THE EFFICIENCY AND EQUITY IMPLICATIONS OF PERTH'S INCLINING BLOCK URBAN WATER TARIFFS

Donna Brennan
Policy and Economics Research Unit
CSIRO Land and Water
Floreat, WA
donna.c.brennan@csiro.au

ABSTRACT

Inclining block tariffs, where the unit price is dependent on the volume consumed, are widely used in urban water pricing. These tariffs attempt to satisfy both efficiency and equity goals by providing pricing signals to influence consumption decisions at the margin, whilst making non-discretionary consumption available at a lower cost. In practice, heterogeneity in demand and the water utility's requirement for cost recovery lead to efficiency and equity trade offs in the design of inclining block tariff schedules.

An equilibrium displacement model of Perth residential water demand, which differentiates between consumer groups according to household size and outdoor use characteristics, is used to assess the efficiency and equity implications of the inclining block tariffs charged by the Water Corporation in Western Australia. Alternative pricing options, including a modified inclining block proposal that has recently been recommended by the state economic regulator and an efficient uniform price, are also evaluated. The efficiency costs and income distributional consequences of "over generous" inclining block tariffs are demonstrated.

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INTRODUCTION

Inclining block tariffs schedules, where the price paid per unit is dependent on the volume consumed, are widely used in urban water pricing. Inclining block tariffs attempt to satisfy both efficiency and equity goals by providing higher prices to influence consumption choices at the margin, whilst making non-discretionary consumption available at a lower cost. An international review of pricing trends in over the 1990s revealed that there has been increased adoption of inclining block tariffs in OECD countries (OECD 1999). Most utilities in Australia practice some form of inclining block pricing.

When consumers have heterogeneous demand characteristics, as they do in the case of water demand, the design of inclining block pricing structures is problematic. The application of price discounts to target households with large inelastic demand can distort price signals to those with low and elastic demand, resulting in inefficient level of consumption. The extent to which efficiency arise in the design of inclining block pricing structures depends on the degree of heterogeneity in demand and the welfare goals of the policy. In this paper, an empirical study is conducted on the efficiency and equity impacts of changing from the complex 5 block tariff structure currently used in Perth, to two alternative pricing methods: a simplified two component inclining block schedule that was recently recommended by the economic regulator, and a uniform volumetric pricing policy. The analysis is conducted using an equilibrium displacement model (EDM) where demand heterogeneity is accounted for using census data on the characteristics of households, and using secondary data about the nature of demand as affected by these characteristics.

The outline of the paper is as follows. First, theory and practicalities of inclining block tariffs are outlined and some evidence is provided on how inclining block tariff schedules are applied by different utilities in Australia. The second part reports on the method and results of the quantitative analysis, and draws conclusions on the efficiency and equity impacts of alternative pricing options for Perth. The difficulties in designing efficient block tariffs and the distributional implications of both inclining block and uniform tariffs are highlighted.

INCLINING BLOCK PRICING: RATIONALE AND PRACTICAL ISSUES

The appeal of inclining block tariffs can be demonstrated using a simple diagram, as shown in Figure 1, using a simple two-component block tariff where the upper block is set at long run marginal cost (LRMC). The shape of the demand curve drawn here reflects the two components of household demand, very inelastic ‘essential service’ demand for water, representing water needs for nutrition and hygiene, and in addition a more elastic portion that reflects what is often called ‘discretionary’ demand. The two-block tariff can achieve an efficient outcome while at the same time providing water for ‘essential uses’ at a lower cost to the consumer. As long as the size of the discounted block is correctly set so that it does not intersect the demand curve (as demonstrated here), the consumer receives the LRMC price signal at the margin. The shaded area is a non-distorting welfare transfer to the consumer.

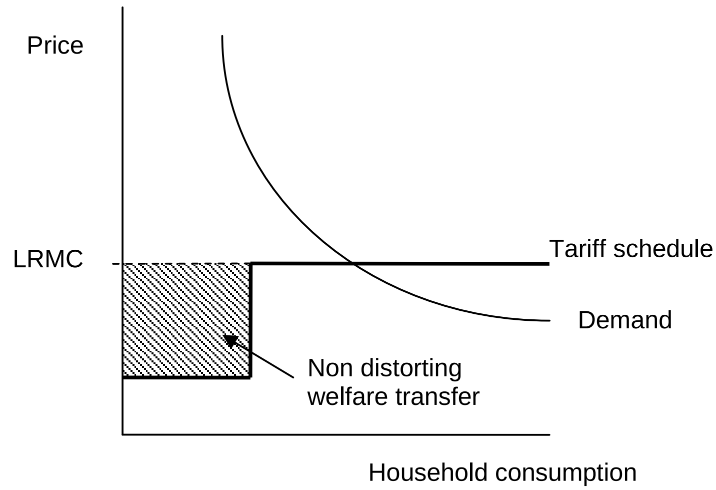

Figure 1: The 'equity' appeal of inclining block tariffs: Providing cheap essential water

Definition of efficient price

In all of the analysis and discussion in this paper, long run marginal cost is deemed to be the efficient price, and all discussion of efficiency refers to deviations from the LRMC allocative outcome. The use of LRMC is in contrast to pricing principles applied in other regulated industries, where prices are usually set to cover short run or avoidable cost, and revenue to cover lumpy infrastructure investments is generated through Ramsey pricing. The use of LRMC in this paper is consistent with widespread adoption of LRMC pricing by economic regulators. Dynamic efficiency is the main justification for the use of LRMC as the efficient price. Demand for urban water is constantly growing as population expands, and the incremental costs of supply expansion are typically increasing. At the same time, many of the decisions made by the consumer regarding water using appliances are long term in nature, so from a dynamic efficiency perspective they should be making these decisions in the context of the cost of supply augmentation.

Heterogeneity in demand

Where there is heterogeneity in demand, the goal of providing cheap 'non-discretionary' water can lead to efficiency losses. This is illustrated in Figure 2, with the introduction of a second demand curve with a larger non-discretionary demand component. If the social policy is to provide 'non-discretionary' consumption at the discounted price, this requires an increase in the discounted component from B to B*. But if it is not possible to identify users on the basis of size of discretionary demand, so that the B* applies to all households, then the smaller household will no longer equate their own use with the higher tariff which represents the long run marginal cost. The efficiency cost is denoted by the shaded area. On the other hand, if prices are set to give the correct price signal to the smaller consumer, the larger consumer ends up paying high prices for a substantial portion of their non-discretionary consumption, so the welfare/political goal of cheap non-discretionary pricing is not met.

