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Effectiveness of two pricing structures on urban water use and conservation: a quasi-experimental investigation

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Abstract

Residential water demand management using price and non-price measures to conserve water has gained considerable international attention from water utilities over the last few decades. The objective of this paper is to explore the effectiveness of different pricing schemes on water conservation. In this study, we compare the 'conservation-orientedness' of two pricing schemes. These are a uniform pricing scheme and an increasing block tariff scheme (IBT) structure. A quasi-experimental method is used for this purpose involving 150 suburbs in the Brisbane City Council (BCC) in Queensland, Australia for a 4-year period between 2005 and 2008. Our results show there are more conservation benefits associated with an IBT pricing scheme than a uniform pricing scheme.

Keywords

Demand for residential water Increasing block rates Conservation Quasi-experiment Pricing schemes Efficiency Australia

1 Introduction

In recent years, the demand for urban water has been growing globally due to the pressure of economic growth and population expansion. As a result, water utilities have increasingly implemented a range of demand management strategies to conserve water. While traditional methods of education and conservation programs are still playing a role, rate structures have frequently been used as a conservation tool. In particular, in the recent past, pricing policies involving IBT schemes have been adopted in preference to uniform pricing schemes.

The literature on urban/residential water demand has proliferated over time with a changing scope and emphasis including the development of novel econometric techniques. Even though the direct emphasis of these studies is usually not on water conservation itself, many focus on traditional demand models and its variants that indirectly have important implications for water conservation. In particular, these studies explore the responsiveness of demand to price changes, a measure that can be used to devise effective water conservation policies. These studies range from some of the earliest (e.g., Gottlieb 1963) to most recent (e.g., Zhao et al. 2016 and Hung et al. 2017). Furthermore, the literature has extended into studies of non-price tools such as water allocations, use restrictions, public education and free quotas (Nieswiadomy 1992; Dandy et al. 1997; Renwick and Archibald 1998; Andersen 1999; Renwick and Green 2000; Gaudin 2006; Kenney et al. 2008). Studies that compare both price and non-price measures include Martínez-Espiñeira and Nauges (2004) and Olmstead and Stavins (2009).

In this strand of literature, researchers are interested in comparing various rate structures to determine the most effective for water conservation. A study that directly explores this issue in detail is Nieswiadomy and Cobb (1993) which employs a non-experimental means to elucidate the nature of water pricing and finds the IBT scheme is more 'conservation-oriented'. During the last few decades, several studies have been conducted to explore the same question from a different perspective, i.e., whether consumers respond to average or marginal price of water. For example, among many, Stevens et al. (1992) compared the price elasticity between different tariff schemes and concluded that price elasticities were not statistically different across the various price specifications. Foster and Beattie (1981), Schefter and David (1985), Nieswiadomy and Molina (1989) and Timmins (2003) have included both increasing and decreasing block schemes to explore the elasticities. Hewitt and Hanemann (1995) used a discrete choice modeling framework to produce a different set of price elasticities. Olmstead et al. (2003, 2007) employed a piecewise-linear budget constraint created by block pricing to determine the demand elasticities of households facing different tariff schemes. They concluded that behavioral responses to price structure may lead to observed differences in demand. The literature in this area of research is still growing. However, two comprehensive surveys (i.e., Arbués et al. 2003; Worthington and Hoffman 2008) are noteworthy.[1]

Flowing from the above discussion, our study attempts to explore the conservation implications of the IBT employing a quasi-experimental approach. Nataraj and Hanemann (2011) also exploited a natural experiment—an introduction of a three tired pricing scheme—to explore the demand for water and conservation. Their study is the first to add a quasi-experimental approach to the existing water demand literature whilst other studies have typically used non-experimental methods of utility pricing.[2] This approach is considered methodologically superior given it circumvents the problem of omitted variable bias that arises from unobserved, location specific characteristics in cross-sectional data. The longitudinal studies can avoid this problem to a certain extent; however, they often fail to control for other factors that change concurrently with prices (Nataraj and Hanemann 2011). Our study is distinct from Nataraj and Hanemann's (2011) as the unit of analysis is almost identical in all other aspects, differing only in the pricing scheme. This, then, is an ideal methodology with which to compare different pricing policies (see, for example, Reynaud et al. 2005 and Olmstead et al. 2003 for further details). In this regard, our study adds to the literature by addressing the exact nature of the relationship between rate structure changes and residential water demand. Consequently, the present study enables us to empirically identify the most effective scheme between two rate structures in terms of urban water conservation. This is an important policy-relevant outcome that has not been addressed explicitly in the literature.

This study also sheds light into the wider debate on the role of water pricing on economic efficiency.[3] This is achieved by exploring the conservation gains associated with the IBT particularly when municipal utilities face constraints in water availability. Essentially, the outcomes of the study assist policy makers in considering the extent of conservation gains against negative economic consequences—including efficiency loss—arising from use of an IBT.

