The effects of centrally determined water prices on irrigation water demand: evidence from the Victorian State Rivers and Water Supply Commission, 1908-1984

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1. Introduction

There is a vast literature that examines the outcomes of government management of the irrigation sector (for example, Kanazawa, 1993; Foster, Calvin, Johns, and Rottschaefer, 1986; Candee, 1989; Harris, 2007; Howitt, Watson, Adams, 1980; Anderson and Snyder, 1997; Anderson and Hill, 2004; Sampath, 1992; Cummings and Nercissiantz, 1992). Much of this work emphasises the net costs of government administration resulting from inefficient pricing and allocation policies leading to government failure. However, no studies have empirically tested the relationship between water demand and low prices typical of central planning. Theoretically it would be expected that demand for water is like other goods that is, a downward sloping curve: as price increases, quantities demanded decrease. Nevertheless, if we are to accept the argument that water has several unique characteristics distinguishing it from other scarce resources (Howitt, *et al,* 1980; Dinar, Rosengrant, and Meinzen-Dick, n.d.), then there is no reason to assume these theoretical demand relationships hold. Using data from the Victorian State Rivers and Water Supply Commission (SRWSC) between 1906 and 1984, this paper aims to ascertain the exact relationship between irrigation water demand and price. For much of the life-span of the SRWSC, unit prices were set below the cost of supply, maintenance, and management requirements. The effects of underpricing were reflected in three ways: a subsidy per capita; a proportion of the annual capital costs being absorbed by the Government; and writing off of district capital liabilities on the SRWSC accounts (Harris, 2007). To provide a more meaningful analysis, in addition to price, we also include variables expected to influence water demand. Specifically, annual rainfall, production profile, and aggregate water right entitlements.

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Historically, government administration, typically characterised by setting prices and allocating volumes to individuals has dominated the institutional arrangements for irrigation sector management in many countries, including Australia. Traditionally, economists favoured the use of government administration of the water sector due to problems of endemic market failure. Market failures occur because of the very nature of the good as a common pool resource. Moreover, even if these problems can be internalised, pricing systems are largely inefficient as an allocative mechanism for irrigation water (Howitt, *et al*, 1980). Government administration also had an advantage in overcoming the public good problems of infrastructure investment in irrigation brought about by economies of scale. In addition, the expansion of irrigation can create social benefits, contributing to agricultural sector development and regional economic growth (Sampath, 1992). In more arid areas, irrigation can also limit the crop and stock losses caused by drought. However, in recent years, economists have recognised that as much as the market is prone to fail, so too is government.

Generally, government failure results from a divergence between private and social costs. Two schools of thought outline why government failure arises: public choice, specifically 'capture' theory and; Austrian political economy. Capture theory argues that self-interest of all groups in the political sector, politicians, bureaucrats, voters, and special interest groups leads to inefficiency within the political sector (for instance: Downs 1957; Olson 1965; Stigler 1971, 1974; Mueller 1989). In this model self-interest generates deception (Ikeda, 2003). Deception occurs because public choice theorists assume planners have perfect information, creating avenues for opportunistic behaviour.[1] The logic is as follows: politicians are motivated by the desire to be re-elected. Re-election is a function of the number of votes that can be secured as well as political currency, for example, campaign contributions. Bureaucrats want to maximise their personal income as well as the size of their budget and number of employees in their department. Voters remain rationally ignorant because information is complex and costly to attain. Special interest groups (or industry) exploit voter ignorance and provide politicians with political currency manipulating outcomes in the political sector by creating previously unavailable rents. Stigler (1971) notes there are four ways in which industries may secure state action to increase profitability: via direct subsidies; controls over entry a variant of which is the protective tariff; impacts on substitutes and compliments; and price-fixing policies. All of these state actions generate cumulatively larger societal costs than the benefits they generate.

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[1] Both planners and special interest groups can act opportunistically because high transaction costs and asymmetric information exist in these settings. Ikeda (2003) argues this creates a divergence between announced and actual intentions.

Conversely, Austrian political economy assumes bureaucratic benevolence but imperfect information as the reason for government failure. In other words, deception does not cause intervention to fail, error does. Error stems from radical ignorance leads to a divergence between intended and actual outcomes. Radical ignorance refers to actors' unawareness of the existence of relevant knowledge that could be known at zero cost (Ikeda, 2003).

Government failure in the water sector is primarily characterised by regulating prices, specifically, failure to price water equal to marginal cost. In this context, price regulation is similar to a price ceiling creating a dead weight loss and associated decreases in consumer surplus. Moreover, two social costs are associated with centrally administered pricing: negative externalities and subsidies. Negative externalities, particularly salinity, reduces on-farm productivity as well as affecting production downstream from the source because return flows increase in-stream salinity (Harris, 2007). In part, this is caused by incentives to over-use water when prices are set below marginal cost. Over-use is the result of the distortion of factor input mix favouring water-intensive production techniques (Kanazawa, 1993) and the extension of agriculture onto marginal lands producing low valued crops (Candee, 1989; Harris, 2007). Below cost prices also reduce revenues for irrigation authorities limiting funds available for maintenance of irrigation infrastructure that can add to negative externalities and create water losses via seepage effects. Water lost due to poorly maintained infrastructure will limit supplies available for environmental (in-stream) flows decreasing in-direct benefits particularly life-support contributions and non-use benefits, for instance habitat values of river ecosystems.

Pricing below cost can also create subsidies for irrigation farmers, imposing welfare losses to consumers for example taxes (Foster, Calvin, Johns, and Rottschaefer, 1986). This implies the benefits of irrigation are concentrated on subsidised producers while the costs are spread across society as a whole. Centrally determined allocations also add to social costs of government administration of the irrigation sector because they do not reflect individual water demand. This can lead to over supply at the farm level due to incomplete information on the part of planners. Accompanied by the inability to trade water, this compounds the problem of over-use caused by pricing below marginal cost.

