The Australian Journal of Agricultural and Resource Economics, 51, pp. 227–241

Pricing Sydney water*

R. Quentin Grafton and Tom Kompas[†]

The paper estimates an aggregate daily water demand for Sydney using rainfall, temperature, and price data from 2001 to 2005, and a dummy variable to account for reductions in demand following the introduction of water restrictions in October 2003. Analyses based on the estimated price elasticity, and also values one and two standard errors above and below this estimate, are used to model the effects of different pricing and water supply scenarios. The simulations indicate that without a fundamental change in water policy (pricing and supply) Sydney faces the possibility of critical water shortages in the short- to medium-term should there be a continuation of low rainfall events.

Key words: water pricing, water policy, urban water.

> *Australian cities are currently facing severe, and in most cases chronic, shortages of water, relative to the demand at prevailing prices.*
>
> John Quiggin (2006, p. 14)

1. Introduction

Many of Australia's urban water consumers are obliged to follow water restrictions in terms of when they can use water, and for what purposes (Quiggin 2006). These quantitative restrictions are in response to an imbalance between expected supply and demand that is caused by various factors, including a lack of investment in water infrastructure supply in the past 20 years (Dwyer 2006), an increasing urban population, regulatory restrictions on rural–urban water trading (Productivity Commission 2006), and urban water pricing that fails to account for large temporal variations in supply.

Using daily water demand data and dam levels in the Sydney catchment, we estimate an aggregate water demand model and undertake scenario analysis of the effects of different urban water pricing and additional sources of supply on total water storage. The results indicate that, even with expected supply increases, the scheduled water prices are not sufficiently high to balance supply and demand should there be another low rainfall period similar to that which occurred over 2001–04. An alternative water pricing model for

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* An earlier version of this paper was presented at the February 2006 AARES meeting in Sydney. We are grateful to the helpful comments of two anonymous reviewers and also Jack Pezzey, Steve Dowrick and David Campbell. We also thank Quynh Nguyen and Pham Van Ha for valuable research assistance.

[†] R. Quentin Grafton (email: quentin.grafton@anu.edu.au) and Tom Kompas are from the Crawford School of Economics and Government at the Australian National University, Canberra, ACT, Australia.

doi: 10.1111/j.1467-8489.2007.00390.x

Sydney based on the amount of water in the catchment, with preset trigger and volumetric prices and possibly a fixed fee connection charge, is recommended as a short- to medium-term response to balance supply and demand.

In Section 2 we review the supply, demand and pricing issues in Sydney water. Section 3 provides estimates of the aggregate daily water demand we use to simulate the increase in water prices that would have been required to keep storage levels above given levels over the period 2001–05. Section 4 explores the effects of different water prices and supply scenarios over the next four years beginning at current water storage levels (40 per cent) and assuming the rainfall and evaporation pattern that occurred over the 2001–05 period were repeated. Section 5 provides policy implications in terms of supply and demand management, especially water pricing, in low rainfall periods. Section 6 offers brief concluding remarks.

2. Sydney water: background

The water used to supply urban consumers in the greater Sydney area is owned and operated by the Sydney Catchment Authority (SCA), a New South Wales (NSW) government agency. SCA provides the water infrastructure used to supply bulk customers who then filter and distribute the water to retail customers. The retail water distributor is Sydney Water – a NSW state-owned corporation that supplies households with drinking water, wastewater and stormwater services and recycled water.

The NSW Independent Pricing and Regulatory Tribunal (IPART) sets the maximum retail price for water in Sydney. Its stated preference is to specify water prices with reference to the long-run marginal cost of supply ($LRMC$) which it estimates to be between \$1.20 and 1.50 per kilolitre (KL) in 2004/2005 (IPART 2005, p. 18). In its latest determination that sets prices until 30 June 2009, IPART also stated that water pricing should account for the '. . . imbalance between the demand for water and the available supply . . .' (IPART 2005, p. 105). To this end, the Tribunal recently established a two-tier increasing block pricing system where the higher Tier 2 price is imposed when households exceed 100 KL per quarter. These scheduled water price charges are given in Table 1. The 2005/2006 Tier 1 price of \$1.20/KL represents a 70 per cent increase from its level in 1995/96 of \$0.70/KL.

The Sydney water supply is determined by the quantity of water in the dams owned by the SCA that changes on a daily basis. The last time the

Table 1 Sydney water's maximum water charges effective 1 October 2005 to 30 June 2009 (\$/KL)

Charge	1 October 2005 to 30 June 2006	1 July 2006 to 30 June 2007	1 July 2007 to 30 June 2008	1 July 2008 to 30 June 2009
Tier 1 charge	1.20	$1.23 + CPI_1$	$1.26 + CPI_2$	$1.31 + CPI_3$
Tier 2 charge	1.48	$1.59 + CPI_1$	$1.72 + CPI_2$	$1.85 + CPI_3$

Notes: 1. CPI = consumer price index.

overall dam level was at 100 per cent capacity was in 1998. There have been substantial falls in water levels (measured as a percentage of total capacity) in the second half of 2002 (dropping from around 80 per cent to about 60 per cent of capacity) and the first half of 2004 (dropping from around 60 per cent to less than 50 per cent of capacity). There are 11 dams that supply water for Sydney, and the largest is the Warragamba Dam. It is by far the biggest in terms of its overall capacity and has suffered the greatest declines of water in storage in the past five years. As of 1 March 2007, the total water available in the dams was about 1000 billion litres (GL), or a little less than 40 per cent of the total water storage capacity of some 2500 GL.

