Residential Water Consumption: A Cross-Country Analysis

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Abstract

Survey data from about 1,600 households in ten countries are used to analyze the determinants of residential water demand. Results show that in every country the price elasticity is negative and statistically significant. Households that do not face volumetric water charges consume about a third more water than similar households that do incur such charges. Attitudinal characteristics do not have a statistically significant effect on total water consumption but do increase the probability of undertaking some water saving behaviors, as does a volumetric water charge. Full-cost water pricing appears to be a highly effective instrument to manage residential water demand.

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1. Introduction

An increasing number of countries face concerns over maintaining water reliability in response to climate variability and rising populations. This is because, in many locations, the cost of increasing water supply is much more expensive than supplying water from existing sources. Supply augmentation may also require several years of planning and large capital investments before the water is available. In response to these challenges, governments are developing strategies to promote water conservation, particularly with residential consumers.

One of the principal policy levers of water conservation available to governments and water utilities is to impose a volumetric charge on households in terms of the water they use. This requires that (1) households have water meters and (2) the water bill of households depends on the amount of water consumed. To better understand the impact of volumetric water prices on water consumption, and also socio-economic and attitudinal variables on water saving behaviors, we use a unique survey data set of over 10,000 households collected by the OECD Secretariat in 2008 from 10 countries. The survey data include responses to a range of water consumption, household characteristics and attitudinal questions.

Analysis of the survey data provides the first ever detailed quantitative study of the determinants of residential water for OECD countries based on a common survey instrument. The common survey instrument across ten countries permits us to make valid cross-country comparisons. Data in the survey instrument on household characteristics, environmental attitudes, and household environmental behaviors and actions also allows us, for the first time, to analyze the effects of attitudinal variables, water saving behaviors and various socio-economic characteristics on residential water consumption.

Statistically significant results from analysis of the survey data indicate: (1) households that pay a volumetric charge for their water consume, on average, about a quarter less water than those that do not; (2) households in all ten countries have a lower water consumption the higher is the average volumetric price of water; (3) environmental attitudes, as measured in the survey, do not have a statistically significant effect on overall water consumption but do increase the likelihood of undertaking some specific water saving behaviors; (4) household characteristics that include the number of people in the household (adults and children), residence size, having undertaken higher education and household income all have a statistically significant and *positive* effect on household water consumption; (5) households that incur a volumetric water charge have a higher likelihood that they will undertake water saving behaviors; (6) the use of dual flush toilets and age of residence (years) have a statistically significant and *negative* effect on water consumption; and (7) the water demand of high-income households is less price elastic than the water demand of low and medium-income households.

Section 2 provides a brief review of the literature on water pricing and residential water demand with a particular focus on OECD countries. Section 3 gives a summary of the data, corroboration of the data to previous studies and an overview of the survey instrument. Section 4 presents regression results using the survey data and statistical tests on the variables that are hypothesized to influence household water demand. Section 5 reviews the policy implications for OECD countries, and section 6 concludes.

2. Review of the Literature

There is an extensive literature of residential water demand that has developed over the past fifty years. One of the pioneering and most comprehensive water demand and supply studies, based on US data, was by Hirshleifer et al. (1960). Some of this large literature is summarized and reviewed by Dalhuisen et al. (2000); Ferrara (2008); Hahneman (1998); Renzetti (2002, 17-34); Shaw (2005, 100-135); Schleich and Hillenbrand (2008); and Young and Haveman (1985); among others.

2.1 Elasticity of Demand

A pioneering study on residential water use by Howe and Linaweaver (1967) provided one of the earliest estimates of the price elasticity of water demand. They used data from 39 areas in five climatic regions of the United States to distinguish between indoor and outdoor (sprinkler) uses by obtaining consumption data over the entire year. They attributed higher consumption in summer to outdoor or sprinkler use and observed that sprinkler demand was more price elastic than indoor water demand, but the overall or weighted price elasticity of demand was inelastic or -0.4. Thus, on average across all their study areas, a one per cent increase in the price of water would *reduce* consumption by about 0.4 per cent.

Since the Howe and Linaweaver study, hundreds of estimates of price elasticities have been derived. Summaries of some of these studies are available in Dalhuisen et al. (2000, p. 6), Ferraro (2008), Hahneman (1998), OECD (1987, p. 51), OECD (1999a, p. 134), Schleich and Hillenbrand (2008, p. 10-11), among others. Almost all the existing residential water demand studies find that the price elasticity of demand is inelastic, but significantly different from zero.

Two meta-analysis studies that use the results from previously published studies find the price elasticity of residential water demand is inelastic. Espey et al. (1997) used 24 published articles to yield 124 elasticity estimates and obtained a median short-run price elasticity of demand of -0.38 and a median long-run price elasticity of demand of -0.64. Dalhuisen et al. (2003) combined 64 previously published residential water demand studies that generated 296 price elasticity estimates to give an overall mean and median price elasticity of -0.41 and -0.35 with a standard deviation of 0.86 (Dalhuisen et al. 2003, p. 295).

Dalhuisen et al. (2003) calculate an overall mean and median income elasticity of demand of 0.43 and 0.24 with a standard deviation of 0.79. In other words, much of the literature finds that, all else equal, households with larger incomes will consume more water than households on lower incomes. High-income households may also be less price elastic in terms of their water consumption than low-income households. For instance, Renwick and Archibald (1998) use data from two communities in California and find that higher income households have a statistically significant smaller consumption response to water price changes than lower income households. In particular, they calculate that households with incomes in excess of US$ 100,000 had a price elasticity of demand of -0.11 while households with incomes less than US$ 20,000 had a price elasticity of -0.53.

For the volumetric price to influence water consumption consumers must be metered. Nauges and Thomas (2000) calculate that a one per cent increase in the proportion of single housing units (all of which have water meters) in 116 French communities would, all else equal, result in a 0.44 per cent reduction in residential water demand. Gaudin (2006) has further shown, using US data from 383 water utilities, that if consumers are informed about the volumetric price that they pay on their water bill, this can increase the price elasticity of demand by 30-40 per cent.

A summary of past studies shows that the price elasticity of water demand tends to be greater for outdoor or so-called discretionary uses, and also that consumers are more responsive to price changes the longer they have to adapt (Renwick and Green 2000; Dalhusien et al. 2000). The observation that outdoor use is more price elastic than indoor use provides support for the use of seasonal pricing to reduce water consumption in periods of high demand and reduced supplies, such as the summer months. The finding that the price elasticity of demand can be much greater in the long run than the short run is important for water authorities when considering the impact of volumetric water price increases on water conservation (Nauges and Thomas 2003). Water demand is also likely to be more price elastic the higher is the real volumetric price because water charges will account for a larger share of household expenditures.

2.2 Household and Residential Characteristics

Factors other than price and income have been shown to effect residential water demand. In terms of household characteristics, a factor that has a positive effect on household water consumption is the number of people at a residence (Hanke and Maré 1984; Lyman 1992). The age distribution within the household has also been shown to affect residential water use with older people, all else equal, consuming less water than younger people (Lyman 1992). Nauges and Thomas (2000) using data from France support this finding and show that communities with more seniors have lower water consumption. By contrast, Schleich and Hillenbrand (2008) find the converse, namely, that as people get older they consume *more* water per person.

Residential characteristics associated with houses and properties have, in some studies, been shown to affect household water consumption. Nieswiadomy and Molina (1989) find a statistically significant effect that household water consumption increases with house size, and also lawn size. Lyman (1992) also finds a statistically significant and positive effect on household water consumption from lawn size, as does Renwick and Green (2000). Lot size also appears to be associated with a lower price elasticity of demand (Mansur and Olmstead 2007). Nauges and Thomas (2000, p. 83) using French data from 116 communities find that, all else equal, the older the house the more water is consumed. This effect is attributed to higher leakages.

Domene and Sauri (2005) use Spanish data to test the affect of housing density on water consumption and find that 'higher density' households in apartments with fewer water fixtures and who do not have outdoor gardens use a lower amount of water per household than households in 'mid-density' or 'low-density' housing. They find that the installation of water saving devices and water saving behaviors reduce water consumption. Using household data from England, Gilg and Barr (2006) find that water saving behaviors are positively associated with respondents' status as owner occupiers, whether they have a tertiary education, are members of community groups and are 'committed environmentalists'.

