This article examines the economic impacts of policy alternatives for addressing allocative inefficiencies among agricultural, urban, and environmental uses of federal water. The Central Valley Project Improvement Act, composed of multiple incentive-based and command-and-control policies, forms the context for this analysis. Estimated multi-output agricultural revenue functions and urban water demand functions are incorporated into a nonlinear programming model designed to predict changes in water use, returns to agriculture, and urban consumer surplus. Results suggest that analysis that does not explicitly model policy instruments implemented at sub-optimal levels and, as part of a package of reforms, could over- or underestimate the costs, benefits, and effectiveness of each policy instrument.

Key words: Bureau of Reclamation, CVPIA, environmental water allocation, revenue function, tiered water prices, water markets.

In much of the western United States, the river systems supplying the irrigation water necessary to sustain agricultural production also supply water for municipal and industrial uses, provide habitat for numerous species, and provide an outlet for the discharge of waste water. Each of these services is governed by an increasingly complex array of state and federal legislation and regulations. First and foremost in terms of the geographic and economic spheres of influence are the policies of the U.S. Bureau of Reclamation (Bureau), which controls significant (40–85%) portions of river flows in nearly all major river basins in the West. The Bureau’s water supply policies, which historically included subsidized prices, long-term contracts, and restrictions on the sale of water by farmers, resulted in well-documented allocative inefficiencies (e.g., Hartman and Seastone and Wahl, among many others). Environmental degradation associated with reclamation projects has also been well documented (U.S. Department of the Interior 1996a).

A sweeping reform bill, the 1992 Central Valley Project Improvement Act (CVPIA), ushered in a new era in the Bureau’s water policies. The act addresses severe conflicts over scarce water resources in California while simultaneously creating a potential model for federal water policy reform elsewhere in the west. Those conflicts could threaten drinking water supplies for two-thirds of the state’s population and irrigation water for farmers producing $3 billion of crops annually.

Many of the CVPIA provisions are broadly familiar in the environmental economics literature, including economic incentives and an environmental water allocation, a “command and control” policy. However, little empirical analysis considers either the implications of implementing these policies simultaneously or the inefficiencies created by the vagaries of a policy-process unlikely to set optimal levels for policy instruments. This article examines, conceptually and empirically, economic changes arising from the complex package of policy reforms embodied by the CVPIA.

Previous studies have relied solely on econometric approaches to estimating agricultural benefits from water use (e.g., Kanazawa, Just, Zilberman, and Hochman, and Moore and Dinar, among others) or on mathematical programming models parameterized with agronomic yield relationships, crop budgets, or pre-existing process models (e.g., Booker and Young, Knapp, Vaux and Howitt, Willis and Whittlesey). This article combines the two approaches by estimating a revenue function.
and then incorporating it into a nonlinear programming model.

**Problem Setting**

Conflicts over the allocation of federal water in California arise between agricultural, urban, and environmental water uses. The Federal Central Valley Project (CVP) is the largest, most ambitious water supply project in the country; it consists of twenty dams and more than 500 miles of major canals that, in average years, store and deliver 7 million acre-feet (maf) of water—roughly 30% of California’s developed surface water supplies. On average, 90% of CVP deliveries go to agricultural uses. Urban centers in California are among the fastest growing in the country, and with populations predicted to increase by 50% over the next 25 years (California 1998), water shortages likely will occur with increasing frequency and severity. Although they do not now receive significant quantities of CVP water, nearly all urban water districts in the state are looking toward the CVP as a potential source for addressing state-wide water shortages projected to reach 2.4–6.2 maf by 2020 (California 1998).

As regional water development and withdrawals have increased over time, so have the environmental consequences. One indicator of poor ecosystem conditions is a decline in resident fish populations. More than half the fish species native to the Sacramento and San Joaquin Rivers and delta are in serious decline, endangered or extinct. Reduced delta outflows, due in part to CVP diversions, are a primary cause of the decline in many of those species (U.S. Department of the Interior 1996c).

The CVPIA has been hailed as pathbreaking legislation. Four sets of the act’s provisions are of particular interest for this study—water markets, tiered water prices, environmental surcharges, and fish and wildlife water allocations—and are briefly introduced here. First, the act grants any CVP contractor the right to sell water to any user for any (beneficial) use at any price. However, it places several constraints and conditions on those transfers, including directing the Bureau to charge full-cost rates for water transferred to urban uses.1 Second, it creates an increasing block-rate pricing structure. The (subsidized) contract rate applies to the first 80% of a district’s water allotment, the second tier applies to the next 10% of the water allotment, and is set midway between the contract and full-cost prices, and the final tier applies to the last 10% of the water allotment and is charged at the full-cost price. Third, it imposes a number of surcharges to finance a fish and wildlife restoration fund. The surcharges include a $25 per acre-foot (af) charge on water transfers for sales to non-CVP urban water users, charges of up to $6/af on all agricultural water users and $12/af on all urban water users (indexed to 1992 dollars), and an additional charge of $7/af on Friant Division water (eastern San Joaquin Valley).

A fourth set of provisions allocates CVP water for environmental purposes. The act allocates 800,000 af to in-stream use to protect and enhance fish and wildlife habitat in the Central Valley. Another provision allocates 400,000 af to wildlife refuges. Of that total, 260,000 af were to be allocated immediately, bringing the total mandatory environmental allocation to 1.06 maf. The remaining 140,000 af for the refuges were to be secured from voluntary transactions at the rate of 10% a year between 1992 and 2002. Yet another provision enhances the Trinity River. The CVP currently diverts water from that river into the Sacramento River. Increasing Trinity River flows could require reducing the volume of water diverted out of that watershed and consequently would reduce CVP water supplies, though the quantity by which it will do so is not yet clear. The best available estimate is that, in average years, CVP supplies would be reduced by 100,000 af to 200,000 af (U.S. Department of the Interior 1996b). The average of those values, or 150,000 af, brings the estimated CVPIA environmental water allocation to 1.35 maf. For more detail on these and other CVPIA provisions see Weinberg or Loomis.

**Conceptual Framework**

This section examines, conceptually, the potential effectiveness of a particular policy tool or set of tools. CVPIA provisions form a point of

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1 Full-cost rates include construction costs, operation and maintenance charges and interest on payment obligations outstanding as of 1982. They are less than the government’s total cost, but are closer to it than contract rates. Full-cost prices vary based on the district’s location and the age of the project component serving the district. In the CVP, full-cost prices range from $8 to $255/af (U.S. Department of the Interior 1997a), but fall between $10 and $40/af for 92% of all districts.
departure for this analysis, but, to examine the broader question of the potential effectiveness of options for reforming western water policies generally, individual policy tools are examined independently and in various combinations.