The findings presented here suggest price does not exert a significant influence on water demand. Moreover, where the price variable is significant, it is positive. This indicates that the expected theoretical relationships between demand and price may not hold in the water sector. In part, this may be caused by a perfectly inelastic demand curve for irrigation water empirical studies have estimated occurs at below $20 per unit (Collins *et al*, 1996; Hall, Poulter, and Curtotti, 1994; Read, Sturgess and Associates, 1991). Low prices result in water remaining a low cost input and prevent substitution into more efficient irrigation technologies in the medium to long-run. As a result, the maintenance of low prices over time creates a circular relationship between water demand and price responsiveness. Specifically, the persistence of low prices encourages demand because it is only at very high prices that demand becomes elastic. Historically, charges by the SRWSC exceeded $20 per unit in only some irrigation districts and in only four out the 76 years included in the analysis. Further, the findings suggest that crop mix was a more important factor in determining irrigation water demand over the period being examined. The dominance of water intensive pastures and broadacre crops, such as lucerne and cereals, created high levels of demand for water. In turn, low prices encouraged the extensive production of these crops because prices did not reach a threshold level beyond which water demand was elastic. The findings suggest that demand management may not been an effective policy tool in the irrigation water sector because demand is inelastic. However, the introduction of water markets and their subsequent impact on price may act to overcome some of the limitations of centralised management by increasing prices to a point beyond which demand is elastic. In turn, this may encourage production to shift away from low valued, water intensive crops.

The structure of the paper is as follows: section 2 outlines the role of SRWSC and describes the data being used. Section 3 presents the model and data analysis, including discussion of the results. Section 4 offers some brief concluding comments and areas for future research.

2. Water pricing and allocation of the SRWSC

The SRWSC was a statutory corporation responsible for the allocation and pricing of water supplied to Victorian irrigation areas from 1908 to 1984. Its aim was two-fold: overcome large financial losses associated with decentralised management in preceding decades; and encourage irrigation sector expansion to support economic development. Under SRWSC control, an irrigator's water allocation had two components: water rights and sales water. Water rights were the perpetual entitlement for each individual irrigator that is, the per annum volume of water as measured in acre-feet (or megalitres). An irrigator could expect that in ordinary rainfall years, 100% of this right would be available thus making this entitlement highly reliable. In drought years supply would decrease to 70% of the water right. Water rights were assigned on a one for one principle; that is for every acre deemed suitable for irrigation users were allocated one acre-foot of water. Irrigators' paid a uniform price for each acre-foot (or megalitre) of water right supplied. However, they were not free to determine the quantity of water right utilised each season due to the application of a minimum compulsory charge. The compulsory charge required an irrigator to pay for a minimum volume regardless of whether it was used or not. For example, assume irrigator A had a per annum water right of 100 acre feet priced at $1 an acre foot with a minimum compulsory charge of 50 acre feet. This meant that even if she used only 20 acre foot, the required seasonal water payment was $50.

Sales water could be purchased annually in addition to water rights allocations. Specifically, in each normal rainfall season the SRWSC allowed farmers to purchase sales water restricted to 30% of their entitlement. Therefore, the total amount of water available to an irrigator in an ordinary rainfall season was 130% of her water rights. For instance, irrigator A's water right is 100 acre feet, 30% of this amount can be purchased as sales water increasing A's available water within a season to 130 acre feet. Irrigators paid the same price for sales water as for water rights – in our example, $1. For irrigator A that meant if she used her entire water right allocation plus purchased the maximum available sales water the total cost of water for that season would be $130. In this way, water pricing included both a fixed and variable cost element. Fixed costs included water rights up to the minimum compulsory charge amount. Variable costs included residual water rights above the minimum charge plus any sales water purchased. In our example, with a minimum compulsory charge of 50 acre feet, irrigator A paid a maximum annual fixed cost of $50, regardless of whether the volume used was below this level. The remaining volume, 80 acre feet (50 acre feet of water right plus 30 acre feet of sales water), was a variable cost determined by the volume used above the minimum 50 acre feet. The magnitude of variable costs were a function of several factors including, price per unit, seasonal rainfall, crops produced, soil type, and the individual's total water right.

The data employed in our analysis is sourced from SRWSC annual reports during its lifespan (1905-1984). These reports are an extremely rich source of district level financial and water delivery data. Each irrigation district, about 20 in total, had information recorded relating to price per unit, aggregate water rights allocated, sales water purchased, and crops produced. Each irrigation districts price per unit (acre feet or megalitres) was determined annually by the SRWSC. Uniform unit prices were applied for both water rights and sales water and these prices did not tend to change every year often remaining static for as long as a decade. However, there is some variation that may allow us to isolate the impact of prices on demand. The reports do not contain information on the individual or district volume to which the compulsory charge applied but they do contain records of sales water purchased annually in each district. It is expected that fluctuations in this variable may allow us to capture the effects of price changes on demand for water over the period. As noted, if theoretical demand relationships hold, an increase the price per unit should lead to a decrease in sales water purchased across all districts.

In addition to price, several factors will affect water demand in any one season. We have included several variables in the analysis: crop production, the amount of land laid fallow, and annual rainfall. Crop production patterns are documented on a per district basis in the SRWSC annual reports. Production is measured by the acreage devoted to different crop types in each district. Several categories are included, specifically: cereals, lucerne, fodder, pasture, and vineyards. It is expected that each crop would have a different elasticity of demand affecting irrigators responsiveness to water price. However, it is not possible to estimate elasticities with the available data. A number of studies have estimated elasticities for irrigation water independent of crop type and findings suggest demand is inelastic at low prices (Schoengold, Sunding, and Moreno, 2006; de Fraiture and Perry, n.d; Appels, Douglas, and Dwyer, 2004; Hall, 2003; Collins, Hall, and Scoccimarro, 1996; Read, Sturgess and Associates, 1991). Moreover, a sub-set of these studies have concluded that at very low prices, primarily between $0 and $20 per unit (acre feet or megalitres) demand is perfectly inelastic (Collins *et al*, 1996; Hall, Poulter, and Curtotti, 1994; Read, Sturgess and Associates, 1991). As a result, there is a general contention within the literature that irrigation water demand becomes price responsive only beyond some threshold. Further, as prices increases beyond the threshold, elasticity of demand increases so that at very high prices, demand is highly elastic. Recent empirical evidence from Watermove water markets that administers trading in much of the geographical area included in this study and where average monthly prices tend to exceed $20 per unit, estimate price elasticity of demand between -1.51 and -3.53 (Brooks and Harris, 2008; Wheeler, Bjornland, Shanahan, and Zuo, 2008).[2] These findings support the contention that demand is inelastic at low water prices.