We obtained data from the BCC, Queensland, Australia, where an IBT scheme for residential water use was introduced in 2006. This introduction, which is similar to a quasi-experimental setting, is important for comparing the effectiveness of the two pricing schemes. Therefore, we considered data recorded for the first six quarters of the period 2005–2008 under a uniform rate and data recorded for the next ten quarters under an IBT scheme to test our hypothesis of the 'conservation-orientedness' of the two pricing schemes.[4]

The key results of the study suggest that moving to an IBT produces a significant negative effect on water consumption, indicating that an IBT structure is more 'conservation-oriented' than a uniform pricing policy.

The rest of the paper is organized as follows: The next section describes the data and methodology used in the econometric estimation of the models. Section three presents the results and section four discusses the implications of the results and concludes the paper.

2 Data and methodology

For this study, we used quarterly data from approximately 150 suburbs in the BCC in Queensland, Australia for a 4-year period, 2005–2008. Brisbane is located on the Eastern Coast of Australia with a population of approximately 1.8 million in 2014 (Australian Bureau of Statistics 2015). The water services during this period were provided by the BCC to all 150 suburbs selected for the study. In the third quarter of 2006 the BCC introduced a three-tiered pricing scheme for water users.[5] Until then, each kilolitre of water for households was priced at AUD 0.89 with a water access charge of AUD 27.50 per quarter. The marginal prices applied in the third quarter of 2006 were AUD 0.91, AUD 0.95, AUD 1.20 for the first 50 kilolitres (kL), 51–75 kL and above 76 kL, respectively. In addition, this scheme included an AUD 0.05 water surcharge for every kL used and an AUD 28.25 water access charge per quarter. These rates have changed every year since the tiered pricing scheme was introduced in the second half of 2006. Table 1 summarizes the changes in water rates under an IBT during the study period. One notable observed change was the introduction of the state government bulk water charges in July 2008. This charge was applied for each KL consumed. Hence, it can be considered that the price of each tier rate increased. This was taken into account in this study by adding it to the tier rate system.

Table 1

Water rates during the study period, 2005–2008

Types of charges	Before 2006 Q3	2006 Q3–2007 Q2	2007 Q3–2008 Q2	2008 Q3–2008 Q4
Tariff under uniform rate	0.89	–	–	–
Tier 1		0.91	1.19 (30.76%)	0.59 (27.73%)
Tier 2		0.94	1.23 (30.85%)	0.63 (26.82%)

Types of charges	Before 2006 Q3	2006 Q3–2007 Q2	2007 Q3–2008 Q2	2008 Q3–2008 Q4
Tier 3		1.2	1.69 (40.83%)	1.12 (21.31%)
State government bulk water charge		–	–	0.93
Water access charge ($ per quarter)	27.5	28.25	35.00 (23.89%)	37.03 (5.80%)

The state government bulk water charge for each KL has been added to each tier rate to estimate the percentage change in water charges. Prices were given in AU$ per kilolitre. Figures within parenthesis are the percentage change from the previous price. The letter, “Q” indicates quarter

We consider the policy changes in water charges from a uniform rate to a block rate as a quasi-experiment. This is because the policy change allows us to analyze the demand for water under two pricing schemes when the other water demand determinants are controlled.

Before presenting the econometric methodology, we provide a description of contemporaneous weather conditions, and non-price policies to validate how we disentangle the effects of change in tariff structure from other effects. In terms of weather, the BCC region was affected by a drought particularly in dam catchments and consequently dry conditions were experienced over the 2006–07 period. As illustrated in Fig. 1a, the monthly rainfall is below the long-term average of the BCC region during most of the quarters in 2006–07.[6] On the other hand, the temperatures recorded in the BCC region during this period do not show a significant deviation from the long-term averages (Fig. 1b).

Open image in new window Fig. 1

Fig. 1

Rainfall and temperature during the study period compared with their long-term averages

Due to these drought conditions, urban water restrictions were introduced in the South East Queensland region as a state government strategy to conserve water. Since 2005, such restrictions have been in place with the BCC imposing their most severe level in November 2007. These level 6 restrictions banned outdoor use of water for established gardens, the washing of vehicles, and filling or topping up of swimming pools, with a publicity campaign launched to encourage residents to reduce water use to less than 140 L per person per day. Prior to these restrictions, the BCC exercised level 5 and level 4 water restrictions commencing, respectively, from April 2007 and November 2006. In the third quarter of 2008 these restrictions were revised, then further relaxed (The details of these restriction levels are given in Beal et al. (2011). Please see Annex 1 for the data table adopted from this source).

