Irrigation Districts and Water Markets: An Application of Cooperative Decision-Making Theory

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ABSTRACT. Water supply organizations control a large portion of agricultural water rights in the western U.S. This paper applies cooperative and club theory models to analyze the response of these organizations to potential rural-to-urban water transfers. Application of the models is to a proposed water trade between Southern California's Imperial Irrigation District and Metropolitan Water District. The analysis reveals that substantial intraorganizational conflict can emerge in response to specific transfer proposals, and this conflict may be sufficient to defeat or delay otherwise beneficial transfers. Poorly defined property rights and a failure to align these rights with operational control in the water supply organization are pinpointed as key sources of conflict. (JEL Q15)

I. INTRODUCTION

Nearly 90 percent of all water consumption in the Western U.S. occurs in irrigated agriculture, prompting the observation that modest transfers of water from rural to urban users could satisfy the growing nonagricultural demand for years to come (Howe, Lazo, and Weber 1990). However, in some Western states, including California, rural-to-urban transfers have been slow to take place (Smith 1989; Macdonnell et al. 1990) despite a gradual recognition of the desirability of such transfers among policymakers (Smith 1989).

Smith (1989, 448) suggests that about 50 percent of irrigated acreage in the western U.S. is served by either a private mutual company or public water district. For irrigation from surface water, the figure is close to 100 percent. This fact makes these organizations key players in structuring water transfers and has prompted calls for analysis of their role in stimulating or obstructing rural-to-urban water transfers. The water district function of supplying the input water is closely parallel to the functions performed by cooperative and club organizations (Tregarthen 1983; Bain, Caves, and Margolis [BCM] 1966). This paper applies club theory and cooperative theory models to analyze decision making within a water supply organization regarding whether the organization will participate in water transfers.

The specific application is to the proposed water trade between the Imperial Irrigation District (IID) in southern California and the Metropolitan Water District (MWD), a wholesaler of water to urban areas of southern California. An analysis by Vaux and Howitt (1984) estimated that economic gains with a capitalized value of $3 billion could be achieved if 1,090,000 ac. ft. of water were transferred annually from the Imperial Valley to urban users. Yet trade talks between IID and MWD languished throughout the 1980s before an agreement was eventually reached in 1989. The volume to be traded annually under the arrangement, 100,000 ac. ft., is less than 10 percent of the amount that could be traded profitably based on the Vaux and Howitt analysis.

Our analysis documents that substantial intraorganizational conflict can emerge within a water district in response to specific water trade proposals, and this conflict may be sufficient to defeat or delay proposed transfers that would otherwise yield substantial net benefits. Thus, although Vaux and Howitt (1984) may be correct in their conclusion that water trading "may be one of the few policy changes in which all

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participants can be gainers" (p. 791), the present analysis serves notice that these gains may not be realized under the typical proposals for structuring rural-to-urban transfers.

In the next section we describe structure and decision making in Western water supply organizations and explore their linkages to club and cooperative associations. Two contemporary models of decision making among heterogeneous cooperative members, one based on voting theory and the other on game theory, are summarized. The application of these models to the IID-MWD water trade negotiations then follows.

II. STRUCTURE AND DECISION MAKING IN WATER SUPPLY ORGANIZATIONS

This section focuses on water supply organizations with special reference to California. Public water supply organizations may differ in their structure across states and even within states for districts authorized under different enabling statutes. The most important public water supply organizations in California are reclamation districts, irrigation districts, water districts, and water storage districts (Gardner 1983). Most western states followed California law in designing their own water statutes (Smith 1989), and, therefore, much of this analysis should apply generally to western U.S. water supply organizations.1

Irrigation from a given source to a contiguous geographic area is supplied under conditions of increasing returns to scale (BCM 1966, ch. 6), and the provision of water for irrigation is, therefore, a natural monopoly. Gardner (1983) suggests the aggregate price elasticity of demand for irrigation water in 17 western states is about \(-0.35\) and about \(-0.65\) in California. These relatively inelastic demands indicate that a for-profit monopoly provider of irrigation water would have substantial market power. Businesses facing monopoly power have incentive to integrate upstream to avoid losses from monopolization by providing the monopolized input themselves (Sexton 1986). In cases where the scale of operation upstream exceeds substantially the scale of the downstream firms, efficiency dictates that integration proceed jointly through a cooperative organization. These dual incentives for cooperative formation (market failure and economies of scale) were observed in the California water industry. Private irrigation companies with monopoly power, formed from 1870–1920, were gradually replaced by cooperative water supply organizations in the form of public water agencies or private mutual companies (BCM 1966, ch. 9).

Public water supply organizations in California are legally constituted governmental entities that are endowed with general corporate power and the power to assess property and tax their constituencies (Jameson et al. 1974). In most cases they act as trustee for landowners within the district and are limited in this trust capacity to receive and distribute water to landowners. Financing in public water supply organizations may involve both per-unit charges for water deliveries, per acre water availability charges, and tax levies on land. Irrigation districts in California obtain most of their revenue from user charges. In the IID, for example, user charges have comprised between 92 and 96 percent of operating revenues during the 1980s (IID Annual Reports, 1980–89).

Most California irrigation districts including IID were organized under law which specifies that voting is on a one-person one-vote basis, with eligible voters being all registered voters within the district. This universal franchise contrasts with the law specifying that the district as titleholder to the water rights must exercise that title for the equitable and beneficial interests of landowners (Smith 1989). However, enabling statutes for other California public water supply organizations restrict voting. In reclamation districts, water districts, and water storage districts voting rights are restricted to landowners, who

1 Saliba and Bush (1987) provide an overview of water statutes in several western states.
vote in proportion to the assessed valuation of their land. In water conservation districts one vote is allocated per acre of land.