3. Survey Data

The data for our analysis comes from an environmentally-related questionnaire implemented using a web-based access panel by the OECD Secretariat. The survey includes approximately 10,000 respondents in ten OECD countries (Australia, Canada, Czech Republic, France, Italy, Korea, Mexico, Netherlands, Norway and Sweden). Respondents were asked a series of questions regarding their household characteristics (age, income, employment status, residence, etc.), environmental attitudes and general activities (concern about the environment, participation in civil society, etc.) and household environmental behaviors and actions (waste and recycling, transportation choices, energy use, organic food consumption, gender differences, and water use). Definition of the variables used in the analysis are provided in Appendix A and the questions asked in the survey instrument in terms of environmental attitudes and water use are provided in Appendix B.

Summary statistics of the key continuous variables are provided in Table 1. It shows that of the 10,251 households in the survey up to 1,660 provided details about their water consumption. As a proportion of the households responding to the question whether they face water charges (see question 87 in Appendix B), 80 per cent stated that they were subject to such charges, and as a proportion of these households, 84 per cent incur water charges based on their level of consumption (see question 89 in Appendix B).

Table 1 indicates there is a large amount of variation in the data for the key variables across the surveyed households. Summary of the observations per country and the mean and median values for water consumption by household (kL per household), water price (€/kL), household income (€), household size (# people) and size of residence (square meters) are provided in Table 2.

The substantial differences between the mean and median values for water consumption by household in Table 2 are caused by the large consumption values provided by some respondents. In the estimation, only responses in the range of 40-4,000/kL per year were included in the models to control for these outliers. Those countries with the highest median levels of water consumption (Korea and Mexico) have the lowest average water price. Similarly, the country (France) with the lowest average levels of residential water consumption has the highest average water price. Measures of household income by country reflect the relative rankings of per capita income in the OECD with Norway having the highest average income and Mexico the lowest. Differences in household size reflect, to a great extent, variation in the demographic transition across countries. Countries with younger populations (such as Korea and Mexico) have the largest households which, coupled with lower average water prices, helps to explain their high levels of household water consumption. Although there is considerable variation in residence size across the ten countries, there is no one-to-one relationship between residence size and water consumption by country.

Data Corroboration

Given that the data were obtained from a direct survey, it is useful to compare and corroborate the responses to other data sources. Table 3 provides various estimates of per capita residential water consumption in liters per day for the ten OECD countries included in the survey. A comparison between the values from previously published sources and those from the OECD (10) survey indicates the median survey responses are similar to that reported in the literature. This suggests, overall, respondents provided reasonable estimates of their water consumption (see question 90 in Appendix B).

Another way to compare the results from the survey to previous studies is to use the burden of water charges as a percentage of income or household expenditures. Unlike cross-country comparisons using water prices, there is no need to make conversions into a common currency and over time as the water burdens are directly comparable because they are measured as percentages. A comparison from two published data sources of the average burden (OECD 1999b and 2003) to those calculated from the survey is provided in Table 4. With the exception of the water burden for Canada and Sweden, the ratios calculated from the survey are very similar to those reported earlier by the OECD.

The calculated price elasticities of demand can also be used for comparative purposes. Figure 1 shows that for all ten countries there is an inelastic price elasticity of demand that ranges from a low of -0.33 for Norway to a high of -0.88 for Italy. The average price elasticity across the entire sample is -0.56. These price elasticities are well within the range of residential demand elasticities calculated in previous studies. For instance, they all lie well within one standard deviation of the mean price elasticity of -0.41 from a meta-study derived from 64 previous studies containing 296 price elasticity estimates (Dalhuisen et al. 2003). Overall, the survey data appear to be corroborated by previous studies of water consumption, the calculated burden of water charges by households, and estimated price elasticities.

4. Results

The analysis is grouped into two categories. First, we regress water use in thousands of liters (kL) against a range of socio-economic characteristics including whether households are charged according to their actual water consumption and, where relevant, the average price charged (€/kL). The second category of analysis uses ordered probit estimation to regress water saving behaviors against a wide range of continuous and categorical variables. Combined, the analyses seek to answer the following questions:

(1) Is there a significant difference in water consumption between households that face unit water charges and those which do not?
(2) How do general attitudes towards the environment (environmental awareness, membership in environmental organization…) influence water consumption?
(3) How does household water consumption vary with differences in water charges? and
(4) Who would be most adversely affected by increases in average water charges?

4.1 Effect of Unit Water Charges

The estimated annual water consumption (WCONS) by households is regressed against a range of independent variables including a dummy variable equal to one for households where the water bill is based on the amount of water consumed (WFEETYPE_UNIT). The form of the estimated model is found to be log-linear using an artificially nest model developed by Mackinnon et al. (1983). Using the Ramsey (1969) test we fail to reject the null hypothesis of no functional form misspecification in the log-linear model.

Several methods of estimation were employed including weighted least squares (WLS) accounting for heteroskedasticity, ordinary least squares with heteroskedastic-consistent errors, quantile (median) regression, and truncated regression to test the robustness of the results. In all cases for the OECD (10) countries, the coefficient on the dummy variable WFEETYPE_UNIT is negative and statistically significant different from zero at the 5 per cent level of significance. Thus, the survey data show there is a significant difference in water consumption between those households that face volumetric charges and those that do not.

After accounting for all other potential factors (income, household size, employment, ownership status, residential characteristics, environmental concerns, etc.) households that face a volumetric charge will, on average, consume about a quarter less water than households who do not. The WLS results with a full set of independent variables are provided in Table 5. The estimated coefficients on many of the variables are not significantly different from zero at the standard levels of significance, including income. In the general model, the variables that appear to have a statistically significant effect on water consumption are highlighted. They include the number of adults in the household (+), number of children in the household (+), having a higher education (+), residence size (sq. m.) (+), residence age (years) (-), residence in an urban or suburban region (+), and the use of a dual flush toilet (-). With the possible exception of residence age, these finding are consistent with previous water consumption studies. The coefficients on the environmental attitudinal variables do not have a statistically significant effect on water consumption at the traditional levels of significance.

As a check on the robustness of the results a specific model using a general-to-specific modeling approach developed by Hendry (1995) is given in Table 6. The results were obtained using a general-to-specific (Gets) algorithm, implemented in PcGets (Hendry and Krolzig 2001), to select a preferred model. The modeling begins with a general unrestricted model that is ‘congruent’ with the data, i.e., displays no evidence of misspecification and then variables with coefficients that are not statistically significant are eliminated in order to obtain a simpler congruent model that encompasses rival models in the sense that no important information is lost (Hendry 1995, p. 365). Monte Carlo evidence (Krolzig and Hendry 2001; Hendry and Krolzig 2005) indicates that the overall algorithm ensures that model selection is consistent and the size of the model selection process is close to the nominal size of the tests used in the search.

The results given in Table 6 are the final or specific model with right-hand side (RHS) variables included in the specific model then re-estimated using WLS. Overall, the results are similar to the general model in Table 5 for the key variables of interest. In particular, the estimated coefficient on whether households are charged volumetrically for their water use is negative and statistically significant at the 10 per cent level of significance. In the specific but not the general model, the coefficients for the variables whether respondents are employed full-time (EMPL_FT) and whether they are owners of the residence (RESOWNR) are statistically significant from zero.

In summary, there is a statistically significant and negative effect on residential water consumption from charging households on the basis of the volume of water they use. A number of socio-economic and household characteristics variables are also shown to have a statistically significant effect on residential water use. However, there is no statistical evidence that environmental attitudes, as measured in the survey, have an impact on household water consumption.

4.2 Differences in Household Consumption due to Water Charges

To determine the effect of water prices on household water use, we construct a variable equal to the average annual cost of water (€/kL) based on the responses to questions 89 and 90 in the survey instrument (see Appendix B), indicating expenditures and quantities for those customers charged a volumetric price. For those households whose bill is based on their water use, the total annual cost of their water bill (converted to Euros for each country) was divided by the quantity of water used. An average price specification has been applied in at least 17 water demand studies and Arbués et al. (2003, p. 86), who tabulate estimated price elasticities from published sources, find that whether the variable is marginal or average price is not important in explaining elasticity differences. Households with unreasonably large stated levels of water consumption (greater than 4,000 kL/year) or extremely low water consumption (less than 40 kL/year) were deleted from the analysis.

Table 7 presents the results of the overall effects (across all countries) of the average water price, including a full set of independent variables, on water consumption. The coefficient of the average price variable is negative and statistically significant at the one per cent level of significance. It indicates that a one per cent increase in the average water price across households in the OECD (10) would lower water use by about 0.56 per cent.