In terms of elasticity of demand for the crop types recorded in our data set, we can identify expected elasticities for each group based on water use requirements. This will allow us to establish certain expectations as to how demand for sales water might be influenced by crop

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[2] For more detailed information on the average monthly prices on Watermove from 2002/03 to 2007/08 please refer to the website: www.watermove.com.au.

type. For districts dominated by pasture it is expected that water demand will be price inelastic. The reasoning is as follows: pasture is a water intensive crop produced over a growing season to store for later use. This acts to reduce price responsiveness in districts with greater areas devoted to pasture. Therefore, there will be a positive relationship between pasture and water sales. Nevertheless, lucerne and fodder crops are substitutes for perennial pastures. As a result, if water prices increase substantially but lucerne and fodder prices remain low, irrigators might find it cost-effective to substitute at the margin (Appels, *et al*, 2004). This suggests a threshold for demand might exist for producers of pasture. In other words, assuming prices of fodder and lucerne remain constant, sales water demand will remain inelastic until water reaches very high prices. Past that point, irrigators producing pasture will substitute water for comparatively lower priced fodder and lucerne. Like pasture, cereals, lucerne, and fodder are also water intensive crops suggesting that with larger areas devoted to production of these crops, demand for water would be high regardless of price (Zaman, Davidson and Malano 2005; Oczkowski 2005). In other words, for these crops, we expect water demand to be relatively price inelastic. Therefore, there will be a positive relationship between water sales and the area devoted to cereals, lucerne, and fodder.

One option for irrigators to reduce water demand is to substitute production for increasing the area of fallow (not cultivated) land. Decisions to lay land fallow would be influenced by a number of factors including, the potential future increase in output and thereby, revenue streams earned from ‘resting’ land; falling crop prices; and reduction in the availability of water (particularly during drought years). The higher the acreage devoted to fallow, the lower the demand for sales water. Therefore, we expect a negative relationship between water demand and fallow land.

Vineyards and orchards are less water intensive than the other crops recorded in the annual reports; therefore we expect districts with a larger area of land employed in production of vineyards will, on balance, demand less water regardless of price. However, a lack of input substitution options could suggest that demand is inelastic. Therefore, there will be a positive relationship between water sales and area devoted to vineyards. This positive relationship is not expected to be as strong as that for pastures, cereals, lucerne, and fodder crops. Demand for sales water will also be influenced by seasonal rainfall because it is a substitute for water supplied from SRWSC storages. Annual rainfall data for each district was sourced from the Bureau of Meteorology. In all cases, the closest rainfall station to the particular district covering the entire period of observation was used. Rainfall is a substitute for water supply provided from SRWSC infrastructure and therefore, it is expected that rainfall will be negatively related to sales water purchases. In other words, there will be reduced demand for sales water during wetter years.

There are several additional factors that may influence water demand over the period of observation that we have not included in our model specifications: technology changes and output prices. Technological innovation in irrigation techniques will reduce water demand. For instance, replacing flood irrigation with trickle or drip methods results in large reductions of demand over time. The adoption of technology change is difficult to measure at the farm level and there is an absence of data at the district level. However, evidence suggests there was little technological innovation within the irrigation sector over much of the time period being examined and currently, flood irrigation is still the dominant method of water use in Victorian irrigation regions. Moreover, low water prices would have provided little incentive for farmers to invest in improved technology to reduce demand. Output prices also exert an important influence on production profiles within irrigation districts. Assuming irrigators are rational, profit maximisers, we would expect that an increase in output price would provide an incentive for them to dedicate more acreage to production of that output. If this expansion took place for water intensive irrigated crops, then sales water demand may increase regardless of price. As yet, we do not have information on price variables but will incorporate these variables in subsequent research.

For all the post-1940 model specifications an additional dependent variable has been included that was not available in the pre-1940 data: water rights allocated per district. Specifically, this variable captures changes in the aggregate water entitlements over time in each district. The relationship between water sales and water rights could be either negative or positive. Theoretically, a negative relationship would be expected that is, as more entitlements are allocated to a district, irrigators will become less reliant on sales water. Therefore, demand for sales water will decrease regardless of price. However, this relationship may be positive that is, an increase in entitlements will increase the demand for sales water if the allocation of additional entitlements over time lead irrigators to expand production beyond the entitlement allocation. Moreover, a higher volume of water rights will increase the volume of sales water available to each irrigator, reinforcing this effect. As a result, irrigators may become more dependent on sales water as entitlement volumes increase over time. Reforms in the Australian water sector over the last two decades, including the introduction of water markets have, in part, been predicated on the premise that historically low water prices have led to the expansion of irrigation onto marginal lands, producing low value crops. A positive relationship between water sales and water rights in the post-1940 specifications may provide some support to this contention.

3. Model and data analysis

Our data set is divided into two components for analysis for two reasons. First, because measurement of the dependent variable, water sales, changes across time. Specifically, prior to 1940, SRWSC annual reports record water sales in terms of revenue collected that is, pounds (£). After 1940 this variable is recorded in volume that is, acre feet of sales water purchased. Second, prior to 1940 the total water right allocated to each district is not recorded; after 1940 this data is included. As noted, changes in aggregate water rights allocations may exert an important influence over demand for water sales.