The services provided by public water supply organizations can also be provided by mutual companies or private corporations. Hence, public water supply organizations are closely related to private clubs and specifically to agricultural cooperatives. Cooperatives often supply inputs such as fertilizers, seeds, petroleum, and chemicals to farmers. The water district function of supplying the input water is closely parallel, and the economic motivations for forming water supply organizations are very similar to those for forming an agricultural cooperative.

Four defining principles for a cooperative are as follows (Vitaliano 1985):

1. Service at cost,
2. Benefits in proportion to use,
3. Member-user control,
4. Limited returns on equity capital.

Public water districts are organized as nonprofit corporations, and, thus, meet a necessary component of the service at cost principle. However, most districts do have the power to tax unimproved property. Unless the assessments levied bear a close relationship to the benefits derived from the district, a district’s pricing will violate the service at cost principle. However, Smith (1989) argues that both legal and economic theory support the use of property assessments to reasonably approximate the benefits received from irrigation. Mutual companies are also organized on a nonprofit basis and lack the power to tax and, thus, satisfy the service-at-cost principle.

Patrons of water districts receive benefits as users of water, not as owners of district resources. Benefits from water use are roughly proportional to the amount of water used and so the benefits in proportion to use principle is also met. The same conclusion holds for members of mutual water companies.

The principle of member-user control means that control in a cooperative is vested in members as users, not as owners. Most cooperatives base voting on a one-person one-vote system, as in the typical irrigation district, but some allocate votes in proportion to use in conformity with the voting systems used by California water districts, reclamation districts, and water storage districts. Voting in mutual water companies is in proportion to stock owned, but, since stock ownership defines a farmer’s water rights, this system also effectively allocates votes in proportion to use. As Vitaliano has noted, “proportional voting does not imply less control over a cooperative by member-users than under [one-person one-vote systems] but rather a redistribution of voting power with emphasis on use of the organization instead of on mere membership” (1985, 147).

The fourth principle, limited returns on equity capital, does not apply directly to public water districts, where members accrue no equity capital as such.3

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3Court opinions on water district matters affirm this observation. For example, in upholding departures from one-person one-vote decision making, the court in Thompson et al. v. Bd. of Directors of the Turlock Irrigation District [245 Cal. App. 2d 587, 1967] concluded, “when the principal purpose is to provide a service that can be and is sometimes provided by a private or quasi-public corporation, without exercising the general powers of government, the district is not subject to the ‘one man, one vote’ rule.”

3Service at cost implies that the water district provides service based on the actual financial costs incurred by the district. Water districts may not pay the full social or even the full financial costs of irrigation water. For example, interest expense on water development projects incurred by the Federal government are not passed on to individual districts. The sole cost to IID for water supplied through Bureau of Reclamation projects is the annual payment on a non-interest-bearing obligation. Gardner et al. (1982) have estimated that over 70 percent of the financial costs incurred by IID are subsidized.

3Efficiency in pricing requires that the input be priced to members at the marginal cost of its provision. When the input is provided under increasing returns to scale, as is the case for irrigation water, marginal cost pricing will result in a deficit. Thus, efficient pricing requires user charges based on marginal cost, and a fixed fee, such as a tax on land, set to satisfy the break-even requirement (Sexton 1986).

The equivalent of equity capital in a public water district is provided by their authority to issue bonds backed by their taxing capacity. Therefore, members provide funding for infrastructure development in this manner, but, unlike in the typical agricultural coopera-
III. MODELS OF DECISION MAKING IN COOPERATIVE ORGANIZATIONS

Recent research on cooperative organizations has emphasized the importance of heterogeneity among participants to the cooperative decision-making process. One approach uses median-voter decision theory to analyze the choice process within the organization (Zusman 1982). An alternative approach, based on cooperative game theory, stresses that cooperation will not be undertaken unless it represents the best alternative available for the participating individuals and coalitions (Staatz 1983; Sexton 1986). Both models are summarized briefly and then applied to analyze the IID-MWD water trade.

Models of voter choice assume that individuals can rank policy alternatives according to the utility or income level each will generate and vote for the higher or highest ranked alternative. In comparisons of two alternatives, the choice receiving the majority of the votes is enacted. Majority rule voting may not yield an equilibrium due to cycling. Cycling occurs when an organization’s preferences over several alternatives are not transitive (pairwise voting produces an endless cycle) even though each member’s preferences are transitive (Arrow 1950). If voters’ preferences can be depicted along a single dimension, such as the volume of water to be traded, then the equilibrium voting outcome is the solution preferred by the median voter (Mueller 1976). However, proposed interdistrict water sales are likely to be multidimensional, involving compensation issues and investment decisions as well as price-quantity dimensions. Cycling may emerge in these cases.

A voter decision model assumes the decision preferred by the majority is imposed on all voters. It thus allows for the possibility of losers from the enactment of policy compared to the status quo, because the minority must accept the decision of the majority. Ordeshook (1986) provides an extensive overview of voting decision theory.