Statistically significant coefficients on the variables that have a *positive* effect on water use include household income, the number of adults and the number of children in the household and the residence size. The variables that have coefficients that are statistically significant and have a *negative* effect on water consumption include the average volumetric price of water charged to households and whether households have adopted dual flush toilets. A contrary result is that the coefficient on the dummy variable for households who claim to have water efficient washing machines is positive and significant at the 10 per cent level of significance. However, in models where there is correction for heteroskedastic errors using WLS, there is no statistically significant (at the 10 per cent level) coefficient for the water efficient washing machine variable.

A possible concern is that the average water price variables are observed with error because they are constructed from self-reported data. An error in a single variable can bias the corresponding coefficient. Consequently, we generated instrumental variable estimates for the model provided in Table 7 (available from the authors on request). The preferred instrument set establishes binary variables for each country, or alternatively, average water bill by country, designated as rural and urban. By construction, these measures are uncorrelated with the noise component, and correlated with the signal component, yielding a valid instrument. In all cases, the instrumental variable estimates for the price elasticities are statistically significant and comparable to that reported in Table 7. Further, we performed a Hausman test that does not reject the OLS estimates in Table 7, at the 80 per cent confidence level. We find that with the preferred instrument set, the estimated price coefficient for the OECD (10) is -0.456, with a standard error of 0.036.

Table 8 provides a similar set of results to Table 7 but accounts for country effects which are identified by an interaction terms between country dummies and the average price of water. In this regression, the variables that have *positive* and statistically significant coefficients at the one per cent level include the number of adults and the number of children in the households, household income and the size of the residence.

An important result, statistically significant at the one per cent level of significance for all countries, is that an increase in the average water price reduces water consumption. By contrast, there is no evidence that attitudes to the environment or participation in environmental groups or activities, as measured in the survey, have a statistically significant effect on residential water consumption. The country coefficients in Table 8 are the price elasticities of demand from the general model are summarized in Figure 1. The results indicate that households in Italy have the most price elastic response while households in Norway have the least.

Table 9 provides estimates of the effects on water consumption from a full set of independent variables but with country interaction effects identified by country dummies and the natural logarithm of household income. With the exception Mexico, all countries have a positive income effect but only in three countries (Canada, Italy and Sweden) are the estimated coefficients statistically different from zero at the 10 per cent level of significance. However, a characteristic that is likely to be substantially determined by income, residence size, does have a statistically significant effect on overall water consumption.

In summary, higher water prices reduce water consumption in all countries but income is only shown to have a statistically significant effect on consumption in three of the ten countries included in the survey. A robust finding is that the estimated coefficients for the variables on the number of people in the households (adults and children) and residential size are statistically significant and positive such that these variables increase household water consumption.

4.3 Household Effects of Higher Water Charges

To better understand the impact of an increase in water charges on households, Table 10 presents a model that includes interaction terms between low-income households (lower quartile) and high-income households (upper quartile) with the average water price. The results indicate that the coefficient on the high income and price interaction terms is positive and statistically significant from zero at the five per cent level of significance. It implies that higher incomes households would be *less* responsive to changes in the average price of water than medium and low income households. This suggests that higher income households will be less affected than low income households from price changes, and the biggest proportional change in residential water consumption will come from low and medium income households. A test of the effect of the number of people in the household on water consumption and the average price of water was also performed. Coefficients of the interaction terms between the number of people in the household and the average price of water, however, indicate that there is no statistically significant difference in the responsiveness in water use to changes in the average price of water based on household size.

Table 11 summarizes the substantial differences in the average income of households across the ten countries and the average price paid for water in €/kL. The median value of the average price paid for water over the relevant sub-sample is 1.30 €/KL with the lowest value observed for Mexico (0.31 €/KL) and the highest for France (2.88 €/kL). The overall proportion of household income spent on residential water consumption is a little less than one per cent and varies from a low of 0.46 per cent in Korea to a high of 1.91 per cent for the Czech Republic. Consequently, equivalent price changes in the ten countries would have different water use responses and distributional impacts.

Figure 2 maps the ratio of the water bill to household income against average income in the OECD (10). It shows that households in the two lowest income deciles spend, as a percentage of income, between two and three times as much on their water bill than households in the highest income decile. This finding is consistent with earlier work that shows that the burden of water charges can be much higher for the lowest decile income group compared to the average burden across all households (OECD 2003, p. 42).

4.4 Water Saving Behaviors

A key policy lever in managing water demand is campaigns to conserve water use through a change in water-use practices. In the OECD (10) survey, respondents were asked to provide an indication of what water savings practices they undertook (question 91 in Appendix B) and their frequency (Never, Occasionally, Often, Always and Not Applicable). Using these responses, a series of ordered probit models were estimated to test whether a range of right-hand side variables increase the probability of undertaking water-savings behaviors.

Table 12 indicates that the largest overall effect on increasing the probability of respondents undertaking water saving behaviors is whether households incur a volumetric water charge. Volumetric water charges increase the probability of: (1) turning off the water while brushing teeth; (2) taking a shower instead of a bath; (3) watering the garden in the coolest part of the day; and (4) collecting rainwater and recycling waste water. A contrary result is obtained to the behavior 'plugging in the sink when washing dishes' where facing water charges appears to *reduce* the probability of this behavior. By contrast to the estimates with household water consumption as the dependent variable, some attitudinal variables, such as having a high level of concern about the environment, do have a statistically significant effect on the marginal probability of undertaking water saving behaviors. However, based on the regressions in sub-sections 4.1 and 4.2, an increased probability of undertaking such behaviors is insufficient to show a statistically significant effect on household water consumption.

Using various assumptions about the water savings associated with household behaviors, it is possible to estimate the overall impact on residential water consumption from facing volumetric water charges. These savings in kL per year for a four person household are presented in Table 13 for illustrative purposes only to show the relative importance of different water saving behaviors using water saving data from Australia. The table indicates that the overall effect of facing volumetric water charges is to reduce household water consumption by about 40 kL per year, provided that a household undertakes all the water saving behaviors. The overall savings from these behaviors combined represents about a quarter of the OECD (10) median annual household water consumption of 140 kL (see Table 1). Interestingly, the proportional effect of water charges on water savings from the five behaviors is similar to the results reported in Tables 5 and 6 where the dependent variable is household water consumption. Namely, households facing volumetric water charges have, on average, between 24-28 per cent lower water consumption than households that do not face volumetric water charges.

4.5 Factors Encouraging Households to Reduce Water Consumption

In question 94 of the survey, respondents were asked to indicate the importance of seven listed factors (practical information on how to save water, money savings, environmental benefits, availability of water efficient products, confidence in water-efficiency labels, lower cost water efficient equipment and mandatory water restrictions) in encouraging them to reduce water consumption. A summary of these responses is provided in Table 14.

The summary responses indicate that price or cost factors are most important in encouraging households to reduce water consumption. In particular, 43 per cent of households responded that ‘money savings’ were very important in reducing water consumption and 85 per cent of households rated this factor as either ‘fairly important’ or ‘very important’. The second most important factor was ‘lower cost water efficient equipment’ that 39 per cent of households rated ‘very important’ and 84 per cent of households rated it as either ‘fairly important’ or ‘very important’.

5. Policy Implications

The survey results provide a number of policy implications for OECD governments interested in managing residential water demand to limit household water consumption. First, and foremost, the results show the effectiveness of charging households for the amount of water they use as a means to promote water conservation. This action alone would, on average, lower household residential water consumption by about one quarter. Second, residential water consumption is price inelastic but the finding that the price elasticity of demand is statistically different from zero in all ten surveyed countries indicates that an appropriate volumetric charge for water can promote water conservation. Third, increases in the volumetric price of water in the absence of a reduction in the fixed fee/connection charge or increased rebates will pose a greater burden on low-income households who spend a more than twice as much of their income on their water bill than do high-income households. Fourth, a volumetric charge for water increases the likelihood that households will undertake several water saving behaviors in some OECD countries. This suggests that water charges can work in tandem with water saving campaigns to reinforce desired water conservation.