**Farmer's Decision Framework**

Figure 1(a) portrays the decision framework for a single (aggregate) farmer. The marginal benefit of water use is reflected in the demand curve $D_{ag}$. A farmer with access to an unlimited supply of water at a contract price of $P_c$ will choose to apply a quantity of $C$. However, substantial evidence exists suggesting that federal water is, in practice, a quantity-allocated resource, rather than a price-allocated one (e.g., Kanazawa and Moore and Dinar). Water allotments ($A$) are specified in districts’ contracts with the Bureau. The marginal value of water at $A$ is depicted as $V$ (in figure 1(b)). Following Neary and Roberts, this price, which is the sum of the actual price and the shadow value on the resource constraint, represents the “virtual price” for the resource. That is, it is the price at which the resource constraint will “just” bind.

**Water Markets: Interactions Between Farmers and Cities**

An extensive literature (beginning with Gardner and Fullerton, and extending to Vaux and Howitt, Saliba, and Wahl, among others) details the potential for water markets to improve allocative efficiencies of western water resources. Assuming that the aggregate CVP farmer (see figure 1(a)) is the only supplier to the market and that cities are the only source of demand, the market supply curve ($S$) for water transfers is the inverse of the demand curve ($D_{ag}$) (figure 1(b)). Supply is perfectly inelastic at a quantity of $A$ because the allotment binds at that point. Urban demand for federal water is depicted by $D_{urban}$, while the price of water for urban uses at the initial allocation is denoted by $P_u$. A fully functioning water market would clear at a price $P^*$. In that case, the farmer would use $W^*$ and transfer a quantity $T^*$ ($T^* = A - W^*$). As drawn, urban consumers capture most of the gains from trade. The actual size of the gains is an empirical question, but this outcome is likely given generally more elastic estimates of water demand in agricultural than in urban uses.

**Tiered Water Prices**

Tiered water prices have gained attention as a means for achieving water conservation objectives without the income effects of uniform water price increases (Wichelns). The price schedule “$TWP^*$” in figure 1(a) is illustrative of the schedule specified in the CVPIA. As illustrated, that policy would provide some conservation incentive; farmers’ water use falls to 90% (the quantity at which the highest tier is applied). However, because the price associated with the highest tier is far below $P^*$ water use is still significantly larger than $W^*$.

Clearly, the conservation incentive created by tiered prices depends on the relative levels of the upper tiers and the marginal benefits of water use for each farmer. A demand curve farther from the origin might indicate no change in water consumption with tiered prices. On the other hand, a demand curve shifted to the left could increase or decrease the level of conservation. Likewise, if that farmer was in a district with a lower full-cost price, the tiered prices might have no effect; if the full-cost rate were higher, the tiered prices would have a greater effect (Loomis).

**Environmental Surcharge**

The implications of a surcharge will depend on the level of the new price (the contract price plus the surcharge) relative to the virtual price of water given the allotment; surcharges will reduce consumption only if the water allotment does not bind at the new price. However, in either case, surcharges raise revenues for environmental restoration.

Theory suggests that the optimal design for a schedule of surcharges depends on the objective of the surcharge program. Two common, but potentially conflicting objectives include generating revenues for environmental projects and encouraging water conservation. If the sole objective in establishing a surcharge is to raise revenues, a set of Ramsey prices—higher prices for user groups with less elastic demands—would be most efficient. This form of price discrimination is appropriate when the goal is to minimize distortions in consumption. However, modifying behavior may be the program objective; the optimal pricing structure is to invert the relative sizes of the surcharges if the sole objective is to encourage water conservation.

Whether intended or not, the CVPIA creates a rough example of Ramsey pricing by
setting a $6 surcharge for agriculture, a $12 surcharge for municipal and industrial (M&I) uses, and a $25 surcharge for water transferred to M&I use. Agricultural users have more options for adjusting to reduced water supplies, and thus tend to be more price responsive, than urban users.

Environmental Water Allocation

An obvious implication of allocating more water for the environment is a reduction in the amount of water available to farmers, depicted in figure 1(a) as a shift in the agricultural water allocation, from $A$ to $A_2$. Given binding water allotments, it will also increase the shadow value, and thus the virtual price, of water used in agriculture (from $V$ to $V_2$).

Water Market and Environmental Water Allocation

In the presence of a water market, agricultural and urban consumers share the costs of an environmental water allocation. Reducing the supply of water to agriculture would reduce the supply of water from agriculture (illustrated in figure 1(b) as a shift in the market supply curve from $S$ to $S_2$). To the extent that the environmental allocation accurately reflects the relative value society places on instream flows, a water market combined with an environmental allocation would provide socially optimal levels of water for each use: $A - A_2$ for fish and wildlife, $W^{**}$ for agriculture, $T^{**}$ for transfers to urban use, and a price of $P^{**}$.

The remainder of this section examines potential deviations from the optimal water allocation arising from adding policy tools to a reform package that already includes water markets and an environmental allocation.

Water Market and Surcharges

The environmental surcharges drive a wedge between the price paid by farmers and the effective price received for water transfers. Graphically, the urban surcharge differential shifts the urban demand function in (from $D^{\text{urban}}$ to $D_u^{\text{urban}}$). The surcharges tend to increase agricultural water use and decrease water transfers relative to a water market without the surcharges. However, the magnitude of the change is smaller (due to the surcharge on agricultural use) than it would have been if surcharges were imposed only on M&I use.

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2 This is not meant to imply that the environmental allocation is optimal. A comprehensive measure of the (non-market) values associated with in-stream water flows does not exist. As noted by an anonymous reviewer, such an allocation is more likely to represent a political compromise.
Water Market, Environmental Water Allocation, and Tiered Water Prices

Combining the tiered water prices with a water market and supply reductions due to an environmental water allocation, as the CVPIA does, may render the tiered prices ineffective, despite the fact that they may have created a conservation incentive when implemented alone. As long as the price at the top tier is below the market-clearing price, the tiered prices will not affect an individual farmer’s decisions. The tiered water prices do not shift the supply curve. This somewhat counterintuitive result occurs because they must be paid regardless of the water’s end use. Thus, the farmer depicted in figure 1(a) would sell a quantity of \( T^* \) whether the tiered water prices are in place or not.