Players in cooperative games are allowed to make binding commitments, and, as such, the cooperative game methodology is particularly useful in analyzing environments where players can merge into coalitions. The characteristic function of a cooperative game specifies the payoff each possible coalition of players can guarantee itself irrespective of behavior by players outside the coalition. Let \( N = \{1, \ldots, n\} \) denote the set of players in a water supply organization and \( S \) any subset of \( N \). Then let \( V(S) \) denote the characteristic function for all \( S \subseteq N \). The superadditivity of \( V(S) \) is necessary to insure gains to coalition building:

\[
V(R \cup S) > V(R) + V(S), \quad R \cap S = \emptyset, \quad \text{for all } R, S \subset N. \quad [1]
\]

A vector of payoffs cannot represent a solution to the cooperative game if some players are dissatisfied with their proposed payoff and are in a position to do something about it. Consider a proposed payoff, \( X = (x_1, \ldots, x_n) \) to the members of a water supply organization from a water transfer. The payoff \( X \) is a core solution to the cooperative game defined by \( \{N, V(S)\} \) if it satisfies the following conditions:

\[
x_i > V(\{i\}), \quad i = 1, \ldots, n, \quad [2]
\]
\[
\sum_{i \in N} x_i = V(N), \quad \text{and} \quad [3]
\]
\[
\sum_{i \in S} x_i \geq V(S) \quad \text{for all } S \subset N. \quad [4]
\]

The conditions in [2] require each member to receive at least as much as he/she could receive unilaterally. Condition [3] requires that the total payoff equal that which the players could attain if they acted jointly. The conditions in [4] define coalition rationally; no subgroup of players may receive less than that attainable on its own.\(^6\)

\(^6\)The core of a cooperative game is empty if no payoff allocation satisfies conditions [2], [3], and [4].
Analysis based on the core assumes that group membership and participation are voluntary. Therefore, payoff allocations satisfying [2], [3], and [4] are stable in that no individual or coalition has both the desire and ability to defect from the proposed solution. By the same token noncore allocations are potentially unstable. Core allocations also generate no cross subsidies among the players in \( N. \) Absence of cross subsidies, in turn, is often considered to define a "fair" allocation (Faulhaber 1975).

Specification of the characteristic function is the key to a cooperative game modeling of a water supply organization's behavior in water markets. The nature of the characteristic function and, hence, the likelihood of achieving core solutions depends upon the legal structure of water rights within the organization.

Consider the hypothetical case where individual members of a water district hold clear, transferrable rights to the water supplied by the district. Individuals, subgroups, or the district, acting for the group as a whole, could then freely negotiate sales with outside agencies such as MWD. The advantages to conducting trade jointly through the district would be twofold: there would be transactional economies to negotiating a single sale, and there may be gains to a unified bargaining stance. The characteristic function for this game would specify the amounts individuals and subgroups could get from negotiating unilateral sales or from continuing to apply the water in crop production. Any district-level sales arrangement would have to generate at least as much value to each individual and subgroup \( (x_i \geq V(i)), i = 1, \ldots, n \) and \( \Sigma_{i \in S} x_i \geq V(S), S \subseteq N, \) respectively) to enlist its participation in the proposed sale. Arrangements which met these criteria would comprise the core of the game.

Actual water rights in either public water supply organizations or mutual water companies are not as clearly defined as in this illustration. Water rights in mutual companies may or may not be appurtenant to the land (BCM 1966; Saliba and Bush 1987). Nonappurtenant water rights may be traded freely within a mutual company, but outside sales may require substantial transaction costs, including possible public utility regulation. These costs may diminish what individuals or subgroups can accomplish unilaterally and expand the number of allocations from company-wide sales that satisfy the core conditions.

California law has been interpreted to preclude individual members of public water districts from claiming specific water rights (see Madera Irr. Dist. v. All Persons [47 Cal 2d. 681, 1957]). However, legislation currently pending in California would grant farmers in water districts rights to sell their water allocations. Less clear are the rights that accrue to subgroups of farmers who break off from an extant district to form a new district. BCM (1966, 315) discuss the limited experience with this phenomenon in California. For example, the Chowchilla Water District broke away from the Madera Irrigation District in 1949 and was able to secure water rights from the Friant unit of the Central Valley Project.

IV. ANALYSIS OF THE IID/MWD WATER TRADE

California's Imperial Irrigation District was formed in 1911. It consists of nearly 1.1 million acres with about 500,000 acres under cultivation. IID delivers water to about 6,900 farm accounts, 2,000 of which are owner operated, with the rest tenant operated. Most operators have more than one

Loosely speaking, the core is more likely to be nonempty the greater are the gains to coalition building among the set of players in \( N. \) See Sorensen, Tschirhart, and Whinston (1978) and Sexton (1986) for a rigorous analysis of core existence conditions.

A cross subsidy occurs when a subgroup within an organization receives a lower payoff from the organization than it could attain on its own. In the context of allocating costs, absence of cross subsidies is equivalent to no subgroup paying more than its "stand-alone" costs.

This structure is implicit in the recent work by Saleth, Braden, and Eheart (1991) which explores use of multilateral bargaining rules to facilitate trade in thin spot water markets.

Assembly bill 2090 has passed the California Assembly and is currently in committee at the Senate.
account. During the 1980s about 2.6 million ac. ft. of water were diverted annually by IID from the Colorado River through the All-American Canal. Delivery losses have averaged 300,000 ac. ft. and on-farm losses 500,000 ac. ft. per year, with on-farm consumption averaging about 1.8 million ac. ft. The area receives almost no rainfall.

Agriculture in the IID has been divided on about a 4 to 1 basis between field crops and garden crops. The leading field crops during the 1980s were alfalfa (about 200,000 acres), wheat, sugar beets, and cotton. The leading garden crop was lettuce with about 30,000 acres. Gross income per ac. ft. of water varies widely among the alternative crops, ranging from $2,400 for some garden crops to $70 for alfalfa with an average of $240 (Imperial County Agricultural Commissioner). Based on our survey data for Imperial Valley, net income per crop averages roughly 20 percent of gross income.