The survey results suggest that charging households based on the amount of water they consume is an effective method of regulating water demand. To efficiently price water, however, the volumetric price must not only include the marginal costs of the water supplier but also the external costs that water abstraction and consumption imposes on others. In cases where raising the short-run price of water can postpone supply augmentation and, thus, generate a lower average price of water to consumers in the long run, then a scarcity price component should also be included in the price charged to consumers (Griffin 2001). In periods of low water supply, scarcity pricing can be used to help balance supply and demand; and the extra revenue over and above average costs of supply can be refunded back to households in the form of a reduced fixed water fee (Grafton and Ward 2008). Such an approach has been estimated to generate welfare savings in urban Australia by as much A$ 900 million/year or about $A 150/household per year relative to the use of mandatory outdoor restrictions on water use (Productivity Commission 2008).

6. Conclusions

Using a unique OECD data set of up to 1,600 households interviewed in ten different countries in 2008, we provide a detailed analysis of the factors that affect residential water demand. We find that although water expenditures represent, on average, about one per cent of household income, households that are metered and are charged a volumetric price for their water have statistically significant lower water consumption. Households that incur a volumetric charge for their water also have a greater likelihood they will undertake some water saving behaviors.

Attitudinal characteristics of households, as measured in the survey, do not have a statistically significant effect on water consumption. However, some environmental attitudes increase the marginal probability of undertaking water saving behaviors. The most important causal factor overall, however, in increasing the marginal probability of undertaking water saving behaviors is whether households face a volumetric charge for water. This suggests that water demand management policies that include campaigns to promote water saving behaviors (such as taking a shower instead of a bath) and use water saving devices (such as dual-flush toilet) would be more effective if households faced a volumetric charge for their water consumption.

The key policy implication of the study is that metering and charging consumers on the basis of the water they consume is highly effective at managing residential water demand. In all ten countries there is a robust, statistically significant and negative relationship between the average price of water faced by households and household water consumption. For the OECD (10) countries as a whole, a one per cent increase in the average price of water will reduce household water consumption by about half of one per cent.

Appendix A: Definition of Variables

AGE — age (from Q4)
= 2008-BIRTHYR (with BIRTHYR = 1931 for 'before 1932')

ADULTS — number of adults (from Q5)

CHILDREN — number of children (from Q6)

HHOLDSIZE — number of people of the household
= ADULTS + CHILDREN

HIGHEDUC — dummy: having high education (from Q8)
=1 for diploma / bachelor / postgraduate

EMPL_FT — dummy: having full-time job (from Q9)
=1 for full-time job, i.e. EMPL =1

EMPL_PT — dummy: having part-time / casual job/student (from Q9)
=1 for part-time /casual job/student, i.e. EMPL= 2 or EMPL =7

INCOME_CONT — income in EUR (from Q11)

LINCOME_CONT — = ln of income

LINCOME — dummy: having low income (from Q11)
= 1 if the income of the household is in the two lowest classes of income, i.e. INCOME_CLASS = 1 or INCOME_CLASS = 2

HINCOME — dummy: having high income (from Q11)
= 1 if the income of the household is in the two highest classes of income, i.e. INCOME_CLASS = 11 or INCOME_CLASS = 12

RESOWNR — dummy (from Q13)
= 1 if the household owns the residence
= 0 if not

RESDSIZE — size of residence (m2)
Calculated from Q15A: using interval averages and using lower limit for the last interval

GRDNSIZE — size of garden (m2)
Calculated from Q15B: using interval averages and using lower limit for the last interval

RESDROOMS — number of rooms (excluding bathrooms) from Q16

RESTYPE_HOUSE — dummy: living in a detached or semi-detached house (Q14)
=1 if RESTYPE = 3 or RESTYPE = 4

AREADESC_URBN — dummy: living in an urban or suburban region (from Q17)
=1 if AREADECS = 3 or AREADESC = 4

RESDAGE — house age (years)
Calculated from Q19 : using interval averages and using lower limit for the last interval

CAN, NLD, FRA, MEX, ITA, CZR, SWE, NOR, AUS, KOR: — dummies variables for countries: Canada, Netherland, France, Mexico, Italy, Czech Republic, Sweden, Norway, Australia, Korea (from H_COUNTRY)

ENVR_RANK — ranking of environmental concerns (from Q22_3)
Values 1-6, lower values mean more concerns about environment

WPOL	degree of concern about water pollution (from Q23_4) = WPOL_LKRT, except that value “5” is replaced by “.”. Values 1-4, higher values means higher concern degree
NRSC	degree of concern about natural resource depletion (from Q23_5) = NRSC_LKRT, except that value “5” is replaced by “.”. Values 1-4, higher values mean higher concern degrees
VOTE	dummy: voted in the past 6 years (from Q24) =1 if VOTENATL=1 or VOTELOCL = 1
TIMEENVR	dummy (from Q25_2) =1 if supported / participated in activities of an environmental organization
ENVMEMBER	dummy: member / contributor / donator of an environmental organization (from Q27) =1 if ENVMEMBER = 1; =0 if ENVMEMBER=2
BETTRENV	degree of agreeing that each household can contribute to a better environment (from Q28) = BETTRENV_LKRT except that value “5” is replaced by “.”. Values 1-4, higher values mean higher degrees of agreeing
OVRSTATE	degree of agreeing that environmental impacts are frequently overstated (from Q28) = OVRSTATE_LKRT except that value “5” is replaced by “.”. Values 1-4, higher values mean higher degrees of agreeing
FUTRGNRS	degree of agreeing that environmental issues should be dealt with primarily by future generations (from Q28) = FUTRGNRS_LKRT except that value “5” is replaced by “.”. Values 1-4, higher values mean higher degrees of agreeing
TECHPROG	degree of agreeing that environmental issues should be resolved primarily through technological progress (from Q28) = TECHPROG_LKRT except that value “5” is replaced by “.”. Values 1-4, higher values mean higher degrees of agreeing
NOTCOSTS	degree of agreeing that environmental policies should not cost me extra money (from Q28) = NOTCOSTS_LKRT except that value “5” is replaced by “.”. Values 1-4, higher values mean higher degrees of agreeing
ENVATTID_INDX	reflect attitudes to environment, constructed from Q28. Lower values mean better attitude towards environment
WCHRG	dummy: being charged for water consumption (from Q87) =1 if WTRCHRG = 1; = 0 if WTRCHRG = 2
WFEETYPE_UNIT	dummy: being charged according to amount of water used (from Q89, Q87) = 1 for households being charged according to amount of water used, =0 for households facing flat fee or not being charged)
WCONSYR	volume of water used (kL) (from Q90G2_1)
WCONS	volume of water used (kL)

= WCONSYR except that values < 40 or > 4000 were treated as outliers and were replaced by "."

LWCONS = ln(WCONS)

WEXPS cost for water consumption per year (EUR)
Calculated from Q90G1_1 after changing the unit into EUROS by the provided nominal exchange rates

WRICE water price (EUR / kL)
= WEXPS/WCONSYR

WPRICEUNIT = WPRICE if WFEETYPE_UNIT =1 (i.e. WPRICEUNIT have values only if the household facing unit water charges)
Values 0 or >= 10 were treated as outliers and replaced by "."

LWPRICEUNIT = ln(WPRICEUNIT)

WBHV_TETH_1: frequency level of "turn off water while brushing teeth" behavior (from Q91_1)
= WBHV_TETH after changing the value "5" into ".". Values 1-4, higher values mean more frequent

WBHV_SHWR_1: frequency level of "take shower instead of bath specifically to save water" behavior (from Q91_2)
= WBHV_SHWR after changing the value "5" into ".". Values 1-4, higher values mean more frequent

WBHV_PLUG_1: frequency level of "plug the sink when washing dishes" behavior (from Q91_3)
= WBHV_PLUG after changing the value "5" into ".". Values 1-4, higher values mean more frequent

WBHV_COOL_1: frequency level of "water garden in the coolest part of the day to reduce evaporation and save water" behavior (from Q91_4)
= WBHV_COOL after changing the value "5" into ".". Values 1-4, higher values mean more frequent

WBHV_RAIN_1: frequency level of "collect rainwater or recycle waste water" behavior (from Q91_5)
= WBHV_RAIN after changing the value "5" into ".". Values 1-4, higher values mean more frequent

WBHV_TETH_2 = WBHV_TETH_1, except that WBHV_TETH_2 = 6 if WBHV_TETH_1 = 3 or WBHV_TETH_1 = 4, i.e. WBHV_TETH_2 =6 for the answers "Often" and "Always"

WBHV_SHWR_2, WBHV_PLUG_2, WBHV_COOL_2, WBHV_RAIN_2 are constructed in the same way as WBHV_TETH_2

WINV_WMCH_1 dummy: having water efficient washing machine from Q92_1
=1 if WINV_WMCH =1 or WINV_WMCH =3

WINV_DUAL_1 dummy: having low volume of dual flush toilet from Q92_2
=1 if WINV_DUAL = 1 or WINV_DUAL = 3

WINV_LOWF _1 dummy: having water flow restrictor taps / low flow shower head from Q92_3
=1 if WINV_LOWF =1 or WINV_LOWF =3

WINV_RAIN _1 dummy: having water tank to collect rainwater from Q92_4
=1 if WINV_RAIN = 1 or WINV_RAIN = 3

WBHV_EXPS the importance level of 'money saving' in encouraging the household to reduce water consumption. Values 1-4, higher values mean more important.

