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Political Structure and Management Decisions
in California's Agricultural Water Districts

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ABSTRACT

In California, special districts which provide agricultural customers with water supplies and service control the vast majority of water rights and contracts. The structure of these districts has been identified as an impediment to changing water management and distribution practices. This study explores how differences in the governance rules and political structures among these water-supply district “cooperatives” affect their management decisions.

Most districts use either the common “universal suffrage / one-man, one vote” (PV) electoral system, such as irrigation districts, or a “land-owner enfranchised / assessed-value-weighted vote” (AVV) method, such as California water districts, to elect board members and to approve various tax and bond measures. AVV districts most closely mirror what would be used in an aggregate wealth-maximizing cooperative; PV districts distribute a greater amount of benefits to non-land-owners. As a result, PV district managers tend to rely less on water sales revenues and more on property-based taxes and assessments to fund district operations. In addition, PV districts tend to set district policies that encourage more local-input-intensive crops such as orchards over field crops.

Key words: Ground water and ground water hydrology; Hydropower; Flow, instream; Ground water movement; Ground water recharge; Agriculture; Economics; Resource inventories and surveys; Water pricing; Water rights; Water-use data and monitoring.

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1. INTRODUCTION

Agricultural water districts are perhaps the most important players in efforts to reform water-resource management in California. According to several observers, a key impediment to the evolution of California water markets is the requirement in state law that water districts must approve any transfer of water rights outside of their borders (Holburt, Atwater, and Quinn 1988; Smith and Vaughan 1988; Thompson 1993a; Thompson 1993b). Agricultural irrigation districts have been particularly reluctant to participate in sales that would apparently transfer water from low-valued agricultural uses to higher-valued urban and industrial consumption. How these districts might distribute the costs and benefits associated with these trades has been the focal point of removing this particular barrier to developing viable water markets (Rosen 1992; Smith 1989). In addition, the 1992 Central Valley Project Improvement Act focused on water districts as the agents for implementing water conservation and efficiency measures (U.S. Congress 1992). On the other hand, recent attempts to establish water market protocols in California that bypass district control have met stiff resistance to date from agricultural interests.¹

Proposals by economists to reform water-resource management and to develop water markets generally have not considered the institutional context in which the targeted agricultural districts operate. Most analyses of water rights markets assume that the participants are attempting to gain the maximum net profits or monetary benefits. However, this presumption may be off target, particularly if public-enterprise agencies dominate the water management

¹See for examples of recent legislative reform attempts: Assembly Bill 2090 (Katz 1992) and Assembly Bill 97 (Cortese 1993).

structure as is the case in California. Given that most future water transfers in California are likely to occur among public agencies, looking beyond typical neo-classical assumptions about the “theory of the firm” may be important to understanding how water markets might develop (Holburt, Atwater, and Quinn 1988 p. 45). Previous political economy studies of irrigation districts have looked at some of aspects of how district decision-making processes work (Bain, Caves, and Margolis 1966; Goodall, Sullivan, and DeYoung 1978; McDowell and Ugone 1982; Rosen and Sexton 1993), but none has examined California districts across political structures in an economic framework.

The emergence of two recent issues adds to the importance of better understanding the incentives embodied in various water-district forms. The first is that use of any electoral system other than universally-enfranchised, popular-vote was challenged successfully in part in federal court (U.S. District Court 1995). The Association of California Water Agencies intervened with an *amicus curiae* brief to defend the voting system now in use in California water districts (Marchini et al. 1996). The second is the recent passage of Proposition 218 in November 1996. This new law requires in many instances that certain types of special-purpose taxes must be approved by a majority vote of the assessed-benefit, and fees and charges by a majority of “property owners” within the relevant jurisdiction (O'Malley 1996). Many of the dynamics that now affect water districts using assessed-value voting will come to bear in a larger context among many local governments.

The objective of water district management is not necessarily to maximize the district's net wealth; rather, it is more likely to please the maximum number of voting members of the district, depending on the institutional design of the district. Water districts in California generally select their board members using one of three methods—by popular "one-person/one-vote," by property-ownership-enfranchised size- or valuation-weighted vote, or by county-board appointment (Goodall, Sullivan, and DeYoung 1978). Yet, while the interaction between institutional structure and management decisions is evident, the relationship is not well understood in this setting.

Three key questions are assessed in this analysis:

- First, how do water districts differ in behavior from private firms in whether they maximize net revenues to their members and how they distribute those benefits?
- Second, do districts differ substantially in how they manage their resources and distribute benefits to their members based on their political structure and governance rules?
- And third, do the distributions of benefits within districts mirror the relative political "strength" of each member as measured by the formal voting rules?

This study represents just a first step formalizing the political-economic description of agricultural water districts in California. Most institutional work to date has been historical or anecdotal; little theoretical or empirical work has estimated parameters that might broadly describe the differences in behavior between districts. We build on motivational theories for public enterprises and cooperatives to create an objective function for water districts driven by institutional, physical and economic parameters. The analytic objective is to estimate the importance of these incentives in water pricing, use efficiency and trading.

