16 % respectively). Thirdly, having formal title to the house raises average house value by 21 % everything else equal.[22] Fourthly, there are significant partial effects of electricity and telephone

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[22] We here of course also have the danger of selection bias e.g. because titled properties may be better maintained than nontitled ones.

service at the house. These effects are greater for telephone (where the ratio of houses serviced is far lower, about 40 % on the average, versus 90 % for the former).[23]

To put the estimated effects of water service on residential prices into perspective, the estimated average value effect of a residential unit with metered tap connection with daily service, relative to a unit with no connection (3376 + 5283 = 8659 USD) can be compared to average (PPP adjusted) household incomes for households in our sample (865 USD). Our results here indicate an average present discounted value of having a metered connection with daily service as equivalent to about 10 monthly household incomes.

Table 4.3. Relationships between property prices and water availability and background variables. Regressions on entire sample (3424 obs.).

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	
Constant	-14985	5.98
Multiple r squared (adjusted)	0.189	0.412

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[23] It may appear strange that telephone service is associated with greater increase in house value than electicity service. We conjecture that this is also mainly due to selection factors: having telephone service is probably a good proxy for living in a “good” neighborhood (and may have some independent prestige value), while electricity service is sufficiently widespread to not have significant such effects.

Tables 4.4 – 4.5 provide more detailed results (on the basis of linear and log-linear estimations) for each city. Here the estimations are much less precise, due to the smaller numbers of observations for each city. We have in these estimations found it appropriate to remove the dummy variable indicating daily service, and concentrate on effects of unconditional metered and nonmetered tap service. Overall, log-linear relationships give the better fit, although not in all cases. In all log-linear relationships metered and nonmetered tap coefficients are positive, and in almost all cases they are highly significant. Coefficient sizes vary, but are generally higher for metered than for nonmetered 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.

In all relationships we identify a large partial effect of better water service on house prices. This indicates a large willingness to pay to obtain better water service, or alternatively, for access to a house in districts with better water service (for given other amenities). It is a bit less clear what the implication this result has, 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 be correlated with the quality of water services.

Table 4.4. Results for individual cities, linear relationships Effects in USD, PPP adjusted. (Significance at 5 % (**) and 10 % levels (*) indicated).

Variable	Ma	SA	Son	SM	PC	Co	GC	VN	Mi
Size	106**	113**	114**	108**	73**	116**	77**	66**	79**
Lot	4.6	13**	60**	13*	6.5*	43**	-14	28*	-3.9
Income	1.55**	1.62**	9.7**	1.14	13.2**	18.9*	0.7	0.3	1.2
Metered tap	7868	4229	3490	17825*	3201	71094**	-277	8250	
Nonm. Tap	2680	3206	1239	16164*	7141	50466*	4076**	1894	7163
Title	4320	-422	1971	1377	12482**	-2275	3878	3410	-911
Electr	2841	5814	-2008	20371	474	-4995	-2947	3867*	-944
Tel	36420**	10605	2484	13024	15561**	25732	3047	12450**	12677**
Obs	652	308	318	295	383	56	218	672	399
Average	26.3	23.1	30.4	42.3	41.8	45.0	8.6	11.4	34.0
Av. inc.	1205	495	435	529	1266	1228	611	742	710
R sq	0.1899	0.3601	0.4228	0.0962	0.1906	0.4566	0.1381	0.1221	0.1230

Explanations to tables 4.4 – 4.5:
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, nonm. 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.

A different problem in using these data for distributional analysis is that we do not know how residences were acquired by current owners. One might argue that a house owner who happens to reside in an area with good water service is “lucky” as his or her house has a high value due to this service. But it may instead happen that the owner has paid full house value in order to acquire it, implying no (or very small) net gain for this owner.

Table 4.5. Results for individual cities, loglinear relationships (significance at 5 % (**) and 10 % levels (*) indicated).

Variable	Ma	SA	Son	SM	PC	Co	GC	VN	Mi
Size	0.54**	0.36**	0.29**	0.28**	0.26**	0.32*	0.38**	0.27**	0.29**
Lot	-0.09	0.18*	0.26**	0.15**	0.17**	0.22	0.12	0.50**	0.21**
Income	0.13**	0.11*	0.13**	0.05	0.04*	-0.04	0.03	0.00	0.04*
Metered tap	0.71**	0.33*	0.69**	0.28*	0.2	1.52**	0.65	1.07	
Nonm. tap	0.31*	0.27	0.63**	0.31**	0.20	1.26**	0.35**	0.28**	0.50**
Title	0.28**	-0.10	0.21**	0.07	0.39**	-0.16	0.50	0.29**	0.06
Electr	-0.25	0.51	0.23	1.09**	0.19	0.05	-0.17	0.72**	0.18
Tel	0.83**	0.50**	0.29**	0.27**	0.53**	0.78**	0.21	0.78**	0.25**
Obs	652	308	318	295	383	56	218	672	399
R sq	0.4122	0.2225	0.5597	0.2278	0.2332	0.2709	0.0895	0.1657	0.2157