By dividing the data into two sets; 1908 to 1939 and 1940 to 1984, we are able to account for both of these variations. We explore two specifications of the model, one excluding the water rights variable (equations 1 and 2), and one including the water rights variable (equations 3 and 4). For the analysis in the post-1940 data we run both specifications of the model. We consider specifications in both levels (equations 1 and 3) and first differences (equations 2 and 4) to adjust for non-stationary, and we report panel unit root tests in our analysis.

The models that are estimated are shown by the equations below:

$$\begin{aligned} w\_sales_t &= \beta_0 + \beta_1 c\_charge_t + \beta_2 cereal_t + \beta_3 lucerne_t + \beta_4 fodder_t \\ &+ \beta_5 pasture_t + \beta_6 vineyards_t + \beta_7 fallow_t + \beta_8 rainfall_t + e_t \end{aligned} \tag{1}$$

$$\begin{aligned} \Delta w\_sales_t &= \beta_0 + \beta_1 \Delta c\_charge_t + \beta_2 \Delta cereal_t + \beta_3 \Delta lucerne_t + \beta_4 \Delta fodder_t \\ &+ \beta_5 \Delta pasture_t + \beta_6 \Delta vineyards_t + \beta_7 \Delta fallow_t + \beta_8 \Delta rainfall_t + e_t \end{aligned} \tag{2}$$

$$\begin{aligned} w\_sales_t &= \beta_0 + \beta_1 c\_charge_t + \beta_2 wr + \beta_3 cereal_t + \beta_4 lucerne_t + \beta_5 fodder_t \\ &+ \beta_6 pasture_t + \beta_7 vineyards_t + \beta_8 fallow_t + \beta_9 rainfall_t + e_t \end{aligned} \tag{3}$$

$$\begin{aligned} \Delta w\_sales_t &= \beta_0 + \beta_1 \Delta c\_charge_t + \beta_2 \Delta wr + \beta_3 \Delta cereal_t + \beta_4 \Delta lucerne_t \\ &+ \beta_5 \Delta fodder_t + \beta_6 \Delta pasture_t + \beta_7 \Delta vineyards_t + \beta_8 \Delta fallow_t + \beta_9 \Delta rainfall_t + e_t \end{aligned} \tag{4}$$

Where w_sales is water sales purchased in a district in a year; c_charge is the compulsory charge for that year; Wr is the total water rights allocated to a district in a year; Cereal, Lucerne, Fodder, Pasture, and Vineyards are the acreage planted with each of these crops respectively; Fallow is the acreage of land laid fallow; Rainfall is the annual rainfall in the district. Our models aim to explain district level water sales as a function of a price variable (the compulsory charge), allocated water rights, levels of agricultural production, and rainfall.

Our data set has a panel structure, in that we have data for a number of variables across a number of districts on an annual basis. In a panel data setting there are a range of possible models that can be estimated to allow for fixed effects or random effects in the modelling. Fixed effects models control for omitted variables that are assumed to differ between cases but are constant over time. Random effects models are employed where it is believed that some omitted variables are constant over time but vary between cases and others are fixed between cases but vary over time. The models used here also allow for fixed or random effects at the district or period level. The different techniques and their associated specifications of the intercept term are panel LS (β_0), fixed districts (β_{iD}), fixed period (β_{it}), fixed districts and period (β_{iD}, β_{it}), random district ($\beta_{iD}=\beta_i+\varepsilon_{iD}$) and, random period ($\beta_{it}=\beta_i+\varepsilon_{it}$).

Table 1 reports estimation results for the period 1908 to 1940 (pre-1940 for the levels specification of the model). The structure of this table (and all the following results tables) is as follows. Table 1 reports parameter estimates and p-values for the coefficients on each of the variables in the model for six different model estimation techniques (least squares, three fixed effects specifications and two random effects specifications). The table also reports a range of diagnostic tests including p-values for testing for panel unit roots, p-values for testing for redundant fixed effects, and p-values for testing for correlated random effects. As expected, the results indicate a significantly positive relationship between water sales and the acreage devoted to cereal and pasture across all models. The acreage devoted to lucerne is also significantly positive, conforming to our expectations. However, this relationship is only identified in some of the models (panel LS, fixed period, and random period). Further, as expected, the results for fodder are significantly positive but this only occurs in the fixed districts model specification. The compulsory charge variable remains insignificant across all models but with a changing sign. The test for redundant fixed effects is significant at the 5% level for cross-section, period and cross-section/period respectively, and the correlated random effects are also significant. These outcomes demonstrate the need to consider more complex panel data specifications. Unit root tests indicated that all the variables are I(1) thus motivating the need to consider a model in first differences. The adjusted R^2 is higher for the fixed districts and fixed period techniques.

Table 2 consists of the estimation results of the differenced series for the pre-1940s data. We find that cereal and rainfall are significantly positive across all models, although the sign is not as expected for rainfall. The positive sign on the rainfall variable may result from the fact that irrigators are risk averse and face limited information regarding actual rainfall over the length of the season at the start of that season. In an analysis of water trading patterns across the Goulburn-Murray Irrigation District, which includes the majority of the SRWSC districts included here, Brennan (2006) argued irrigators will hold more water at the beginning of a season because information regarding rainfall is limited. As this information is revealed throughout the season, trading volumes will increase (Brennan, 2006; Brooks and Harris, 2008). The results for rainfall in table 2 may be a reflection of this information asymmetry. Specifically, if irrigators expected low rainfall over a season, which later proved to be false, they might have demanded more sales water in order to insulate themselves from the risks associated with water scarcity and subsequent crop losses. Moreover, a positive relationship between rainfall and water sales demand may reflect the lag between when irrigation water is required and when rain actually falls. In other words, if rain was scarce at times when crop watering was needed to maximise production, demand for sales water may have increased. However, later season rainfall may have been high causing the positive relationship between these variables shown in table 2. The compulsory charge has the expected negative sign across all model specifications if the expected demand relationships hold however, none of these are significant. The adjusted R^2 are quite small for all the models however this is a typical characteristic for differenced data. Rho is zero for random district which means that coefficients for panel LS and random district are the same. The redundant fixed effects are significant at the 5% level for period from fixed period model and fixed district and fixed period model. The correlated random effects are significant for both random district and period.