Water supply and demand are negatively correlated because low rainfall and high temperatures that reduce supply also coincide with greater water demand. This makes balancing supply with demand a difficult task in a variable climate subject to extended periods of low rainfall. The supply challenge is made worse by the substantial cost (in excess of $2 billion) and time required (upwards of 10 years under normal rainfall conditions) to build and fill a new dam (New South Wales Government 2004).

Median yields or net inflows into the Sydney catchment are a little less than 600 GL/year, but can be much less in low-rainfall periods (NSW Government 2004). For instance, net physical inflows in 2004 were 314 GL while the total consumption was 539 GL. A population predicted to be more about 20 per cent higher in a generation and an estimated decline in net water inflows due to climate change are both expected to make the balancing of supply and demand even more difficult in the future (Young *et al.* 2006).

To help address supply concerns, the NSW government initiated water restrictions in October 2003 that reduced demand, but were not sufficient to balance supply and demand. As a result, more severe Level III restrictions were introduced in June 2005 – still in force at the beginning of 2007 – that include limits on the watering of gardens to Wednesday and Sunday before 10 am and after 4 pm, no hosing of hard surfaces or vehicles, and permits to fill a pool larger than 10 KL (Sydney Water 2006). There are also subsidies to households to retrofit water-efficient products and install rainwater tanks, in addition to building codes on new dwellings designed to reduce water consumption by 40 per cent compared to the current Sydney household average (NSW Government 2004).

On the supply side, the SCA has undertaken major capital works to access deep water at the Warragamba and Nepean dams that allows for the use of previously inaccessible water of about 40 GL at a cost of some $120 million (NSW Government 2006, p. 82). Groundwater supplies have also been identified that might be sustainably withdrawn at about 5–10 GL/year, and possibly more for temporary periods during droughts (SCA 2006a). In addition, recycling investments are under way that, by 2015, are expected to deliver up to 70 GL/year in additional supply (NSW Government 2004, 2006). The largest scale recycling project, not currently planned, that would transform sewerage into potable water could increase potable water supplies by as much as 180 GL/

year at an initial capital cost of some $3 billion/year and annual operating costs of $175 million/year (Business Council of Australia 2006, p. 32).

The possibility also exists to increase current diversions from the Shoalhaven River by 30 GL/year if the capacity of the Tallowa Dam were raised at a cost that ranges from tens of millions of dollars to as much as $300–400 million depending on the chosen options (SCA 2006b, p. 36). A desalination plant would be able to provide 125 million litres (ML) per day, or some 46 GL/year if operated continuously, with the potential that an additional investment could deliver as much as 500 ML/day. The initial capital cost of a 125 ML/day plant is $1.3 billion and has an estimated operating cost of some $38 million/year if the plant were used only intermittently (NSW Government 2006, p. 93). However, annual costs could be four times as much if the desalination plant were used continuously and if carbon offsets were included as a cost of production (Business Council of Australia 2006, p. 32).

3. Estimating and forecasting Sydney water demand

To forecast the effect of IPART pricing and to simulate alternative pricing arrangements on water storage in Sydney we need to estimate aggregate water demand. Using data from the period 20 October 2001 to 30 September 2005 we estimate aggregate daily water demand (DEM) from the Sydney catchment as a function of residential water prices (LNP), daily temperature (LNT) and daily rainfall (RAIN) data from the Sydney Observatory, and a dummy variable (DUM1) for water restrictions that began in October 2003. The starting point of the data coincides with the beginning of the most recent low rainfall period, and the end point is immediately before the implementation of two-tier block pricing that began 1 October 2005. By not explicitly accounting for the two tier tariff in our model, the impact of a change in price on water demand may be biased downwards in predictions.

The estimated coefficients and diagnostics of the demand model are provided in Table 2 using nominal prices and in Table 3 using real prices. Both set of results are similar, but we choose to use the nominal price estimates because of the short sample period, and because it allows us to directly compare to scheduled IPART prices over the 2001–05 period and in our simulations. All variables are in natural logs with the exception of rainfall because of zero values. The estimated models include a first order autoregressive process to account for lags in adjustment, and we reject the null hypothesis in both models (nominal and real) that water demand and temperature have a unit root. As the models are in natural logs, the estimated coefficient on the price variable is a point estimate of the aggregate elasticity of demand. Our simulations are based on the Table 2 price elasticity estimate, but also values that are plus and minus one and two times the standard error. All estimated coefficients in both models are different from zero at the 1 per cent level of significance.

