AERE Newsletter V24 #1 May 2004

ESSAY

"Cash and Carry" Irrigation Water Prices in a Cost-Contained World

Eric C. Schuck
Department of Agricultural and Resource Economics
Colorado State State University
Fort Collins, CO 80523

and

Gareth P. Green
Department of Economics and Finance
Seattle University
Seattle, WA 98122

Summary

Policy initiatives by the U.S. Bureau of Reclamation promote adoption of volumetric water prices as a conservation tool. Unfortunately, most irrigation districts use per acre water fees and place restrictions on total water costs that limit the ability to use volumetric water prices. As a result, increases in volumetric prices often require corresponding reductions in per-acre fees such that price changes are revenue neutral. Though these changes may send mixed signals for complimentary inputs, they still work to promote economic efficiency even if they may not lead to reductions in water use.

Introduction

For nearly two decades irrigation districts providing water from the U.S. Bureau of Reclamation (USBR) have been urged to adopt "conservation pricing" systems (USBR, 1998). This is particularly critical for irrigation districts within California's Central Valley Project, the nation's larges single irrigation project. Under the terms of the Central Valley Project Improvement Act (CVPIA), irrigation districts receiving water from the USBR must adopt tiered water pricing (Weinberg, 1997). Based on the simple–and economically sound–premise that irrigation water will be used more efficiently if irrigators pay for their water as they use it and the price reflects scarcity value of water, conservation pricing is a potentially significant change in the way water is managed in the western United States. There is, however, one significant problem: very few systems do it effectively. The vast majority of irrigation water providers charge for water use not on the volume of water delivered, but on the acreage served (Michelsen et al., 1999) and even those that do charge volumetrically set price tiers that are nonbinding so they do not provide incentive for conservation.

Since most irrigation districts use area-based rather than volume-based prices, the first step in adopting conservation prices is to shift water costs from land to water. This is the situation the Arvin Edison Water Storage District ("Arvin") in the Central Valley of California found itself in 1995. In response to USBR conservation price initiatives, Arvin adopted a "cash and carry" water pricing system in 1995. Prior to 1995, irrigators paid a per-acre fee (the "standby" charge) for delivery of a contracted quantity of water specified at the beginning of the growing season. Once the standby charge was paid, irrigators paid an additional volumetric fee (the "delivery" fee) when and if the water was delivered. In 1995 Arvin decreased the standby fee and increased the volumetric delivery fee to create a conservation incentive and compensate for lost revenues from reducing the standby fee. More significantly, Arvin removed the requirement that irrigators contract for a specific quantity of water at the beginning of the growing season. Instead, irrigators simply request and pay for water when and as it is used, giving a "cash and carry" system.

The revenue impact of this change in irrigation water rate structure was a serious concern for Arvin. Under the terms of the Reclamation Reform Act of 1982, irrigation districts can charge prices only up to the full cost of the water they deliver, where full cost is defined as the amortized cost of USBR facilities since 1982 (CBO, 1997). To ensure that the district would have enough funds to operate and stay within USBR cost requirements, Arvin tried to modify its standby and delivery charges in a way that would be revenue neutral[1]. Indeed, based on expected water use, Arvin's rate change should have left total on-farm water costs nearly constant.

[1] Prior to 1995, the standby charge was $118.25/ac and the delivery charge was $45.30/acre-foot. After the rate change, they were $71/acre and $65.30/acre-foot respectively. An irrigator using 3.5 acre-feet per acre (the District average use) would have paid a total of $276.80/acre in water costs before the rate change and $299.50/acre in water costs after the rate change; the difference between the two costs is due to changes in fees paid by the District to the USBR.

The primary effect of the rate-change was to make acreage cheaper and water more expensive while keeping the District's expected revenues steady. However, in shifting the district's revenue base from acreage to the volume of water used, Arvin changed not simply the price of water but also the tariff structure faced by irrigators. The demand consequences of changes in tariff structure have been well-studied in nonagricultural contexts (Oi, 1971), but have not been extended to irrigation water. More specifically, since Arvin purposely designed its rate change to be revenue neutral, the system they adopted is a variation of a two-part tariff with a balanced budget constraint (Ng and Weissner, 1974). Essentially, The rate change adopted by Arvin altered the bias in water costs, moving the burden of water costs from the extensive margin–acreage–to the intensive margin–applied water. Shifting the burden of costs affect not simply how much water is used, but also which crops are grown. Consequently, while Arvin intended its move to be revenue neutral, the resulting flexibility in water use decisions represents a major change in how irrigators make their water use decisions and revenues have actually increased.