These mandatory restrictions were also accompanied by non-mandatory policies such as rebates for water-efficient devices (for example shower taps), dual-flush toilet suites and rainwater tanks.[7]

With the above background in mind, we attempt to examine whether an IBT scheme encouraged water conservation. The treatment group in this experiment was subject to the introduction of an IBT scheme while the control group was subject to the uniform pricing scheme. Because we were interested in investigating the treatment effect of this experiment it was hypothesized that if an IBT scheme was ‘conservation-oriented’, domestic water consumption of the average household should decline with the new pricing policy. To empirically test this, we conducted a simple regression analysis using the water consumption per quarter of the average household (Q_{it}) in each suburb as the dependent variable.[8] We employed a dummy variable to represent the two pricing schemes (0 = uniform pricing schemes, and 1 = IBT). From each suburb, we selected the average household's water consumption over sixteen quarters: from the first quarter of 2005 to the fourth quarter of 2008. The following model specification enabled us to compare the situation with households with a uniform pricing regime and those with an IBT. Our model (hereafter Eq. 1) was specified as follows:

$$Q_{it} = \beta_{0} + \beta_{1} {\text{Tr}}_{it} + \beta_{2} {\text{AP}}_{it} + \beta_{3} {\text{HI}}_{it} + \beta_{4} ({\text{HI}}_{it})^{2} + \beta_{5} {\text{HS}}_{it} + \beta_{6} {\text{Rf}}_{t} + \beta_{7} {\text{Rt}}_{it} + u_{it} ,$$

(1)

where, Q_{it} average household water consumption of *i*th suburb at quarter *t*, Tr_{it} Dummy variable representing treatments of price in *i*th suburb in *t*th quarter (0 = uniform pricing structure and 1 = IBT), AP_{it} Average price faced by households in *i*th suburb in the *t*th quarter, HI_{it} Quarterly mean household income in *i*th suburb in the *t*th quarter, $(\text{HI}_{it})^2$ Square of the quarterly mean household income in *i*th suburb in the *t*th quarter, HS_{it} Average household size in *i*th suburb in *t*th quarter, Rf_t Total rainfall received over a quarter in mms, Rt_{it} Dummy variable to capture the water restrictions in place, U_{it} Error term (assumed to have usual properties).

We have included several control variables including price, contemporaneous weather and several socioeconomic variables that essentially allow the IBT dummy to isolate the tariff structure changes. Firstly, we consider the price effects. The switch in pricing policy provided households with two changes. The first related to the changes in the average price, while the second related to changes associated with the structure of the pricing scheme. The treatment dummy captured the changes associated with the latter. To isolate the changes associated with average price that consumers face we included the average price (AP) in our model. This was calculated by dividing the total water bill by the total consumption over a quarter.

In addition to the price variable, the change in tariff structure is contemporaneous with drought conditions across the BCC region. This effect is captured by the rainfall, measured in terms of quarterly total received by each suburb (Rf_t). As shown in Fig. 1a, the monthly rainfall received by the BCC region is less than the long-term average which indicates drought conditions across the city. We consider that consumers' current water use decisions are affected by prior rainfall received in the area. Consequently lagged rainfall has been included into the model to control for the weather effects. Since the temperature variable does not show a significant deviation from the long-term pattern, we have not included this in the model.

In response to the severe drought conditions BCC employed other water policy changes, particularly water restrictions during 2006/07. We ascribe a dummy variable (Rt_{it}) to capture these restrictions where the water restriction dummy corresponds to (Rt_{it})—the severity of the restrictions. Three different levels of restrictions were included in the model based on the severity of the restrictions following the restriction levels declared by the Queensland water Commission (see Annex 1). The levels are: no restrictions = 0, moderate restrictions from period from 2005 Q2 to 2006 Q3 = 1 and severe restrictions from period 2006 Q4 to 2008 Q2 = 2.[9] Following the heavy rainfalls received after 2008, construction of water grids and a desalination plant, the water restrictions were revised and BCC is now under general water conservation measures which are consistent across all councils in the region.

To analyze the income effect of the price change on water demand, we included mean household income (HI) of the suburb. This data was obtained from the Australian Taxation Office's (ATO) annual publications from 2005 to 2008. The BCC classified households which earned a gross income of AUS$ 88,210 and above, per annum, as high income earners. According to this classification, in the richest suburb more than 63% of the population were high income earners. On the other hand, this figure was slightly above 5% for income earners in the poorest suburb in the study period. This provides an indication of the variation in mean incomes across BCC suburbs. We also include the squared term of the income (HI^2) because, firstly, consumption may be more sensitive to low incomes than to high incomes. Secondly, the squared term was included because high income earners can afford water-efficient technologies in their households to reduce water consumption.