CVPIA Package of Provisions

The final combination is the entire package of CVPIA provisions considered: a water market, an environmental water allocation, environmental surcharges, tiered water prices, and a repayment rate provision. The repayment rate provision requires farmers to pay the Bureau the (higher) M&I rate for water transferred, but not for water used (U.S. Department of the Interior 1993), and thus drives a wedge between the price farmers pay for the water used and the price they pay for the water they transfer. In contrast to the tiered water prices, the difference in repayment rates shifts the market supply curve up, though the shift is complex when the tiered prices and the repayment rate provisions are considered simultaneously. By increasing the cost for water used in agriculture, the tiered prices reduce the divergence in prices created by the repayment rates, and tend to bring the supply curve back in line with the supply curve for the case in which only a water market and an environmental allocation are implemented. The resulting supply curve (depicted as \( S' \) in figure 1(b)) shifts to the left due to the repayment rate provision, but exhibits discrete jumps associated with the three price tiers. Adding tiered water prices to a water market combined with the repayment rate provision is the one case in which adding tiered prices might affect the amount of water transferred. However, the tiered prices will influence the final result only if the volume of water transferred is less than the 20% of water subject to the tiered prices. The equilibrium water allocation is now \( \hat{W} \) and \( \hat{T} \).

Thus, the CVPIA combination of provisions can be expected to increase agricultural water use and lower water transfers relative to the combination including only the water market and an environmental water allocation. The price wedge, which is captured for the fish and wildlife restoration fund, is depicted as the difference between \( \hat{P}_u \), the price paid by urban users for \( \hat{T} \), and \( \hat{P}_a \), the effective price received by farmers for that level of water transfers.

The above discussion ignores the possibility that the money from the environmental surcharges can be used to purchase water for environmental purposes. Using those funds to purchase water shifts the demand curve in figure 1(b) to the right. That action increases instream water use and decreases water transferred to M&I uses, relative to the case with a water market and the fish and wildlife allocation but without the restoration fund. However, because the restoration fund is financed endogenously, the net effect on agricultural water use is ambiguous. The net effect of the surcharges is to increase agricultural water use, while the net effect of the environmental participation in the water market is to reduce agricultural water use, relative to the case with the water market without the restoration fund.

Empirical Analysis

Characterizing Central Valley Agriculture

CVP water is used to irrigate 2.5 million acres of cropland, producing crops worth more than $3 billion/year. Prior to passage of the CVPIA, the Bureau delivered water to CVP water districts under the terms of forty-year contracts specifying fixed quantities of water (allotments) and a set, below-cost price (see Wahl for a discussion of the evolution and consequences of federal water subsidies). The legacy
of that policy is that irrigation contract prices, typically set in the 1960s, range from only $2/af to $31/af (U.S. Department of the Interior 1997a). In contrast, most urban water districts in the state charge prices approaching or exceeding $1,000/af (California 1998). In some cases, CVP farmers also have access to locally developed surface water and groundwater. However, groundwater overdraft is a significant problem throughout the Valley and increased reliance on groundwater is not thought to be sustainable except as a buffer against short-term droughts (California 1998).

Although CVP farmers have much in common, significant differences exist in such institutional and physical characteristics as water price and quantity, climate, and soils. In addition, a subset of farmers hold water rights pre-dating the CVP. To obtain permission to divert the San Joaquin River’s flows, the Bureau of Reclamation offered water from the delta to “exchange contractors” in exchange for their water rights. Similarly, the Bureau guaranteed delivery of water, without charge, to rights holders along the Sacramento River to gain permission to dam the river’s flows. On average, approximately 2.2 maf/year are delivered to this group of farmers. As a consequence of these differences, cropping patterns, average revenues and prevailing irrigation practices all vary by region. To model this heterogeneity, the CVP is divided into three regions: the Sacramento Valley (Sacramento: 509,000 acres), the western portion of the San Joaquin Valley (West SJV: 896,000 acres), and the southern and eastern portions of the San Joaquin Valley served by the Friant division of the CVP (Friant: 1.05 million acres).

Characterizing Urban Water Use in California

Most of California’s population lives outside the Central Valley, in regions with insufficient local water supplies, and are served by urban water districts that developed high-quality water supplies early in the century. In each case, however, regional population growth has exceeded the system’s capacity or is projected to do so within the planning horizon. In addition, each system is vulnerable to drought, legal or environmental concerns. Purchases of agricultural water have long been shown to be a lower-cost alternative to developing new water supplies, both to moderate the effects of drought and to accommodate future growth.

Two urban demand regions are modeled: southern California and the San Francisco Bay area. The Metropolitan Water District of Southern California (MWD) serves nearly 5.5 million residents in the region. The region imports two-thirds of its water from surface water systems developed in the Sierra Nevada Mountains, 150 miles east of San Francisco, and by hooking into the CVP and SWP systems. Total water use in the region in average years is 1.2 maf.

Framework for Empirical Analysis

An optimization model composed of benefit functions for water use in agricultural and urban sectors is developed for the empirical analysis. Noticeably absent from this analysis is an estimate of the value of the environmental benefits. Rather, the analysis derives from a cost-efficiency perspective, taking environmental allocations as given and examining the efficiency with which policy provisions achieve that objective. The solution to this problem is found by choosing the volume of CVP water

These prices are not directly comparable; a wedge of $100–$300/af can be expected between agricultural and urban water prices to account for treatment and transportation costs necessary to provide drinking water to municipal areas in the southern and coastal portions of the state. Nevertheless, the marginal value of water for agricultural use is clearly below that for municipal use.

For example, water deliveries exceed 5 af/acre for exchange contractors but are 2.5 af/acre for other SJV contractors, and are 3.7 af/acre in the Sacramento Valley. The top crops are: rice in the Sacramento Valley, cotton in West SJV, and cotton (ranked by acres) and table grapes (ranked by value) in Friant. Further details are available from the author.
used in each agricultural region \( (W_{a_i}) \) and each urban region \( (W_{u_j}) \) to

\[
\begin{align*}
\text{Maximize} \quad & \sum_{i=1}^{3} [B_{a_i}(W_{a_i}) - C(W_{a_i})] + \sum_{j=1}^{2} [B_{u_j}(W_{u_j}) - C(W_{u_j})] \\
\text{subject to:} \quad & \sum_{i=1}^{3} W_{a_i} + \sum_{j=1}^{2} W_{u_j} \leq W_{CVP} - W_e \\
& W_{a_2} + \sum_{j=1}^{2} W_{u_j} \leq \bar{E} \\
& W_r \leq \bar{E}_r
\end{align*}
\]

where \( B_{a_i}(\cdot) \) and \( B_{u_j}(\cdot) \) describe benefits to the agricultural and urban sectors as a function of water use. \( W_{CVP} \) is the average supply of deliverable CVP water, and \( W_r \) is the quantity of water allocated to environmental purposes. The water supply constraint is based on historic, aggregate water deliveries to the districts included in the model. Provisions of the CVPIA describe the quantity of water to be allocated to environmental purposes. Other factors are incorporated as appropriate, including water costs, \( C_{a_i}(\cdot) \) and \( C_{u_j}(\cdot) \), physical constraints (e.g., canal capacity), and requirements of the prevailing legislative environment. The implications of the environmental surcharges are examined by including in the water cost functions terms equal to the per unit surcharge times the appropriate quantity of water, except that surcharges and tiered prices are not imposed on deliveries to water rights holders. Tiered prices are modeled as increases in the average cost of water for each district. The cost is calculated as 15% of the difference between district-level contract and full-cost rates. This formulation incorporates the average effect of the CVPIA tiered price structure, but avoids problems with non-differentiability associated with tiered prices.\(^8\)

Price levels for contract, full cost, and repayment rates are reported in U.S. Department of the Interior (1997a and 1997b).