The results show, as expected, that an increase in daily rainfall or a decrease in daily temperature reduce water demand. The estimated coefficient for the

Table 2 Estimated aggregate Sydney water demand (nominal prices); Dependent Variable: DEM; Methods: Least Squares; Sample period: 28 October 2001 to 30 September 2005; Included observations: 1434 after adjustments; Convergence achieved after nine iterations; White Heteroskedasticity-Consistent Standard Errors and Covariance

Variable	Coefficient	SE	*t*-statistic	*P*-value
CONSTANT	6.722693	0.051137	131.4631	0.0000
LNP	–0.352086	0.093741	–3.755950	0.0002
LNT	0.221793	0.016717	13.26743	0.0000
RAIN	–0.000801	0.000229	–3.489058	0.0005
DUM1	–0.107878	0.017547	–6.148067	0.0000
AR(1)	0.597214	0.023791	25.10284	0.0000
R-squared	0.682983	Durbin–Watson stat		2.131385
Adjusted *R*-squared	0.681873	*F*-statistic		615.2993
SE of regression	0.081404	Prob. (*F*-statistic)		0.000000
Sum squared residuals	9.462776	Ramsey RESET(1) (*F*-statistic)		75.93368***
Log likelihood	1565.197	Ramsey RESET(2) (*F*-statistic)		87.95206***
Inverted AR roots	0.60			

Table 3 Estimated aggregate Sydney water demand (real prices); Dependent Variable: DEM; Methods: Least Squares; Sample period: 28 October 2001 to 30 September 2005; Included observations: 1434 after adjustments; Convergence achieved after nine iterations; White Heteroskedasticity-Consistent Standard Errors and Covariance

Variable	Coefficient	SE	*t*-statistic	Prob.
C	6.703416	0.051101	131.1804	0.0000
LNREALP1	–0.418010	0.124918	–3.346283	0.0008
LNT1	0.223561	0.016638	13.43703	0.0000
RAIN	–0.000790	0.000229	–3.447979	0.0006
DUM1	–0.123027	0.015340	–8.020055	0.0000
AR(1)	0.599737	0.023813	25.18514	0.0000
R-squared	0.682320	Durbin–Watson stat		2.134583
Adjusted *R*-squared	0.681207	*F*-statistic		613.4165
SE of regression	0.081489	Prob. (*F*-statistic)		0.000000
Sum squared residuals	9.482593	Ramsey RESET(1) (*F*-statistic)		77.32736***
Log likelihood	1563.697	Ramsey RESET(2) (*F*-statistic)		88.10745***
Inverted AR roots	0.60			

dummy variable indicates that water restrictions appear to have reduced water demand by about 10 per cent. The estimated price elasticity of demand of –0.352 in Table 2 is a short-run rather than long-run elasticity, and equals the median estimate of price elasticities from a meta-sample of 296 price elasticities from around the world collected and analysed by Dalhuisen *et al.* (2003). Our point estimates (nominal and real) are, however, a little less elastic than the short-run average household demand for water in Brisbane of some –0.507 (Hoffman *et al.* 2006) that was calculated from quarterly suburb-level data.

To test the forecast reliability of the estimated model we generated an out-of-sample forecast using the results from Table 2 of the actual daily water storage in the Sydney catchment over the period 1 October 2005 to 30 June 2006 using the following identity:

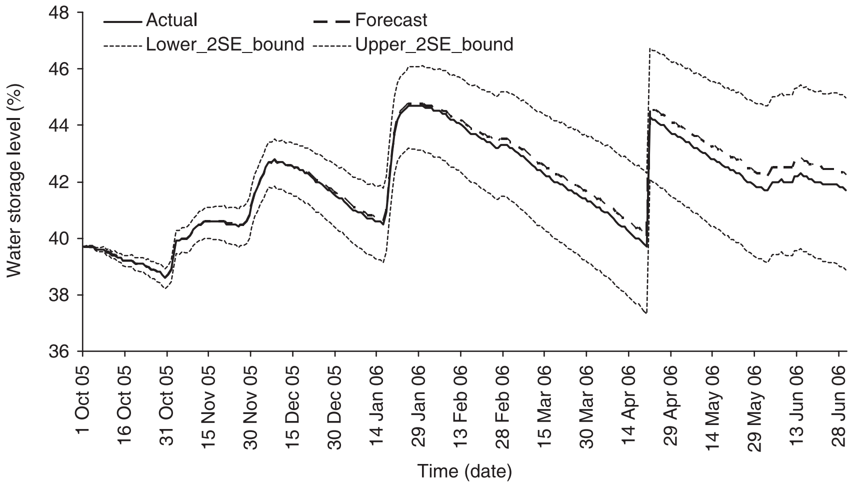

Figure 1 Forecast and actual water storage 1 October 2005 to 30 June 2006.