Arvin's experience in adopting a conservation pricing system raises a key element in the conservation pricing issue that has not yet been addressed in the literature. Given institutional constraints on the transmission of costs to water users and historical practices in pricing water through land rather than water, conservation pricing ultimately reduces to a problem not of optimal pricing of a government-provided service, but of optimal distribution of costs to users across two complimentary inputs. Indeed, the problem here is less "what is the optimal price of water?" and more a matter of "how best to distribute costs between water and land?"

So adopting conservation prices is neither as simple nor as clear-cut as intuition would suggest. Practical considerations related to working within existing institutional constraints and accounting for the common practice of splitting water prices across both land and water means the potential effects of conservation pricing display far more nuances than is typically reflected in discussions of the subject. As closer examination of the experience in Arvin Edison will show, moving to conservation pricing under current institutions changes quite a bit more than just the price of water.

Pricing for Expected On-Farm Cost Neutrality

The examination starts by laying out the on-farm irrigation costs of an individual irrigator. The irrigator obtains irrigation water from a regional irrigation district. The irrigator purchases water from the district through two prices. The first price is an acreage fee, denoted *h*, which entitles the irrigator to receive water. When the irrigator purchases water for delivery, they pay the volumetric price *r* on whatever quantity of water is purchased.

Under this two-part pricing system irrigators demand their water in two stages: first when they allocate acreage, and second when they apply water to planted acreage. Acreage is a function of a vector of crop prices, $\overline{p}$, the acreage-based fee, *h*, the volumetric charge, *r*, and a vector of other input prices, $\overline{w}$. Demand for applied water, *AW*, is a function of a vector of planted acreage, *l*, a vector of crop prices, $\overline{p}$, and the volumetric prices of water, *r*, so:

1) $\bar{l} = l(\overline{p}, r, h, \overline{w})$

2) $AW = AW(\bar{l}\,(\overline{p}, r, h, \overline{w}), p, r)$

Note that since the acreage-based fee is paid prior to water being applied, it affects applied water demand only through acreage allocations. The volumetric charge, however, affects both land use decisions and water applications since expected costs per acre will depend in part on the water use requirements of each crop. Consequently, the decision to plant a crop cannot be made without accounting for the water requirements (and costs) of that crop. Given equations 1) and 2), total on-farm water costs are the sum total of acreage-based fees and volumetric charges. If the irrigator produces *k* different crops, then total on-farm water costs are:

3) $$C(\bar{p},r,h,w)=h\sum_k l_k(\bar{p},r,h,\bar{w})+r\sum_k AW_k(l_k(\bar{p},r,h,\bar{w}),\bar{p},r)$$

Expected revenue neutrality was a key feature of the 1995 rate change by Arvin. In fact, Arvin established a goal that total water charges per acre for a given irrigator would not exceed some target level □. Using the information from equation 3), this implies:

4) $$h+rE\left\{\frac{\sum_k AW_k(\bullet)}{\sum_k l_k(\bullet)}\right\}=\kappa,$$

where E is the expectations operator. Given this additional constraint, the irrigation district simply needs to determine what fraction of □is to be paid through r and what fraction will be paid through h. If □ is the fractional apportionment of □ through r and h, then:

5) $$h=\mu\kappa$$

and

6) $$r=\frac{(1-\mu)\kappa}{E\left\{\frac{\sum_k AW_k(\bullet)}{\sum_k l_k(\bullet)}\right\}}$$

This approach is relatively simple, but its success as a pricing plan hinges on one critical element: the expected water use per acre must be constant for it to lead to a usable division of water prices. If the expected water use per acre varies across farms, the effects of switching the district's revenue base between acreage and water applications will not be cost-neutral and the results anticipated in equation 4) may not be achieved. If this happens, expected per-acre water costs for individual farms may change dramatically. In particular, differences in water use requirements across crops mean that a shift in water costs from acreage to water use that are uniform in expectation will not be uniform in execution, so while some irrigators will see their costs rise, others will see them drop. This indicates the conservation effects of such a rate change are unknown.