Several constraints on the movement of water simulate physical or institutional con-

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\(^8\) Assuming that water supply constraints bind, this specification produces the same results as modeling tiered prices explicitly. Water transfer opportunities ensure that this is the case in relevant scenarios. Further, simulation results indicate that water allocations are binding even when water transfers are not allowed.

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\(^9\) Several large water districts receive only small portions of their total water use from the CVP, yet their entire production is reported as attributed to the CVP. These districts were eliminated from the analysis due to lack of information on their total water use.
characteristics. The multioutput revenue function can be thought of as an extreme version of a restricted multioutput profit function, i.e., a profit function with the total quantity of each input fixed (but allocatable). Following Chambers (p. 263), the revenue function for producers in a water district is defined as

\[
R(p, w, n, x) = \max \left\{ \sum_{i=1}^{l} p_i \cdot y_i : y \in Y(w, n, x), p > 0 \right\}
\]

where \( R \) is revenue, \( p \) is a vector of crop prices, \( p_i \) is the price of crop \( i \) \((i = 1, \ldots, l)\), \( y \) is a vector of crop output, \( y_i \) is output of crop \( i \), \( w \) is the district’s CVP water allocation, \( n \) is its land endowment, \( x \) is a vector of climate and soil characteristics, and \( Y(-) \) is the multicrop producible output set given the resource endowment.

The data for this analysis are mixed panels with a maximum of a thirteen-year time series (1979–1991) of annual crop and water use reports for each of the 142 water districts receiving CVP water (summarized in U.S. Department of the Interior 1979–1991). This time period covers the broadest span available reflecting pre-CVPIA conditions. It is a period including wet years in the early 1980s and the severe drought of the late 1980s to the early 1990s. All CVP water districts are represented, but not all districts receive water every year, so the data do not include thirteen observations for each district. The regression analyses are based on 351, 403, and 325 observations for the Sacramento, West SJV, and Friant regions, respectively. Variables include CVP water deliveries and acreage allocations, total output, and prices for all crops produced. The data were augmented with county-level soil and climate variables developed from USDA’s National Resources Inventory (NRI). Climate variables are historic (temporal) averages, while the soils variables are (spatial) averages for NRI sampling sites, and thus do not vary over time for a given district as do the other variables.

In many ways, this data set is extraordinarily rich. Its panel structure provides information on farmer response to district-level water allocations that vary over time, due to weather-related changes in aggregate water availability, and among districts, for historical and institutional reasons. Unfortunately, the data do not include any information on the use or costs of variable inputs, which precludes estimation of a (less-restricted) profit function. The appropriateness of the revenue function specification arises from the fact that federal water historically has been a quantity-rationed input, and from strong empirical evidence that the water quantity constraints are binding in the study area (Kanazawa, Moore and Dinar). The final stage in specifying agricultural benefits involves adjusting gross revenues to account for variable input costs.

**Revenue Function Estimation**

A revenue function for each of the three regions was estimated to allow for region-specific coefficients.\(^\text{11}\) Specifying a normalized quadratic functional form, total revenue and all prices are divided by an arbitrarily selected output price\(^\text{12}\) that ensures linear homogeneity in prices. The full specification is

\[
R^n = \alpha_0 + \sum_i \alpha_i p^n_i + \sum_{ij} \alpha_{ij} p^n_i p^n_j + \sum_k \beta_k x_k + \sum_{kl} \beta_{kl} x_k x_l + \sum_{ik} \gamma_{ik} p^n_i x_k + \theta_1 D_1 + \theta_2 D_2 + \varepsilon
\]

where \( R^n \) is normalized total revenue \((R/p_n)\), \( p^n_i \) is normalized crop prices \((p_i/p_n)\), \( i = 1–12 \) \((i = 1–11 \text{ for Friant})\), \( p_n \) is the numeraire price, \( x_k \) are fixed inputs, \( k \) = water, land, and soil and climate variables, \( D_1 \) is a dummy variable for districts receiving non-project water, including rights holders, exchange contractors and recipients of surplus water, \( D_2 \) is a dummy variable for 1983 to account for distortions in planted acreage and water use due to the confluence of flood events and the Payment-in-Kind (PIK) policies the Department of Agriculture implemented in that year, and \( \varepsilon \) is a stochastic error term.

\(^{11}\) Chow tests, of all regional combinations, strongly rejected the null hypothesis that no structural differences exist between the three regions.

\(^{12}\) Alfalfa price is the numeraire for the West SJV model, while the wheat price is the numeraire for the remaining regions. In West SJV, more districts devote at least some acreage to alfalfa in more years than to any other crop. Wheat is more common than alfalfa in Sacramento and Friant.
A total of 68 crops are produced in the CVP. Including 68 prices is not desirable, nor is it feasible with this functional form. Therefore, only crops accounting for at least 1% of the total revenue in each region or planted on more than 10,000 acres in each region are included. This screen leaves 13 crops in the Sacramento and West SJV regions and 12 crops in Friant.\textsuperscript{13}

Soil and climate variables include frost (average number of days with mean temperatures less than 32°C), rain (average precipitation), slope (average slope percentage), and salinity (number of sites that need special management due to saline and/or alkali soils).\textsuperscript{14}

With pooled time series—cross section data, ordinary least squares estimates may be unbiased, but are not likely to be efficient. Potential problems include heteroscedasticity, autocorrelation, and problems specific to panel data. In this case, heteroscedasticity may arise from the aggregation inherent in district-level data. To account for these problems, a pooled cross-sectionally heteroskedastic and timewise autoregressive model (Kmenta, pp. 508–512) was estimated.\textsuperscript{15} The error specification is:

\[
E(\varepsilon_{it}) = 0, \quad E(\varepsilon_{it}^2) = \sigma_i^2, \quad E(\varepsilon_{it} \varepsilon_{jt}) = 0 \quad (i \neq j)
\]

and \(\varepsilon_{it} \sim N(0, \sigma_i^2)\), and \(E(\varepsilon_{i,t-1} u_{ijt}) = 0 \quad \forall \ i, j,\)

cross-sectional independence is assumed. Two autocorrelation hypotheses were examined: \(\rho_i = 0 \quad \forall \ i \) (no autocorrelation) and \(\rho_i = \rho \quad \forall \ i \) (autocorrelation coefficient constant across districts). Restricting \(\rho\) to a common value may be preferable with a short time series (Greene, p. 457), so district-specific estimates of \(\rho\) were ruled out a priori. Likelihood ratio tests comparing the two specifications indicated that the model with constant \(\rho\) was preferred for each region.