Table 4 Minimum price increase (%) over actual water price to keep above water given storage levels (2001–05)

	Desired minimum storage levels (% of full capacity)				
Elasticity	60% (in %)	55% (in %)	50% (in %)	45% (in %)	40% (in %)
–0.536	67.96	47.01	29.83	15.55	3.56
–0.446	86.95	59.11	36.89	18.89	4.12
–0.352	120.32	79.64	48.48	24.21	5.00
–0.258	192.59	121.52	70.88	33.78	6.57
–0.165	436.90	246.96	130.85	57.58	10.03

$$\Delta \text{ forecast water storage} = \text{net water inflows} - \text{forecast water demand.} \quad (1)$$

For the forecast, net daily water inflows are calculated as the difference between the actual daily water demand and the change in actual daily water storage. A comparison of the forecast and actual water storage in the Sydney catchment is provided in Figure 1. It shows that the estimated demand provides a good forecast of actual water storage and this is supported by a very low Mean Absolute Percentage Error of about 1 per cent, and a Theil inequality coefficient of 0.006 (Makridakis *et al.* 1998).

The estimated demand can also be used to calculate the percentage increase in the water price over the actual price required to keep the water storage in the Sydney catchment above key thresholds (60, 55, 50, 45 and 40 per cent of full capacity) in the sample period 2001–05. These price increases are provided in Table 4, using the estimated price elasticity equal to –0.352, and one and two standard errors above and below this point estimate. This interval includes the elasticity estimate used by the Sydney Water Corporation for

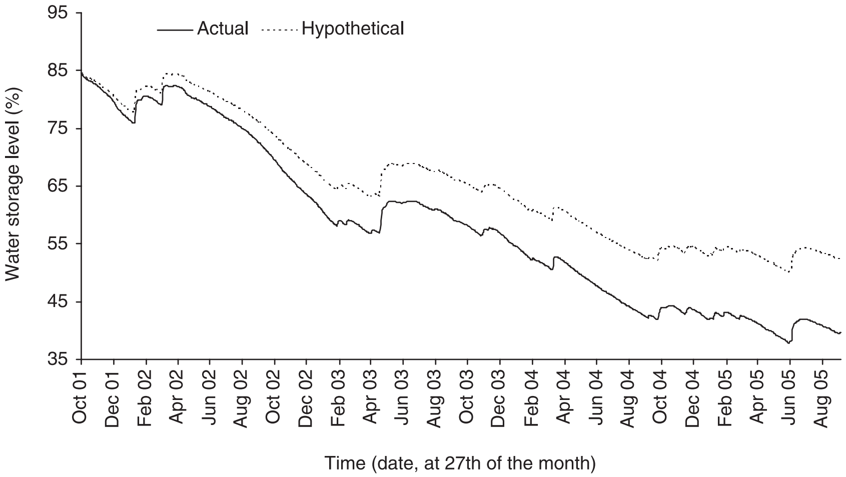

Figure 2 Actual and hypothetical water storage over 2001–05 period.

water planning purposes of –0.20 and also the point elasticity estimate of – 0.418 if we use real rather than nominal prices in the demand model.

The results indicate that the more inelastic the demand and the higher the minimum water storage level, the greater the increase in price that is required to achieve a given storage level. Table 4 shows that, given a water price elasticity of –0.352, the water price would needed to have been almost 80 per cent higher over the period 2001–05 to have kept the water storage levels above 55 per cent of capacity. Given a water price elasticity of –0.418 the price would have needed to be 64 per cent higher over the period 2001–05 to have kept the water storage levels above 55 per cent of capacity. This would have avoided imposition of water restrictions that were triggered at the storage level. Using the –0.352 elasticity, Figure 2 illustrates the actual water storage over the 2001–05 period and compares it to what it would have been with an almost 50 per cent increase in price that would have kept storage levels above half of full capacity.

Table 5 is constructed in the same way as Table 4, but with a hypothetical 50 per cent increase in the net physical inflows relative to that which actually occurred over the period 2001–05. It shows that in 'normal' rainfall years the existing pricing arrangements would have been sufficient to keep storage levels between 55 and 60 per cent of full capacity. Thus, the problem of balancing supply and demand is primarily an issue during extended periods of low rainfall.

4. Simulations of alternative water scenarios

The key issue facing water consumers in Sydney is to ensure that supply matches demand in low rainfall periods. If we use the actual daily net physical

Table 5 Minimum price increase (%) over actual water price to keep above water storage levels (2001–05) with a hypothetical 50% increase in net physical inflows

	Desired minimum storage levels (% of full capacity)				
Elasticity	60% (in %)	55% (in %)	50% (in %)	45% (in %)	40% (in %)
–0.536	7.12	–5.70	–16.27	–24.18	–30.56
–0.446	7.83	–7.59	–19.93	–28.60	–35.81
–0.352	8.92	–10.40	–24.97	–34.88	–43.09
–0.258	10.84	–15.06	–32.60	–44.42	–53.75
–0.165	15.07	–24.21	–46.40	–60.40	–70.32

inflows over the period 2001–05, we can simulate water storage levels over the next four years if we assume the same net physical inflows are repeated. This allows us to evaluate the effects of different supply and pricing arrangements on expected water storage levels in a low rainfall period.