The Metropolitan Water District was founded in 1929. MWD covers 5,000 square miles and is a wholesaler of water for 27 municipal and county water districts serving 131 incorporated cities. The local retail districts vary in their reliance upon MWD. The largest retailer, Los Angeles, obtained only 18 percent of its water in 1986–87 from MWD, while the second largest retailer, San Diego, obtained 85 percent. In general, reliance on MWD is increasing over time.

The suggestion that IID and MWD negotiate a water transfer first was publicized by the Environmental Defense Fund (1983). A proposal was considered whereby MWD was to pay $10 million per year to IID to divert 100,000 ac. ft. of water. The funds were to be invested in conservation facilities by IID. Reaction in the Imperial Valley to the proposed transfer was negative, and the agreement was not ratified by the IID Board of Directors.

Communications continued between the two Districts, and a new agreement was ratified in December 1989. The volume to be traded remained at 100,000 ac. ft. per year. Payments to IID are to be $92 million over five years for irrigation system improvements in the IID, $23 million to offset indirect impacts of the project, and $3.2 million per year for maintenance, operations, and liability costs.

Thus, although IID and MWD eventually consummated an agreement, several aspects of the process deserve examination: the agreement occurred only after several years of wrangling, the volume to be traded is substantially less than the amounts that Vaux and Howitt (1984) have suggested could be profitably transferred, and all benefits accrue to members indirectly in terms of irrigation system investments rather than directly in terms of cash.10

Data and Methodology

Data to analyze the IID-MWD trade were obtained from a comprehensive survey of Imperial Valley agriculture conducted in 1982 (Zering 1984). In-person interviews were conducted with farm operators, who were divided into seven size strata. Of the 31 operators completing the survey, 26 grew wheat, 21 cotton, 26 alfalfa, 17 sugar beets, and 11 produce, and 25 leased some land through 156 cash leases and 45 share leases. The survey somewhat overrepresented large farms but otherwise constituted a representative sample.

The surveys provided information by crop type for each farm on expected price, expected yield, and cash costs per acre for materials, wages, water, rent, and harvesting. Investment costs were derived to approximate debt repayment and the servicing of financial commitments associated with owning land and machinery. The opportunity cost of owned land was set equal to the typical cash rent by crop.

To apply the voting and game theory models to the IID-MWD water trade negotiations, programming models for each

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10 External threats to the water rights of IID may also have influenced negotiations. In 1984 the California Water Resources Control Board (WRCB) required IID to draft a conservation plan to save 100,000 ac. ft. of water by 1994. In 1988 the WRCB required IID to locate funding and establish a schedule for meeting this deadline. Also in 1988 Congress (see Senate Bill 795) gave MWD authority to finance and construct conservation projects in IID.
of the 31 survey farms were developed to compute the profit effect on each farm from alternative water trade scenarios. Total farm profits consist of net profits from farm operations and a share of IID's operating deficit or surplus. The deficit or surplus was allocated among District members based on a per-acre availability charge for water in accord with IID policy.

The specific methodology used was the positive mathematical programming (PMP) approach developed by Howitt (1991). The PMP differs from conventional linear programming (LP) in that it seeks to incorporate observed behavior and concurs that what is optimal from the farmer's point of view is also considered optimal from the model's viewpoint.

Because farmers are price takers, attaining equilibrium requires that they face decreasing marginal products for variable inputs and, hence, increasing marginal costs in the short run. PMP augments the objective function of the LP model by adding a positive nonlinear cost term based upon the difference between the value of average product implicit in the LP formulation and the value of marginal product implied by observed crop activities. Therefore, given the survey information on revenues, input use, variable costs, and resource constraints, the production technology for each operator was reconstructed, and the production impact of alternative water trade scenarios was simulated by varying the price of water in accord with the parameters of proposed trade. From [2] farm profit in the base (no trade) case is \( V(I) \). The revenue impact of each alternative water trade scenario consists then of three components: the change in farm profit due to a change in the water price, any change in assessments due to changes in the District's deficit or surplus, and the amount, if any, of trade revenues received.

To limit the scope of the analysis, all of the alternative water trade policies considered here involve the annual transfer of 100,000 ac. ft. of water from IID to MWD. This volume was maintained consistently throughout discussions between IID and MWD and was the volume eventu-

ally agreed upon, although it is substantially less than the amount Vaux and Howitt (1984) concluded could be profitably traded. To investigate specifically the genesis of disagreement concerning the 1985 tentative sales agreement, we adopt the transfer price of $100 per acre foot specified therein.

We also use a scaled-down, representative model of IID to conform to the survey of IID farms. The survey included roughly one-eighth of the acreage and water use in IID. Therefore, prior to a trade we assume that the survey farms had entitlement to divert 358,000 ac. ft. of water with on-farm deliveries of 320,000 ac. ft. The volume of water to be traded annually associated with the survey farms is 12,500 ac. ft.

The Policy Alternatives

Four alternative policy responses to the proposed transfer were evaluated from the IID members' perspectives. The first, baseline alternative was to not participate in a trade. In Johnson and Libecap's (1982) parlance this is the policy of limited entry (entry and access by MWD to IID water is limited). The second policy is expanding the resource whereby all trade revenues would be invested in system conservation. This was the policy advocated by the Environmental Defense Fund (1983) and the IID Board of Directors and eventually was the policy adopted. The types of conservation projects available to IID and the estimated costs per ac. ft. of water saved per year are shown in Table 1.