Groups of interaction variables:

(1) Interactions with ln of water price

AUSLPRICE=AUS*LWPRICEUNIT
CANLPRICE=CAN*LWPRICEUNIT
CZRLPRICE=CZR*LWPRICEUNIT
FRALPRICE=FRA*LWPRICEUNIT
ITALPRICE=ITA*LWPRICEUNIT
KORLPRICE=KOR*LWPRICEUNIT
MEXLPRICE=MEX*LWPRICEUNIT
NLDLPRICE=NLD*LWPRICEUNIT
NORLPRICE=NOR*LWPRICEUNIT
SWELPRICE=SWE*LWPRICEUNIT

LOWINCOMELPRICE=LINCOME* LWPRICEUNIT
HIGHINCOMELPRICE=HINCOME* LWPRICEUNIT

(2) Interactions with ln household income

LINCOME_AUS =AUS*LINCOME_CONT
LINCOME_CAN =CAN* LINCOME_CONT
LINCOME_CZR =CZR* LINCOME_CONT
LINCOME_FRA= FRA* LINCOME_CONT
LINCOME_ITA = ITA* LINCOME_CONT
LINCOME_KOR = KOR* LINCOME_CONT
LINCOME_MEX = MEX* LINCOME_CONT
LINCOME_NLD = NLD* LINCOME_CONT
LINCOME_NOR = NOR* LINCOME_CONT
LINCOME_SWE = SWE* LINCOME_CONT

LOWINCOMEPRICE=LINCOME* WPRICEUNIT
HIGHINCOMEPRICE=HINCOME* WPRICEUNIT

Appendix B: Selected Questions from the OECD (10) Survey Instrument

Attitudinal Characteristics

22. Please rank the following issues in order of their importance to you.
1 stands for the most important and 6 for the least important.
Drag or double click on an issue on the left to move it to the right hand side. If you want to reorder an issue once it is on the right hand side, select it and then use the up and down arrows

1. International tensions (terrorism, war)
2. Economic concerns (unemployment, inflation)
3. Environmental concerns (waste, air pollution)
4. Health concerns (Bird flu, AIDS)
5. Social issues (poverty, discrimination)
6. Personal safety (crime, theft…)

23. How concerned are you about the following environmental issues?
Please select one answer per row

	Not concerned	Fairly concerned	Concerned	Very concerned	No opinion
Waste generation					
Air pollution					
Climate change (global warming)					
Water pollution					
Natural resource depletion (forest, water, energy)					
Genetically modified organisms (GMO)					
Endangered species and biodiversity					
Noise					

Have you voted in any of the following types of elections in the past 6 years?
Please select all that apply

1. National elections
2. State elections
3. Local government elections

98. None of the above

25. In the past 24 months have you given any of your personal time to support or participate in activities of any of the following types of groups/ organisations?
Please select as applies

1. Parent-teacher association
2. Environmental organisation
3. Local community organisation
4. Charitable organisation

97. Other association/ organisation
99. None of the above

27. Are you currently a member of, or contributor/donator to, any environmental organisations?

1. Yes

2. No
3.

28. To what extent do you agree with each of the following statements? *Please select one answer per row*

	Strongly disagree	Disagree	Agree	Strongly agree	No opinion
Each individual/household can contribute to a better environment					
Environmental impacts are frequently overstated					
Environmental issues should be dealt with primarily by future generations					
Environmental issues will be resolved primarily through technological progress					
Environmental policies introduced by the government to address environmental issues should not cost me extra money					

29. Please rank the following sources of information on environmental issues in terms of their trustworthiness.
1 stands for the most trustworthy and 5 for the least trustworthy

1. Independent researchers and experts
2. National/ Local governments
3. Environmental non-governmental organisations (NGOs)
4. Consumers' organisations
5. Producers' and retailers' associations

31. For each of the following categories, how often does your household choose to use the products listed, rather than the alternatives?
Please select one answer per row

	Never	Occasionally	Often	Always	Don't know
Paper with recycled content (e.g. stationery)					
Products with reduced toxic content (e.g. environmentally friendly cleaning products)					
Refillable containers (e.g. bottles, washing detergents)					
Reusable shopping bags					

<u>Water Use</u>

87. Is your household charged for water consumption in your primary residence?

1. Yes
2. No
3. Not sure

IF Q87=2, ASK Q88

88. What would best describe your situation in your primary residence?

1. Not connected to the mains water (using a well/bore, a rainwater tank)
2. Connected to the mains water but not charged for water consumption
97. Don’t know

IF Q87=1, ASK Q89

89. How is your household charged for water consumption?

1. Charged according to how much water is used (e.g. via a water meter)
2. Flat fee (e.g. lump sum included in charges or rent)
97. Don’t know

ASK IF Q87 = 2

90. Approximately how much was the total annual cost for water consumption for your primary residence?

Please indicate if possible amount in $ and corresponding annual consumption in kL

Amount in $ per year *Please provide answer to the nearest dollar*	Volume of water consumed in kL

91. How often do you do the following in your daily life?
Please select one answer per row

	Never	Occasionally	Often	Always	Not applicable
Turn off the water while brushing teeth					
Take showers instead of bath specifically to save water					
Plug the sink when washing the dishes					
Water your garden in the coolest part of the day to reduce evaporation and save water					
Collect rainwater (e.g in water tanks) or recycle waste water					

94. How important are the following factors in encouraging you to reduce your water consumption?

	Not at all important	Not important	Fairly important	Very Important
Practical information on things you can do to save water at home				
Money savings				
Clear importance of the environmental benefits of saving water				
Availability of water-efficient products				
Confidence in water-efficiency labels				
Lower cost of water-efficient equipment				
Mandatory water restrictions (e.g. periodic bans on watering garden)				
None of the above **(code 99)**				

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Table 1
Summary Statistics of Key Continuous Variables

	WCONS	INCOME_CONT	WPRICEUNIT	HHOLDSIZE	# ADULTS	# CHILDREN	RESDSIZE	GRDNSIZE	RESDAGE
Mean	293.6018	30258.16	1.77	2.89	2.24	0.65	101.25	77.22	31.55
Median	140.0000	25800.00	1.3	3.00	2.00	0.00	75.00	30.00	22.50
Maximum	4000.000	124361.1	9.87	10.00	5.00	5.00	200.00	300.00	80.00
Minimum	40.00000	239.8394	7.23E-05	1.00	1.00	0.00	12.50	0.00	2.50
Std. Dev.	489.1133	21633.08	1.74	1.45	1.02	0.96	50.70	107.01	22.91
Skewness	4.307166	1.278477	1.72	0.77	0.91	1.47	0.43	1.32	0.76
Kurtosis	24.80278	5.023552	6.49	3.63	3.40	4.67	2.30	3.08	2.56
Jarque-Bera	38011.79	4223.429	1,660.495	1,177.438	1,475.77	4,924.06	491.48	2,745.37	1,026.16
Probability	0.000000	0.000000	0.00	0.00	0.000000	0.00	0.00	0.00	0.000000
Sum	487379.0	2.88E+08	2,937.67	29,639.00	23,004.00	6,635.00	962,150.0	73,0375.0	308,042.5
Sum Sq. Dev.	3.97E+08	4.46E+12	5,044.44	21,602.94	1,0747.33	9,486.47	24423348	1.08E+08	5,123,492.
# Observations	1660	9533	1,660	10,251	10,251	10,251	9,503	9,458	9,765

Notes:

1. See Appendix A for definition of variables.

Table 2
Mean and Median Values for Key Variables by Country and OECD (10)