Moving the cost burden toward volumetric water (measured by a declining μ) will reduce water applications and will generally be considered incentive for water conservation since water effectively becomes more expensive and land becomes cheaper. At this point, the way each price affects the two inputs matters a great deal. Per-acre fees are uniform across crops. Consequently, they will tend to influence if a crop is profitable or not and whether or not a crop will be considered. This is an extensive margin problem. Volumetric fees affect crops differently depending upon relative water requirements. This determines the relative profitability of crops, and therefore determines the relative preferences across crops–an intensive margin problem. Consequently, shifting the distribution in water costs will cause some crops to enter or exit the set of crops producers consider while simultaneously re-ordering the relative profitability of crops depending upon their relative water needs. The end result is that even a price change whose effects are expected to be revenue-neutral on irrigators does not have a clear effect and may or may not promote changes in input usage that lead to water conservation.

Brief Analysis of Changing the Distribution of in Water Price

The extent to which the distribution of water costs in water price matters can be seen through a brief simulation model built on an updated version of a water-pricing model developed by Schuck and Green (2002). Built on District GIS records of cropping patterns and irrigation technology in 1998, the model uses Positive Mathematical Programming (Howitt, 1995) to develop a calibrated model of agricultural production and water use for the District. Unlike the original Schuck and Green model that uses dynamic stochastic programming, the current model is simplified to a single time period for expediency and brevity.

Table 1 shows the price, average yield per acre, water use consumption per acre, costs per acre to produce and acreage in 1998 for the 12 dominant crops in the District. Yields and price are the 10-year average from the Kern County Agricultural Commission (Kern County, 1987-1999); Costs are taken from University of California crop budgets. Expected consumptive water use requirements per crop are taken from District records (JMLord, 1998).

Table 2 shows the price per acre-foot of water and acre across different apportionment of costs between the two inputs.

Table 1: Summary of Data for Simulation Model

	Price	Yield/per acre	Water Consumption /Acre	Cost/acre	Acres
Alfalfa	$91.83	7.90	3.96	$285	2009
Almonds	2461.82	0.74	3.46	1596	1760
Carrots	117.89	29.48	1.49	3772	1151
Citrus	366.09	12.31	2.80	4243	10034
Cotton	0.87	1183.98	2.57	580	3637
Peaches	979.93	6.57	3.37	9495	3501
Grains	121.79	2.65	1.85	214	3372
Melons	133.42	22.93	1.91	1594	1096
Onions	63.89	21.40	2.31	589	2226
Potatoes	188.20	17.93	1.73	582	7785
Tomatoes	62.83	36.03	2.14	1246	2369
Vine	431.46	8.67	2.30	5764	10631
Fallow					1222
TOTAL					50793

Table 2: Sample Volumetric and Per-Acre Water Fees

Portion of charge that is acreage based (κ)	Volumetric Charge (r)	Acreage Charge (h)
0	$84.29	$0
0.125	73.75	36.88
0.25	63.21	73.75
0.375	52.68	110.63
0.5	42.14	147.5
0.625	31.61	184.38
0.75	21.07	221.25
0.875	10.54	258.13
1	0	295

Note: Assumes the District is attempting to recover costs equal to $295/acre. Volumetric fees are given for the District average of 3 pumping lifts. Prices at lower or higher elevations will vary.