Based on the availability of data, other control variable included in the analysis was average household size (HS). The data for this were obtained from the BCC community profile which was based on the Australian Bureau of Statistics household survey data (BCC 2011).

First, we employed an OLS estimator (with robust standard errors) for the pooled sample to estimate conservation-orientedness (Eq. 1). We also employed a fixed effects (FE) and random effects (RE) estimator. The Hausman test (Hausman 1978) was used to test the null hypothesis that the random effects (RE) estimator was valid.

It can be argued that the BCC made the recent policy change due to the recent history of increases in water demand and drought conditions. This implies that a change in the pricing structure is endogenously determined with demand. Even though the FE models partially addresses this type of endogeneity issue by eliminating suburb-specific unobserved heterogeneity that is time-constant, both FE and RE models do not produce consistent estimates. We have employed another approach to address endogeneity in the context of static environments. We used a static panel instrumental variable (IV) estimation that produces consistent estimators. The instruments for this type of analysis have to be carefully chosen and fulfill the requirement that they are uncorrelated with the error term while correlated with the endogenous variable.[10] In this study, the endogenous regressor, the IBT dummy, was instrumented using the lagged average quarterly rainfall of the state of Queensland in which the BCC is located. The instrumental variable with fixed effects (FE 2SLS) model and robust standard errors were used to provide better estimates that equally control for suburb specific heterogeneity and endogeneity arising from simultaneity. We then undertook several tests to verify the validity of the instruments used.

3 Results and discussion

The results of Eq. (1) used to test whether an IBT structure was conservation-oriented are presented in Table 2. We estimated several forms of the equation to test robustness and improve model estimation properties. Almost all the models point to the same conclusion in terms of coefficient signs and their significance in determining conservation behaviors of users in response to tariff change. For the first two models, the data appear to fit reasonably well with R^2 equalling an average 0.65. The first is a pooled OLS model although, due to the well-known inconsistency of these estimators, panel FE and RE models are estimated. The results of the diagnostic test (the Hausman test), used to indicate the better of the FE and RE models, favored the FE model. The FE2SLS model addresses the issue of endogeneity by instruments and an FE estimation. Use of the Sargan–Hansen test for over-identifying restrictions suggests that the instruments are valid: that is, they are uncorrelated with the error term. For completeness we report the Random Effects (RE2SLS) model in the last column in which estimates are consistent with expected outcomes.

Table 2

Results of the regressions for the estimation of 'conservation-orientedness' (dependent variable Q_{it})

Variable	OLS	FE	RE	IV (FE2SLS)	IV (RE2SLS)
Tr_{it}	− 7.621 (9.30)**	− 10.268 (8.19)**	− 9.364 (11.90)**	− 9.873 (3.36)**	− 3.939 (2.99)**
AP_{it}	− 21.604 (34.19)**	− 17.556 (18.63)**	− 19.942 (32.61)**	− 15.573 (13.65)**	− 15.978 (29.49)**

Variable	OLS	FE	RE	IV (FE2SLS)	IV (RE2SLS)
HS_{it}	8.675 (15.39)**	11.025 (3.05)**	9.097 (12.07)**	8.303 (2.98)**	7.614 (12.82)**
$1.Rt_{it}$	– 15.154 (22.80)**	– 14.222 (24.18)**	– 14.623 (23.73)**	– 2.578 (2.82)**	– 5.548 (5.81)**
$2.Rt_{it}$	– 11.371 (17.88)**	– 10.496 (17.61)**	– 10.722 (18.12)**	– 4.204 (3.39)**	– 7.384 (13.26)**
$L.Rf_t$	– 0.008 (– 1.38)	– 0.018 (3.41)**	– 0.013 (2.39)*	– 0.011 (2.42)*	– 0.002 – 0.46
HI_{it}	0.008 (8.13)**	0.016 (8.23)**	0.011 (10.19)**	0.019 (4.89)**	0.007 (7.84)**
$(HI_{it})^2$	– 2.8E–07 (6.86)**	– 6.7E–07 (10.54)**	– 4.2E–07 (9.24)**	– 6.5E–07 (6.60)**	– 2.7E–07 (7.12)**
Constant	26.09 (4.66)**	– 25.331 – 1.77	5.264 – 0.82	– 63.415 (2.60)**	13.041 (2.33)*
R^2	0.65	0.66			
Hausman test (χ^2)		41.21 (0.000)[a]			
Sargan statistic (χ^2)				30.597 (0.000)[a]	
Price elasticity before 2006 Q2	– 0.58	– 0.47	– 0.53	– 0.42	– 0.43
Price elasticity after 2006 Q2	– 1.35	– 1.09	– 1.24	– 0.97	– 0.99
N	1982	1982	1982	1849	1849