4.3. Deriving consumer surplus due to tap water connections from estimated demand functions

Consumer surpluses from tap water consumption can in principle be derived on the basis of estimated water demand functions. In this section we will attempt to perform such calculations. Our main aim will be to derive measures of increases in economic value, when a previously unconnected household acquires a water connection, i.e., a measure similar to that derived from the hedonic price calculations in section 4.2. In chapter 2 it was demonstrated that tap and nontap households are likely to have radically different water demand functions. In this light we will use as a basis only the demand functions estimated for tap households, when deriving consumer surplus measures for the group of connected households.

In chapter 2 linear and log-linear demand functions were estimated for metered tap households. The precision of estimation was about the same, overall, for the two sets of functions (in terms of R-squared and numbers of significant coefficients). For the entire set of households (when also including those without tap) the log-linear functions gave the superior fit. This perhaps speaks in favor of basing consumer surplus calculations on estimated log-linear demand functions. A further problem with basing such calculations on linear functions is that marginal willingness to pay measures are constant as demand is reduced along the demand functions. It may be argued that this will lead unrealistically low predicted marginal water valuations at low quantities (i.e., at quantities which are generally much lower than those observed in the data).

In view of these observations we will here attempt to derive consumer surplus measures based on both linear and log-linear estimated demand functions. Those derived from linear functions (based on the results in the second column of table 2c) are included mainly for comparison, as indicating an extremely conservative calculation likely to (perhaps severely) underestimate true consumer surplus. Our estimates from (one main) log-linear relationship are argued to be more realistic, and are used for the further analyses of distributional impacts.

4.3.1 Consumer surplus calculations from linear demand functions

We start with the linear case, and postulate a water demand function of the simple type

$$W = \alpha - \beta P \tag{4.1}$$

such that

$$P = \frac{\alpha}{\beta} - \frac{1}{\beta} W \equiv \gamma - \tau W \; . \tag{4.2}$$

The parameter α may here be household specific and then in principle capture effects of all other variables than price on the household's water demand. β is by contrast assumed to be common for all households. Define now a per-household consumer surplus (CS) measure for tap households, CS(1), as follows:

$$(4.3)\, CS(1) = \int_{W=W_0}^{W_1} (\gamma - \tau W) dW - P_1 W_1 + P_0 W_0 = \gamma (W_1 - W_0) - \frac{1}{2} \tau ({W_1}^2 - {W_0}^2) - P_1 W_1 + P_0 W_0 .$$

Here W_1 is interpreted as actual household (metered tap) water consumption, and P_1 as price (average, marginal, or some average of the two) paid for this amount of water. W_0 is some assessed minimum amount of water that could reasonably be secured in the absence of tap connection, and

P_0 is a stipulated (standard) average price to be paid for this water. In calculating CS we will take P_0 to be an average truck price, which is most comparable to tap prices in terms of convenience (from the discussion in section 2.2). The sum of the two first terms on the right-hand side of the equation is the net consumer surplus from excess consumption of the tap over the nontap households. The sum of the last two terms is the net monetary saving, for tap relative to nontap households, at their respective (actual and stipulated) consumption and prices.

CS(1) here represents only the CS from water consumption in excess of the “minimum” W_0, in addition to a stipulated value P_0 for each unit of the initial level W_0. This does not necessarily represent the “true” total CS, in particular since the marginal value of W is likely to exceed P_0 for very low water quantities. It is however impossible to directly estimate or infer such marginal values for tap households, since we do not have observations in these ranges.

We have little basis for providing sophisticated CS calculations for coping households, and will not do so, see the discussion below.

To consider reasonable values for parameters and variables, from the calculation in table 2c the “best” linear estimation in column 2 implies a β coefficient of about 15 (given a simultaneous increase in marginal and average water price). The “true” value of α differs in practice by city and background variables for individual households. It is possible to derive a reasonable average value for α for metered tap households in our sample by considering average water consumption at average (marginal and average) prices across metered households. At an average of about 30 (m^3) for W, and an average of about 0.4 (USD) for P, average α is about 36. This implies “average” values of γ = 12/5 and τ =1/15.

We can now find a (rough) average value of CS (in USD per month per household with metered tap connection), as an estimate on the CS over and above households without tap. We then set W_1 and at 30, P_1 at 0.4. Set also W_0 at 5 and P_0 at 8, as an indication of the consumption and price experienced by an average nontap household. Inserting these values into the equation implies CS of about 58 (USD per month, PPP adjusted).