	Water Consumption (kL/year)			Water Price (€/kL)			Household Income (€/year)			Household Size (# persons)			Residence Size (sq. meters)		
	Mean	***Median***	***N***	***Mean***	***Median***	***N***	***Mean***	***Median***	***N***	***Mean***	***Median***	***N***	***Mean***	***Median***	***N***
Australia	442	190	163	1.292	0.662	177	34981	31138	913	2.872	3	1006	93	75	701
Canada	491	194	52	1.346	0.880	53	38548	33841	932	2.632	2	1003	115	125	853
Czech Republic	200	105	193	1.805	1.440	191	11710	10211	636	3.023	3	701	89	75	669
France	130	100	338	3.108	2.875	323	32349	30650	1007	2.568	2	1075	96	75	1057
Italy	404	200	256	1.188	0.929	252	30735	26000	1300	3.119	3	1417	110	125	1400
Korea	508	220	111	0.667	0.361	157	24912	21617	946	3.704	4	1000	92	75	982
Mexico	407	265	201	0.709	0.314	196	6782	5158	948	3.814	4	1009	106	75	951
Netherlands	180	102.5	198	2.277	1.935	189	28467	25800	948	2.296	2	1015	89	75	896
Norway	183	140	57	2.510	1.717	35	58627	53023	968	2.556	2	1019	121	125	996
Sweden	215	130	91	2.618	2.357	87	28743	25239	935	2.309	2	1006	94	75	998
OECD (10)	294	140	1660	1.770	1.302	1660	30258	25800	9533	2.891	3	10251	101	75	9503

Table 3: Comparison of average water consumption per head per day

Estimate of per capita household water consumption
Litres per head per day (lhd)

Country	1970	1975	1980	1985	1990	1991	1992	1993	1994	1995	1996	1997	2004	2008	**OECD 2008 *Median***
Australia		256	285								268		236[a]	230[b]	**192**
Canada		255				350					326				**263**
Czech Republic		138	157	165			137			121		113			**103**
France												137			**110**
Italy			211					251		249		213		195[b]	**205**
Korea		62	69	103		160	164	169	181	175	181	183			**186**
Mexico															**182**
Netherlands				122	130	128	129	125	128	129	130			130[b]	**137**
Norway			154	175								140		190[b]	**151**
Sweden	229	207	196	195	197	195	201	203	199	191				180[b]	**137**

Sources:
Data 1970 - 1997: *The Price of Water - Trends in OECD Countries*, OECD (1999a), p.19
Data 2004, 2006: Calculated from *International Statistics for Water Services*, IWA (2008), p.10 and Productivity Commission 2008 (p. 23, using data for Sydney and assuming 4 person household)
OECD 2008 is from this survey

Notes:
1. a = Productivity Commission
2. b = IWA
3. Blank cells indicate data for that period or source is not available

Table 4: Comparison of the Burden of Water Charges as Percentage of Income or Expenditures

Country	OECD ([a] = 1999b; [b] = 2003)			Productivity Commission (2008, p. 21)[1]	OECD 2008 survey
	year	denominator	%	%	%
Australia	1996	income	0.79[a]	0.65	0.62
Canada	1996	income	1.05[a]		0.74
Czech Republic	1996	income	2.2[a]		1.91
France	1995	income	0.9[b]		1.01
Italy	1997	expenditures	0.7[b]		0.90
Korea	1997-98	expenditures	0.6[b]		0.46
Mexico	2000	income	1.3[b]		1.42
Netherlands	1999	income	0.6[b]		0.75
Norway	1996	income	0.45[a]		0.50
Sweden	1996	income	0.59[a]		0.98

Notes:

1. Based on New South Wales and as a percentage of total expenditure on goods and services in 2003-2004.
2. OECD (1999b) data refers public water supply and is obtained from Table 22.
3. OECD (2003) data refers to public water supply and is obtained from Table 2.2.
4. Blank cells indicate data not available.

Table 5

Water Consumption, Volumetric Pricing and a Full Set of Independent Variables

Dependent Variable: LWCONS
Included observations: 1,429
White Heteroskedasticity-Consistent Standard Errors & Covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
WFEETYPE_UNIT	-0.243224**	0.113194	-2.148724	0.0318
INCOME_CONT	-1.36E-07	1.35E-06	-0.100743	0.9198
ADULTS	0.228233***	0.028432	8.027391	0.0000
CHILDREN	0.047525*	0.026507	1.792894	0.0732
HIGHEDUC	0.093927*	0.051987	1.806728	0.0710
RESDSIZE	0.001557**	0.000678	2.297326	0.0217
RESDAGE	-0.002045**	0.000939	-2.176515	0.0297
AGE	0.002503	0.002450	1.021496	0.3072
EMPL_FT	0.104526	0.064292	1.625807	0.1042
EMPL_PT	0.094053	0.086535	1.086872	0.2773
RESOWNR	0.099367	0.064533	1.539792	0.1238
AREADESC_URBN	0.120868**	0.055119	2.192870	0.0285
RESTYPE_HOUSE	-0.060780	0.066387	-0.915535	0.3601
VOTE	-0.038623	0.098218	-0.393241	0.6942
TIMEENVR	0.036494	0.086012	0.424290	0.6714
ENVIMEMBER	0.031836	0.079234	0.401805	0.6879
BETTRENV	0.013451	0.037322	0.360413	0.7186
OVRSTATE	0.009539	0.030739	0.310316	0.7564
FUTRGNRS	0.025775	0.026767	0.962929	0.3357
TECHPROG	-0.029311	0.034220	-0.856552	0.3918
NOTCOSTS	-0.018586	0.031341	-0.593039	0.5533
WINV_WMCH_1	0.028629	0.052046	0.550065	0.5824
WINV_DUAL_1	-0.096167*	0.056054	-1.715637	0.0864
WINV_LOWF_1	0.008651	0.051364	0.168430	0.8663
WINV_RAIN_1	-0.075538	0.060718	-1.244090	0.2137
WBHV_EXPS	-0.035792	0.037590	-0.952170	0.3412
C	4.513889***	0.314191	14.36669	0.0000

Weighted Statistics			
R-squared	0.891049	Mean dependent var	5.067772
Adjusted R-squared	0.889029	S.D. dependent var	2.526885
S.E. of regression	0.841765	Akaike info criterion	2.512083
Sum squared resid	993.4139	Schwarz criterion	2.611556
Log likelihood	-1767.883	F-statistic	8.597494

Notes:

1. * = significantly different from zero at the 10 per cent level of significance
2. ** = significantly different from zero at the 5 per cent level of significance
3. *** = significantly different from zero at the 1 per cent level of significance

Table 6 Water Consumption, Volumetric Pricing and a Limited Set of Independent Variables Using a General-to-Specific Modeling Approach and WLS

Dependent Variable: LWCONS
Included observations: 1,535
Weighting series: 1/H52

Variable	Coefficient	Std. Error	t-Statistic	Prob.
WFEETYPE_UNIT	-0.280785*	0.152785	-1.837780	0.0663
INCOME_CONT	-8.94E-07	9.36E-07	-0.955479	0.3395
ADULTS	0.211877***	0.021949	9.653101	0.0000
CHILDREN	0.058416***	0.021349	2.736206	0.0063
HIGHEDUC	0.081053*	0.042362	1.913340	0.0559
RESDSIZE	0.001845***	0.000446	4.137302	0.0000
RESDAGE	-0.002422***	0.000794	-3.050507	0.0023
AGE	0.002091	0.002070	1.010161	0.3126
EMPL_FT	0.093937**	0.046137	2.036028	0.0419
RESOWNR	0.097524*	0.050141	1.945013	0.0520
AREADESC_URBN	0.134740***	0.041641	3.235739	0.0012
WINV_DUAL_1	-0.089158**	0.041023	-2.173345	0.0299
C	4.422778***	0.207145	21.35110	0.0000

Weighted Statistics

R-squared	0.877523	Mean dependent var	5.065657
Adjusted R-squared	0.876558	S.D. dependent var	2.412156
S.E. of regression	0.847496	Akaike info criterion	2.515371
Sum squared resid	1093.175	Schwarz criterion	2.560564
Log likelihood	-1917.547	F-statistic	17.20006
		Prob(F-statistic)	0.000000

Notes:
1. * = significantly different from zero at the 10 per cent level of significance
2. ** = significantly different from zero at the 5 per cent level of significance
3. *** = significantly different from zero at the 1 per cent level of significance

Table 7 Water Consumption and Average Water Price and a Full Set of Independent Variables