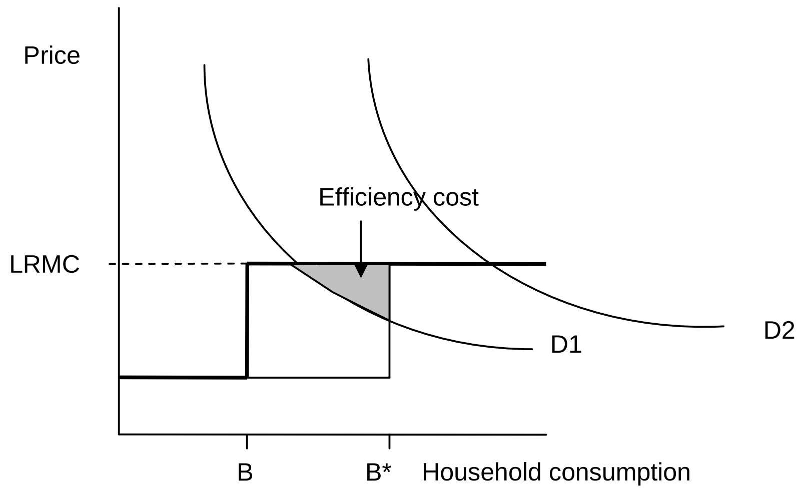

Figure 2: The efficiency cost of extending the discounted block to account for larger non-discretionary consumers

Drivers of demand differences between consumers

The most important factor affecting non-discretionary water demand is household size, as each individual requires a certain quantity for basic needs. Total water use is also affected by the household garden characteristics which determine outdoor water use. The effect of these two demand drivers on total household consumption is illustrated in Table 1, using data from a survey of domestic water use conducted in Perth in 1998 – 2001 (Loh and Coghlan 2003). Comparing between cells in the table, it can be seen that a one-person household with a garden watered by automatic reticulation would consume just a little more than a six-person household living in a flat. A subsidy aimed at making indoor consumption cheap for large families would benefit this small household with large outdoor use. Similarly, a two-person household maintaining a garden using manual reticulation would consume less than a six-person flat-dwelling household, and would benefit from block discounts designed to target households with larger non-discretionary consumption.

Table 1: Illustration of demand heterogeneity as determined by household size and garden characteristics

	Total water use per household kL per year			
	Household size (occupants)			
Garden watering characteristics	1	2	4	6
Indoor use = Total use if no garden or backyard bore	56.6	113.2	226.3	339.5
Total use for suburban block with manual reticulation	252.6	309.2	422.3	535.5
Total use for suburban block with automatic reticulation	442.7	499.3	612.5	725.6

Source: Authors calculations based on per capita consumption data and outdoor water use data from Loh and Coghlan (2003)

Cost recovery constraints and implications for fixed charges

By applying price discounts to early block consumption, the total revenue earned from volumetric charges is less for inclining block tariffs than it would be if prices were uniformly set equal to LRMC. Since corporatised utilities are required to recover costs, it is necessary to levy fixed charges to make up for revenue shortfalls. Inclining block structures that have more substantial price discounts require larger fixed charges for cost recovery.

IMPLEMENTATION OF INCLINING BLOCK TARIFFS IN AUSTRALIA

The design of inclining block tariffs requires the determination of what constitutes 'non discretionary' consumption (the horizontal dimension of the block), what constitutes a 'fair price' for such consumption (the vertical dimension of the block), and the fixed charge required to recover costs. Characteristics of water prices charged by a range of Australian water utilities are demonstrated in Table 2 and, with the exception of Queensland utilities, all use inclining block tariffs. Most commonly, the first block represents an allowance of around 40-60 kL per person for the average household[1]. The exception is Sydney Water, which has only recently moved away from a flat pricing structure[2], as part of a drought response strategy aimed at discouraging high discretionary use. In determining the size of the step, IPART justified the 400kL first step as being sufficient to meet average household consumption of five-person households[3] (IPART 2004). A review of pricing decisions made by other economic regulators failed to find any written justification of the choice of block sizes in other states.

Table 2. Pricing by selected water utilities in Australia

Utility	*City*	*Number steps*	*Location first step*	*Bill at 250kL*	*Proportion of bill as fixed charge*
Water Corporation	Perth	5	150 kL	$256	59%
South East Water	Melbourne	3	160 kL	$238	18%
City West	Melbourne	3	160 kL	$291	33%
Yarra Water	Melbourne	3	160 kL	$253	23%
ACTEW	Canberra	3	100 kL	$303	24%
Sydney Water	Sydney	2	400 kL	$375	20%
SA Water	Adelaide	2	125 kL	$324	43%
Brisbane City Council	Brisbane	Uniform	n/a	$332	33%

With five blocks, Perth has the most complex tariff structure, offering very substantial discounts on early consumption compared to the other cities. Perth's complete pricing schedule is illustrated in Figure 3, along with schedules for Sydney and Melbourne. Sydney consumers pay three times the price of Perth consumers for the first 150kL of consumption. The horizontal extent of the discounted block structure is much larger

[1] Based on national average household size of 2.6 persons, from ABS Population and Household Census 2001.
[2] Sydney Water had a 'single step' or constant usage charge from 1995 to 2004 (IPART 2004).
[3] This was based on total water consumption. The 'indoor demand' of a five person household is more likely to be less than 300kL.

for Perth than for the other two cities. While the last step in the tariff schedules for Sydney and Melbourne is around 350 to 400kL, prices in Perth continue to increase up to a consumption level of 950kL. Since only 2% of households in Perth actually consume more than 950kL, it is the second last block that sets the marginal price paid for most households with larger than average demand. This price is $1.20 per kL, equivalent to the minimum charge that Sydney consumers pay.

The substantial discounts offered to Perth consumers have implications for fixed charges that must be levied to cover the water utility's costs. As shown in Table 2, the proportion of the typical household bill that is made up of fixed charges is 59 percent in Perth[4]. With the exception of Adelaide, the fixed charge represents less than 30 percent of the average household bill in all other cities.

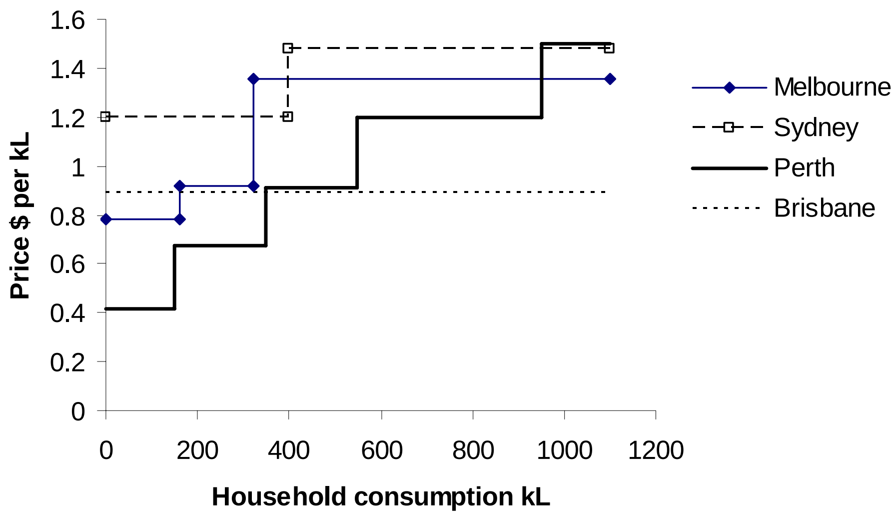

Figure 3: Residential water price schedules in the 4 largest Australian cities

PRICING OPTIONS FOR METROPOLITAN PERTH

A recent inquiry into Perth's water tariffs was conducted by the state economic regulator, and a simplification of the tariff structure was recommended, from five to two blocks, with a higher volumetric charge on early consumption (Economic Regulatory Authority, 2005b). The recommended tariff schedule is compared to the current schedule in Figure 4, where the distribution of consumption for Perth households in the year 2000 is also shown. The vertical dimensions of the two blocks were justified as "the likely range of possible LRMC". No justification was given for the choice of the horizontal dimension of the first block (550kL). It can be seen from the figure that a considerable proportion of households have consumption of 550kL or less. In fact, based on 2000 figures, 85% of the population has water consumption of less than 550kL and therefore would receive the charge of 82 cents per kL, and for some consumers, the marginal price will fall. The size of the first block is well in excess of the 'non discretionary' allowance made in other states. In fact, the proposed