Solving for γ from (4.2) we may express CS(1) as follows:

$$CS(1) = \frac{1}{2\beta}(W_1 - W_0)^2 + (P_0 - P_1)W_0. \qquad (4.4)$$

(4.4) may alternatively be used as basis for CS calculations. For metered (nonmetered) tap households, W_1 may be identified with actual (imputed) water consumption, and P_1 with actual average water price. P_0 and W_0 may here be identified with average price and consumption values for coping households, in the respective cities. For coping households we may switch in the sense that we used actual data for P_0 and W_0 and city averages for P_1 and W_1.

(4.4) is implemented using (actual and imputed) water consumption for W_1, using an assessed minimum of 5 m^3/month for W_0, an assessed average truck price (PPP adjusted) of 8 USD, and (actual or imputed) average water price for P_1.

4.3.2 Consumer surplus calculations from log-linear demand functions

Consider next the log-linear case. Here the demand function takes the basic form

$$\ln W = A - b \ln P. \tag{4.5}$$

This is expressed alternatively

$$W = e^A P^{-b} . \tag{4.6}$$

We will consider the elasticity parameter b as estimated commonly for all households. In our CS calculations we will maintain the value of 1/3 for b (which is a good point estimate given that P represents both marginal and average water price, as we assume here). If b is assumed to be common for all households, e^A can be assumed determined independently by household. To assess this value for a given household we may consider it determined from (4.6) 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 for a household facing W_1 and consuming P_1,

$$e^A = W_1 P_1^b . \tag{4.7}$$

Inverting (4.6) we derive the following solution in terms of P:

$$P = e^{\frac{A}{b}} W^{-\frac{1}{b}} \equiv aW^{-\frac{1}{b}} . \tag{4.8}$$

(4.8) defines the (individual-specific) parameter a. Define now the per-household consumer surplus from a water connection in the following way, CS(2), in a way similar to (4.3):

$$CS(2) = \int_{W=W_0}^{W_1} aW^{-\frac{1}{b}} dW + P_0 W_0 - P_1 W_1. \tag{4.9}$$

Here again P_0 and W_0 are "backstop" prices and quantities (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. In the present case (with log-linear demand functions) this is a "conservative" assumption in the sense that the calculated water price at low quantities, along the water demand function, here can easily 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 (4.9), CS(2) may be written as

$$CS(2) = \frac{a}{1-b}\left(W_0^{-\frac{1-b}{b}} - W_1^{-\frac{1-b}{b}}\right). \tag{4.10}$$

Since a as noted in general is individual specific, it is more useful for empirical purposes, to derive an alternative expression for CS(2) by substituting for a from (4.8), yielding the following expression:

$$CS(2) = \frac{1}{1-b} P_1 \left(W_0^{-\frac{1-b}{b}} W_1^{\frac{1}{b}} - W_1\right). \tag{4.11}$$

Assume now our central estimate of b = 1/3. Then (4.11) is simplified to

$$CS(2) = \frac{3}{2} P_1 W_1 \left(\frac{W_1^{2}}{W_0^{2}} - 1\right). \tag{4.12}$$

Maintaining a common price elasticity of demand (–1/3) for all tap households (metered or nonmetered), a further simplification may be obtained by expressing CS(2) in terms of P_0, where the latter variable is our estimate of the “backstop” coping-water (truck) price. We then arrive at our final expression for CS in the log-linear case:

$$CS(2) = \frac{3}{2} P_1 W_1 \left(\left(\frac{P_0}{P_1} \right)^{\frac{2}{3}} - 1 \right). \tag{4.13}$$

This expression is used for calculating household-specific CS among tap households. These calculations are done using actual water outlays for P_1W_1, average water price (actual or imputed) for P_1, and an assessed average truck price (8 USD, PPP adjusted) for P_0.

4.3.3 The empirical CS measures

The CS measures discussed so far have been defined relative to a stipulated minimum consumption level, W_0. In the linear case W_0 was taken to equal 5 m^3/month, with an associated backstop water price of 8 USD. In order to compare tap and coping households in a common framework, we need similar measures of consumer surplus from current water consumption for coping households. This is a more demanding issue as there is less precise information on the marginal value of water at current consumption at the individual level for coping households. Moreover, trying to measure marginal utilities of water consumption much below existence minimum is a dubious undertaking. In the following we take a rather rough approach to this issue by 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. If their truck price, P_t, is higher or lower than this level, we assume that they experience 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. Obviously, this implies an imprecise measure of CS for coping households. It mainly reflects their excessive financial costs of providing coping water relative to the defined benchmark (5 m^3/month at 8 USD/m^3). It is needed to stress that the main purpose of this exercise is not to provide correct measures of CS for individual households, but rather to value the (average) change in CS when tap water is provided to currently coping households.