The dependant variable is the average water consumption per quarter (Q_{it}); ***significant at 1%; **significant at 5%; *significant at 10%. Numbers in parenthesis are standard errors

H Hausman test for the validity of random effects

[a]Probability

Our preliminary calculations show that on average, household water consumption per quarter in BCC suburbs was 54.27 KL during the uniform rate system compared to 34.46 KL under the IBT system. According to these figures, there has been an average reduction of approximately 36.5% in water use after the introduction of new rate structure in BCC. The reasons for this decrease can be, in part, explained using the results of our study.[11] First, the results of tariff shift dummy (Tr_{it}) suggest the shift from uniform pricing to an IBT policy has a significant negative effect on the quarterly water consumption of the suburb. Besides the tariff structure change, as expected, consumers have been responsive to the average price of the domestic water. The average price variable reported in Table 2 has a negative sign in all the models suggesting that there is a significant negative effect on the average quarterly water consumption due to the price rise. The price elasticities reported in the table shows robust pattern of increasing price responsiveness under IBT. The water restriction dummy also produces a strong decrease suggesting that water restrictions in place during the study period lowered water consumption, which is consistent with extant literature (see Andersen 1999; Mini et al. 2015). Furthermore, negative coefficient for the lagged rainfall in the models also implies that consumers concern about the weather variables in their water conservation decisions. In combination, all above factors have significantly lowered water consumption in BCC suburbs. In terms of the magnitudes and significance levels of coefficients of these factors, mean level of price that households face appears to play the most important role in water conservation decisions in BCC. The effect of rate structure change strengthens this negative effect. In light of these findings, it can be concluded that there are greater conservation benefits to be derived from an IBT pricing structure than from a uniform pricing policy.[12] These results also support the literature which describes the notion of extrinsic treatments (e.g., prices and price instruments) producing persistent conservation outcomes as oppose to intrinsic treatments (Ito et al. 2014).

The above outcomes also imply that the conservation outcome of an IBT is positive, producing long-term economic gains in the presence of constrained availability of resources. If these conservation gains are able to offset efficiency losses, then market-based IBTs are, to a certain extent, capable of addressing the issue efficiently (see Olmstead and Stavins 2009, for a discussion of this conclusion). Furthermore, as in other market-based instruments that typically encourage consumer behavior through price signals, IBTs also provide direct price signals to change consumer behaviors.

The results presented above additionally suggest that there are several factors that are unlikely to enhance water conservation. Firstly, the mean income of households showed a significant positive sign. This outcome is consistent with the typical income elasticity estimates of water given it is a normal good (see Dalhuisen et al. 2003 for a discussion). The negative coefficient for squared income suggests that the relationship between income and water consumption is non-linear in the sense that higher income levels enable reduced water use in BCC suburbs. In terms of conservation policies, this is the preferred outcome: that is, high income consumers can reduce water use through investment in water conservation devices.

Secondly, our findings show that a larger average household size leads to a significant increase in quarterly water consumption. In the extant literature it is well accepted that household size affects water demand positively (Dahan and Nisan 2007; Arbués et al. 2010; Rathnayaka et al. 2014) thus the result is consistent with the literature. It is also important to note that the lagged rainfall variable is highly significant having a negative link with water consumption in this study. In the BCC region, some residents use domestic water for gardening/lawn maintenance but obviously with more rain, water usage is likely to decrease as less water would be used for lawns.[13]

4 Conclusions

This paper explores the effectiveness of two pricing structures on water use and conservation. We empirically test this by a set of panel data for residents living within the BCC region, Queensland, Australia. The analysis includes all 16 quarters of the 4-year period of 2005–2008. Our hypothesis was that an IBT pricing structure is more effective in reducing water demand relative to a uniform pricing structure. Our data show that on average, there was an approximately 36.5% per cent reduction in water consumption by moving from a uniform rate to an IBT scheme. The results shows that this reduction is likely to be due to the combined effect of the pricing structure changes, average price changes, and water restrictions in place during the period. The results suggest that moving to an IBT offers a significant negative effect on water consumption, and that, therefore, an IBT structure is more 'conservation-oriented' than a uniform pricing policy.

In conclusion, the results of this study indicate that an IBT scheme is more effective in reducing the demand for water than a uniform pricing scheme. This outcome provides useful input for policy makers who are seeking more efficient ways to conserve water. In particular, the outcomes provide useful input into the debate concerning the extent of efficiency losses arising in an IBT pricings scheme in the presence of pricing other than marginal cost pricing of water. To the extent that conservation gains are able to offset efficiency losses in situations of constrained availability of resources, the insights provided here are important for policy decisions. However, further research is warranted to explore if these gains outweigh any efficiency losses arising from IBTs.

Footnotes

1. 1.