[4] Based on weighted average household consumption for the 4 largest cities over 1999-2000 to 2003-4 years, which was 245kL per household (calculated from WSAA facts 2005).

block is sufficient to satisfy the indoor/non-discretionary consumption of a family of 10 people. The fact that discounted prices apply to such a large proportion of household consumption would imply that there are likely to be considerable efficiency costs associated with the proposed pricing structure[5]. This will be investigated in the following section by comparing the efficiency and equity implications of the proposed schedule and a uniform tariff schedule based on LRMC.

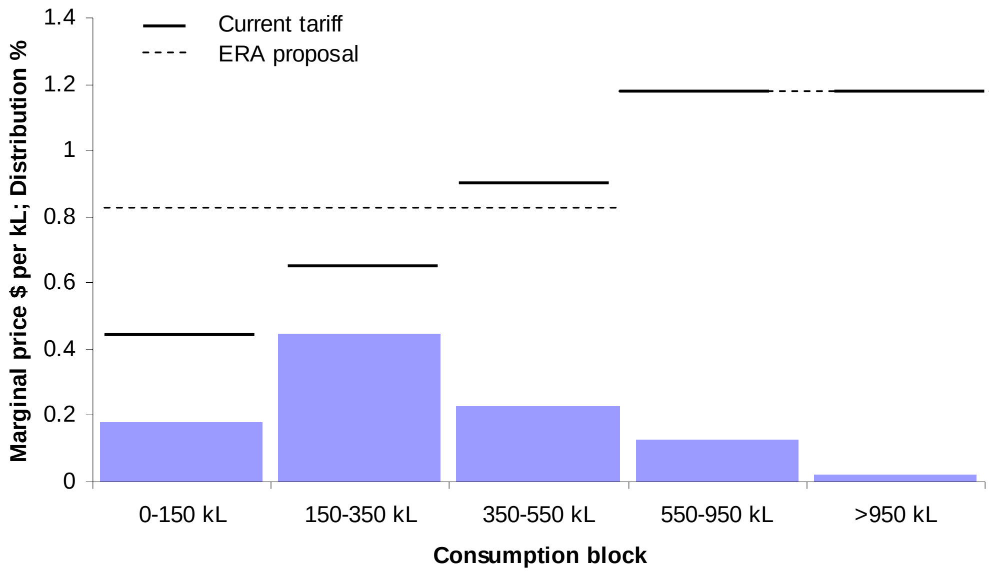

Figure 4: Distribution of consumption and inclining block marginal prices: Current and proposed tariff structures

ESTIMATING THE WELFARE IMPACTS OF ALTERNATIVE PRICING POLICIES

The impact of pricing reform on household welfare is made up of three components. These are the change in consumer surplus associated with changes to prices at the margin, the income effect associated with changing the structure of (infra-marginal) discounted prices, and the income effect of the change in the fixed charge that is associated with a particular pricing schedule. The first two components are illustrated in Figure 5. The net impact of these changes to an individual household will depend on how its demand curve is positioned relative to the discounted block schedule, the extent to which the marginal price changes, and the change in the fixed charge. The change in the fixed charge depends upon the distribution of consumption, which affects revenue earned under the original tariff and the consumption response to price changes. These changes must be estimated in a model that represents the distribution of different representative households. Similarly, the estimation the total impact on demand, and the efficiency costs associated with a particular pricing policy, requires

[5] Clearly, this depends on the interpretation of the long run marginal cost. See discussion later on the LRMC chosen for this analysis.

representation of consumer groups that have different demand characteristics, and face different marginal prices under the inclining block tariff structure. Empirical estimation of these effects can be done using an equilibrium displacement modeling approach.

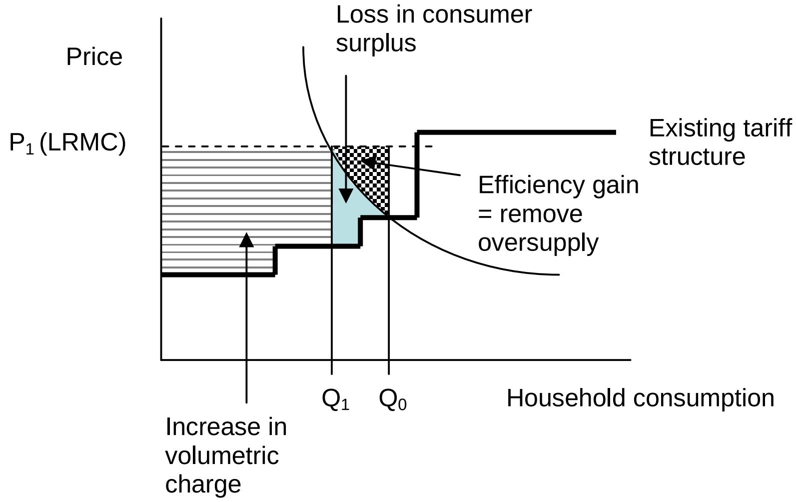

Figure 5a: Welfare impacts of price reform where marginal price is increased

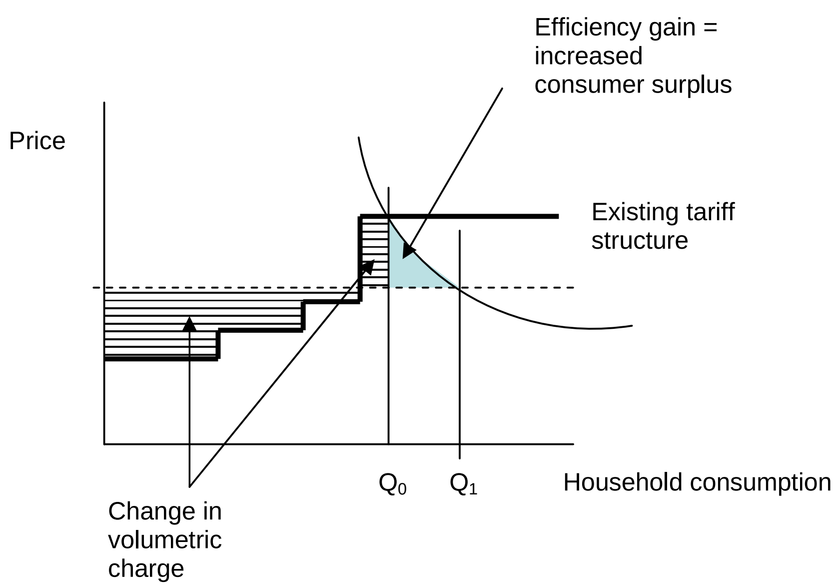

Figure 5: Welfare impacts of price reform where marginal price is reduced

Equilibrium displacement modeling has been widely used in assessing impacts of price or tariff changes in multi-product agricultural markets (Rude and Meilke 2004). The advantage of the approach is that it makes use of scarce information, requiring only baseline prices and quantities and expert judgment on price elasticities, and is able to predict the likely market response to price changes. Where the price changes being analyzed are small then the simulated results are a valid approximation for any underlying functional form for demand and supply (Piggot *et. al.* 1993). When price changes are more substantial, the approach implies an additional assumption that the nature of demand is of constant elasticity functional form.