Table 4.6 presents such average CS calculations for households in each city, for metered tap, nonmetered tap and nontap households. The first two columns in the table give results for tap households based on the linear demand functions, where calculations are made on the basis of the relationship (4.4). In the next two columns present results based on the log-linear demand function, and using the formula (4.13). Calculations are made separately for metered and nonmetered households. Overall, CS estimates derived from linear functions are lower than those from log-linear functions. This is in line with comment above, that linear functions are likely to (perhaps seriously) underestimate CS by assuming that marginal valuation of water is constant when consumption decreases, while under log-linear functions marginal valuations increase with decreasing consumption. Overall, there is little difference between metered and nonmetered households in a given city and for a given type of calculation. On average the CS measure is about 65 USD per month from the linear functions, and about 110 USD from the log-linear functions. There is rather small variation in average numbers across cities, which mainly reflects the property that average tap water consumption is similar across cities, both for registered metered households and for imputed values ascribed to nonmetered households. The CS calculations for nonmetered households in cities where we have no observation of metered consumption (essentially all the last 11 cities in the table) are here of course particularly uncertain.

These calculations imply no direct value to the individual households of a water meter as such, for households that already have tap connections. Our analysis in section 4.2 indicates that meters may be valued independently. A possible reason is for some households a more efficient water water consumption, and another possible reason that a water meter may serve to formalize the household's relationship with the authorities.

For nontap households CS is as noted calculated relative to a standard coping (actual or imputed truck) water price level of 8 USD/m^3 (PPP adjusted). Thus calculated CS is negative if the truck price is above 8 USD, and positive when it is below 8 USD. It is implicitly assumed that nontruck coping water is associated with a total cost (including hauling and other inconvenience cost) equal to that of truck water. Average CS figures are here largely negative, with city averages (in USD per household per month, PPP converted) ranging from a low of –48 for San Miguel, to a high of 5 in Mixco.

These calculations will probably often not correctly reflect true relative CS values for individual coping households. In particular, for many the true cost for nontruck water (including hauling costs etc.) is likely to be lower than the truck water cost, in which case the CS for households consuming other water than truck water is in turn likely to be higher than the figures reflected in table 4.6.

On the other hand, the CS calculations for tap households, even those from the log-linear functions, may also be biased downwards. The marginal value of tap water is namely capped at 8 USD/m^3 also for these, which is likely to be too low (one must here remember that from the calculations in section 2.3 we found that water demand among metered tap households is much higher than that among coping households, for any given water price, indicating that tap households are willing to pay considerably more than nontap households for one additional m^3 of water, at any given consumption level). A related reason is that for tap households the predicted consumption level at 8 USD/m^3, W(8), is in general considerably higher than the average level for nontap households, 5 m^3, while we are implicitly only valuing consumption levels in excess of W(8). This should indicate that average CS gain from a water connection need not be seriously overestimated.

Table 4.6 Net consumer surplus calculations, for tap and nontap households, averages by city. USD per month, PPP adjusted. Numbers of households in samples in parentheses.

City	Linear, metered hh	Linear, non metered hh	Log-linear, metered hh	Log-linear, non-metered hh	Nontap Hh
Managua	57.8 (366)	59.8 (1022)	115.2	108.6	
Santa Ana	69.7 (153)	62.2 (219)	106.6	103.8	1.9 (143)
Sonsonate	72.3 (143)	62.2 (205)	108.6	102.5	-10.3(225)
San Miguel	66.7 (111)	65.7 (149)	104.7	110.0	-48.4 (195)
Panama	67.9 (218)	60.7 (581)	124.6	116.1	-7.4 (19)
Colon	71.7 (37)	59.8 (172)	136.7	116.3	-15.5 (10)
Barquisimeto		87.8 (238)		116.6	
Merida		72.4 (590)		103.1	
Tegucigalpa		54.6 (379)		75.3	-14.6 (839)
San Pedro		50.8 (32)		82.5	-13.6 (181)
Choluteca		69.8 (323)		99.4	-13.4 (28)
Santa Rosa		72.7 (91)		112.9	-5.9 (22)
Comayagua		63.8 (196)		90.2	-8.9 (31)
Guatemala	43.3 (5)	58.7 (97)	46.0	86.0	-14.3 (233)
Villa Nueva	40.2 (1)	59.9 (670)	62.2	104.3	-2.7 (206)
Chinautla		61.3 (100)		103.2	4.1 (68)
Mixco	40.4 (1)	71.4 (474)	62.0	103.7	5.0 (130)
Total	65.1 (1035)	64.3 (5538)	114.2	104.0	-13.0 (2330)

We have also done some more detailed calculations on the relationship between net CS calculations due to being connected, as function of certain explanatory variables, such as income, household size and degree of rationing. The individual CS values are here the CS(2) value found from the log-linear relationships, from which we have subtracted the city-specific net utility figure for unconnected households given in the right-hand column of table 4.6. These calculations are presented in table 4.7. They show that

Table 4.7 Regression of net consumer surplus due to water connection (using log-linear demand functions), as function of different variables. USD per household per month, PPP adjusted.