   In a recent study, Ito et al. (2014) finds strong support that consumers better respond to average price than marginal price based on a theoretical prediction on consumers' perceived price that involves electricity prices.

2. 2.

   Quasi-experiments are not necessarily designed experiments. However, the variation that occurs naturally provides researchers the means to test their hypotheses (Meyer 1995). A novel strand of literature that describes laboratory based experimental economics can be found in the water demand literature as well. See, for example, Murphy et al. (2000).

3. 3.

   See Boland and Whittington (2000), Rogers et al (2002), (Olmstead and Stavins 2009), Monteiro and Roseta-Palma (2011), Hu et al (2016) for a discussion on efficiency, equity and trade-offs in water allocation.

4. 4.

   Water utilities generally apply two-part tariffs where a volumetric tariff is combined with a fixed charge. In the current study we consider, two types of volumetric tariff; (1) a uniform price in which the charge is proportional to consumption and (2) IBT tariffs which are divided into a number of blocks with increasing charges for successive blocks.

5. 5.

   Since the mid-1990s Australian water reforms were mainly targeted at urban water pricing with the objective of efficient use of water with incentives for efficiency related investments such as storm water reuse and recycling of water. In line with these reforms, the BCC introduced volumetric pricing in 1995/96 and subsequently moved to a three-tiered IBT structure in 2006.

6. 6.

   The long-term average is the rainfall from 1985 to 2004 averaged monthly.

7. 7.

In addition to these state regulations on water conservation, various awareness campaigns and educational programs have been implemented by local councils. One most publicly visible campaign was 'Target 140' undertaken by Queensland Water Commission (QWC) (Walton and Hume 2011).

8. 8.

   Note that this is the average consumption per quarter per average household.

9. 9.

   The most publicly visible campaign 'Target 140' also coincided with the timing of highest water restriction level. Therefore, we did not include a separate variable for campaigns as it becomes redundant in the model (in our preliminary regressions this dummy is an insignificant determinant of water consumption).

10. 10.

    See Deller et al. (1986) and Dharmaratna and Parasnis (2011) for conventional instruments used in water demand literature.

11. 11.

    The results are consistent across all five models and point to the same inferences. Hence, we present a concise general description here.

12. 12.

    Similar reasons have been identified (without econometric analyses) for the observed reduction in residential consumption in most Australian cities by the National Water Commission of Australia in their 2011 "Review of pricing reform in the Australian water sector" report.

13. 13.

    Our sample includes houses (free standing) and not units. These households used water supplied by the BCC to water their gardens. Thus, it is possible to see a decrease in water use during wet periods.

Notes

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Annex 1

See Table 3.
Table 3

Summary of key water residential restrictions for each restriction level based on information from the Queensland Water Commission

Source: Beal et al. (2011)

Category of reticulated mains water use	Restriction level declared by Queensland Water Commission								
	Level 1 (May '05)	**Level 2 (Oct '05)**	**Level 3 (Jun '06)**	**Level 4 (Nov '06)**	**Level 5 (Apr '07)**	**Level 6 (Nov '07)**	**High (Jul '08)**	**Medium (Mar '09)**	**PCM (Dec '09)**
Established gardens/lawns									
Irrigation systems	Note 1	✗	✗	✗	✗	✗	✗	Note 11	Note 13
Hand held hose with trigger/twist	✓	Note 1		✗	✗	✗	Note 10	Note 12	✓
Bucket/can	✓	✓	✓	Note 1	Note 1	Note 1	✓	✓	✓
New gardens/lawns									
Irrigation systems	Note 2	Note 2	✗	✗	✗	✗	✗	Note 11	Note 14
Hand held hose with trigger/twist	✓	✓	Note 5	Note 5	Note 5	Note 5	Note 5	✓	✓
Bucket/can	✓	✓	✓	Note 1	Note 1	Note 1	Note 1	✓	✓
Topping up existing pools/spas	Note 1	Note 3	Note 3	Note 7	Note 8	Note 8	Note 8	Note 12	Note 15
Filling new pools/spas	Note 4	Note 4	Note 6	Note 7	Note 9	Note 9	Note 9	Note 12	Note 13
General outdoor cleaning (house/cars/boats/caravans)									
Hand held hose with trigger/twist	✓	✓	✗	✗	✗	✗	Note 10	Note 12	✓
Bucket/can	✓	✓	✓	✓	✓	✓	✓	✓	✓

Note 1 Restricted times across 3 non-consecutive days. Not on Mondays

Note 2 As for Note 1 and must be an automatic shut-off sprinkler only

Note 3 As for Note 1 but hose to be hand held only

Note 4 Children's pools of < 1000 L filled anytime. Hose does not need to be attended

Note 5 One hour of day using trigger/nozzle hose for 14 days after establishment only