We examine four scenarios assuming that the net physical inflows over the period 2001–05 are repeated from October 2006 until October 2010 and using the elasticity of –0.352. The larger (more negative) is the price elasticity the greater the impact of price on curbing demand, and the lower the required price increase to balance supply and demand in low rainfall periods. Should the net physical inflows be greater than what occurred over 2001–05 then water storage levels would be correspondingly higher and price increases needed to balance supply and demand would be lower.

In all four cases we use the scheduled IPART prices that are set until June 2009, given in Table 1, and assume the consumer price index increases by 3 per cent/year. All scenarios begin with the actual water storage level as of October 2006 of 40 per cent.

4.1 Scenario One

In this scenario, we forecast the actual water storage levels with the IPART scheduled prices plus we allow for an increase in water supplies from ground water of 15 GL/year (SCA 2006a) and from recycling initiatives of 24 GL/year (NSW Government 2004). The hypothetical storage with and without the extra water supplies is presented in Figure 3. The results indicate that in the absence of extra water supplies beyond the projected 39 GL/year, or other demand control measures beyond existing water restrictions, water storage levels could be as low as 25 per cent by 2010 if the rainfall and temperature pattern in the past four years were repeated. At this point, should low rainfall conditions continue, it is possible for Sydney to exhaust water supplies in its dams in about 12 months. This finding is disturbing because it suggests that the current plans to balance water supply and demand in Sydney are insufficient in low rainfall periods, and could also place Sydney at a point of critical water supply availability within the next four years.

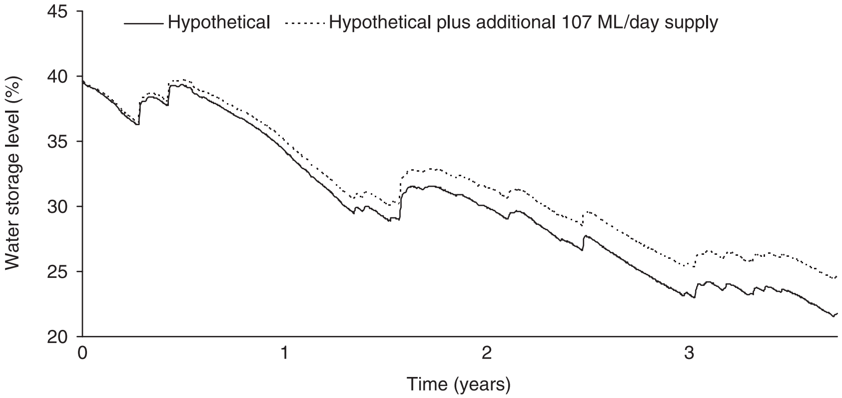

Figure 3 Hypothetical water storage levels with IPART scheduled prices plus additional water supplies of 107 mL/day or approximately 39 GL/year – four year projection.

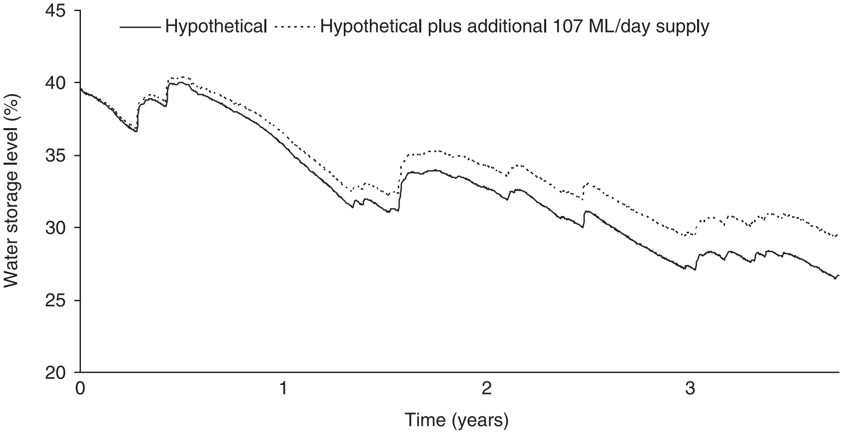

Figure 4 Hypothetical water storage levels with 48.48 per cent increase above IPART scheduled prices plus additional water supplies of 107 ML/day or approximately 39 GL/year – four year projection.

4.2 Scenario Two

In this scenario we simulate an increase in the scheduled IPART price of 48.48 per cent along with a 39 GL/year increase in supply. The 48.48 per cent price increase is the price rise required over the period 2001–05 given a price elasticity of –0.352 needed to keep water storage levels above 50 per cent. The results, shown in Figure 4, indicate that although the almost 50 per cent price increase keeps water storage levels above 30 per cent it is insufficient to match supply with demand. Under this scenario, water storage levels are expected to fall from 40 per cent to about 30 per cent over the four-year projection. Using a price elasticity of –0.418, a price increase of 39.31 per cent is required to keep storage levels above 50 per cent over the period 2001–05, storage levels are predicted to fall from 40 per cent to 32 per cent over the four year projection.