Estimation results including the water rights variable are summarised in table 3 for post-1940s data. As expected, cereal and lucerne are significantly positive across all models. The variable WR (water rights) is also significantly positive. This may reveal an underlying incentive for farmers to extend irrigated area as entitlements increase over time in excess of the additional water rights available, intensifying the reliance on sales water. This argument is supported by the general contention that historically, irrigation production in Victoria expanded on to marginal lands (Harris, 2007). If this expansion was dominated by production of water intensive crops, such as cereals and lucerne, then the significantly positive relationship between water rights and water sales demand is less surprising.

As expected, table 3 shows the variable pasture is significantly positive for some of the model specifications (panel-LS, fixed districts, and random districts). In the other specifications the positive sign is as expected but the results are not significant. The compulsory charge variable is also significantly positive for some model specifications (panel LS, fixed districts, and random districts). Assuming the theoretical demand relationships hold that is, as price increases, quantity demanded decreases the sign for the compulsory charge was not expected. However, this outcome may support the contention that many crops being produced in SRWSC irrigation areas were both water intensive and price inelastic with regard to water. Evidence indicates price per unit of sales water over this period was very low suggesting any price increase may have had little effect on water demand because the threshold at which demand becomes elastic was not reached. Further, as noted, at very low prices, demand may be perfectly inelastic. Empirical studies have shown that perfectly inelastic water demand occurs between \$0 and \$20 per unit (Collins *et al*, 1996; Hall, *et al* 1994; Read, Sturgess and Associates, 1991). During the post-1940s period, compulsory charge prices remained below \$20 per acre-foot (megalitre) until 1981/2 when the charge in a limited number of districts was increased beyond that price. This may provide some explanation of the results in table 3. Specifically, the low price of the compulsory charge produced a perfectly inelastic demand curve for sales water. Therefore, it could be argued that the expected theoretical relationship between price and quantity demanded did not apply here, producing a positive relationship between water sales and the compulsory charge at very low prices.

As expected, the variable fallow is significantly negative in all model specifications except fixed districts and fixed periods. Further, as expected, the rainfall variable is significantly negative in some of the model specifications (panel least-squares, fixed districts, and random district). In two out of the three other model specifications, fixed period and random period, rainfall retains the correct sign but is not significant. In table 3, the adjusted R^2 is higher for fixed district and fixed period model. The redundant fixed effects are significant at the 5% level for period and cross-section/period respectively and the correlated random effects are also significant. A rho of zero produced the same coefficients for the panel LS and random district. From the unit root tests we can again find that the variables are I(1) suggesting a first difference specification is required.

Table 4 incorporates results of the differenced series. We find that WR, cereal, and pasture remain significantly positive across all models. As expected, vineyards are significantly positive in all model specifications except fixed period and fixed districts and fixed period. Moreover, like the differenced series reported for pre-1940s (table 2) the compulsory charge again has a negative sign across all specifications nevertheless, it remains not significant. The adjusted R^2 are quite small for all the models. From the redundant fixed effects we find that only period and cross/section period are significant for fixed period model and fixed district and fixed period model respectively. The coefficients of panel LS and random district are the again the same for this specification because rho is zero. In the differenced series the correlated random effects are not significant.

Table 5 consists of the estimation results from 1941 to 1984 excluding the variable water rights. We can see there are fewer significant variables when WR is excluded from the models. Cereals and pasture retain the expected results being significantly positive across all models. As expected, lucerne is significantly positive in all but the fixed district specification. Vineyards are significantly positive in some model specifications (panel LS, random district, and random period). The sign on the compulsory charge for all model specifications except fixed districts and fixed period remains positive, much like the outcomes for the post-1940s estimations that include WR (table 3). This lends support to the contention that low prices may have produce perfectly inelastic demand for sales water. The adjusted R^2 is higher for fixed district and fixed period. The redundant fixed effects are significant at the 5% level for all the models using fixed effects and the correlated random effects are significant for random period. Unit root tests show the variables are I(1) again warranting consideration of the models in first differences. Estimation results for the differenced series are shown in table 6. As expected, we find that cereal, lucerne, pasture and vineyards are all significantly positive across all models. Moreover, four of the models show a negative sign for the compulsory charge that we would expect if the theoretical demand relationships hold however, none of these results are significant. The redundant fixed effects show that only period and cross/section period are significant for fixed period model and fixed district and fixed period model respectively. A zero rho for the random district model means, like the results in table 1, the coefficients of panel LS and random district are the same. The correlated random effects are significant for random period.

In addition to the results above, in order to isolate the relationship between sales water demand, rainfall, and the compulsory charge we ran all of the models again using a new variable: total production. Total production was the aggregation of all the production variables in the previous models that is, the total acreage devoted to production. Generally, the results of these tests demonstrated similar outcomes to those reported here and therefore, we have not included them. Specifically, total production was significantly positive; rainfall had a changing sign but where it was significant it was positive; and water rights were positive and significant for the post-1940s specifications. However, in all of the tests, across all time periods, we found that using aggregate production resulted in the compulsory charge being negative and significant more often than in the results reported here. This would be expected if the theoretical demand relationships held. Moreover, this suggests that at the aggregate level there may have been a negative relationship between water sales and price. Nevertheless, even at the aggregate level the negative relationship was not consistently significant across the time period or model specifications. As a result, on balance, we could argue that in this case water demand does not fit the theoretical predications in regard to price. This has important implications for demand management policies.