Goodness of fit measures were extremely high (Buse \(R^2\) were greater than 0.9) for all three models. Problems with multicollinearity and the large numbers of coefficients contributed to disproportionately low \(t\)-statistics for many variables. However, coefficients on the water terms were generally of the expected sign, and significance levels on water variables were disproportionately high relative to other variables.\textsuperscript{16}

The final step in specifying the agricultural benefits component of the optimization model (equation (1)) is to express district-level revenues \((R_{d})\) solely as a function of water and sum over districts for each region (where regional indices are omitted to alleviate notational complexity) and to adjust for input costs:

\[
B_d(W_d) = \sum_d \Omega_d R_d = \sum_d \Omega_d (a_{0d} + a_{1d} W_d + a_{2d} W_d^2)
\]

where

\[
a_{0d} = (\hat{\alpha}_0 + \sum_i \hat{\alpha}_i \bar{P}^n_{id} + \sum_{i,j} \hat{\alpha}_{ij} \bar{P}^n_{id} \bar{P}^n_{jd} + \sum_{k \neq w} \hat{\beta}_k \bar{x}_{kd} + \sum_{k \neq w, j \neq w} \hat{\beta}_{k,j} \bar{x}_{kd} \bar{x}_{jd} + \sum_{i,k \neq w} \hat{\gamma}_{ik} \bar{P}^n_{id} \bar{x}_{kd} + \hat{\theta}_1 \bar{D}_{1d} + \hat{\theta}_2 \bar{D}_{2d}) \bar{P}_{nd}
\]

\textsuperscript{13}Crops included for each region (in alphabetical order) are: Sacramento (alfalfa, almonds, corn, dry beans, melons, other grapes (wine and raisins), pasture, prunes, rice, sugar beets, tomatoes, walnuts, and wheat); West SJV (alfalfa, alfalfa seed, almonds, barley, cotton, corn, cotton, oranges, wine and raisin grapes, sugar beets, tomatoes, walnuts, and wheat); and Friant (alfalfa, almonds, barley, corn, cotton, oranges, wine and raisin grapes, pasture, prunes, table grapes, walnuts, and wheat). With this type of data it is inevitable—even when only the top 12 or 13 crops are considered—that some districts will not have produced a given crop in a given year and so will have a zero price for that crop and year. However, the actual price for that crop and year should be included in the analysis because it represents an opportunity cost of not producing that crop. This problem was addressed by replacing all zero prices with county-level mean prices. In a few cases no other districts in that county produced that crop. In that case the regional mean price was used.

\textsuperscript{14}Significant variation exists in these variables to include them in the Sacramento region, but severe collinearity dictated that only rain remain in the Friant regression and none remained for West SJV.

\textsuperscript{15}The “Kmenta” model is slightly more general than the fixed or random effects models commonly applied to panel data. Rather than making assumptions about the structure of the model (particularly the intercept), as the fixed effects model does, it addresses problems in the error structure. On the other hand, it does not take advantage of specific information about the nature of the data, as panel models do. However, the Kmenta model does allow for tests of the nature of the autocorrelation. Moreover, the autocorrelation correction may be more appropriate than that included in panel data methods in that it allows for declining influence of the disturbance over time, whereas panel data models impose the same difference regardless of the distance in time between any two observations.

\textsuperscript{16}In the West SJV region, the linear and squared water terms were significant at the 5 and 1% levels, respectively; and 60% of the terms involving the water variable were significant at the 10% level or better. In the Sacramento and Friant models, respectively, 47% and 40% percent of the terms involving the water variable were significantly different from zero (with a 10% confidence level or better). Detailed regression results are available from the author.
mental Protection Agency, p. 5, so Joaquin Valleys, respectively (U.S. Environmental Protection Agency, p. 5), so

\[ a_{1d} = (\hat{\beta}_w + \sum_k \hat{\beta}_{wk} \bar{x}_{kd} + \sum_i \hat{\gamma}_{iu} \bar{p}_{id}^n) \bar{p}_{nd} \]

\[ a_{2d} = \beta_{ww} \bar{p}_{nd} \]

\( \hat{\alpha}, \hat{\beta}, \hat{\gamma}, \hat{\theta} \) are estimated coefficients, \( W_d \equiv x_w \) is water use by district \( d \), \( \bar{p} \) and \( \bar{x} \) are district means (averaged over time) for prices and inputs (other than water), and other variables are previously defined.

Gross revenues are adjusted proportionately, by a factor \( \Omega \), to provide a measure of net benefits for use in the simulation model. Net revenues are an estimated 36% and 49% of gross revenues in the Sacramento and San Joaquin Valleys, respectively (U.S. Environmental Protection Agency, p. 5-4), so \( \Omega_d = 0.36 \) for all districts in the Sacramento region, and \( \Omega_d = 0.49 \) for all remaining districts. The assumption embodied by this specification is that variable input costs will change in proportion to changes in gross revenues in response to the policy scenarios. The basis for this assumption is two-fold. First, variable inputs are frequently assumed to be used in fixed proportions for a given crop. Second, evidence suggests that the share of irrigated acreage allocated to each crop will not change significantly with the CVPIA (although total irrigated acreage is predicted to fall) and that net revenues as a proportion of gross revenues will vary by less than half a percent across all scenarios (U.S. Department of the Interior 1999).

Urban Water Demand Functions

Published measures of demand elasticities are used to develop the urban benefit functions. For the southern California area, the demand function is based on the Metropolitan Water District of Southern California’s (MWD) analysis. The demand function for the San Francisco region is based on two studies of the East Bay Municipal Utilities District (EBMUD), but is adjusted to reflect regional water use conditions. MWD estimates of demand elasticities are: \(-0.31\) for single-family units, \(-0.14\) for multi-family units, and \(-0.28\) for commercial and industrial uses (Metropolitan Water District).\(^17\) The aggregate demand elasticity estimate for EBMUD is \(-0.20\) (Weber).\(^18\) These values are within the range of estimates developed for urban water demand in various U.S. and Canadian cities (e.g., Billings and Day and Nieswiadomy and Molina).