The third policy considered was a negotiated certificates plan proposed by Smith (1989), which, in turn, is similar to the transferable water entitlements concept suggested by Randall (1981). Under this plan water rights are apportioned among

11The quadratic Leontief production technology developed from the PMP application captures farmers' shift of production mix to less irrigation intensive crops and the removal of land from production in response to higher water prices. It fails to capture any reductions in water application and associated reductions in yield or adoption of water-saving technologies.
TABLE 1

WATER CONSERVATION ALTERNATIVES AND COSTS FOR THE IMPERIAL VALLEY

<table>
<thead>
<tr>
<th>Unit Cost</th>
<th>Acre Feet Savings per Year</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Imperial Valley</td>
</tr>
<tr>
<td>Delivery losses that are district controlled:</td>
<td></td>
</tr>
<tr>
<td>Spill receptor system</td>
<td>$16</td>
</tr>
<tr>
<td>Canal seepage recovery system</td>
<td>26</td>
</tr>
<tr>
<td>Line main canals and laterals</td>
<td>57</td>
</tr>
<tr>
<td>Regulatory reservoirs</td>
<td>104</td>
</tr>
<tr>
<td>Line All-American canal</td>
<td>212</td>
</tr>
<tr>
<td>Application losses that are farmer controlled:</td>
<td></td>
</tr>
<tr>
<td>On-farm tailwater delivery system</td>
<td>19</td>
</tr>
</tbody>
</table>

Sources: Imperial Irrigation District (1985) and California Department of Water Resources (1981).

IID members on the basis of assessed valuation of land excluding improvements. The plan is analogous to a corporate tender offer and is designed to give District members tradeable rights, while remaining consistent with present State law specifying the district as title holder to the water. Under the plan the IID Board of Directors would offer to repurchase members’ certificates at a per unit price consistent with the proposed sale to MWD. Members choose whether or not to tender their certificates. If certificates to more water than the proposed sale are tendered, purchases are prorated among those tendering certificates (Smith 1989, 453). Water diversions to farmers would be reduced based on the number of certificates purchased from each farmer. Farmers, in turn, could react to reduced diversions by reducing irrigation intensity, idling land, or undertaking on-farm conservation.

It is straightforward to deduce that, if it is desirable for a member to tender any certificates, it is generally desirable to tender all of them. Therefore, in modelling Smith’s plan we assume all certificates are tendered in response to the proposed trade, and, thus, that trade revenues are allocated to members in proportion to their land holdings.

The final policy considered was a composite of the negotiated-certificates and expand-the-resource policies. This policy, known as maintaining the resource, involved investment in conservation sufficient to maintain water deliveries at their pre-trade levels, with any remaining funds dispersed according to Smith’s plan. This plan might be considered a political compromise between the expand-the-resource and negotiated-certificates plans.

The base price of water in the IID under limited entry was $7.50 per ac. ft. The per unit price under the other policies was computed to equate water demand with the available supply, with demand being computed from the scaled-down PMP model of the Imperial Valley aggregated from the 31 survey farms.

Table 2 summarizes the estimated changes in water availability, price that equates supply with demand, and change in annual payoff for the survey farms from the alternative trade policies. Limited entry, of course, produces no payoff change. The negotiated certificates plan increases the annual payoff by $\sum_{i\in N} x_i - \sum_{i\in N} V\{i\} - an estimated $1,233,527 ($1,250,000 in trade.
revenues less foregone revenues from reduced use of water in agriculture). Absent any investments in conservation, sale of 12,500 ac. ft. in the survey region reduces water deliveries by 11,180 ac. ft., and the market-clearing price is estimated to increase to $8.90. Investing all of the trade revenues in conservation initiatives under the expand-the-resource policy increases the water flow to the survey members above pre-trade levels and reduces the per ac. ft. price to an estimated $5.35. However, the resulting annual gain to survey farmers was estimated to be only $81,954. The composite maintain-the-resource policy invests in conservation so as to maintain water availability at pre-trade levels and achieves an estimated annual payoff to the survey farmers of $940,910.

The cheapest of the conservation initiatives from Table 1, spill receptor systems at $16 per ac. ft., is estimated to cost considerably more per ac. ft. of water conserved than the estimated $8.90 post-trade use value of the water in agriculture. No investments in conservation, either on- or off-farm, are economic in the IID given the present marginal value product of water in farm production. Smith’s plan, which rebates proceeds directly to farmers, must maximize the aggregate payoff associated with the water trade.

Analysis of Public Choice Among the Policy Alternatives

Results from the 31-farm PMP model support the conclusions of Vaux and Howitt (1984) that large gains to an IID-MWD water trade are possible. In the case of the 31 survey farms, the annual gains potentially approach 10 percent of total farm income. However, the analysis also shows that much of the gains are dissipated if trade revenues are invested in uneconomic conservation systems.