Variable	Effect	T value
Household income (100 USD)	1.02	22.8
Persons in household	3.98	18.8
Water daily	25.6	11.7
Water 10-29 d/month	10.8	4.0
Metered tap	3.63	2.8
Santa Ana dummy	3.61	1.7
Sonsonate dummy	17.1	8.0
San Mateo dummy	57.8	24.1
Panama City dummy	19.7	12.5
Colon dummy	32.5	12.4
Barquisimeto dummy	10.2	4.1
Merida dummy	-1.4	-0.8
Tegucigalpa dummy	-3.3	-1.5
San Pedro Sula dummy	-3.9	-0.6
Santa Rosa de Copan dummy	22.1	5.6
Comayagua dummy	-1.5	-0.6
Guatemala City dummy	0.2	0.0
Villa Nueva dummy	6.6	3.7
Chinautla dummy	-1.3	-0.4
Mixco dummy	33.7	1.8
Constant	49.4	44.2

Table 4.8 shows calculations where net CS from water supply, calculated from log-linear demand functions, is added to regular household income, in order to create a more “comprehensive” concept of current income.[24] The two first columns of the table give such current averages for metered, nonmetered tap and nontap households, where figures in columns 3-5 of table 4.6 are added to the average income figures in table 1j. A feature of these numbers is that the differences in “real income” between those with and those without water connections, now are greater than differences found from regular income alone (in table 1j). This follows from the fact that nontap households have a lower regular income than others overall, and at the same time a lower (often negative with our definition) addition to “real income” due to net benefits of water service.

The right-hand column of table 4.8 gives calculated averages for “real income” after connection to the water service, for households who are currently unconnected. The basic presumption here is that the net consumer surplus enjoyed by these after connection, equals the average value of CS(2) by city, for currently connected households. We are thus assuming that, after being connected, a given household in a given city will enjoy the average level of water service, as an average across all connected households in our sample, and are willing to pay exactly the same amount for this service as currently connected households are. Essentially, this moves overall "real income" back up to the level enjoyed by currently connected ones, i.e., the differences between the two left-hand columns and last column of table 4.7 is approximately the same as the differences found between the three columns of table 1i.

Table 4.8 Distribution of income including "assessed net consumer surplus" from water consumption, derived from log-linear demand functions for tap households (3 last columns in table 4.6). USD per month per household, PPP adjusted.

City	Metered tap households	Nonmetered tap households	Nontap hh, current state	Current nontap when given service
Managua	1570	1319		
Santa Ana	612	713	383	483
Sonsonate	651	659	290	413
San Miguel	634	753	343	547
Panama City	1705	1491	839	966
Colon	1670	1417	953	1084
Barquisimeto		1428		
Merida		1299		
Tegucigalpa		638	454	559
San Pedro Sula		551	610	720
Choluteca		990	817	943
Santa Rosa		1086	304	430
Comayagua		858	284	392
Guatemala City		832	527	625
Villa Nueva		873	709	809
Chinautla		645	513	602
Mixco		854	602	690
Total	1226	1075	482	596
Total obs.	1035	5525	2330	2330

Table 4.9 gives an overview of the figures used in correcting "real income" variables as a result of a water connection, for currently unconnected households. These figures are for most cities in the neighborhood of 100 USD/month, and for some cities (such as San Miguel, Panama and Colon) a bit higher. The second column gives these assessed additions as average fractions of regular household incomes, for households who are currently without tap water, by city. These fractions are

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[24] This income concept is clearly not fully comprehensive, as a number of other public services in principle ought to be included, such as sewerage, electricity and telephone service. Derivation of such more comprehensive welfare measures would however be way beyond the scope of the current project.

high, in several cases more than 60 %, and with an average of more than 40 %. While these exact numbers should be viewed with some care, they clearly indicate that adding water service may add tremendously to the real welfare of these households.