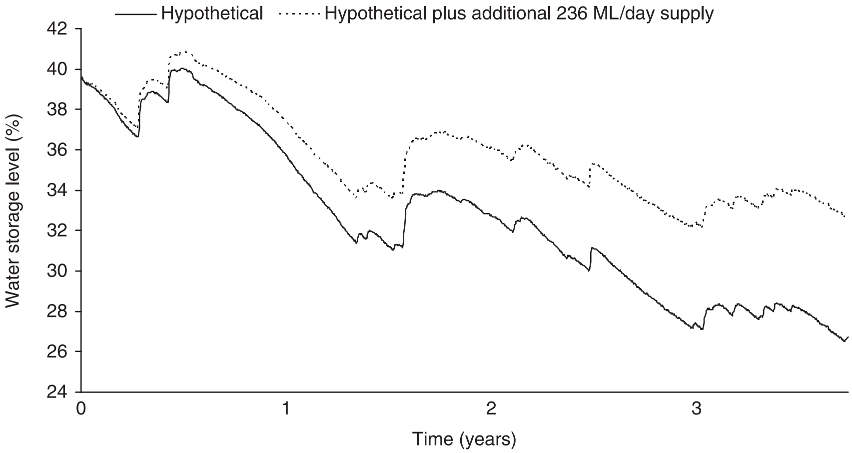

Figure 5 Hypothetical water storage levels with 48.48 per cent increase above IPART scheduled prices plus additional water supplies of 236 MLs/day or approximately 85 GL/year – four year projection.

4.3 Scenario Three

The NSW government has announced a number of water supply initiatives over the next 5–10 years that involve several different recycling projects. These projects combined are expected to increase water supplies by about 70 GL/year by 2015 (NSW Government 2006). In the simulation, we assume these supplies are available immediately along with groundwater supplies of 15 GL/year, and we also increase the IPART schedules price by almost 50 per cent. Figure 5 shows that even with these substantial increases in supply and large price increases water storage levels would continue to fall in low rainfall periods – declining from 40 per cent to about 33 per cent. If the chosen price elasticity were –0.418 and the price increase were 39.31 per cent, or what is required to keep storage levels above 50 per cent over the period 2001–05, predicted storage levels fall from 40 per cent to 36 per cent over the four year projection. In both cases, it suggests that the current supply planning, even with a large price increase and current water restrictions, is not sufficient to balance supply and demand in periods of low rainfall.

4.4 Scenario Four

Figure 6 presents simulations that are identical to Scenario 3, but with an additional supply of 50 GL/year. The simulations suggest that if the price elasticity is –0.352 or higher (negative) then additional water sources equal to 135 GL/year coupled with a 50 per cent price increase, are sufficient to match supply with demand over a four-year low rainfall period.

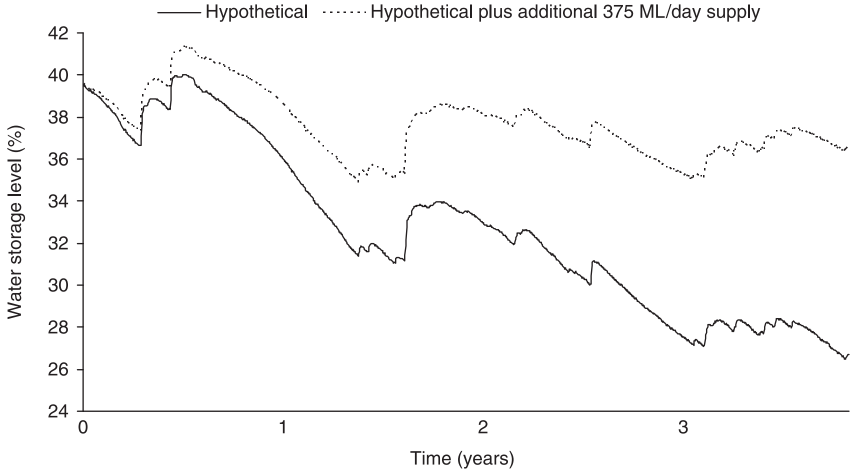

Figure 6 Hypothetical water storage levels with 48.48 per cent increase above IPART scheduled prices plus additional water supplies of 375 ML/day or approximately 135 GL/year – four year projection.

5. Policy implications

The simulations indicate that in low rainfall periods Sydney's current planned water supply increases and scheduled water prices are insufficient to prevent water storage levels reaching critical thresholds. The modelling shows that it is only through substantial increases in the water supply of 135 GL/year and at least 50 per cent increase in the scheduled water prices will supply match demand in low rainfall periods of up to four years duration. This provides a number of policy implications regarding supply and demand management of Sydney water.