Given the demand elasticities and information on average prices and quantities consumed, linear demand functions are developed for each region with simple algebraic manipulation of the formula for line and elasticity definitions. An aggregate demand function for southern California is derived by horizontal summation of the inverse demand functions for the three MWD user groups. Finally, a measure of the total regional benefit from water use is derived by integrating under the demand function between the old and new levels of water consumption.

The gross benefit to urban consumers of water transfers to each region is thus described as

\[ B_{U_j} = \int_{w_{U_j}}^{w_{U_j}^*} P_m(w) \, dw \]

\[ = (b_1 W_{U_j}^* + 0.5b_2 W_{U_j}^{*2}) - (b_1 W_{U_j}^o + 0.5b_2 W_{U_j}^{o2}) \]

where water transfers account for the difference between initial (\( W_{U_j}^o \)) and optimal (\( W_{U_j}^* \)) urban water use levels. Benefit function coefficients are: \( b_1 = 1692.50 \) and \( b_2 = -0.000422 \) for MWD, and \( b_1 = 1725.64 \) and \( b_2 = -0.001200 \) for San Francisco. Base water use levels for MWD and San Francisco are 3.6 maf and 1.2 maf, respectively (California 1994).

Simulation Results

As in the conceptual analysis, a set of policy scenarios is developed to examine incrementally more complex combinations of CVPIA provisions.\(^19\) Results are presented in table 1.

\(^{17}\) Updated information based on 1990 census figures provided by Grace L. Chan, Metropolitan Water District, June, 1994. MWD

\(^{18}\) Fisher et al., note that this value may represent an underestimation of the true elasticity of demand. Sensitivity analysis on elasticity estimates for this region of up to \(-0.4\) demonstrated the robustness of the analysis with respect to this parameter.

\(^{19}\) Simulation results are not path dependent with respect to policy choice. Thus, while comparisons in this section are relative to the baseline or are for an incremental change in a policy combination, numerous other comparisons can be made. However, those additional comparisons are left to the reader.
Table 1. Estimated Changes Arising from CVPIA Water Policy Reform Provisions

<table>
<thead>
<tr>
<th>Scenario:</th>
<th>West SJV Agriculture</th>
<th>Sacramento Agriculture</th>
<th>Total Agriculture&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Urban Transfers</th>
<th>Water Market</th>
<th>Efficiency Gains/&lt;br&gt;Losses&lt;sup&gt;b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Water Use (1000 af)</td>
<td>Crop Returns&lt;sup&gt;b&lt;/sup&gt; ($ mill.)</td>
<td>Net Returns&lt;sup&gt;b&lt;/sup&gt; ($ mill.)</td>
<td>Water Use (1000 af)</td>
<td>Crop Returns&lt;sup&gt;b&lt;/sup&gt; ($ mill.)</td>
<td>Net Returns&lt;sup&gt;b&lt;/sup&gt; ($ mill.)</td>
</tr>
<tr>
<td>Baseline</td>
<td>2154</td>
<td>552</td>
<td>552</td>
<td>1797</td>
<td>117</td>
<td>117</td>
</tr>
<tr>
<td>1. Water Markets</td>
<td>Change from Baseline</td>
<td>−155</td>
<td>−5</td>
<td>−187</td>
<td>−6</td>
<td>−6</td>
</tr>
<tr>
<td>2. Water Markets and All Water Price Provisions</td>
<td>Change from Baseline</td>
<td>−103</td>
<td>−3</td>
<td>−124</td>
<td>−4</td>
<td>−16</td>
</tr>
<tr>
<td>3. Water Markets and an Environmental Water Allocation of:</td>
<td>Change from Baseline</td>
<td>−304</td>
<td>−17</td>
<td>−621</td>
<td>−21</td>
<td>−21</td>
</tr>
<tr>
<td>(a) 800,000 acre-feet</td>
<td>Change from Scenario 1</td>
<td>−349</td>
<td>−12</td>
<td>−434</td>
<td>−15</td>
<td>−15</td>
</tr>
<tr>
<td>(b) 1.2 million acre-feet</td>
<td>Change from Baseline</td>
<td>−671</td>
<td>−24</td>
<td>−844</td>
<td>−30</td>
<td>−30</td>
</tr>
<tr>
<td>(c) 1.35 million acre-feet</td>
<td>Change from Scenario 1</td>
<td>−516</td>
<td>−19</td>
<td>−657</td>
<td>−25</td>
<td>−25</td>
</tr>
<tr>
<td>Change from Baseline</td>
<td>−734</td>
<td>−27</td>
<td>−27</td>
<td>−927</td>
<td>−34</td>
<td>−34</td>
</tr>
<tr>
<td>Change from Scenario 1</td>
<td>−579</td>
<td>−22</td>
<td>−22</td>
<td>−740</td>
<td>−28</td>
<td>−28</td>
</tr>
<tr>
<td>4. Water Markets, Environmental Water Allocation (1.2 maf), and Surcharges</td>
<td>Change from Baseline</td>
<td>−634</td>
<td>−22</td>
<td>−31</td>
<td>−796</td>
<td>−28</td>
</tr>
<tr>
<td>Change from Scenario 1</td>
<td>−27</td>
<td>−7</td>
<td>48</td>
<td>2</td>
<td>−3</td>
<td>85</td>
</tr>
<tr>
<td>5. CVPIA Package: Water Markets, Environmental Water Allocation (1.2 maf), Surcharges and Average Price Increase from Tiered Prices</td>
<td>Change from Baseline</td>
<td>−621</td>
<td>−22</td>
<td>−35</td>
<td>−779</td>
<td>−27</td>
</tr>
<tr>
<td>Change from Scenario 2</td>
<td>−518</td>
<td>−19</td>
<td>−15</td>
<td>−655</td>
<td>−24</td>
<td>−18</td>
</tr>
<tr>
<td>Change from Scenario 1</td>
<td>−50</td>
<td>−2</td>
<td>−11</td>
<td>65</td>
<td>3</td>
<td>−4</td>
</tr>
</tbody>
</table>

<sup>a</sup>Total Agriculture includes West SJV, Sacramento and Friant regions. Baseline figures for Friant are 1.2 million acre-feet of water use and crop returns of $583 million. The Friant figures change only for expenditures for water price increases and surcharges.