Table 4.9 Calculated average increases in consumer surpluses due to water connections, for currently unconnected households, at current average service levels

City	Average CS addition from adding water connection, USD/month	Average CS addition as fraction of initial income, %	Average rel. total income, nontap vs. tap, %	Same average rel. total income when all have tap, %
Santa Ana	103.1	57.1	56.9	72.0
Sonsonate	115.3	85.0	44.3	62.9
San Miguel	156.4	69.5	48.9	77.8
Panama	125.4	21.5	54.2	62.4
Colon	125.5	18.9	65.2	74.1
Tegucigalpa	89.6	38.4	71.2	87.6
San Pedro	96.6	23.7	110.9	130.9
Choluteca	112.4	43.0	82.5	95.2
Santa Rosa	118.9	67.6	28.1	39.5
Comayagua	98.8	60.6	33.1	45.7
Guatemala	98.3	25.6	63.4	75.2
Villa Nueva	106.7	25.3	81.2	92.7
Chinautla	98.9	27.5	79.5	93.2
Mixco	99.0	29.3	70.6	81.0
Total	119.0	42.7	55.9	73.8
Average for nonration nonm.	121.2			
Average for nonration met.	140.2			

The two last columns of table 4.9 give numbers for the relative “real income”, for currently unconnected versus currently connected households, by city. The first of these columns give such fractions in the current state, while the last (right-hand) column gives such numbers after tap service has been extended to those currently without tap. The overall figures indicate that, on average, “real incomes” of currently unconnected households relative to those of connected households, increase from about 56 to about 74 %. This indicates that extending water service to new household groups will contribute significantly toward reducing real income differences, between the groups in question here.

These results are derived under the assumption that the distributions of new water connections, in terms of rationing and metering, will correspond to existing distributions, within each city. The two figures in the bottom lines of table 4.9 are calculated average CS values across all cities, in the hypothetical case where all new connections would be unrationed. The first of these figures show this average when new connections are nonmetered, and the second figure when the new connections are metered. CS values are, obviously, higher in this case, but not very much higher (the differences in values according to whether the connections are rationed or not appear from table 4.7).

4.4 Comparision of hedonic-price and demand-function derived CS values of water connections

The hedonic price calculations in section 4.2 give some basis for an overall average calculation of the value of being connected to the water system, by degree of rationing and according to whether water consumption is metered. These calculations are however too imprecise to yield meaningful information on these values in each individual city. The demand-function—based CS calculations in section 4.3 by contrast yield such values at city or even household level, but we have here not attempted to do any comparison of CS values by degree of rationing. It is also obvious that the effect of metering is quite different in the two sets of calculations.

A problem is to translate the two calculations to a common denominator. One possible denominator could be in terms of a measure of annual gain from having a water connection. In the demand function calculations, it seems reasonable to base there on the log-linear functions as argued above, i.e. the figures in column 3 and 4 of table 4.6. These figures are annualised by multiplying them by 12.

The corresponding gains to be derived from hedonic-price calculations are most reasonably the coefficients on metered and nonmetered connection and daily water service, in table 4.3. Taking a concrete example, with a discount rate of 15 %,[25] the annualised values of these coefficients are, respectively, 506, 62 and 792 USD (PPP adjusted). Thus e.g. a metered and unrationed connection has an annual average value of 506+792 = 1298 USD, across all cities in our sample. This is somewhat less than the corresponding value derived for unrationed metered households, from table 4.9, which is (140*12 =) 1680 USD. The value of a nonrationed nonmetered tap connection is 62+792 = 854 USD from the hedonic price relationship, and 121*12 = 1452 USD (the assessed average over all nonmetered households in the case of nonrationing) from the demand function

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[25] This is a high real rate of discount; remember however that households in this part of the world typically face very 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.

relationship. Here the latter is larger by a wider margin. Still, the two types of calculations are close by any reasonable measure.

Two main differences between the two types of calculations appear to be greater effects of both metering and nonrationing on CS, in the hedonic price relationship than in the demand function relationship. This is intuitively reasonable, as the demand function relationships are likely not to capture all beneficial effects of nonrationing and metering. First, metering permits each household to optimise its water consumption in ways that cannot fully be captured in our calculations. Secondly, metering may as noted have other side effects such as serving as formalization of the relationship with the authorities (in which case the full effect probably should not be ascribed to the water service as such). For rationing we have similar differences. Our demand function estimations are likely to not be able to capture all inconveniences of rationing, such as the necessity of instalment of tanks and inconvenient distribution of water consumption over the day or week. Such inconveniences will be captured in a hedonic price relationship where households implicitly may express willingness to pay to avoid these. On the other hand and as already noted, the hedonic price relationship is likely to capture also expected future service changes, implying that future expected improvements in water service at currently unconnected (or poorly serviced) addresses tend to lower the current capitalized value of connections, thus tending to undervaluing these.

4.5 Water demand effects of changes in water prices and metering

We will now turn to another important element of the analysis of changes in water policy, namely demand responses to changes in water prices. We will consider some such effects by starting with repeating some of our results from chapter 3, concerning the assessed demand responses for nonmetered households, to being metered at current rates. Such figures can be read out of table 3.10, column 2 and 3. These figures are restated here, in table 4.10, first two columns, more conveniently as the differences between the figures in the second and third versus the first column of table 3.10. The response figures in table 4.10 are presented as “large” and “small” responses. In the case of “large” responses, we note, as also noted in chapter 3, that household are assumed not to respond at all to prices and price changes when not metered. This implies that water consumption is affected differentially both by marginal and average water prices, according to the estimated demand relationships in chapter 2. Under “small” responses it is instead assumed that households react to average water prices even when they are not metered. The response to metering then shows up solely through the effect of marginal price on demand, which is about one third of the effect of average and marginal price simultaneously. The right-hand column of table 4.10 shows how average realized demand of currently nonmetered households would change if all nonmetered tap households in each of the cities would be offered unrationed service, instead of many of these being rationed as is the case today.