Note 6 No portable/child pools to be filled by mains water

Note 7 Only when QLD Government recommended water-efficient measures are shown to be used on the property

Note 8 As for Note 7 and restricted to 3 h on non-consecutive days

Note 9 Requires written approval from local government to construct pools and spas

Note 10 Only hand held allowed for half hour every 7 days

Note 11 Only if systems emit < 9 L per minute with a timer for up to 30 min a day

Note 12 Filled at anytime but requirements as per Note 7. Child pools less than 500 L capacity

Note 13 As for Note 11 but 4 pm to 10 am. No Mondays and must use water-efficient irrigation equipment

Note 14 As for Note 13 but can be watered anytime on day of establishment

Note 15 Only after all rainwater has been used to top up and 3 out of 4 water-efficient devices installed in property

References

1. Andersen MS (1999) Governance by green taxes: implementing clean water policies in Europe 1970–1990. Environ Econ Policy Stud 2(1):39–63CrossRefGoogle Scholar
2. Arbués F, Garcıa-Valiñas MÁ, Martınez-Espiñeira R (2003) Estimation of residential water demand: a state-of-the-art review. J Socio Econ 32(1):81–102CrossRefGoogle Scholar
3. Arbués F, Villanúa I, Barberán R (2010) Household size and residential water demand: an empirical approach. Aust J Agric Resour Econ 54(1):61–80CrossRefGoogle Scholar
4. Australian Bureau of Statistics (2015) Retrieved from http://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/3218.02014-15?OpenDocument. Accessed Oct 2016
5. Beal C, Gardner T, Sharma A, Chong M (2011) A desktop analysis of potable water savings from internally plumbed rainwater tanks in South East Queensland. Urban Water Security Research Alliance Technical Report No. 26Google Scholar
6. Boland JJ, Whittington D (2000) Water tariff design in developing countries: disadvantages of increasing block tariffs (IBTs) and advantages of uniform price with rebate (UPR) designs. World Bank Water and Sanitation Program, Washington, DC, p 37Google Scholar
7. Brisbane City Council (BCC) (2011) Brisbane community profiles. Community profiles data in 2001 and 2006. Retrieved from http://profile.id.com.au/Default.aspx?id=327&pg=14&gid=10&type=enum. Accessed Feb 2009
8. Dahan M, Nisan U (2007) Unintended consequences of increasing block tariffs pricing policy in urban water. Water Resour Res 43:1–10CrossRefGoogle Scholar
9. Dalhuisen JM, Florax RJGM, de Groot H, Nijkamp P (2003) Price and income elasticities of residential water demand: a meta-analysis. Land Econ 79:292–308CrossRefGoogle Scholar