Table 3 summarizes the estimated changes in annual payoff, \( x_i - V(\{\}) \), from the policies of negotiated certificates, expanding the resource, and maintaining the resource relative to the baseline policy of limited entry. An asterisk indicates the preferred alternative for each farmer. All farmers are estimated to benefit from the composite maintain-the-resource policy. Although it generates the maximum overall benefit, Smith’s negotiated-certificates policy actually reduces the payoff to 17 of the 31 survey farmers. The main reason is that revenues from tendering certificates under Smith’s plan accrue to landowners in accord with State law. However, many of the survey farmers rent some or all of their land and, hence, their losses from higher water prices exceed any revenues they receive from tendering certificates.\(^\text{13}\)

Five players are also estimated to lose from the expand-the-resource policy promulgated by the IID Board of Directors. This outcome results from the ensuing decrease in the market-clearing water price and the

\(^{13}\) It is reasonable to expect that land rental rates would eventually adjust downward in response to higher water prices, and this effect would somewhat offset losses to renters.
TABLE 3
CHANGE IN PAYOFFS TO IID MEMBERS UNDER ALTERNATIVE WATER TRADE SCENARIOS

<table>
<thead>
<tr>
<th>Farm Number</th>
<th>Negotiated Certificates</th>
<th>Maintaining the Resource</th>
<th>Expanding the Resource</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$8,319*</td>
<td>$6,611</td>
<td>$839</td>
</tr>
<tr>
<td>2</td>
<td>-935</td>
<td>41</td>
<td>522*</td>
</tr>
<tr>
<td>3</td>
<td>2,766*</td>
<td>2,257</td>
<td>357</td>
</tr>
<tr>
<td>4</td>
<td>-1,455</td>
<td>73</td>
<td>579*</td>
</tr>
<tr>
<td>5</td>
<td>-6,984</td>
<td>351</td>
<td>2,792*</td>
</tr>
<tr>
<td>6</td>
<td>-6,975</td>
<td>394</td>
<td>1,802*</td>
</tr>
<tr>
<td>7</td>
<td>-1,857</td>
<td>119</td>
<td>155*</td>
</tr>
<tr>
<td>8</td>
<td>-5,666</td>
<td>220</td>
<td>3,779*</td>
</tr>
<tr>
<td>9</td>
<td>9,773*</td>
<td>8,174</td>
<td>3,522</td>
</tr>
<tr>
<td>10</td>
<td>-3,794</td>
<td>184</td>
<td>1,326*</td>
</tr>
<tr>
<td>11</td>
<td>-1,911</td>
<td>136*</td>
<td>-220</td>
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<tr>
<td>12</td>
<td>-4,110</td>
<td>1,782*</td>
<td>-3,474</td>
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<tr>
<td>13</td>
<td>-6,064</td>
<td>401</td>
<td>4,673*</td>
</tr>
<tr>
<td>14</td>
<td>10,851*</td>
<td>8,947</td>
<td>1,590</td>
</tr>
<tr>
<td>15</td>
<td>8,556</td>
<td>9,745*</td>
<td>-251</td>
</tr>
<tr>
<td>16</td>
<td>-3,362</td>
<td>1,498</td>
<td>2,866*</td>
</tr>
<tr>
<td>17</td>
<td>19,149*</td>
<td>14,518</td>
<td>144</td>
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<tr>
<td>18</td>
<td>-1,114</td>
<td>8,361*</td>
<td>573</td>
</tr>
<tr>
<td>19</td>
<td>-7,127</td>
<td>553*</td>
<td>-1,563</td>
</tr>
<tr>
<td>20</td>
<td>-2,681</td>
<td>6,099*</td>
<td>5,041</td>
</tr>
<tr>
<td>21</td>
<td>7,074</td>
<td>8,488*</td>
<td>2,471</td>
</tr>
<tr>
<td>22</td>
<td>19,404*</td>
<td>6,539</td>
<td>4,374</td>
</tr>
<tr>
<td>23</td>
<td>31,939*</td>
<td>26,917</td>
<td>4,627</td>
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<tr>
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<td>-11,397</td>
<td>7,726</td>
<td>13,309*</td>
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<tr>
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<td>-6,628</td>
<td>17,012*</td>
<td>3,614</td>
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<td>-5,399</td>
<td>712</td>
<td>1,643*</td>
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<tr>
<td>27</td>
<td>15,516</td>
<td>19,275*</td>
<td>4,568</td>
</tr>
<tr>
<td>28</td>
<td>99,097*</td>
<td>75,821</td>
<td>2,300</td>
</tr>
<tr>
<td>29</td>
<td>85,042*</td>
<td>66,826</td>
<td>5,810</td>
</tr>
<tr>
<td>30</td>
<td>122,921*</td>
<td>102,457</td>
<td>17,189</td>
</tr>
<tr>
<td>31</td>
<td>63,057*</td>
<td>49,227</td>
<td>-3,003</td>
</tr>
<tr>
<td>Survey farmers</td>
<td>426,005</td>
<td>451,466*</td>
<td>81,954</td>
</tr>
<tr>
<td>Land owners</td>
<td>807,522*</td>
<td>489,444</td>
<td>0</td>
</tr>
<tr>
<td>Totals</td>
<td>1,233,527</td>
<td>940,910</td>
<td>81,954</td>
</tr>
</tbody>
</table>

The attendant increase in the District’s operating deficit. Those who bear a comparatively large burden of the deficit (allocated in proportion to acreage) relative to their opportunity to benefit from cheaper water lose under the policy. This group consists primarily of farmers operating relatively large tracts of land upon which crops with low marginal values are grown.

The voting decision model is applied by simulating a series of pairwise votes among the four alternatives. The model yields a decisive winner: the policy of maintaining the resource is preferred on a vote of (20, 11) over negotiated certificates; (20, 11) over expanding the resource; and (31, 0) over limited entry. Thus, the “cycling” phenomenon discussed earlier is not observed in this context, and maintaining the resource is the Condorcet winner among the alternative policies despite the fact that it generates a lower total payoff than the policy of negotiated certificates. In fact, although it may seem paradoxical, negotiated certificates lose in every pairwise vote: (11, 20) with maintaining the resource; (14, 17) with expanding the resource; and (14, 17) with the no-trade option of limited entry.