Generally, the results of the above analysis suggest that in both time periods and for most model specifications, the compulsory charge did not determine water sales demand. Further, where the p-value of this variable is significant, the sign indicates a positive relationship between price and demand. This outcome implies water demand in irrigation areas over the bulk of the twentieth century may have been perfectly inelastic. There are two reasons why this may have occurred. First, as an input, water accounted for only a small part of production costs. Therefore, it could be argued that the persistence of low prices over the period of SRWSC administration in itself led to this outcome. In turn, this may reflect the importance of irrigation expansion to support agricultural sector growth and underpin regional development (Sampath, 1992). In other words, it may be argued that the social costs of low water prices, including over use resulting in negative externalities and expansion of production onto marginal lands may have been considered lower than the social benefits accruing for regional and state-wide economic growth. Combined with the fact that the costs of in-stream salinity only became recognised in the 1960s, it may be the case that the full social costs of low prices were not known for much of the twentieth century. However, even once these problems were recognised water prices did not increase to reflect marginal cost pricing.

Second, there may have been limited substitution possibilities, particularly in the form of efficient technology. Even today, flood irrigation is the main technique used by Victorian farmers to irrigate, particularly pastures and broadacre crops such as cereal and lucerne. Appels *et al* (2004) suggest that even when water markets were introduced in the 1990s resulting in a significant increase in water prices for those participating in trade, flood irrigation remained the most common technology applied. Moreover, Renzetti (2002) found that most irrigation technology adoption models show the application of modern irrigation technologies, like pivot or trickle irrigation, is more likely when input prices, including water are high and the costs of switching technologies is low. During the period being examined here water prices were low increasing past $20 per megalitre for only four years of the seventy-six year period for which data is available. In addition, while there is limited data available on the costs of irrigation technologies, for a bulk of the period, techniques such as pivot and spray irrigation were not available. It was more likely that investment in technology took the form of laser grading paddocks to smooth out variations in the surface and reduce puddles forming after watering that cause water logging of the soil and on-farm salinity. However, while data on the extent of laser grading adoption is not available, the persistent reliance on low valued crops in many Victorian irrigation areas and the variability of farm incomes this created suggests that this expenditure may not have been low cost. Findings in Appels *et al* (2004) support the contention that farmers in many irrigation districts used in this study are capital constrained in the medium to longer term limiting their ability to investment in water saving technology. This inability to substitute water for more efficient irrigation techniques may have reinforced price inelastic water demand.

The analysis here suggests crop mix plays a more important role in irrigation water demand than price. Specifically, in the pre and post-1940 model specifications the water intensive crops of pasture, lucerne, cereal, and fodder remain significantly positive. This has important implications for demand management policies because it implies that crop type has, on balance, a greater influence on water demand than prices. Therefore, policies to increase efficiency of water use in the irrigation sector should focus, in part, on creating incentives for adoption of less water intensive crops. In part, the introduction of water markets in Australia and other countries such as, the United States, can provide one method by which to encourage a low cost shift to less water intensive crops by reallocating water from low to high value activities (Department of Natural Resources and Environment 2001; Productivity Commission 2002).

Nevertheless, it is also important to acknowledge a shift to less water intensive crops is, to some degree, determined by prices for output, which may be subject to further government intervention in the form of price subsidies. The existence of output price subsidies may prevent water reallocation even if the price of water increases. Broadly, the findings here may suggest that demand side management in the form of marginal cost pricing may be less effective when production is dominated by water intensive crops that are price inelastic.

4. Conclusion

This paper analysed the effect of centrally determined water prices on water demand using data from the Victorian State Rivers and Water Supply Commission between 1908 and 1984. The modelling incorporated several other variables thought to exert an important influence on demand, including acreage devoted to certain crop types, water right allocation in districts, and annual rainfall. Generally, the results indicate that demand for water is positively significantly related to the acreage devoted to the production of pastures, lucerne, fodder, cereals, and vineyards. Water right allocation in districts, included in the post-1940 model specifications, were also positively significant, which suggest that an increase in the availability of water rights over time may have encouraged expansion of production onto marginal lands and increased reliance on water sales. Annual rainfall, where significant, had a positive sign, which was unexpected. This outcome may have been the result of information asymmetries facing risk averse irrigators. Water prices, where significant, did not exert the theoretically expected influence on demand. It has been argued that this may have been caused by inelastic water demand in the agricultural sector that becomes perfectly inelastic between $0 and $20. This indicates demand management via prices may not be the most effective method to encourage water use efficiency in the irrigation sector because demand only become price elastic at very high prices. Moreover, it suggests that crop mix exerts a much more important influence over water demand. In turn, the findings here provide support for continued expansion of water markets to provide a reallocation mechanism from low, water intensive to higher valued, lower water intensive crops. These outcomes suggest several areas for further research. First, if, as has been argued, low water prices encourage the expansion of water intensive crops, further government intervention in the agricultural sector via output price subsidies may reinforce inefficiencies within the irrigation sector reducing water use efficiency. Further study examining the extent of subsidies that may have been used to maintain prices of irrigation crops and thereby, encouraged expansion of production of water intensive output, may lead to a better understanding of why the positive relationship between water demand and price in these results. Second, and relating to the first point, studies should be conducted to analyse the exact relationship between price and demand in the presence of water intensive crops compared with those that have a lower water requirements. This may uncover some important policy implications for the role of prices in water reallocation. Third, because output prices exert an important influence on production mix, it is important that the models here include price variables. Subsequent research will incorporate such variables. Finally, these results should be replicated using data from developing countries to determine whether the relationships between crop type and demand hold. Such studies would have important implications for the use of demand side management in those countries.