A simple EDM model of urban water demand is described as follows. Define N different household groups denoted by subscript j, and two different types of demand. Because in this analysis demand is divided according to indoor and outdoor uses, the subscript I and O are used to refer to these different demand types, which roughly correspond to non-discretionary and discretionary demand.

Total quantity demanded by each household group j is:

$$Q_j = Q_j^I + Q_j^O \qquad (1)$$

Because of the inclining block tariff structure, the marginal price signal to household j is determined by the total consumption of that individual household:

$$P_j = f(Q_j) \qquad (2)$$

The impact of a price change on an individual household can be written:

$$dQ_j = \frac{\partial Q_j^I}{\partial P_j}.dP_j + \frac{\partial Q_j^O}{\partial P_j}.dP_j \qquad (3)$$

Making use of the elasticity formula $(\eta = \frac{\partial Q}{\partial P}.\frac{P}{Q})$ equation 3 can also be written:

$$dQ_j = \eta_j^I.\frac{Q_j^I}{P_j}dP_j + \eta_j^O.\frac{Q_j^O}{P_j}dP_j \qquad (4)$$

The total change in quantity demanded in response to a change in the price schedule will be:

$$\Delta Q = H.\sum_j^N \phi_j.[\eta_j^I.\frac{Q_j^I}{P_j}dP_j + \eta_j^O.\frac{Q_j^O}{P_j}dP_j] \qquad (5)$$

where H is the total number of households;
ϕ_j is the proportion of the population in household group *j*
ΔQ is total change in demand for residential water consumption

Representing consumer groups

The population of households was divided into groups according to the main determinants of consumption, being household size which determines indoor use; and outdoor garden characteristics which determine outdoor use. Whilst the effect on income on household demand characteristics would be helpful in interpreting the results on the income distributional impacts of pricing reform, representative demand groups were not differentiated on the basis of income due to lack of data.

Initial estimates of indoor demand were based on Loh and Coghlan's (2003) estimate of per capita indoor use, and census data on the distribution of household size by dwelling type. Dwelling type is used to differentiate households according to outdoor demand characteristics. The probability distribution of indoor demand is represented as shown in Table 3.

Table 3: Representing indoor demand for Perth households

Household size	*Indoor demand kL per household*	*Total population*	*Flats*	*Medium density*	*Separate dwellings*
1	57	25%	13%	6%	5%
2	113	33%	26%	5%	2%
3	170	16%	14%	1%	0%
4	226	16%	16%	1%	0%
5	283	7%	7%	0%	0%
6	339	3%	3%	0%	0%

Characteristics of outdoor demand were represented by further stratifying the single dwelling households according to garden characteristics, as shown in Table 4. Initial parameter estimates for outdoor consumption by each group were obtained from Loh and Coghlan (2003).

Table 4: Outdoor demand groups within separate dwellings category

Outdoor demand groups	*Distribution*
Households with bores	28% of single dwellings
Households using scheme water with fully automatic reticulation	25% of single dwellings using scheme water
Households using scheme water without fully automatic reticulation	75% of single dwellings using scheme water

It was further assumed that there was no relationship between household size and the likelihood of owning a bore or an automatic reticulation system. This meant a full probability matrix could be developed for each household size and outdoor demand group, by multiplying the single residential row in Table 3 with the distribution of single household garden characteristics in Table 4. The one and two-person household groups were further divided into seniors, pensioners and non-seniors groups, so that the impact of additional price discounts on elderly concession card holders could be estimated[6]. In total, there were 8 household size categories by 5 outdoor garden categories which provides 40 groups.

[6] Based on data from Purdy and Hall 2005, which differentiates the over 60s population according to lone person and couple households, and whether they held pensioner concessions cards.

Elasticity assumptions

To complete the equilibrium displacement model, elasticity estimates for indoor and outdoor use are necessary. Household consumption is not typically measured according to indoor and outdoor components, so most estimates of demand elasticity are at the level of total household consumption. Several recent reviews have found wide variation in price elasticity estimates for total household consumption (Dalhuisen *et. al.* 2003; Arbues *et. al.* 2003). The mean price elasticity from all the 269 studies examined by Dalhuisen *et. al.* (2003) was -0.41, and the median was -0.35.

Several contingent valuation studies have been conducted in Australia that attempt to separate indoor and outdoor use (NERA 2001). Elasticity estimate are shown in Table 5. Evidence from time series analysis on summer and winter demand can also be used to justify indoor and outdoor demand elasticities, as winter use is predominantly indoor, whereas summer contains both indoor and outdoor. Results from a Western USA study which also distinguishes between short and long run estimates are shown in Table 5. One of the most recent studies on demand elasticity reported for an Australian city is Dandy *et. al.*'s (1997) analysis of time series data from Adelaide (using data from 1979 to 1992) which estimated a long run elasticity range from -0.63 to -0.77. They attributed the relatively high elasticity estimate to the high proportion (50%) of outdoor use there in Adelaide. This is the same proportion as in Perth.

Since the analysis is focusing on the efficiency implications of pricing decisions, the use of long run elasticity estimates is appropriate, so the higher elasticity estimates shown in Table 6 are preferred. These values were chosen so that the aggregate value matched the mean result from Dalhuisen et. al.'s (2003) review, and guided by the range of values in Table 5. It can be noted that this estimate is lower than Dandy *et. al.*'s (1997) so can still be considered a conservative estimate. Sensitivity analysis will be conducted for a lower set of elasticity estimates where the parameter values come straight from the contingent valuation study of Thomas *et. al.* (1983).

Table 5: Estimates of price elasticity of demand for water from the literature

Region	*Indoor*	*Outdoor*	*Reference*
Perth	-0.04	-.31	Thomas, Syme and Gosselink (1983) reported in NERA (2001)
Melbourne	-0.025	-0.22	Yann Campbell Hoare and Wheeler (1992) reported in NERA (2001)
Perth*	0 to -0.05	-0.04 to -0.31	
Melbourne	-0.025	-0.22	Yann Campbell Hoare and Wheeler (1992) reported in NERA (2001)
Wetern USA	-0.07 (short run) -0.19 (long run) (winter)	-0.21 (short run) -0.33 (long run) (winter)	NRA (1993) reported in NERA (2001)

*Different response reported for different hypothesized price changes

Table 6: Elasticity assumptions used in empirical analysis

Scenario	***Indoor***	***Outdoor***	***Implied aggregate***
High	-0.1	-0.7	-0.4
Low	-0.04	-.31	-0.12

Calibration of the model

The model was calibrated to match as closely as possible Perth residential demand[7] in 2000. Mean indoor and outdoor consumption parameters provided a starting point for the calibration, but for internal consistency it is necessary to adjust the consumption in each household group according to the assumed price elasticity and the deviation in marginal price paid by that group, compared to the mean marginal price. Parameters were adjusted to ensure that the resulting mean indoor and total consumption matched the baseline mean, and that the predicted probability distribution of total consumption matched the actual consumption data from the calibration year, 2000. This year was chosen because it represented average seasonal conditions and was the most recent year of data prior to the imposition of outdoor water restrictions. The resulting fit is illustrated in Figure 6.