Table 4.10. Average calculated demand responses, to metering among currently nonmetered tap households given current water pricing system and two different demand-response alternatives, and to removal of rationing. Based on linear demand functions. m^3 per month per household.

City	Reduction from current cons, small response	Reduction from current cons, large response	Cons. incr. under no rationing
Managua	4.0	11.1	0.3
Santa Ana	2.8	5.8	0.6
Sonsonate	2.7	5.4	1.0
San Miguel	1.7	4.8	1.5
Panama City	3.7	10.4	2.2
Colon	4.6	12.6	2.5
Barquisimeto	4.4	7.5	4.6
Tegucigalpa	1.1	3.3	3.8
San Pedro Sula	1.9	6.8	1.5
Guatemala City	1.3	3.3	5.0
Villa Nueva	2.0	5.7	3.1
Chinautla	1.7	4.8	1.1
Mixco	1.4	3.9	1.9
Average	2.5	6.4	1.9

The first columns in tables 4.11-4.12 indicate the magnitude of LRMC (as provided from ESA Consultores), in USD, PPP adjusted, where we use the standard World Bank adjustment factors, except that we use the (more reasonable) factor 4 for Managua (instead of the factor 6.3 as otherwise used). Columns 2-5 in table 4.11 give our estimated effects of LRAC pricing for metered households. Such effects are calculated only for cities where we have observations on actual metered consumption. Four types of calculations are presented in the table. The first two, presented in columns 2-3, are based on an assumption that only the marginal price increases up to LRAC for all metered households, while the average water price is kept constant for all. This is hypothetical but serves as a useful reference point. The formulae used for calculations are here as follows:

$$dW(m1) = 4.3(lrac - mp) \qquad (4.14)$$

(4.15) $$dW(2) = W(mp)(1 - e^{0.1(\ln(lrac) - \ln(mp))}),$$

where mp is the marginal price currently facing the respective households, and lrac is the long-run average cost. The difference between figures in columns 2 and 3 is here that the first is based on reactions along the linear demand curve, and the second on reactions along the log-linear curve. Overall, the effects are negligible for the cities in El Salvador (where current, average and marginal, water prices are already at least at LRAC levels). For the other three cities the effects are however noticeable and lie in the general range 3-6 m^3 per household per month.

The two following columns of the table show similar effects where also the average water price is increased up to LRAC levels. The formulae for calculating these are as follows:

(4.16) $$dW(3) = dW(1) + 10.7(lrac - ac)$$

(4.17) $$dW(4) = dW(2) + (W(mp) - dW(2))(1 - e^{0.2(\ln(lrac) - \ln(ac))}).$$

Here ac is the average water price currently facing the household. The effects of average water price, using coefficients from the linear and log-linear relationships in chapter 2, are now included in addition to the effect of marginal water price. Also now we find that there are essentially no effects for El Salvador, while the effects for the other cities now are approximately double those found in columns 2-3.

Given a certain faith in our estimated demand functions, one can perhaps claim that the calculations in columns 2-3 (based on only marginal price increases) form sort of “minimum responses” to LRAC pricing, while the calculations in columns 4-5 indicate a sort of “maximum responses”. In practice it is impossible to increase only marginal price for a large set of households initially facing different marginal prices and consuming different quantities, without at the same time increase average water price. On the other hand, increasing average water price all the way up to LRAC for all households is a very drastic measure, and probably not one that will be contemplated in practice (due to its adverse income distribution effects among the group of tap households, and it political infeasibility). Thus it is relatively safe to assume that, in practice, average water prices will increase somewhat but not all the way up to LRAC, given that marginal water prices are set at LRAC. In this case, the actual effects will be somewhere in between those from columns 2 and 4 in the case where calculations are based on linear functions, and somewhere in between those from columns 3 and 5 when calculations are based on log-linear demand functions.

Table 4.11. Estimated effects of marginal cost (LRMC) pricing on effective water demand of metered households. m^3 per household per month.