10. Dandy G, Nguyen T, Davies C (1997) Estimating residential water demand in the presence of free allowances. Land Econ 73:125–139CrossRefGoogle Scholar
11. Deller SC, Chicoine DL, Ramamurthy G (1986) Instrumental variables approach to rural water service demand. South Econ J 53(2):333–346CrossRefGoogle Scholar
12. Dharmaratna D, Parasnis J (2011) Price responsiveness of residential, industrial and commercial water demand in Sri Lanka. Asia Pac J Econ Bus 15(2):17Google Scholar
13. Foster HSJ, Beattie BR (1981) On the specification of price in studies of consumer demand under block price scheduling. Land Econ 57:624–629CrossRefGoogle Scholar
14. Gaudin S (2006) Effect of price information on residential water demand. Appl Econ 38:383–393CrossRefGoogle Scholar
15. Gottlieb M (1963) Urban domestic demand for water in the United States. Land Econ 39(2):204–210CrossRefGoogle Scholar
16. Hausman JA (1978) Specification tests in econometrics. Econometrica 46(6):1251–1271CrossRefGoogle Scholar
17. Hewitt JA, Hanemann WM (1995) A discrete/continuous choice approach to residential water demand under block rate pricing. Land Econ 71(2):173–192CrossRefGoogle Scholar
18. Hu Z, Chen Y, Yao L, Wei C, Li C (2016) Optimal allocation of regional water resources: from a perspective of equity–efficiency trade-off. Resour Conserv Recycl 109:102–113CrossRefGoogle Scholar
19. Hung MF, Chie BT, Huang TH (2017) Residential water demand and water waste in Taiwan. Environ Econ Policy Stud 19(2):249–268CrossRefGoogle Scholar
20. Ito K, Ida T, Tanaka M (2014) The persistence of intrinsic and extrinsic motivation: experimental evidence from energy demand. Working Paper. http://www.abef.jp/event/2014/pdf_abst/PR0005.pdf. Accessed Jan 2017
21. Kenney DS, Goemans C, Klein R, Lowrey J, Reidy K (2008) Residential water demand management: lessons from Aurora, Colorado. JAWRA J Am Water Resour Assoc 44(1):192–207CrossRefGoogle Scholar
22. Martínez-Espiñeira R, Nauges C (2004) Is really all domestic water consumption sensitive to price control? Appl Econ 36:1697–1703CrossRefGoogle Scholar
23. Meyer B (1995) Natural and quasi experiments in economics. J Bus Econ Stat 13:151–161Google Scholar
24. Mini C, Hogue TS, Pincetl S (2015) The effectiveness of water conservation measures on summer residential water use in Los Angeles, California. Resour Conserv Recycl 94:136–145CrossRefGoogle Scholar
25. Monteiro H, Roseta-Palma C (2011) Pricing for scarcity? An efficiency analysis of increasing block tariffs. Water Resour Res 47(6):6510CrossRefGoogle Scholar
26. Murphy JJ, Dinar A, Howitt RE, Rassenti SJ, Smith VL (2000) The design of "Smart" water market institutions using laboratory experiments. Environ Resour Econ 17(4):375–394CrossRefGoogle Scholar
27. Nataraj Shanthi, Hanemann WM (2011) Does marginal price matter? A regression discontinuity approach to estimating water demand. J Environ Econ Manag 61:198–212CrossRefGoogle Scholar
28. Nieswiadomy ML (1992) Estimating urban residential water demand: effects of price structure, conservation, and education. Water Resour Res 28:609–615CrossRefGoogle Scholar
29. Nieswiadomy M, Cobb SL (1993) Impact of pricing structure selectivity on urban water demand. Contemp Policy Issues 11:101–113CrossRefGoogle Scholar
30. Nieswiadomy M, Molina DJ (1989) Comparing residential water estimates under decreasing and increasing block rates using household data. Land Econ 65:280–289CrossRefGoogle Scholar
31. Olmstead SM, Stavins RN (2009) Comparing price and non-price approaches to urban water conservation. Water Resour Res 45(4):W04301. https://doi-org.ezproxy.library.uvic.ca/10.1029/2008WR007227 CrossRefGoogle Scholar
32. Olmstead MO, Hanemann M, Stavins R (2003) Does price structure matter? Household water demand under increasing-block and uniform prices, paper presented at Environmental Economic Working Group Meeting. National Bureau of Economic Research, CambridgeGoogle Scholar
33. Olmstead SM, Hanemann WM, Stavins RN (2007) Water demand under alternative price structures. J Environ Econ Manag 54(2):181–198CrossRefGoogle Scholar
34. Rathnayaka K, Maheepala S, Nawarathna B, George B, Malano H, Arora M, Roberts P (2014) Factors affecting the variability of household water use in Melbourne, Australia. Resour Conserv Recycl 92:85–

94CrossRefGoogle Scholar
35. Renwick ME, Archibald SO (1998) Demand side management policies for residential water use: who bears the conservation burden? Land Econ 74:343–359CrossRefGoogle Scholar
36. Renwick ME, Green R (2000) Do residential water demand side management policies measure up? An analysis of eight California water agencies. J Environ Econ Manag 40:37–55CrossRefGoogle Scholar
37. Reynaud A, Renzetti S, Villeneuve M (2005) Residential water demand with endogenous pricing: the Canadian case. Water Resour Res 41(11):W11409. https://doi-org.ezproxy.library.uvic.ca/10.1029/2005WR004195 CrossRefGoogle Scholar
38. Rogers P, De Silva R, Bhatia R (2002) Water is an economic good: how to use prices to promote equity, efficiency, and sustainability. Water Policy 4(1):1–17CrossRefGoogle Scholar
39. Schefter JE, David EL (1985) Estimating residential water demand under multi-tariffs using aggregate data. Land Econ 61:272–280CrossRefGoogle Scholar
40. Stevens TH, Miller J, Willis C (1992) Effect of price structure on residential water demand. Water Resour Bull 28:681–685CrossRefGoogle Scholar
41. Timmins C (2003) Demand-side technology standards under inefficient pricing regimes: are they effective water conservation tools in the long run? Environ Resour Econ 26:107–124CrossRefGoogle Scholar
42. Walton A, Hume M (2011) Creating positive habits in water conservation: the case of the Queensland Water Commission and the Target 140 campaign. Int J Nonprofit Volunt Sect Mark 16:215–224CrossRefGoogle Scholar
43. Worthington AC, Hoffman M (2008) An empirical survey of residential water demand modelling. J Econ Surv 22(5):842–871CrossRefGoogle Scholar
44. Zhao J, Ni H, Peng X, Li J, Chen G, Liu J (2016) Impact of water price reforms on water conservation and economic growth in China. Econ Anal Policy 51:90–103CrossRefGoogle Scholar

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