¹⁴The term “Condorcet winner” originates from the early work on voting by the Marquis de Condorcet, who is credited with the discovery of cycling.
Therefore, the voting decision model suggests that Smith's proposed policy had little chance of emerging as the policy of choice in the Imperial Valley, despite the fact that it maximizes total payout from the water trade. The reason for negotiated certificates' comparative unpopularity again hinges on the owner-renter dichotomy. Absentee landowners are an important component of the property structure in the Imperial Valley and would benefit significantly from Smith's proposed policy, but under Irrigation District law, they have no vote in District matters.

The game theory approach to cooperative decision making emphasizes that the majority may be limited in terms of the policies it can foist upon a minority. In particular, a minority can defect from a proposed coalition structure and payoff if its proposed payoff is less than the group can attain on its own outside the grand coalition. This intuition underpins the conditions defining a core allocation described earlier.

A complete cooperative game analysis of decision making in IID concerning the MWD water trade requires determining the capabilities of \(2^n - 1\) nonempty coalitions. Given that \(n = 31\) generates over two billion unique coalitions, this task is unmanageable. The alternative pursued here is to consider four coalitions that might emerge naturally in response to considering alternative water trade possibilities. These coalitions are determined based on the payoffs shown in Table 3 and are set forth in Table 4 along with the estimated change in payoff to each coalition from the alternative trade proposals relative to the baseline, limited entry case.

Coalition \(LO\) consists of the absentee landowners who benefit most from the negotiated-certificates policy but lack a direct say in District affairs. Coalition \(NC\) consists of the 11 farm operators identified in Table 3 who also prefer the policy of negotiated certificates. Coalition \(NC\) consists of operators who are landowners. Coalitions \(LO\) and \(NC\) are natural allies.

The coalition \(MR\) consists of the 9 players who prefer maintaining the resource. This group consists of farmers who own some land but mostly rent. This group tends to specialize in producing high-risk produce crops and earns higher operating profits per acre than the survey average. Coalition \(ER\) consists of the 11 players who prefer expanding the resource. This group consists almost exclusively of renters. From Table 4 coalitions \(MR\) and \(ER\) are also natural allies.

When coalition \(LO\) is included in \(N\) for the cooperative game, the payoff from negotiated certificates maximizes the total payout, \(\sum_{i \in \mathcal{E}_M} x_i = \$1,234,000\), among the alternatives under consideration. All other proposed policies, including maintaining the resource, as shown in Table 4, do not satisfy the group optimality requirement, [3], for a core allocation. However, nearly

<table>
<thead>
<tr>
<th>coalition</th>
<th>Limited Entry Base Case</th>
<th>Negotiated Certificates</th>
<th>Maintain Resource</th>
<th>Expand Resource</th>
</tr>
</thead>
<tbody>
<tr>
<td>(LO)</td>
<td>$0</td>
<td>$808,000</td>
<td>$489,000</td>
<td>$0</td>
</tr>
<tr>
<td>(NC)</td>
<td>0</td>
<td>472,000</td>
<td>368,000</td>
<td>38,000</td>
</tr>
<tr>
<td>(MR)</td>
<td>0</td>
<td>8,000</td>
<td>72,000</td>
<td>11,000</td>
</tr>
<tr>
<td>(ER)</td>
<td>0</td>
<td>-54,000</td>
<td>12,000</td>
<td>33,000</td>
</tr>
<tr>
<td>(MR \cup ER)</td>
<td>0</td>
<td>-46,000</td>
<td>84,000</td>
<td>44,000</td>
</tr>
<tr>
<td>(NC \cup LO)</td>
<td>0</td>
<td>1,280,000</td>
<td>857,000</td>
<td>38,000</td>
</tr>
<tr>
<td>(NC \cup MR \cup ER)</td>
<td>0</td>
<td>426,000</td>
<td>452,000</td>
<td>82,000</td>
</tr>
<tr>
<td>(LO \cup NC \cup MR \cup ER)</td>
<td>0</td>
<td>1,234,000</td>
<td>941,000</td>
<td>82,000</td>
</tr>
</tbody>
</table>
two-thirds of the total payoff from negotiated certificates goes to coalition \( LO \), whose members lack a direct say in the operation of the IID.

Does the policy of maintaining the resource generate a core allocation for the game excluding absentee landowners? Considering \( N \) to consist only of the union of the coalitions \( NC \), \( MR \), and \( ER \), we can review the core requirements. From Table 4, the policy maximizing the payout is now maintaining the resource, which generates a total annual payout to the group of $452,000 compared to $426,000 under negotiated certificates. Condition [3] is, thus, satisfied for the policy of maintaining the resource.

Assume that coalitions are able to defect from IID and preserve proportional shares of the District’s water rights as well as utilize the existing canal structure.\(^{15}\) Separate water districts in the Imperial Valley would incur duplicate fixed costs for management. The portion of duplicate costs associated with the survey farmers was estimated to be about $250,000 per year.\(^{16}\)

Table 5 analyzes the hypothetical situation where coalition \( NC \) breaks away from the aggregate district (now consisting of the natural allies, coalitions \( MR \) and \( ER \)) and is able to retain its proportional share of water rights. Both groups are assumed to participate in the water market, with \( NC \) disbursing trade revenues via negotiated certificates and \( MR \cup ER \) choosing the policy of maintaining the resource. As a component of IID, \( NC \) was estimated to receive a total annual payout of $6.63 million from farming and membership in the aggregate district based on a maintaining-the-resource policy. It is estimated to be able to obtain $6.66 million on its own, if it retains proportional rights to water. Thus,

\[
\sum_{i \in NC} x_i < V(NC), \tag{5}
\]

and the policy of maintaining the resource is estimated to not satisfy the core conditions because it fails to satisfy the conditions in [4]. Quite clearly the inequality in [5] would also hold for an allocation based on the policy of expanding the resource.