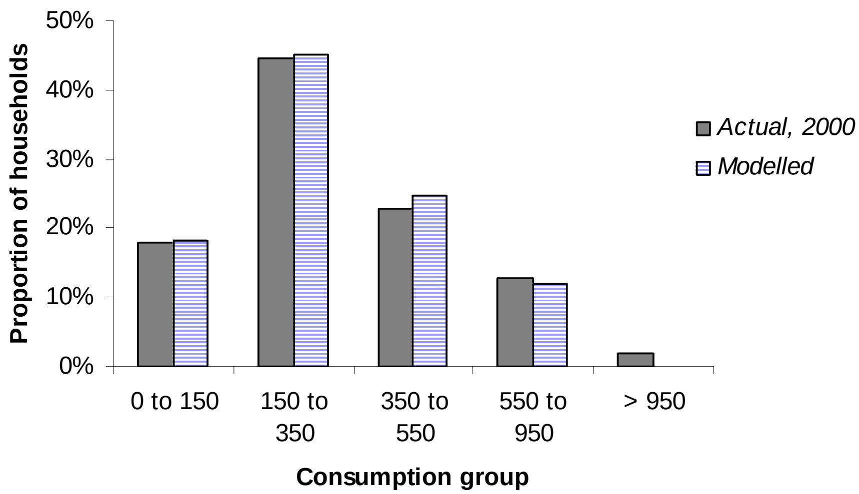

Figure 6: Distribution of consumption: Comparison of modeled and actual 2000 data

[7] Perth residential demand makes up 71% of all water supplied with the Integrated Water Supply Scheme. In addition there is 7% supplied to rural residents, the remainder to commercial users. The benefits of pricing reform calculated here only estimate the Perth residential demand component. Pricing reform in rural and commercial areas would provide additional benefits.

Comment on the influence of income on consumption

Income is likely to have an important impact on ownership of water using appliances, which in turn influence both indoor and outdoor use. The income elasticity of demand for water across 269 empirical studies reviewed Dalhuisen *et. al.* (2003) was 0.43. The model does not separately account for income groups because of inadequate data on the income characteristics of the population, once it is already stratified by household size and dwelling characteristics; and because of a lack of information on how elasticity for indoor and outdoor demand varies according to income.

However, it is possible to make some inferences about which demand groups are more likely to be the high income households. Data from a consumer survey that was conducted in Perth in 1999-2000 (ARCWIS 2002) provides some information on the influence of income on ownership of assets affecting outdoor water consumption, as shown in Table 7. Ownership of automatic reticulation (which uses twice as much water as manual reticulation) is significantly influenced by income, as is swimming pool ownership. Mean consumption was significantly higher for the higher income groups. Thus it can be concluded that a greater proportion of the high water using groups represented in the model are likely to be higher income households, although these groups will also contain some households with lower incomes.

Table 7: Effect of income on ownership of outdoor appliances and total water use

	Low Income	*Medium income*	*High income*	*Statistical test*
Has Bore	28%	27%	28%	Not significantly different
Has automatic reticulation	21%	40%	59%	High > medium > low
Block size m^2	750	755	740	Not significantly different
Number of people	2.49	3.20	3.68	High > medium > low
Has swimming pool	15%	20%	42%	High > medium, low
Mean annual consumption	271	346	446	High > medium > low

Representing efficient costs

The representation of the efficient long run marginal cost is critical to the analysis presented in this paper. Estimation of the long run marginal cost of water is difficult because of uncertainty regarding the yield and cost of alternative augmentation options, and because supply costs are considered in the context of existing water allocation mechanisms, which do not necessarily represent the socially optimal use of water at the State level[8]. Whilst it might be possible to supply urban water at a lower cost if water governance arrangements were changed, an assessment of the economic efficiency of a particular pricing regime should be conducted in the context of supply augmentation decisions that are being made in practice. However, the most recent decision regarding supply augmentation, which was to build a desalination plant at a

[8] For example, current water arrangements do not permit direct trade between farmers and the urban sector; nor between land uses affecting recharge and consumptive users of groundwater, which is the dominant source of urban water in Western Australia.

long run marginal cost of $1.20 per kL[9] was done in the context of prolonged drought, or possibly long term climate change, and it is likely that lower cost options might have been possible if a longer lead time had been politically acceptable.

In their draft determination, the Economic Regulatory Authority stated that the long run marginal cost was $0.97 per kL (Economic Regulatory Authority 2005a), but in their final decision they chose to determine a range of LRMC, of between $0.82 to $1.20 per kL (Economic Regulatory Authority 2005b). The lower end of the range might be appropriate if climate returns to normal, and if an application to develop a groundwater source in the South West of the state is successful. On the other hand, if the next augmentation decision is to be a second desalination plant, then the upper bound is appropriate. Because of the critical nature of long run marginal cost, the analysis is conducted for over the range of possible values published by the Economic Regulatory Authority.

Policy simulations

The efficiency and equity implications of changing from the current tariff schedule to two alternative pricing schedules were estimated, and for each pricing option, two elasticity scenarios, and three long run marginal cost assumptions were examined. In the case of the uniform pricing option, price was set at the assumed long run marginal cost. The fixed charge for each scenario was estimated from within the model. Changes in prices alter the revenue earned from volumetric charging, and reductions in demand reduce the costs of supply. It was assumed that the benefits of reduced supply are fully passed on to the consumer, and Excel solver was used to determine the fixed charge that was consistent with the volumetric pricing schedule and the supply cost savings. Estimated fixed charges, and the variable charges used in each policy scenario, are shown in Table 8. When the uniform price is $1.20 per kL, the fixed charge is actually negative. In this case it is assumed this is passed back to consumers in their bill. The value is low enough to be non-distorting, because while it effectively gives the first 30-40kL for free, the minimum consumption level for the smallest demand group in the model is 52 kL.

Table 8: Estimated fixed charges associated with alternative price policies

Scenario Name		**Fixed Charge***		**Variable charge**
Current Tariff		*As per July 2005 tariff rates*		
	LRMC	***More elastic***	***Less Elastic***	
ERA tariff schedule	*$1.20/kL*	$75.01	$76.81	*$0.82 per kL up to 550kL and $1.20 per kL afterwards*
	$1/kL	$76.31	$78.59	
	$0.82/kL	$77.48	$80.19	
Uniform price	*$1.20/kL*	-$50.41	-$44.42	*$1.20/kL*
	$1/kL	$14.40	$20.26	*$1/kL*
	$0.82/kL	$77.45	$82.64	*$0.82/kL*

* Calculated to achieve revenue neutrality for utility net of short run variable costs. Fixed charges calculated this way for ERA scenario differ from that reported in ERA (2003). It is not clear how their

[9] Authors calculations, based on capital and operating estimates reported in Water Corporation (2004).

number was derived, and for consistency the fixed charge estimated from the model was used for comparison with the other scenarios.