Table 1: Pre-1940s estimation results and unit root testing

		Panel LS	Fixed Districts	Fixed Period	Fixed Districts and Fixed Period	Random District	Random Period	Panel Unit Roots (Levin, Lin & Chu t*)
C_CHARGE		10.500 (0.233)	5.809 (0.582)	-3.293 (0.686)	-0.124 (0.990)	8.595 (0.332)	2.907 (0.713)	0.000
CEREAL		0.090 (0.001)	0.111 (0.000)	0.107 (0.000)	0.116 (0.000)	0.096 (0.000)	0.095 (0.000)	0.000
LUCERNE		0.051 (0.000)	0.025 (0.252)	0.062 (0.000)	0.041 (0.071)	0.038 (0.012)	0.058 (0.000)	0.000
FODDER		-0.078 (0.175)	0.162 (0.025)	-0.054 (0.355)	0.046 (0.538)	0.024 (0.686)	-0.063 (0.247)	0.000
PASTURE		0.049 (0.000)	0.065 (0.000)	0.031 (0.003)	0.042 (0.003)	0.055 (0.000)	0.040 (0.000)	0.000
VINEYARDS		0.000 (0.995)	0.021 (0.689)	-0.026 (0.346)	-0.062 (0.297)	0.007 (0.866)	-0.015 (0.593)	0.000
FALLOW		0.024 (0.124)	0.015 (0.304)	0.034 (0.117)	0.012 (0.645)	0.018 (0.196)	0.026 (0.110)	0.000
RAINFALL		0.153 (0.751)	0.263 (0.622)	1.027 (0.168)	0.954 (0.450)	0.193 (0.680)	0.511 (0.347)	0.000
Adj R^2		0.366	0.494	0.514	0.588	0.270	0.390	
Redundant Fixed Effects χ^2	Cross-section		0.000		0.000			
	Period			0.000	0.000			
	Cross-section/Period				0.000			
Rho						0.138	0.100	
Correlated Random Effects						0.000	0.000	

Table 2: Pre-1940s estimation results for differenced series

		Panel LS	Fixed Districts	Fixed Period	Fixed Districts and Fixed Period	Random District	Random Period
ΔC_CHARGE		-7.789 (0.533)	-6.113 (0.642)	-1.525 (0.897)	-2.017 (0.870)	-7.789 (0.529)	-4.770 (0.676)
ΔCEREAL		0.092 (0.003)	0.095 (0.002)	0.108 (0.001)	0.108 (0.001)	0.092 (0.003	0.108 (0.000)
ΔLUCERNE		0.080 (0.190)	0.087 (0.153)	0.057 (0.331)	0.076 (0.199)	0.080 (0.186)	0.058 (0.313)
ΔFODDER		0.117 (0.245)	0.178 (0.090)	0.024 (0.828)	0.090 (0.427)	0.117 (0.241)	0.069 (0.502)
ΔPASTURE		0.000 (0.994)	-0.025 (0.337)	-0.015 (0.567)	-0.037 (0.179)	0.000 (0.994)	-0.009 (0.711)
ΔVINEYARDS		-0.303 (0.087)	-0.321 (0.075)	-0.187 (0.261)	-0.227 (0.179)	-0.303 (0.084)	-0.219 (0.179)
ΔFALLOW		0.036 (0.143)	0.029 (0.236)	0.015 (0.742)	0.007 (0.872)	0.036 (0.139)	0.025 (0.390)
ΔRAINFALL		1.700 (0.009)	2.087 (0.002)	3.391 (0.035)	3.364 (0.039)	1.700 (0.009)	2.268 (0.024)
Adj R^2		0.132	0.148	0.309	0.334	0.132	0.113
Redundant Fixed Effects χ^2	Cross-section		0.168		0.042		
	Period			0.000	0.000		
	Cross-section/Period				0.000		
Rho						0.000	0.256
Correlated Random Effects						0.013	0.523

Table 3: Post-1940s estimation results and unit root testing

		Panel LS	Fixed Districts	Fixed Period	Fixed Districts and Fixed Period	Random District	Random Period	Panel Unit Roots (Levin, Lin & Chu t*)
C_CHARGE		160.535 (0.021)	234.429 (0.006)	-4.303 (0.951)	-75.889 (0.391)	160.535 (0.022)	58.658 (0.383)	0.000
WR		0.248 (0.000)	0.248 (0.000)	0.324 (0.000)	0.365 (0.000)	0.248 (0.000)	0.289 (0.000)	0.000
CEREAL		1.757 (0.000)	1.970 (0.000)	1.294 (0.010)	1.894 (0.001)	1.757 (0.000)	1.469 (0.002)	0.000
LUCERNE		1.000 (0.003)	1.151 (0.020)	1.285 (0.000)	2.046 (0.000)	1.000 (0.003)	1.189 (0.000)	0.000
FODDER		-2.005 (0.058)	-1.540 (0.220)	-1.073 (0.308)	0.059 (0.963)	-2.005 (0.059)	-1.416 (0.163)	0.000
PASTURE		0.174 (0.000)	0.172 (0.005)	0.047 (0.390)	0.066 (0.367)	0.174 (0.000)	0.103 (0.041)	0.000
VINEYARDS		-0.105 (0.560)	0.200 (0.356)	-0.322 (0.067)	0.025 (0.906)	-0.105 (0.562)	-0.224 (0.188)	0.000
FALLOW		-1.297 (0.015)	-1.465 (0.024)	-1.137 (0.031)	-0.944 (0.134)	-1.297 (0.015)	-1.219 (0.016)	0.000
RAINFALL		-13.649 (0.045)	-15.348 (0.046)	-4.743 (0.652)	0.590 (0.977)	-13.649 (0.046)	-9.893 (0.232)	0.000
Adj R^2		0.424	0.417	0.531	0.534	0.424	0.435	
Redundant Fixed Effects χ^2	Cross-section		0.797		0.141			
	Period			0.000	0.000			
	Cross-section/Period				0.000			
Rho						0.000	0.133	
Correlated Random Effects						0.051	0.001	