<sup>b</sup>Crop returns are a proportion of gross revenues (36% for Sacramento and 49% for other regions). Gross benefits from water transfers are the area under the demand curve. Net returns are crop returns net of charges (the cost increases due to water price increases and surcharges). Those measures do not include payments for water transfers. Though not in the table, farmers' total net returns are net returns plus payments and urban consumer surplus is gross urban benefits less transfer payments. Efficiency gains and losses are changes in crop returns plus changes in gross urban benefits. Transfer payments net out in that measure. Charges are not included because they represent an income transfer and not an efficiency change.

Note: Numbers may not add to totals due to rounding.
Costs of changes in water allotments are estimated as forgone returns to crop production and water sales. All values are annual. The virtual price (or quasi-rent) for water, as well as the water transfer price in appropriate scenarios, is represented by the shadow value on the water supply constraint.\textsuperscript{20} Summing water use and revenues over all districts in a given region provides the regional results reported for the agricultural sector.

**Baseline Scenario**

A baseline scenario describes estimated water use and associated crop revenues for a year with average rainfall under pre-CVPIA conditions. Estimated net revenues from crop production using 5.15 maf of CVP water total $1.25 billion. Baseline levels of water use in the urban areas generate gross consumer benefits of $4.5 billion. Of that amount, $3.3 billion accrues in southern California and $1.2 billion in the San Francisco Bay region.

**Scenario 1: Water markets.** Results suggest that farmers would sell 342 thousand acre-feet (kaf) of water, or 7\% of their baseline water use, to urban users in southern California at a price of $32/af. Selling that quantity of water would reduce agricultural crop revenues by $10 million from baseline levels and generate $36 million in urban gross benefits, with $11 million transferred to farmers as water payments. All parties benefit from the transfer. The farmers’ total revenues increase by $1 million and net benefits to urban users are $25 million, but, as expected, urban water users capture the vast majority of gains from trade. Total net benefits from the opportunity to participate in water markets is $25 million.

**Scenario 2: Water pricing provisions, with and without water markets.** Increased water rates from surcharges for the fish and wildlife restoration fund, tiered water prices, and a higher repayment rate for transferred water have two general effects: they reduce net benefits to all consumptive uses and they change the relative benefits of agricultural and urban water use. Consequently, the quantity of water used in the two sectors also changes. Those changes, however, are estimated to be relatively small. In fact, in a scenario in which the water pricing provisions are implemented by themselves, for example, without a water market, no change in behavior is predicted, relative to the baseline. This lack of response occurs because, in the absence of a water market, water allocations are binding constraints even in the face of the aggregate price increases. Net benefits fall by $45 million paid in charges to the fish and wildlife restoration fund.

Although they are not predicted to influence farmers’ behavior when implemented alone, introducing price reforms into a water-use sector with a fully functioning water market may dampen water market participation. Results suggest that a scenario with water markets and surcharges will motivate transfers of 227 kaf of water to urban consumers. These transfers reduce estimated net revenues from agricultural production by $7 million relative to the baseline. Revenues from water transfers just slightly exceed losses from crop production. On net, then, farmers are worse off by the $43 million in charges. Water transfers (and revenue reductions) are split roughly evenly between the West SJV and Sacramento regions. Urban benefits increase by $29 million relative to the baseline, but transfer payments are $7 million and surcharges for water transfers are $11 million, for a net change in consumer surplus of $11 million. Total net efficiency gains are $22 million.\textsuperscript{21}

The gains associated with this policy belie the reductions in transfers, and in changes in the surplus measures, relative to a scenario with water markets alone. Adding the surcharges reduces transfers to urban districts by 115 kaf (table 1, row 4). Revenues from crop production rise by $4 million, whereas benefits to the urban sector fall by $6 million, and transfer payments fall to $4 million. Farmers’ revenues from producing crops and selling water thus falls by $1 million, whereas urban consumer surplus falls by $2 million. These results suggest a $3 million efficiency loss associated with a policy instrument (environmental taxes) that, in theory, should be efficiency enhancing. Total water constraints remain binding. No conservation incentive is realized, but the differential price changes serve to

\textsuperscript{20} As noted by a reviewer, this assumption implies that, at the margin, foregone returns from water use represent a market-clearing price for a water market. In fact, foregone returns may serve only as a lower-bound estimate for farmers’ willingness to accept water transfers because the producer could attempt to capture a greater share of the rents.

\textsuperscript{21} Efficiency gains are measured as changes in net benefits to the agricultural and urban sectors excluding the payments associated with the price increases because those payments represent an income transfer and not a change in the economic value of the resource.
modify the agriculture–urban allocation. No account is made of the long-run consequences of paying $55 million in surcharges or of the environmental benefits associated with expenditures of those funds on fish and wildlife restoration.

Scenario 3: Water markets and fish and wildlife water allocations. Scenario 3 examines adjustments related to the fish and wildlife water allocation. Relative to a pre-policy baseline, agricultural water use declines by more than 1.1 maf with an environmental water allotment of 800 kaf (table 1, scenario 3a), due to a transfer of 325 kaf to urban users. Net revenues from crop production fall by $38 million, which is only partially offset by transfer payments of $13 million. Urban consumer surplus increases by $22 million, after subtracting the transfer payment from gross benefits of $35 million.

Higher levels of environmental water allocations magnify this result, with an increasing portion of the changes felt in the Sacramento region. Crop returns fall by $54 million relative to the baseline with a 1.2 maf environmental allocation, and by $60 million when 1.35 maf are allocated to the environment. Water is transferred to urban uses in each scenario, though the quantity falls slightly as the environmental water allotment rises. The change in urban consumer surplus is estimated to be $21 and $20 million in the two scenarios, respectively. In net terms, then, joint implementation of a water market and an environmental allocation will cost agricultural and urban users a total of $3 million, $19 million and $26 million, respectively, for the three levels of environmental water allocations. Environmental benefits associated with increased flows are not measured.

Now consider the changes from Scenario 1, which allows water transfers but allocates no water to fish and wildlife uses. Providing the first 800 kaf of environmental water results in $26 million in forgone agricultural revenues, a 3% reduction in net benefits realized without the environmental water allocation, but with a water market. Agricultural water use declines by 783 kaf, and water transfers to urban areas in southern California decline by 17 kaf. The imputed price for water increases with the environmental water allocation, from $32/af with a market only to $39/af with a water market and 800 kaf environmental water.

Increasing the environmental allocation by half, to 1.2 maf, reduces crop returns another $16 million, or approximately 60%, for a total decline relative to the market only of $44 million. Water transfers to southern California decline by another 10 kaf. Payments from urban areas for the remaining water transfers are $3 million higher, despite the lower quantity transferred, due to a price increase. Net agricultural benefits fall by $15 million. Further increasing the environmental allocation, to 1.35 maf, reduces net agricultural benefits by an additional $6 million.