Dependent Variable: LWCONS
Method: Least Squares
Included observations: 1,337
White Heteroskedasticity-Consistent Standard Errors & Covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LWPRICEUNIT	-0.561119***	0.035337	-15.87909	0.0000
LINCOME_CONT	0.096618***	0.027577	3.503531	0.0005
ADULTS	0.124511***	0.019885	6.261592	0.0000
CHILDREN	0.053333**	0.020878	2.554516	0.0107
HIGHEDUC	-0.011196	0.040463	-0.276691	0.7821
RESDSIZE	0.001447***	0.000417	3.470829	0.0005
GRDNSIZE	7.37E-05	0.000192	0.384611	0.7006
RESDAGE	0.000970	0.000710	1.367193	0.1718
AGE	0.002479	0.001812	1.368641	0.1713
EMPL_FT	0.018888	0.042237	0.447193	0.6548
EMPL_PT	-0.015266	0.065027	-0.234769	0.8144
RESOWNR	0.025446	0.045884	0.554571	0.5793
AREADESC_URBN	-0.021973	0.039745	-0.552863	0.5805
RESTYPE_HOUSE	0.013700	0.044784	0.305907	0.7597
VOTE	-0.081833	0.065480	-1.249732	0.2116
TIMEENVR	-0.060457	0.063127	-0.957701	0.3384
ENVIMEMBER	-0.006254	0.050689	-0.123384	0.9018
ENVATTID_INDX	-0.016434	0.028573	-0.575142	0.5653
WINV_WMCH_1	0.110527***	0.038189	2.894218	0.0039
WINV_DUAL_1	-0.096283**	0.038609	-2.493763	0.0128
WINV_LOWF_1	-0.020689	0.037170	-0.556602	0.5779
WINV_RAIN_1	0.005824	0.042972	0.135539	0.8922
WBHV_EXPS	0.004115	0.024530	0.167743	0.8668
C	3.596627***	0.325563	11.04741	0.0000

R-squared	0.541789	Mean dependent var	5.119361
Adjusted R-squared	0.533762	S.D. dependent var	0.917419
S.E. of regression	0.626429	Akaike info criterion	1.920224
Sum squared resid	515.2382	Schwarz criterion	2.013535
Log likelihood	-1259.670	F-statistic	67.49958
		Prob(F-statistic)	0.000000

Notes:
1. * = significantly different from zero at the 10 per cent level of significance
2. ** = significantly different from zero at the 5 per cent level of significance
3. *** = significantly different from zero at the 1 per cent level of significance

Table 8 Water Consumption, Average Water Price and a Full Set of Independent Variables with Country Price Effects

Dependent Variable: LWCONS Included observations: 1,337 White Heteroskedasticity-Consistent Standard Errors & Covariance				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
LINCOME_CONT	0.071871***	0.026726	2.689208	0.0073
ADULTS	0.140883***	0.019873	7.089269	0.0000
CHILDREN	0.062738***	0.019508	3.216072	0.0013
HIGHEDUC	0.007498	0.037990	0.197374	0.8436
RESDSIZE	0.001373***	0.000405	3.389141	0.0007
GRDNSIZE	9.68E-06	0.000186	0.052016	0.9585
RESDAGE	0.000621	0.000714	0.870046	0.3844
AGE	0.002772	0.001703	1.627523	0.1039
EMPL_FT	0.015618	0.041583	0.375587	0.7073
EMPL_PT	-0.029560	0.063482	-0.465641	0.6415
RESOWNR	0.022537	0.046269	0.487077	0.6263
AREADESC_URBN	0.004361	0.039308	0.110950	0.9117
RESTYPE_HOUSE	0.001805	0.044152	0.040877	0.9674
VOTE	-0.053237	0.063464	-0.838852	0.4017
TIMEENVR	-0.061223	0.060255	-1.016057	0.3098
ENVIMEMBER	0.014292	0.052028	0.274692	0.7836
ENVATTID_INDX	-0.010595	0.027181	-0.389799	0.6967
WINV_WMCH_1	0.099057***	0.036773	2.693749	0.0072
WINV_DUAL_1	-0.098150**	0.038474	-2.551094	0.0109
WINV_LOWF_1	-0.026865	0.037979	-0.707367	0.4795
WINV_RAIN_1	0.009591	0.041236	0.232592	0.8161
WTRBHV_EXPS	0.010085	0.024104	0.418421	0.6757
AUSLPRICE	-0.622924***	0.068333	-9.116016	0.0000
CANLPRICE	-0.667559***	0.139183	-4.796278	0.0000
CZRLPRICE	-0.582838***	0.083549	-6.976013	0.0000
FRALPRICE	-0.549572***	0.034752	-15.81402	0.0000
ITALPRICE	-0.880683***	0.045775	-19.23941	0.0000
KORLPRICE	-0.379152***	0.115549	-3.281308	0.0011
MEXLPRICE	-0.483475***	0.049783	-9.711615	0.0000
NLDLPRICE	-0.624863***	0.059303	-10.53670	0.0000
NORLPRICE	-0.332108***	0.088082	-3.770426	0.0002
SWELPRICE	-0.476778***	0.061378	-7.767828	0.0000
C	3.762899***	0.301279	12.48976	0.0000
R-squared	0.570968	Mean dependent var		5.119361
Adjusted R-squared	0.560440	S.D. dependent var		0.917419
S.E. of regression	0.608243	Akaike info criterion		1.867887
Sum squared resid	482.4270	Schwarz criterion		1.996190
Log likelihood	-1215.683	F-statistic		54.23134
		Prob(F-statistic)		0.000000

Notes:

1. * = significantly different from zero at the 10 per cent level of significance
2. ** = significantly different from zero at the 5 per cent level of significance
3. *** = significantly different from zero at the 1 per cent level of significance

Table 9 Water Consumption, Average Water Price and a Full Set of Independent Variables with Country Income Effects

Dependent Variable: LWCONS
Included observations: 1,337

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LWPRICEUNIT	-0.500960***	0.020056	-24.97845	0.0000
ADULTS	0.144906***	0.014887	9.733764	0.0000
CHILDREN	0.064939***	0.013253	4.900028	0.0000
HIGHEDUC	0.061327**	0.030033	2.041987	0.0414
RESDSIZE	0.001154***	0.000317	3.643674	0.0003
GRDNSIZE	7.71E-05	0.000137	0.564392	0.5726
RESDAGE	0.000257	0.000557	0.462394	0.6439
AGE	0.003643	0.001284	2.836220	0.0046
EMPL_FT	0.008980	0.031477	0.285292	0.7755
EMPL_PT	0.010265	0.048565	0.211375	0.8326
RESOWNR	-0.039232	0.035144	-1.116309	0.2645
AREADESC_URBN	0.010255	0.031383	0.326764	0.7439
RESTYPE_HOUSE	0.054793	0.037901	1.445702	0.1485
VOTE	-0.135117	0.081067	-1.666728	0.0958
TIMEENVR	0.007717	0.058922	0.130973	0.8958
ENVIMEMBER	-0.017998	0.037792	-0.476250	0.6340
ENVATTID_INDX	0.017186	0.019621	0.875888	0.3813
WINV_WMCH_1	0.018267	0.029766	0.613678	0.5395
WINV_DUAL_1	-0.020486	0.027752	-0.738193	0.4605
WINV_LOWF_1	-0.132597	0.026458	-5.011628	0.0000
WINV_RAIN_1	-0.009618	0.034502	-0.278763	0.7805
WBHV_EXPS	-0.008537	0.018828	-0.453387	0.6503
LINCOME_AUS	0.033975	0.026392	1.287322	0.1982
LINCOME_CAN	0.074882**	0.029288	2.556736	0.0107
LINCOME_CZR	0.030074	0.028972	1.038010	0.2995
LINCOME_FRA	0.032811	0.025810	1.271243	0.2039
LINCOME_ITA	0.047102*	0.026674	1.765866	0.0777
LINCOME_KOR	0.009294	0.027323	0.340140	0.7338
LINCOME_MEX	-0.009623	0.030530	-0.315205	0.7527
LINCOME_NLD	0.027728	0.026186	1.058893	0.2898
LINCOME_NOR	0.036277	0.026578	1.364934	0.1725
LINCOME_SWE	0.051366*	0.026525	1.936479	0.0530
C	4.280878	0.281210	15.22306	0.0000

R-squared	0.554976	Mean dependent var	5.119361
Adjusted R-squared	0.544056	S.D. dependent var	0.917419
S.E. of regression	0.619475	Sum squared resid	500.4093