Table 4: Post-1940s estimation results for differenced series

		Panel LS	Fixed Districts	Fixed Period	Fixed Districts and Fixed Period	Random District	Random Period
Δ C_CHARGE		-111.997 (0.220)	-111.555 (0.232)	-39.054 (0.658)	-32.262 (0.721)	-111.997 (0.230)	-60.690 (0.480)
Δ WR		1.038 (0.000)	1.047 (0.000)	1.123 (0.000)	1.130 (0.000)	1.038 (0.000)	1.099 (0.000)
Δ CEREAL		4.352 (0.000)	4.368 (0.000)	3.969 (0.000)	3.981 (0.000)	4.352 (0.000)	4.094) (0.000
Δ LUCERNE		-2.527 (0.104)	-2.619 (0.102)	-1.146 (0.426)	-1.247 (0.401)	-2.527 (0.111)	-1.553 (0.276)
Δ FODDER		0.300 (0.822)	0.262 (0.848)	0.456 (0.725)	0.421 (0.751)	0.300 (0.826)	0.460 (0.715)
Δ PASTURE		0.181 (0.035)	0.186 (0.034)	0.191 (0.039)	0.196 (0.040)	0.181 (0.039)	0.192 (0.026)
Δ VINEYARDS		0.548 (0.005)	0.552 (0.005)	0.367 (0.058)	0.368 (0.063)	0.548 (0.006)	0.444 (0.016)
Δ FALLOW		0.672 (0.481)	0.712 (0.467)	0.298 (0.746)	0.366 (0.698)	0.672 (0.490)	0.423 (0.637)
Δ RAINFALL		3.086 (0.727)	3.363 (0.710)	30.199 (0.147)	30.814 (0.148)	3.086 (0.732)	12.408 (0.298)
Adjusted R^2		0.310	0.279	0.445	0.422	0.310	0.319
Redundant Fixed Effects χ^2	Cross-section		1.000		1.000		
	Period			0.000	0.000		
	Cross-section/Period				0.000		
Rho						0.000	0.168
Correlated Random Effects						0.998	0.029

Table 5: Post-1940s estimation results and unit root testing excluding WR

		Panel LS	Fixed Districts	Fixed Period	Fixed Districts and Fixed Period	Random District	Random Period	Panel Unit Roots (Levin, Lin & Chu t*)
C_CHARGE		101.014 (0.160)	136.981 (0.109)	8.440 (0.910)	-56.630 (0.541)	102.421 (0.161)	41.653 (0.557)	0.000
CEREAL		1.916 (0.000)	2.105 (0.000)	1.230 (0.022)	1.901 (0.001)	1.978 (0.000)	1.575 (0.001)	0.000
LUCERNE		0.763 (0.026)	-0.070 (0.880)	1.396 (0.000)	1.079 (0.019)	0.610 (0.097)	1.100 (0.001)	0.000
FODDER		-4.491 (0.000)	-3.264 (0.010)	-2.631 (0.017)	-1.016 (0.442)	-4.242 (0.000)	-3.497 (0.001)	0.000
PASTURE		0.473 (0.000)	0.427 (0.000)	0.431 (0.000)	0.437 (0.000)	0.470 (0.000)	0.453 (0.000)	0.000
VINEYARDS		0.382 (0.031)	0.390 (0.079)	0.316 (0.063)	0.335 (0.120)	0.383 (0.040)	0.359 (0.031)	0.000
FALLOW		-0.898 (0.103)	-0.960 (0.148)	-0.973 (0.081)	-0.873 (0.187)	-0.983 (0.087)	-0.944 (0.077)	0.000
RAINFALL		-10.791 (0.128)	-11.810 (0.134)	-3.581 (0.749)	-8.965 (0.679)	-10.266 (0.153)	-7.948 (0.353)	0.000
Adj R^2		0.369	0.379	0.468	0.485	0.318	0.369	
Redundant Fixed Effects χ^2	Cross-section		0.078		0.004			
	Period			0.000	0.000			
	Cross-section/Period				0.000			
Rho						0.015	0.110	
Correlated Random Effects						0.286	0.001	

Table 6: Post-1940s estimation results for differenced series excluding WR

		Panel LS	Fixed Districts	Fixed Period	Fixed Districts and Fixed Period	Random District	Random Period
ΔC_CHARGE		-123.256 (0.226)	-123.273 (0.237)	16.857 (0.869)	25.964 (0.803)	-123.256 (0.236)	-45.084 (0.647)
ΔCEREAL		4.264 (0.000)	4.275 (0.000)	3.972 (0.000)	3.963 (0.000)	4.264 (0.000)	4.115 (0.000)
ΔLUCERNE		-7.368 (0.000)	-7.461 (0.000)	-6.279 (0.000)	-6.397 (0.000)	-7.368 (0.000)	-6.715 (0.000)
ΔFODDER		0.679 (0.647)	0.663 (0.663)	0.411 (0.784)	0.384 (0.802)	0.679 (0.655)	0.576 (0.690)
ΔPASTURE		0.323 (0.001)	0.327 (0.001)	0.357 (0.001)	0.354 (0.001)	0.323 (0.001)	0.345 (0.000)
ΔVINEYARDS		0.688 (0.001)	0.691 (0.002)	0.525 (0.019)	0.522 (0.023)	0.688 (0.002)	0.615 (0.004)
ΔFALLOW		1.054 (0.321)	1.066 (0.330)	0.783 (0.463)	0.836 (0.445)	1.054 (0.332)	0.899 (0.381)
ΔRAINFALL		4.651 (0.636)	4.765 (0.636)	28.195 (0.242)	28.716 (0.244)	4.651 (0.643)	11.642 (0.349)
Adj R^2		0.140	0.100	0.255	0.224	0.140	0.116
Redundant Fixed Effects χ^2	Cross-section		1.000		1.000		
	Period			0.000	0.000		
	Cross-section/Period				0.000		
Rho						0.000	0.109
Correlated Random Effect						1.000	0.021

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