Reallocating water charges between acreage-based and volumetric fees has unpredictable results. More specifically, increasing the volumetric fee causes more water-intensive to drop rapidly in their relative profitability, while simultaneously decreasing the per-acre fee causes crops with high per-acre costs to become more profitable. With some crops entering and exiting the production set under each alternative pricing combination and the relative position of each crop within the set also changing, it is almost impossible to determine if the price-reforms are achieving conservation in a physical sense. Indeed, as Figure 1 shows, total water applications tend to be very sensitive at higher volumetric prices but gradually plateau at lower prices. This is due to hitting available acreage constraints rather than any significant modification in water application rates. Yet something critical does happen. As shown in Figure 2, as the distribution of costs moves toward a purely volumetric system, profits per applied acre-foot rise. As a measure of economic efficiency–whether or not water is being sent to its highest and best use–this outcome is critical. It suggests that even without corresponding reductions in water usage the desired economic effect is occurring. Shifting the distribution of water costs toward volumetric pricing moves water toward its relatively more profitable use.

Even though institutional constraints on the District limit how it can price water and force simultaneous changes in per-acre and volumetric fees, adoption of volumetric prices in preference to acreage-based fees promotes economic efficiency. However, calling them "conservation" prices is perhaps a misnomer. At least in this example, the conservation effects of the new prices are negligible. While this outcome is completely an artifact of the constraints under which this irrigation district operates, they are more reflective of the real institutional burdens facing irrigation districts trying to comply with policy initiatives favored by the USBR than is typically recognized. Based on these results it appears that "conservation" prices are more accurately described as "efficiency" prices.

Summary and Conclusions

Recent policy proposals introduced by the USBR promote adoption of conservation pricing systems by irrigation districts receiving federal water. Most analysis of conservation pricing centers on volumetric water prices while most irrigation districts use either acreage-based water fees or a combination of acreage-based and volumetric water fees. Simultaneous changes in the two elements of water price currently used by most water providers can send mixed conservation signals to irrigators. This is because the water price is being levied on two inputs (water and land), not simply one (water).

Simple simulation results through positive mathematical programming confirm these theoretical results and suggest that common institutional constraints limit the ability to conserve water through conservation prices. However, the results also suggest that even without achieving water conservation in a physical sense, changing the system of prices does promote economic efficiency. Overall the results suggest changes in the set of prices for irrigation water, whether through adjustments in acreage-based or volumetric fees, have negligible effects on overall water usage primarily due to restrictions on how the water provider can transmit costs to water users. Yet even with these issues, it is possible to reallocate water costs between water and land in a way that promotes economic efficiency, if not conservation.

Acknowledgements

The U.S. Department of Agriculture (USDA) Regional Project W-190 supported this research. The authors are extremely grateful for the cooperation of Tim Long of the Arvin Edison Water Storage District and to helpful comments offered by Dana Hoag and John Loomis.

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Figure 1: Overall Water Usage

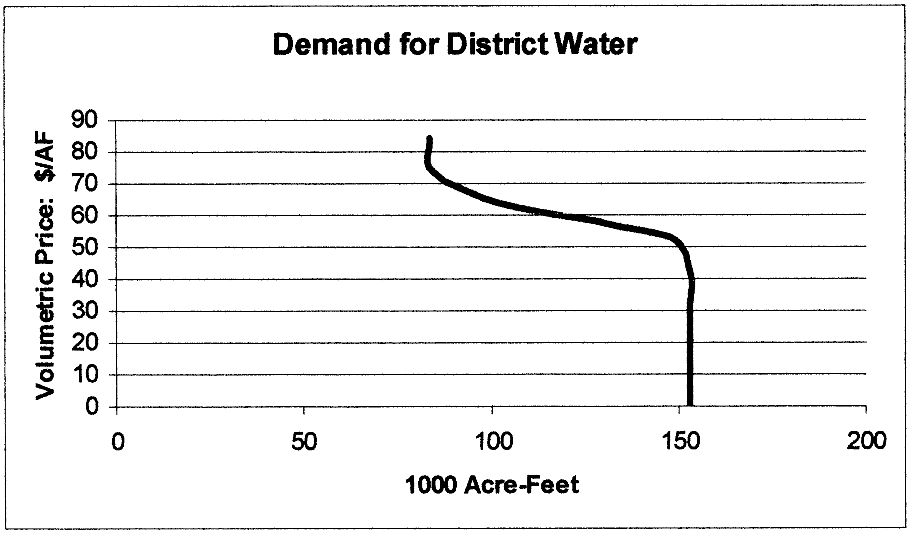

Figure 2: Profits per Applied Acre-Foot