5.1 Water pricing

The variability in rainfall within Sydney catchment and the time lag required to build and fill a new dam suggests that demand management and non-traditional sources of water are required. In particular, the water price paid by consumers should reflect its relative value as measured by the level of water storage. By contrast, under current arrangements the scheduled water prices are set independently of storage levels, and demand is primarily managed through quantitative controls imposed via water restrictions. Although water restrictions reduced demand by about 10 per cent relative to the period immediate before their introduction in October 2003, they impose considerable burdens on consumers and have failed to balance supply and demand. Quantity restrictions also prevent water from being allocated on the basis of marginal willingness to pay (Griffin 2006). In other words, there are likely high value uses of water for some individuals that are no longer possible with water restrictions.

An alternative to water restrictions is to use the water price to provide signals to consumers to adjust their demand. The water price would vary depending on the water storage in the Sydney catchment. In theory, a first-best pricing scheme for a monopoly provider given fixed capacity and declining average cost is to set the price equal to the marginal cost of supply. As this will result in a net loss to the supplier, the difference can be made-up by a lump sum payment allocated among all consumers (Tresch 2002).

Renzetti (1992) has modified the first-best pricing rule for urban water delivery. He argues that the price should equal its *LRMC* in peak demand periods, and equal the short-run marginal cost (*SRMC*) in off-peak demand periods. In the case where peak demand exceeds existing capacity, the price in peak periods should be even higher to ensure demand equals supply.

We propose a modification to the peak-load pricing proposed by Renzetti (1992) where water prices are adjusted every quarter depending on water in storage in the Sydney catchment. Under our pricing arrangement the volumetric water charge should be raised sufficiently to prevent water storage levels going below critical threshold levels. When water storage is at full capacity, the volumetric price charged to consumers would equal the *SRMC* of supplying water from the SCA dams. As water storage declines, perhaps at 5 per cent levels (95, 90, 85, 80 . . . of full capacity), the price of water would increase to help balance water supply and demand, and may need to rise very substantially (upwards of 50 per cent of scheduled IPART prices) in extended low rainfall periods.

Our proposed pricing arrangement is similar to that discussed by Sibley (2006a) and also Crase and Dollery (2006). A common characteristic in these two proposals is that the volumetric price of water should be used to ensure demand equals supply, and to provide appropriate signals and incentives to consumers to reduce demand at periods of low supply.

Sibley (2006a) has argued that a fixed connection charge might also need to be applied to ensure a residual revenue component when water is priced at *SRMC*. Such a fixed connection charge need not be identical across households, and could even be related to property values (Sibley 2006b). A fixed connection charge, however, may not be necessary if there are sufficient low rainfall events as the revenues generated when flexible prices are applied could more than offset potential losses when storage is at full capacity.

A potential drawback to our proposed flexible pricing is the high price that consumers, especially low-income households, will need to pay in low rainfall periods. It is probably for this reason that 50 per cent of respondents in a 2005 survey opposed water prices that rose as the lower water levels in the dams fell, although it was supported by about 40 per cent of those surveyed (IPART 2005). Some of the pricing concerns of households could be addressed by explicit consideration of equity issues associated with high water prices. First, rents collected by Sydney Water or SCA in low rainfall periods could be used to provide 'water bill relief payments' to needy households. Second, if a fixed connection charge is coupled with a flexible water price it may even be possible to have a negative connection charge based on household income. Third, it may even be possible to establish water thresholds for each household based on per capita consumption thresholds such that the water used would be charged at *SRMC*, but greater usage would be charged at a higher price set to balance water supply and demand.

A water usage allowance charged at *SRMC* could be set as a fixed percentage of past household water consumption, a fixed water quantity for every household, or as some allowance per person that would vary depending on the number of people per household for 'essential' uses. Although this approach appears similar to the current two-tier block pricing of IPART, it would be different as the threshold would be set to ensure the vast majority of households would pay the higher price for extra water consumed, and also because the higher price would flexibly adjust over short periods of time (quarters) to the water levels in the dams rather than, as at present, be set years in advance and independent of short-run changes in water availability.

5.2 New water supplies

Our modelling of flexibly upward prices in low rainfall periods suggests that prices more than 50 per cent higher than IPART's scheduled prices are required to help balance supply and demand. This translates into base water prices in excess of $1.90/KL. Such prices would encourage new supply sources such as re-use of storm water, sewerage recycling, cross-catchment transfers, desalination, or water pipe improvements to fix leaks. New sources of supply would increase consumer surplus, and also help lower the volumetric price required to balance supply and demand.

Finally, we observe that without a substantial increase in supply of some 135 GL/year, whatever the source, demand and supply will not balance in extended low rainfall events even with a 50 per cent increase in the volumetric water price. Given that the infrastructure needed to provide new water supplies may take several years to develop, an immediate priority should be given to establishing flexible water pricing to encourage and pay for these extra sources of supply.

6. Conclusions

Most of Australia's major urban centres currently have an imbalance between supply and demand. The standard approach to urban water demand management is to set water prices independent of the water in storage, or available supply, and to restrict consumption via water restrictions. Using data on water storage and demand in Sydney we estimate aggregate daily water demand and use it to evaluate existing and alternative price and supply scenarios.