Conversely, the coalition \( MR \cup ER \) is estimated to receive an annual payoff of $8.25 million in the aggregate District under the negotiated certificates plan but only $8.23 million on its own in a separate district. Thus, for an allocation based on negotiated certificates

\(^{15}\)As noted, the legal status of this possibility is unclear under present California law and is subject to change by pending legislation.

\(^{16}\)Analysis of data generated by BCM (1966) suggests that management costs are roughly 10% of total district costs. The portion of total district costs associated with the survey farmers is about $2.5 million, thus yielding the $250,000 duplicate costs estimate.
\[
\sum_{i \in MR \cup ER} x_i > V(MR \cup ER),
\]

and \( MR \cup ER \) lack a credible threat to defect against a negotiated-certificates plan.

VI. DISCUSSION AND CONCLUSIONS

This analysis has pinpointed the conflict that may emerge within rural water supply organizations concerning possible rural-urban water transfers. It also confirmed the large gains to trade between IID and MWD suggested earlier by Vaux and Howitt (1984) but documented that much of these gains will be dissipated through uneco-
nomic conservation investments under the adopted policy of expanding the resource. As such, farmers in the Imperial Valley are left with little incentive to support a transfer, helping to explain the protracted delays in reaching a trade agreement and that the eventual agreement transfers only a small fraction of the water estimated to be profitably transferable.

California law governing public water supply organizations is responsible for much of the intransigence concerning water transfers. It specifies that water-supply districts hold water rights as trustees for the benefit of landowners, but control in many of these organizations, based on one-person one-vote, is in the hands of renter-operators. This situation introduces a landowner-renter conflict. Renters in general are able to derive little direct benefit from water transfers and, therefore, tend to favor transfer policies mandating conservation projects that insure a continued supply of cheap water. In one-person one-vote districts like IID where the incidence of land rental is high, these preferences may hold sway.

However, District-level conservation policies were estimated to be uneconomic given current use values for water. Even with flows reduced in the IID by the 100,000 ac. ft. transfer to MWD, water's value of marginal product was estimated to be $8.90 per ac. ft., considerably less than the $16 per ac. ft. cost of the cheapest district-level conservation initiative.\(^{17}\) Preferred alternatives are growing less water-intensive crops, on-farm conservation, or idling land. Under Smith's (1989) negotiated certificates proposal, landowners would have incentive to undertake these actions. Passage of the bill currently pending at the California legislature would, by giving farmers specific water rights, facilitate transfers of the type proposed by Smith.

Alternatively, if voting in IID were based on land ownership or assessed value, the support for a negotiated-certificates plan would be overwhelming. Some commentators, however, have been critical of departures from one-person one-vote systems in public water districts (Goodall and Jamieson 1974; Jamieson et al. 1974). Our view is that, if landowners are to be the beneficiaries of district-controlled water rights, economic efficiency is likely to be served if voting control is, in fact, vested in the landowners.

We believe that the game theory and voting theory models adapted to water supply organizations in this paper should be viewed as complements in structuring water transfers and analyzing behavior in water supply organizations. Because membership is compulsory in most public water supply organizations and decisions are based formally on voting power, voting theory models can perform a useful predictive role when multiple proposals are under consideration. The use of cooperative game theory and the core to define subsidy-free allocations can aid in defining "fair" trade policies and, in turn, limiting opposition to proposed transfers.

Our application of these methods suggests that the failure of public water districts to articulate well-defined property

\(^{17}\) If trade volumes were expanded considerably beyond the 100,000 ac. ft. level as suggested by the Vaux and Howitt (1984) analysis, the marginal value product of water in agricultural production would increase, reflecting the reduced amount available for irrigation. Both farm- and district-level conservation would become optimal in this environment.
rights and to align control with those rights is detrimental to the emergence of water markets. Water is effectively a common property resource in public water districts, and farmers lack incentives to idle land or invest in on-farm conservation. The result is to introduce a perverse "tragedy-of-the-commons" effect into the water market calculus. Instead of under-investment in the common property water delivery system, the outcome in the Imperial Valley is to overinvest in the system to the point where, based on Table 2, 95 percent of the potential gain from trade is dissipated. Dissipation of the gains to a water transfer, in turn, reduces incentives to participate in transfers, explaining at least in part the infrequency of rural-to-urban water transfers in California.

In sum, most analysts and policymakers agree that rural-to-urban water transfers need to be expanded. This study suggests that policy reforms are needed to facilitate these transfers. Vesting power in individuals versus organizations is needed to introduce appropriate incentives into water transfer decisions. Such empowerment includes clarifying and strengthening the property rights of individuals and aligning voting control in water supply organizations with property rights. In this proposed environment the water district performs a less active role that is closely related to the functions of a traditional agricultural cooperative, including exploiting economies of size, insuring efficient delivery of water, and providing a vehicle through which members can collectively bargain terms of water transfers.

Admittedly, enactment of these reforms raises an additional set of issues associated with expanded water transfers including water quality concerns, possible recapture of windfall gains, and effects on third parties. These considerations transcend the boundaries of individual water supply organizations and, hence, must also be addressed through the legislative process as part of a comprehensive reform package to facilitate both efficient and equitable water transfers.

References