Results: Efficiency impacts

Efficiency results are shown in Table 9, for two different elasticity scenarios, and the range of LRMC assumptions. The first block of numbers show the results where LRMC is $1.20 per kL, the cost of the most recent supply augmentation decision. Depending on the elasticity assumption, the uniform pricing policy could result in a reduction in demand of between 16 to 30 GL per annum. This is because, if LRMC is $1.20 per kL, then most consumers are paying too little for water at the margin, and the demand response to a price increase will be quite substantial. Relative to consumption under the current tariff, the estimated demand change under uniform pricing is between 9 and 17 percent. The ERA's inclining block tariff proposal has a much lower impact on demand because under the proposed schedule, 85% of consumers still pay less than the efficient price.

The efficiency outcome of the two pricing alternatives is the net difference between the saving in the cost of supply and the loss in the value of consumption associated with the oversupply. Both values are significantly higher under the uniform pricing option. The saving in the cost of water supply ranges from $19 to $35 million per year. When the value of foregone water consumption is accounted for the net result is an efficiency gain of $4.43m to $7.57m. In contrast, the ERA's inclining block tariff only reduces supply costs by $4 to $5.5 million, and the net efficiency gain is only $2.03 m to $2.77 m per annum. The additional gain that could be achieved by adopting a uniform price, rather than the ERA's inclining block tariff is shown in absolute and relative terms in the two right-most columns. The efficiency gain under uniform pricing is more than twice the gain from the proposed inclining block tariff schedule.

The next block of results refers to a situation where the true LRMC is $1 per kL. In this case, the current tariff schedule, which charges $1.20 per kL for consumption over 550kL is overcharging 15% of households, and there will be a demand increase from that group under a uniform price. The net impact on demand from adopting a uniform price is around 7.5 to 12 GL, which is more than half the impact of the scenario where the efficient price was $1.20. This is because where LRMC is only $1 per kL, a higher level of consumption is optimal for some consumers. The efficiency gain from adopting uniform pricing, compared to the existing tariff schedule, is $2.08m to $337m per annum, compared to $1.36m to $1.85m per annum under the ERA inclining block proposal. The relative difference between the two policies is not as large under this LRMC assumption.

If LRMC is really only $0.82 per kL, the impact of a uniform efficient pricing policy is that demand actually increases. This is because of the demand response of those 37% of consumers who are currently paying more than $0.82 cents per kL under the existing tariff schedule. This increase in demand is greater than the reduction in the demand for the consumers who are paying too little under the current tariff. The value of the net increase in consumption is greater than the cost of additional supply, so the efficiency gain is positive, and in the range of $1.42m to $2.62m. In contrast, the efficiency gains under the ERA proposal are between $0.76 and $1.03 m. This is because consumers at the high end of consumption are not given the opportunity to purchase water at the LRMC, so only the benefits of reducing over consumption of those currently paying less than $0.82 per kL are realized.

In summary, the efficiency gains associated with the two pricing proposals are very sensitive to the LRMC. Both pricing proposals result in efficiency improvements over the existing tariff schedule, but the uniform pricing proposal always results in a more efficient outcome than the inclining block tariff proposal. The uniform pricing proposal provides between 53% and 175% more value to benefit in total welfare than the inclining block tariff proposal.

Table 9: Efficiency impacts of changing from existing tariffs to alternative pricing options, annual values

	Change in Demand, GL	Value of Δ in consumption $m	Value of Δ in supply cost $m	Efficiency gain from policy $m	Difference, Uniform & ERA	% Difference Uniform vs ERA
LRMC is $1.20 per kL						
1. Less elastic						
ERA Inclining block	-3.35	-1.99	-4.02	2.03		
Uniform	-15.94	-14.70	-19.13	4.43	2.39	118%
2. More elastic						
ERA Inclining block	-4.58	-2.73	-5.50	2.77		
Uniform	-30.22	-28.68	-36.26	7.57	4.81	174%
LRMC is $1.00 per kL						
1. Less elastic						
ERA Inclining block	-3.35	-1.99	-3.35	1.36		
Uniform	-7.49	-5.41	-7.49	2.08	0.72	53%
2. More elastic						
ERA Inclining block	-4.58	-2.73	-4.58	1.85		
Uniform	-12.36	-8.99	-12.36	3.37	1.52	82%
LRMC is $0.82 per kL						
1. Less elastic						
ERA Inclining block	-3.35	-1.99	-2.75	0.76		
Uniform	0.11	1.51	0.09	1.42	0.66	87%
2. More elastic						
ERA Inclining block	-4.58	-2.73	-3.76	1.03		
Uniform	3.80	5.73	3.12	2.62	1.59	155%

Equity implications

Whilst the efficiency gains are passed on to the consumer in terms of reduced total water bills so that consumers are better off on average, the distributional impact of the two pricing options is important. The uniform pricing option leads to generally lower fixed charges and higher volumetric charges, which impacts upon different consumers. The distributional effects of changes to prices is demonstrated in Table 10 and 11 for two scenarios, being those that show the greatest and least relative difference between the two pricing policies. Rather than present the entire 40 groups, results are aggregated into small, medium, large and pensioner households, and low medium and high outdoor use. Low outdoor use refers to households with bores, and those living in flats. Large outdoor use refers to those single dwelling households with automatic reticulation, and medium outdoor use refers to the remainder.

Detailed welfare results in Table 10 refer to the scenario where the estimated efficiency gains, and the difference between the ERA and uniform tariffs, were the greatest. This was the LRMC scenario of $1.20 per kL and the higher elasticity value. The first two rows show the division of winners and losers at the aggregate level. Slightly more households (54%) are made better off by the uniform pricing policy, compared to the ERA inclining block proposal where losers comprise 49% of the population. The table shows the change in welfare, in dollars per household per year, which is made up of the change in the water bill less the value of the change in consumption, which are also shown. The magnitude of the gains and losses are larger for the uniform pricing policy, at around $56 to $73 per household in absolute value under the uniform price, compared to $7 to 17 per household under the ERA inclining block schedule.

The first set of values show the impact on consumers with low outdoor use. The benefits of the tariff reform tend to be largest for the smaller households, and this is because of the rebalancing of tariffs from fixed to volumetric charging. The magnitude of the effects is larger in the case of the uniform pricing policy, due firstly to the larger change in price, which impacts more on demand and hence the value of foregone consumption, but this is more than compensated by the very large change in the customer bill, associated with significantly lower fixed charges for the uniform tariff policy. In the case of the largest household group, consumers are made worse off by the ERA inclining block price schedule. This demonstrates the importance of the income impact associated with tariff rebalancing. Under the uniform price option, the marginal price is significantly higher for this large-household group ($1.20 compared to $0.82 per kL under the ERA's schedule). Yet all households in this group are worse off under the ERA proposal, and this is because the higher volumetric charges and the loss in consumption value are not sufficiently compensated by a reduced fixed charge. In contrast, the benefit of reduced fixed charges makes up for these impacts for two thirds of the households in the large-household category under the uniform pricing policy. In fact, it is only 6-person households that are worse off.