The modelling and simulations indicate that, should there be another extended low rainfall period in the next four years, Sydney would become critically short of water. As an alternative to existing arrangements, a flexible volumetric water price is proposed that would rapidly adjust upwards as the amount of water in storage declines. At times of full water capacity consumers would be charged the short-run marginal cost of supply, but would pay much higher prices (more than 50 per cent higher than current prices) when water storage levels are low. Flexible water pricing would help balance supply and demand and would obviate the need for on-going water restrictions. A much higher water price set to balance supply and demand in low rainfall periods could also encourage new sources of supply.

Two concerns of the proposed flexible pricing is the high cost of water that would need to be paid in low-rainfall periods, especially by poor households, and the variability and uncertainty it gives to consumers over future water expenditures. Equity issues could possibly be addressed with a connection charge that declines (and may even become negative) with rises in the volumetric price paid by households, welfare assistance that could be partially or even fully financed out of increased revenues that will flow to the NSW Treasury from higher prices in low-rainfall periods, or with a two-part pricing scheme whereby households are provided with an allowance for essential uses that would be charged at a much lower base price, but consumption beyond this amount would be at the higher and flexible price. Rather than being undesirable, price variability where consumers pay more for water when there is less available in the dams provides the feedbacks and incentives necessary to balance supply and demand.

Overall our modelling suggests that without a fundamental change in water policy (pricing and supply) Sydney faces the possibility of critical water shortages in the short- to medium-term should there be a continuation of low-rainfall events. This problem will likely be aggravated by a predicted decline in water yields and population growth. By contrast to current water pricing policies, our proposed flexible pricing offers the means to balance future water supply and demand.

References

Business Council of Australia (2006). *Water under Pressure: Australia's Man Made Water Scarcity and How to Fix It*. Available from URL: http://www.bca.com.au/Content.aspx?ContentID=100665 [accessed 3 Apr 2007].

Crase, L. and Dollery, B. (2006). Water rights: a comparison of the impacts of urban and irrigation reforms in Australia, *Australian Journal of Agricultural and Resource Economics* 50, 451–462.

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

Dwyer, T. (2006). Urban water policy: in need of economics, *Agenda* 13, 3–16.

Griffin, R.C. (2006). *Water Resource Economics*. The MIT Press, Cambridge, Massachusetts.

Hoffmann, M., Worthington, A. and Higgs, H. (2006). Urban water demand with fixed volumetric charging in a large municipality: the case of Brisbane, Australia, *Australian Journal of Agricultural and Resource Economics* 50, 347–359.

Independent Pricing and Regulatory Tribunal (2005). *Sydney Water Corporation, Hunter Water Corporation, Sydney Catchment Authority Prices of Water Supply Wastewater and Stormwater Services Final Report*.

Makridakis, S., Wheelwright, S.C. and Hyndman, R.J. (1998). *Forecasting Methods and Applications*. John Wiley & Sons, Hoboken, New Jersey.

New South Wales Government (2004). *Meeting the Challenges: Securing Sydney's Water Future*. Available from URL: http://www.dipnr.nsw.gov.au [accessed 3 Apr 2007].

New South Wales Government (2006). *Metropolitan Water Plan*. Available from URL: http://www.waterforlife.nsw.gov.au/about_water_for_life/metropolitan_water_plan [accessed 3 Apr 2007].

Productivity Commission (2006). *Rural Water Use and the Environment: The Role of Market Mechanisms*. Research Report, Melbourne.

Quiggin, J. (2006). Urban water supply in Australia: the option of diverting water from irrigation, *Public Policy* 1, 14–22.

Renzetti, S. (1992). Evaluating the welfare effects of reforming municipal water prices, *Journal of Environmental Economics and Management* 22, 147–163.

Sibley, H. (2006a). Urban water pricing, *Agenda* 13, 17–30.

Sibley, H. (2006b). Efficient urban water pricing, *Australian Economic Review* 39, 227–237.

Sydney Catchment Authority (2006a). *Metropolitan Water Plan: Ground Water Investigation Report*. Available from URL: http://www.sca.nsw.gov.au/publications/117.html [accessed 3 Apr 2007].

Sydney Catchment Authority (2006b). *Shoalhaven Water Supply Transfers and Environmental Flows August 2006 Discussion Paper*. Available from URL: http://www.sca.nsw.gov.au/publications/files/SH001.pdf [accessed 3 Apr 2007].

Sydney Water (2006). *Mandatory water restrictions*. Available from URL: http://www.sydneywater.com.au/SavingWater/WaterRestrictions/ [accessed 3 Apr 2007].

Tresch, R.W. (2002). *Public Finance: A Normative Theory*. Academic Press, San Diego.

Young, M.D., Proctor, W., Qureshi, M.E. and Wittwer, G. (2006). Without water: The economics of supplying water to 5 million more Australians. In, *Water for a healthy country, flagship report*. CSIRO and Monash University, Melbourne.