City	Calculated LRAC, USD/m^3 PPP adjusted	Marg price only incr., linear function	Marg price only incr., log-linear function	Both marg and av price incr., linear function	Both marg and av price incr., log-linear function
Managua	1.88	4.78	2.81	8.89	6.81
Santa Ana	0.264	-0.23	-0.63	-0.23	-1.06
Sonsonate	0.279	-0.23	-0.47	-0.13	-0.52
San Miguel	0.326	0	0.06	0.28	1.01
Panama	1.60	6.10	4.32	10.67	9.78
Colon	1.13	3.70	3.88	6.27	8.83

Table 4.12 shows similar calculations for households who are currently not metered, but where metering is introduced and at the same time the water price set at LRAC levels. Here calculations are made only from linear functions (on the ground that it is impossible to predict water demand from log-linear functions, for households who initially face zero marginal cost). The formula for the reduction in water demand is now in the first case (where only marginal cost is increased) simply

$$dW(5) = 4.3lrac, \tag{4.18}$$

while in the second case (where both marginal and average cost are increased)

$$dW(6) = dW(5) + 10.7(lrac - ac). \tag{4.19}$$

Also here ac represents the average water price, now the one paid by initially nonmetered households, while W(0) is the current water consumption of these same households The formula for dW(6) is thus essentially the same as that for dW(3).

Here effects are given in respective the second and fourth column of table 4.12. These are generally somewhat greater than those found for linear functions in table 4.11, which is natural as these households initially face a zero marginal water price, and have this increased by more when demand is metered.

Again empirical effects are small for the cities in El Salvador. For the other cities, effects of increases in marginal water cost only are on the range 5-8 m^3 per household per month, and effects of simultaneous increases in average and marginal price in the range 9-13 m^3 per household per month.

It should be noted that the estimated effects on currently nonmetered households, of simultaneous increases in average and marginal water prices together with the introduction of metering for these, are based on the “conservative” assumption about such households’ reactions to increases in average water prices, as discussed in chapter 3 above. The more “radical” alternative (where it is assumed that nonmetered households have no demand response whatsoever to any type of water pricing) is here seen to lead to implausibly great demand responses, in particular in the linear case (which becomes less reliable in this case; linear-based estimations are reasonable only for a limited range of demand in the vicinity of equilibrium, in particular when prices are increased substantially).

We have for households that are currently nonmetered, also made two sets of calculations where corrections are made for effects of rationing, for cities where such effects have been calculated (for cities where we have no estimates of effects of rationing, no figures are given in these columns). Specifically, we assume in both cases that rationing is completely eliminated in the two cases considered, namely when only marginal price is increased (the calculations in column 3 of table 4.12), and when both marginal and average prices are increased (the calculations in column 5). The assumed elimination of rationing reduced effective water demand by less than the initial effect of water price alone, and may in some cases even lead to increased realized water demand, at least for some groups (who are heavily rationed initially). Under our calculations this is seen not to happen in any of the cases; overall responses are here however very small in some cases (as for the El Salvadoran cities as well as Barquisimeto and Guatemala City in column 3).

The logic behind these adjustments is that when water prices are increased, overall water demand will drop, and there will be less need for physical rationing for given water supply. It is still far from certain that rationing will be completely eliminated, for all households. For some, initial rationing could in part be due to lack of capacity in local distribution networks, such that some bottlenecks will remain even when overall water supply increases. It is also of course more likely that rationing will be significantly reduced, in the case where both marginal and average water prices are increased, when compared to the case where only marginal water price is increased (as more water is freed up in the former case). In that sense the derived effects of reduced rationing must be considered with some care.

Table 4.12. Estimated effects of marginal cost (LRMC) pricing and metering on effective water demand of currently nonmetered households. m^3 per household per month

City	Calculated LRAC, USD/m^3 PPP adjusted	Non-metered hh, marg price only increases, lin. functions	Net effect after complete removal of rationing	Non-metered hh, both marg and ave prices increase, lin. functions	Net effect after complete removal of rationing
Managua	1.88	7.48	7.2	12.89	12.6
Santa Ana	0.264	1.13	0.5	1.80	1.2
Sonsonate	0.279	1.20	0.2	2.07	1.1
San Miguel	0.326	1.40	0	2.26	0.8
Panama	1.60	8.87	5.7	13.43	8.2
Colon	1.13	6.84	2.4	8.73	3.2
Barquisimeto	1.24	5.30	0.7	9.08	4.5
Merida	1.24	5.33		9.26	
Tegucigalpa	1.58	6.80	3.0	13.04	9.2
San Pedro S.	1.58	6.79	5.3	10.65	9.1
Choluteca	1.58	6.79		12.69	
Santa Rosa	1.58	6.79		12.11	
Comayagua	1.58	6.79		12.81	
Guatemala	1.28	5.50	0.5	10.06	5.1
Villa Nueva	1.28	5.50	2.4	9.14	6.0
Chinautla	1.28	5.50	4.4	9.45	8.3
Mixco	1.28	5.50	3.6	9.80	6.9
Arithmetic averages		6.20		10.66	

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