Notes:
1. * = significantly different from zero at the 10 per cent level of significance
2. ** = significantly different from zero at the 5 per cent level of significance
3. *** = significantly different from zero at the 1 per cent level of significance

Table 10 Water Consumption, Average Water Price and Income-Price Interactions

Dependent Variable: LWCONS
Included observations: 1,359
White Heteroskedasticity-Consistent Standard Errors & Covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LINCOME_CONT	0.109053***	0.023993	4.545255	0.0000
ADULTS	0.134007***	0.019246	6.962692	0.0000
CHILDREN	0.055380***	0.019271	2.873707	0.0041
HIGHEDUC	-0.021462	0.037209	-0.576797	0.5642
RESDSIZE	0.001480***	0.000385	3.839986	0.0001
RESDAGE	0.000969	0.000706	1.371386	0.1705
AGE	0.002851*	0.001678	1.699329	0.0895
EMPL_FT	0.010258	0.037200	0.275748	0.7828
RESOWNR	0.023971	0.044608	0.537379	0.5911
AREADESC_URBN	-0.020761	0.038009	-0.546202	0.5850
WINV_DUAL_1	-0.066885*	0.037440	-1.786440	0.0743
WINV_LOWF_1	-0.010855	0.036265	-0.299324	0.7647
LWPRICEUNIT	-0.599684***	0.021861	-27.43205	0.0000
LOWINCOMELPRICE	0.013744	0.061018	0.225238	0.8218
HIGHINCOMELPRICE	0.209174**	0.098638	2.120630	0.0341
C	3.422122***	0.259531	13.18582	0.0000

R-squared	0.550383	Mean dependent var	5.115505
Adjusted R-squared	0.545361	S.D. dependent var	0.918733
S.E. of regression	0.619473	Akaike info criterion	1.891808
Sum squared resid	515.3718	Schwarz criterion	1.953200
Log likelihood	-1269.484	F-statistic	109.5991
		Prob(F-statistic)	0.000000

Notes:

1. * = significantly different from zero at the 10 per cent level of significance
2. ** = significantly different from zero at the 5 per cent level of significance
3. *** = significantly different from zero at the 1 per cent level of significance

Table 11 Summary of Prices, Price Responses and Water Burdens by Country

Country	Median water price (total water cost/total consumption in €/kL)	Water Use Response to Change in Average Water Price	Average water bill (€/year)	Average income (€/year)	Total water bill as % of Total income
Australia	0.66	-0.62	226	36,546	0.62
Canada	0.88	-0.67	332	45,021	0.74
Czech Republic	1.44	-0.58	229	12,008	1.91
France	2.88	-0.55	343	34,015	1.01
Italy	0.93	-0.88	270	30,015	0.90
Korea	0.36	-0.38	116	25,466	0.46
Mexico	0.31	-0.48	104	7,365	1.42
Netherlands	1.93	-0.62	230	30,738	0.75
Norway	1.72	-0.33	318	63,809	0.50
Sweden	2.35	-0.48	394	40,063	0.98
All Countries	**1.30**	**-0.56**	**233**	**27,649**	**0.86**

Table 12 Summary of the Marginal Effects on Probability (often or always) on Water Saving Behaviors

	Marginal effects on Prob("Often" or "Always")				
	Turn off the water while brushing teeth	Take shower instead of bath specifically to save water	Plug the sink when washing dishes	Water the garden in the coolest part of the day to save water	Collect rainwater/ recycle waste water
facing unit water charges	0.1295***	0.0408***	-0.0331***	0.0473***	0.1331***
age (years)	-0.0009**	0.0009**	0.0045***	0.0044***	0.0039***
high education	0.0568***	0.0170***			-0.1423***
having full-time job			-0.0283**		
having part-time job					
income (EUR)	-2.29E-06***	-1.63E-07	1.42E-06***	-8.82E-07***	-2.12E-06***
money saving is more important	0.0339***	0.0298***	0.0135*	0.0424***	0.0333***
house size (m2)	-0.0006***		-0.0004***		-0.0003**
garden size (m2)				0.0004***	0.0005***
number of people	0.0160***	-0.0081***	-0.0076*		0.0210***
residence is a house	0.0678***		0.0921***	0.0859***	-0.1443***
living in urban/suburban	0.0303**		-0.0799***	-0.0262*	-0.0920***
one lower ranking of environmental concerns	-0.0204***	-0.0064**	-0.0159***	-0.0266***	-0.0213***
degree of concern about water pollution	0.0218***		-0.0165**	-0.0147*	
degree of concern about natural resource depletion	0.0293***			0.0410***	0.0396***
voted in elections	0.0367**		0.0303*		0.0395*
participated in environmental activities	0.0722***	0.0259**	0.0782***	0.0652***	0.0979***
member of environmental organizations			0.0344**		0.0400**
degree of agreeing that each individual can contribute to a better environment	0.0360***	0.0299***	0.0226**	0.0405***	

Notes:

1. Black cells indicate the given effect is not statistically different from zero at the 10 per cent level of significance.
2. * = significantly different from zero at the 10 per cent level of significance
3. ** = significantly different from zero at the 5 per cent level of significance
4. *** = significantly different from zero at the 1 per cent level of significance

Table 13 Water Consumption Effect (kL per year) of Residential Water Charges by Water Saving Behaviors

Water Saving Behaviors and Estimated Savings Per Year						
Turn off the water while brushing teeth	Take shower instead of bath specifically to save water	Plug the sink when washing dishes	Water the garden in the coolest part of the day to save water	Collect rainwater	Recycle waste water	**TOTAL**
Per person per year	*Per person per year*	*Per household per year*	*Per household per year*	*Per household per year*	*Per person per year*	*Per household (of 4 people) per year*
-0.688kL	-0.611kL	1.395kL	-3.751kL	-7.235kL	-5.702kl	-37.595kL

Notes:

1. Total water savings based on the assumption of a four person household and assuming 'Never' = 0%, 'Occasionally' = 30%, 'Often' = 60% and 'Always' = 100% of defined water savings.
2. Turning off the tap while brushing your teeth (assume two minutes per time) in the morning and at bedtime can save up to 20 liters/day or 7.3 kL per year based on average tap flows at a rate of 15-30 liters per minute and assumption that brushing of teeth would take 5 liters/minute (source: South Australia Water 2008).
3. Showers of eight minutes duration using water efficiency shower head will use takes 72 liters of water while, on average a bath tub, will hold about 150 liters for a normal bath. Assuming a household member takes a shower instead of bath can, thus, save 78 liters /day or 28.47 kL per person per year (source: Madden and Carmichael 2007).
4. The average tap flows at a rate of 15-30 liters per minutes. Dishwashing by hand in a sink without running the tap continuously takes 18 liters (source: South Australia Water 2008). Estimated water savings from washing in sink is based on assumption it takes five minutes to do the dishes *without* using a plug at a rate of 23.2 liters per minute. This generates savings of at least 98 liters/day or 35.8 kL/year per household if dishes are done once per day.
5. Watering the garden consume around 400 liters per day depending on aspect, vegetation type, soil type and residence size. Watering the garden in the early morning or evening can save up to 50% of water from evaporation (200 liters per day). Assuming the garden is watered every day this will save up to 73 kL per year (source: Edwards 2004).
6. A 5,000 liter water tank connected to 100 square meters of roof when the water is only used for garden watering can provide around 59 kL of water per year depending on the total rainfall and pattern of rainfall and if used for toilet flushing and for the washing machine (source: ACTEW 2007).
7. Recycling grey water from kitchen and bathroom can collect 33.5 kL per capita per year while recycling water from laundry can save up to 13 kL per person per year (source: Troy et al. 2005, pp. 59-62).

Table 14 Importance of Factors Encouraging Reduced Water Consumption

	Summary of the response to Question 94 after adjustment (percentage)			
	Not at all important	Not important	Fairly important	Very important
Practical information on things you can do to save water at home	8	12	51	28
Money saving	7	9	42	43
Clear importance of the environmental benefits of saving water	8	12	50	30
Availability of water-efficient products	7	10	53	30
Confidence in water-efficiency labels	9	18	50	24
Lower cost of water-efficient equipment	7	8	45	39
Mandatory water restrictions	15	25	41	19

Figure titles:

Figure 1: Price Elasticities of Demand by Country and OECD (10)

Figure 2: Total water Bill as a proportion of Total Income for OECD (10)