The results for the medium outdoor use category are mixed, but under the uniform pricing option there is a greater tendency for the smaller households to be better off, compared to the larger households in this category. Relatively more households are worse off under the ERA inclining block schedule, although the magnitude of the cost to those adversely affected households is smaller. Those households that actually experience a price fall under the ERA schedule[10] are worse off, because whilst they increase consumption in response to price signals at the margin, the removal of the discounted early block consumption is not compensated by the reduction in the fixed charge.

[10] As illustrated in Figure 4, those in the 350 to 550kL consumption group pay lower prices under the ERA proposal.

The two pricing options have opposite effects on large outdoor users. In the case of the uniform price, there is a reduction in demand by smaller households who receive a marginal price increase, but all groups are worse off through changes in the total water bill. This is because the income effect associated with a higher volumetric charge is greater than the saving in reduced fixed costs. In the case of the ERA inclining block schedule, small and pensioner households experience a price fall, and increase consumption. Pensioners are worse off because the bill increases more than the value of consumption, whereas small households are better off. Medium to large households with large outdoor use are better off under the ERA proposal, although the magnitude of this effect is small.

In summary, the uniform pricing proposal has a greater positive impact on those who are consuming only non-discretionary consumption; and this comes from a redistribution of income away from larger users (particularly those with high outdoor use). Those households that are worse off that might be the cause of concern are families with more than 5 people, and pensioner households in medium to high outdoor use categories. However, the significant efficiency gains that can be achieved from adopting the uniform price imply that targeted policies aimed at helping these minority households would be preferable to keeping the existing tariff schedule. There are examples of targeted policies elsewhere, for example in Sydney large households are eligible to apply to have their indoor appliances retrofitted to higher water efficiency standards. This same policy could be applied in Perth to ensure that the small negative impact on households of more than 5 people is mitigated. Whether or but it can be noted that institutional mechanisms already exist for assisting this group in the form of reduced fixed charges. Increasing discounts on waste water charges, which are largely fixed due to the difficulty in attributing volumetric use, would be less distortionary if compensation were required.

Compared to the uniform price, the ERA inclining block schedule does not produce as significant an income redistribution between larger and smaller users. Whilst there is some benefit to those with low outdoor use, the main contributors are those with medium outdoor use; those households using automatic reticulation are barely affected by the change in the tariff schedule.

The distributional impacts for the scenario in which the difference between the two pricing options was the least, being LRMC of $1.00 per kL and the relatively low elasticity, are shown in Table 11. For low outdoor use households, the distribution of winners and losers is similar, with the exception of pensioners some of whom are made worse off by the uniform policy. The reason is that when prices are set at $1.00 to reflect the relatively low LRMC, volumetric earnings are lower and the fixed charge needs to be higher (compared to the $1.20 price scenario) in order to recover costs. The benefit of the reduced fixed charge is not sufficient to compensate seniors households, because they receive a 50% discount on the fixed charge. Demand increases for all households with large outdoor use under the uniform pricing policy, because the marginal price is reduced. The net impact on households in this group is mixed.

Table 10: Distributional impacts of alternative pricing options, high elasticity & LRMC $1.20 scenario

	Uniform pricing					*ERA proposal*				
	Proportion	*ΔW$*	*ΔCons$*	*ΔBill$*	*ΔDkL*	*Proportion*	*ΔW$*	*ΔCons$*	*ΔBill$*	*ΔDkL*
Worse	46%	-56.03	-52.47	3.56	-52.04	51%	-7.23	-2.40	4.83	-4.48
Better	54%	73.35	-48.54	-121.89	-53.93	49%	17.52	-7.32	-24.84	-11.78
1. Low outdoor Use										
Households of 1 or 2 people										
Worse off	0%					0%				
Better off	10%	138.12	-16.55	-154.66	-20.48	10%	43.47	-7.08	-50.55	-11.46
Pensioner households										
Worse off	0%					0%				
Better off	9%	93.91	-28.53	-122.44	-40.53	9%	26.96	-13.77	-40.73	-26.80
Households of 3-4 people										
Worse off	0%					0%				
Better off	9%	59.63	-19.39	-79.01	-20.69	9%	8.38	-4.29	-12.67	-5.74
Households of 5 or more										
Worse off	1%	-7.59	-29.37	-21.79	-31.35	3%	-5.37	-5.89	-0.51	-7.88
Better off	2%	19.27	-25.47	-44.74	-27.18	0%				
2. Medium outdoor use										
Households of 1 or 2 people										
Worse off	0%					8%	-2.57	-21.88	-19.31	-29.28
Better off	17%	56.00	-84.82	-140.83	-90.53	9%	9.10	-16.09	-25.19	-21.54
Pensioner households										
Worse off	10%	-31.49	-89.56	-58.08	-95.59	14%	-11.50	-19.16	-7.65	-25.64
Better off	5%	35.55	-73.53	-109.08	-78.48	1%	3.65	-12.66	-16.31	-16.95
Households of 3-4 people										
Worse off	16%	-36.27	-58.23	-21.97	-55.20	18%	-7.34	11.71	19.06	13.26
Better off	2%	29.43	-66.16	-95.59	-70.61	0%				
Households of 5 or more										
Worse off	5%	-62.90	-60.59	2.31	-57.43	5%	-1.28	15.42	16.70	17.82
Better off	0%					0%				
3. Large outdoor use										
Households of 1 or 2 people										
Worse off	4%	-76.96	-34.34	42.62	-32.55	0%				
Better off	0%					4%	2.70	8.74	6.03	10.10
Pensioner households										
Worse off	3%	-142.05	-41.02	101.03	-38.88	3%	-11.67	10.44	22.11	12.07
Better off	0%					0%				
Households of 3-4 people										
Worse off	5%	-84.08	0.00	84.08	0.00	0%				
Better off	0%					5%	3.69	0.00	-3.69	0.00
Households of 5 or more										
Worse off	2%	-84.08	0.00	84.08	0.00	0%				
Better off	0%					2%	3.69	0.00	-3.69	0.00

ΔWelfare = ΔBill+ ΔValue of consumption;

Table 11: Distributional impacts of alternative pricing options, low elasticity & LRMC $1.00 scenario