The change in total net benefits associated with the environmental water allocation is $28 million for an environmental allocation of 800 kaf, $45 million for a 1.2 maf allocation, and $51 million for a 1.35 maf allocation, given the presence of a water market to ensure a least-cost approach to providing that water. Comparing these figures with those relative to the no-policy baseline ($3 million, $19 million, and $26 million, respectively) suggests that the cost of the environmental allocation can be significantly underestimated if an analyst were to focus solely on the joint implementation of the two provisions.

Scenarios 4 and 5: Water markets, environmental water allocation and pricing provisions. The price provisions are addressed incrementally here. First, scenario 4 adds surcharges on water use and water transfers to a scenario (Scenario 3b) with water markets and a 1.2 maf environmental water allocation. This scenario (Scenario 4) results in net returns to agriculture that are $67 million lower than in the baseline, including a $50 million reduction in net revenues from crop production, $26 million in charges and nearly $10 million in transfer payments. Despite levels of water use that are similar to the other regions, payments to the fund are lowest in the Sacramento Valley because tiered prices and surcharges do not apply to deliveries to water rights holders, which constitute nearly two-thirds of all CVP water delivered in the Sacramento Valley. Urban consumers still enjoy positive net benefits; urban benefits are $29 million, less $10 million transferred to farmers.

The final scenario—the CVPIA package (Scenario 5)—adds in the remaining pricing provisions (average cost increases associated with tiered water prices and repayment rates). Relative to the no-policy baseline, the package of CVPIA provisions costs CVP farmers about $75 million, 6% of baseline revenues. That number includes a reduction of $49 million in net revenues from agricultural
production and $34 million that farmers would pay in charges for the restoration fund, partially offset by $8 million in proceeds from water sales. The gross benefit to urban consumers from the entire package of provisions is $27 million, but $8 million of that goes to buy water and $10 million is paid in CVPIA surcharges, for an increase in net benefits of $8 million.

Throughout this analysis, the total water use in the Friant region remains unchanged. Despite the impact of the reduced availability of water in the West SJV and the Sacramento Valley regions, the implicit value of water in the Friant region remains higher than that for the other regions. Further, the CVPIA prohibits taking water from the Friant region to comply with the fish and wildlife water allocations. The Friant region is not completely unaffected, however; water is transferred within the region, and restoration payments, $14 million for the final CVPIA scenario, are higher than in other regions.

Conceptually, the scenario with a 1.2 maf water allotment and water markets (Scenario 3b), should produce the least-cost approach to the objective of allocating 1.2 maf of water to the environment. The impact of the pricing provisions is perhaps best seen in that context. Adding the full set of price increases to the scenario with water markets and a 1.2 maf environmental water allocation (i.e., comparing scenario 5 with Scenario 3b) reduces agricultural net benefits—crop returns less surcharges plus transfer payments—by $34 million. Water transfers fall by 115 kaf, reducing urban net benefits by $8 million (table 1, last row). Payments to the restoration fund increase to $44 million.

Efficiency costs associated with all CVPIA provisions are an estimated $22 million. However, relative to a scenario in which only a water market and a 1.2 maf environmental water allocation are introduced, these cost estimates are only $3 million.

_Sensitivity of the Results to the Availability of Water_

Reform does not occur in a vacuum and both the costs and benefits will vary with the institutional context and with changes in water supply conditions. In wet years, the cost the CVPIA imposes on agriculture may be limited to payments to the restoration fund; the act would not reduce crop revenues in those years. At the other extreme, the act’s costs could be significantly greater than those estimated above under persistent drought conditions, though transfers would have a bigger net benefit. Environmental benefits from the CVPIA will probably also increase in those years. The actual costs and benefits depend critically on how a drought manifests in regional baseline water supply decreases. Similarly, regulations imposed under the Clean Water and Endangered Species Acts reduce CVP water diversions and require that delta outflows be increased. Implementing the CVPIA in combination with other environmental legislation would increase total costs to farmers, though analysis suggests that the incremental cost could decline slightly (see Weinberg).

Summary and Conclusions

Water markets, tiered water prices, and environmental surcharges are all policies that can motivate water conservation and improve allocative efficiency of scarce water resources. However, the success of these policies is not guaranteed; they will only be effective when prices rise above shadow values for this quantity constrained resource. Mandatory water supply reductions are effective in achieving in-stream flow objectives, but may be costly. In addition to improving allocative efficiency among current water users, water markets are critical for minimizing the cost of environmental water allocations.

Empirical results suggest that the net annual cost of the CVPIA will be relatively small; the farmers’ net revenues are predicted to decline by $75 million, approximately 6% of average net revenues. However, these costs will not be distributed uniformly. Some farmers may face significant impacts. Simultaneously, the act will generate positive benefits for urban water users; urban consumer surplus increases by nearly $20 million.

The environment presumably will benefit from additional water supplies and expenditures from a fish and wildlife restoration fund of $44 million. Environmental benefits are not quantified in this study, but previously published estimates suggest that those benefits can be significantly greater than the net cost estimates presented here. For example, estimates of the value of environmental water allocations for commercial and recreational fisheries range from $2 million to $25 million per year (U.S. Environmental Protection Agency and


References


Carey, Evans, and Wilen). Loomis estimates the value of the CVPIA’s refuge provisions to be $122 million. A final study places a value of $2.2 billion on use and non-use values associated with both salmon restoration and refuge protection in the San Joaquin Valley (Hoehn and Loomis)

Results also suggest that price reforms based on full-cost prices, a common feature in Reclamation Law, may do little to motivate behavioral changes. For this reason, however, they will be effective in raising funds to finance environmental restoration policies. Further, surcharges are predicted to dampen farmers’ response to water marketing opportunities.

Generalizing these results to other western states must be undertaken with caution; farmers in other areas may not have the same degree of flexibility CVP farmers have to respond to water policy reform. Local institutions and the nature of water use conflicts, both of which differ from river basin to river basin and state to state, also have an important effect on the appropriateness and applicability of carrying out CVPIA-type reforms in other regions. In any case, the level of the policy tools—specific prices and water quantities—are as important as the type of policy, e.g., price increases, water transfers, and environmental water allocations, in driving the ultimate response to the reforms. Further, effective policy reform requires matching policy tools with reform objectives. The clearest example of tension in this regard is the conflict between revenue and conservation goals in price instruments. Finally, results presented here indicate the need for care when conducting analysis and making policy recommendations if options are implemented as part of a package of reforms.