	Uniform pricing					*ERA proposal*				
	Proportion	*ΔW$*	*ΔCons$*	*ΔBill$*	*ΔDkL*	*Proportion*	*ΔW$*	*ΔCons$*	*ΔBill$*	*ΔDkL*
Worse	47%	-31.44	-6.97	24.47	-9.47	50%	-9.17	-1.69	7.48	-2.78
Better	53%	35.33	-11.78	-47.11	-16.48	50%	13.80	-5.26	-19.07	-8.94
1. Low outdoor Use										
Households of 1 or 2 people										
Worse off	0%					0%				
Better off	10%	81.35	-10.08	-91.44	-14.24	10%	35.99	-6.09	-42.08	-9.85
Pensioner households										
Worse off	2%	-15.60	-27.59	-11.99	-45.68	0%				
Better off	7%	51.08	-20.31	-71.39	-33.63	9%	21.51	-14.30	-35.81	-27.83
Households of 3-4 people										
Worse off	0%					0%				
Better off	9%	27.24	-7.80	-35.04	-9.31	9%	4.69	-3.12	-7.81	-4.17
Households of 5 or more										
Worse off	1%	-16.35	-2.57	13.77	-2.71	3%	-8.55	-2.01	6.54	-2.81
Better off	2%	0.86	-9.32	-10.18	-11.13	0%				
2. Medium outdoor use										
Households of 1 or 2 people										
Worse off	0%					8%	-4.90	-10.16	-5.26	-13.61
Better off	17%	21.37	-22.19	-43.55	-26.51	9%	6.78	-7.75	-14.53	-10.37
Pensioner households										
Worse off	13%	-45.74	-22.88	22.86	-27.34	14%	-14.00	-9.03	4.97	-12.09
Better off	2%	11.57	-15.80	-27.37	-18.88	1%	5.03	-6.32	-11.35	-8.45
Households of 3-4 people										
Worse off	17%	-18.46	-7.20	11.26	-7.64	18%	-8.73	4.76	13.49	5.37
Better off	1%	11.51	-17.53	-29.04	-20.95	0%				
Households of 5 or more										
Worse off	5%	-27.23	-7.07	20.17	-7.40	4%	-2.25	6.32	8.57	7.30
Better off	0%					2%	2.96	6.62	3.66	7.65
3. Large outdoor use										
Households of 1 or 2 people										
Worse off	4%	-26.53	14.74	41.27	12.81	0%				
Better off	0%					4%	3.63	3.86	0.23	4.47
Pensioner households										
Worse off	3%	-88.21	12.28	100.48	10.46	3%	-10.84	4.61	15.46	5.33
Better off	0%					0%				
Households of 3-4 people										
Worse off	3%	-3.08	30.78	33.85	27.98	0%				
Better off	3%	7.96	31.18	23.22	28.34	5%	4.19	0.00	-4.19	0.00
Households of 5 or more										
Worse off	0%					0%				
Better off	2%	22.17	31.70	9.53	28.82	2%	4.19	0.00	-4.19	0.00

ΔWelfare = ΔBill+ ΔValue of consumption;

CONCLUSIONS

Heterogeneity in demand means that it is difficult to design inclining block pricing that assist ‘non discretionary’ consumers without causing inefficient price signals to consumers with more discretionary demand. Uncertainty over the true value of the long run marginal cost of supply makes it difficult to draw conclusions over the efficiency impact of current or proposed inclining block pricing schedules for Perth, but the nature of the trade offs have been demonstrated in the analysis.

If the LRMC is deemed to be the cost of the most recent supply augmentation decision, conclusions can be drawn in the context of current price signals and recent capital investment practice. In this case, it can be concluded that the existing tariff structure results in substantial price discounts over a large range of household consumption, and as a result causes a high level of over consumption. Depending on the elasticity, this over-consumption could range from 9 to 17 percent. The estimated efficiency costs of over supply, made up of the difference between the cost of over-supply and the value of the consumption provided by the over-supply, and are in the range of $4.4 to $7.5 million per year. The cost of the supplying the over consumption is $19 to $36 million per year.

A comparison between the efficient outcome and the existing tariff structure demonstrates the income distributional and efficiency implications of an inclining block tariff that is applied in practice. Since non-discretionary consumption is usually the intended target of inclining block tariffs, the analysis demonstrates that design problems can cause adverse outcomes. Essentially, the horizontal blocks in the current tariff structure are too generous, which requires high fixed charges, the net result in a redistribution of income from low users to high users. Since high use has some correlation with income, so the current tariff policy is tending to redistribute income towards groups that tend to be wealthier.

The inclining block pricing schedule proposed by the Economic Regulatory Authority offers some efficiency improvement over the existing tariff schedule, although the income distributional effects may not be consistent with the principle of providing cheap non-discretionary water, as larger users tend to be better off under the proposed schedule. Moreover compared to a uniform price, the proposed new inclining block schedule is inefficient. The greatest difference between the two pricing options occurs when the LRMC is at the upper bound and when demand is relatively elastic, as it is likely to be in the context of longer term supply augmentation decisions.

The empirical analysis reported in this paper is an application of agricultural economics techniques (modeling representative decision makers; equilibrium displacement modeling) to an urban water pricing problem. The availability of census data which identifies key household characteristics and basic data on how domestic water use is affected by these characteristics allow for development of a detailed model of heterogeneous demand from which welfare impacts could be assessed. Further investigation of the nature of demand and how it varies between different sectors of the community would provide a richer analysis of the welfare impacts of alternative policies.

REFERENCES

ARCWIS (2002).Perth Domestic Water-Use Study: Household Appliance Ownership and Community Attitudinal Analysis 1999-2000. CSIRO Land and Water, CSIRO Urban Water Program, December 2002.

Arbues, F., Garcia-Valinas, M., Martinez-Espineira, R (2003), Estimation of residential water demand: a state of the art review, Journal of Socio-Economics, 32:61-102

Australian Bureau of Statistics, 2001, Census of Population and Housing, Extended community profile, Perth Statistical Division.

Dalhuisen, J., Florax, R., de Groot, H and P Nijkamp (2003), Price and income elasticities of residential water demand: a meta-analysis, Land Economics, 79(2): 292-308

Dandy, G., Nguyen, T., and C. Davies (1997), Estimating residential water demand in the presence of free allowances, Land Economics, 73(1): 125-139.

Economic Regulatory Authority (2005a) Draft report on inquiry into urban water and wastewater pricing, 18th March 2005, Economic Regulatory Authority, Perth.

Economic Regulatory Authority (2005b) Final report: Inquiry into urban water and wastewater pricing, 4th November 2005, Economic Regulatory Authority, Perth.

Loh, M. and P. Coghlan (2003) Perth Domestic Water Use Study, Water Corporation, Leederville.

NERA (2001), A review of Melbourne’s water tariffs, A report for the Department of Natural Resources and Environment, October 2001, Sydney.

OECD (1999), Household water pricing in OECD countries, Working Party on Economic and Environmental Policy Integration, ENC/EPOC/GEEI(98)12/FINAL, Environment Directorate, OECD, Paris.

Piggot, R., Parton, K., Treadgold, E. and B. Hutabarat (1993) Food Price Policy in Indonesia, ACIAR Monograph MN22, Australian Centre for International Agricultural Research, Canberra.

Rude, J and Meilke, K. (2004) Developing Policy Relevant Agrifood Models, Invited paper at the 2004 Southern Agricultural Economics Association Meetings, Tulsa, Oklahoma, 14-16 February.

Purdy, K and G Hall (2005) “Handy Seniors Statistics 2005: Office for Senior’s Interests and Volunteering. www.community.wa.gov.au/.../DCDPROHandySeniorsStatistics2005.doc

Water Corporation (2005) Integrated Water Supply Scheme Source Development Plan 2005: Planning Horizon 2005-2050, www.watercorporation.com.au