1.1 A Review of Political-Economy Models of Agricultural Water Districts

At least six paradigms for the behavior of public enterprise agencies have been proposed in the political-economic literature:

- (1) A political-participation model focused on the relationship between the electoral process of selecting managers and certain financial characteristics of these districts (Goodall, Sullivan, and DeYoung 1978). The study attempted to assess the level of participation by the local electorate based on the electoral rules for each type of district.
- (2) Two political-sociological studies set forth the hypothesis that water districts may want to hold strong property rights in water as a means of exercising power in relations with other districts, even at the expense of lost profits for its members (Coontz 1989; Coontz 1991). This power is used in bargaining for larger shares of water-related infrastructure and better contractual terms, or in creating a sustainable cooperative management solution.
- (3) The classical political-economy model assumes that the district maximizes net profits to members subject to a zero-profit constraint on its own operations. See for example, (Cave and Salant 1987 pp. 273-274; Moore 1986).
- (4) Models using the median-voter concept set out the district managers' objective as a joint vote-benefit maximization problem where the manager balances votes with net profits to members, depending on the voting rules (Bain, Caves, and Margolis 1966; McDowell and Ugone 1982).
- (5) A political-economic bargaining framework model assessed the collective-choice process (Rausser and Zusman 1991; Zusman and Rausser 1994). In this model, the manager is a

the center of an influence process in which each member attempt to gain the most benefit from the district's policies in a non-cooperative game.

- (6) A cooperative-game model of coalition building in a district viewed the decision-making process as directly reflective of the members' choice (Rosen and Sexton 1993). Benefits accrue in proportion to the voting power of each member.

The one example of a political-science study examined how the various electoral rules affected voter participation (Goodall, Sullivan, and DeYoung 1978). The authors, in a report done for the California Department of Water Resources, attempted to explain why property-based rules led to less "democratic" processes than the popular-based methods. Unfortunately, the predictive theory was unclear in the analysis, and the statistical analysis did not strongly support the thesis.

Two comparative studies used sociological methods. Coontz examined the historical development of the Kings River Water Association and maintains that districts single-mindedly pursued physical acquisition and control of water rights either through construction of diversion facilities or by appealing to outside government agencies for assistance in funding of upriver storage structures (Coontz 1991). Eventually, a strong contractual arrangement was structured, and the previously strife-torn parties successfully stood in concert against the U.S. Bureau of Reclamation during contract negotiations. In the Grasslands Area, Coontz found that the legacy of Miller-Lux had left control of the region's water rights and leadership role to the Central California Irrigation District (Coontz 1989). As part of the Miller-Lux operations, neighboring farmers were allocated water portions greater than they might have achieved in fighting Miller-Lux and losing. This cooperative arrangement among districts and farmers continues today.

Both of these situations represent bargaining solutions driven by the perceived disagreement outcomes by each party. In the first case, the upstream districts could physically control the flow of the Kings River, while the downstream Tulare Lake farmers could appeal to outside political power in the USBR and the city of Los Angeles. The result was a hard-driven bargain that required strictly defined behavior. In the second case, Miller-Lux, and later CCID, controlled the lion's share of local water rights. As a result, its neighbors were quite willing to accept a cooperative rather than confrontational solution since they could face substantial losses if they defected.

The classical paradigm in which the district maximizes the total net benefits of all members is the most frequently seen in the economic literature. In each case, the water district is entirely transparent to the motives of the farmers themselves. In other words, these models simply assume that district managers use maximizing aggregate net income as their objective function. The district managers have no individual motives themselves nor do they consider any other objectives than resource-use efficiency.

The three more recent political-economy models approach differently the question of how districts' policies are chosen (McDowell and Ugone 1982; Rosen and Sexton 1993; Zusman and Rausser 1994). The first two models treat the institutional management-selection rules as the focal point of policy decisions, while the latter one examines the importance of informal political influence. The first and third models put the districts' managers at the center of the decision-making process, while the second one implies that decisions directly reflect the wishes of the districts' members. The latter two models rely on information about individual members within each district, either about farming activities or relative political influence. None of the models

assume that a district manager maximizes the total net benefits to member, but rather coalitions are built by targeting benefits to certain groups within a district.

In the first model, district managers attempt to maximize district profits while maintaining a sufficient level of voting support in a median-voter or "isoprofit/isovote" model (Bain, Caves, and Margolis 1966; McDowell and Ugone 1982). This model focuses on managers as the decision-making unit. Unfortunately, McDowell, did not adequately specify the empirical model to give meaningful empirical results.

In the second model, management policies are chosen based on which policy draws the greatest political support among the district's members, which is done by comparing the relative economic benefits that each would receive (Rosen and Sexton 1993). This approach views the members' operations as the units of analysis and aggregates to the district level. The model sees the managers as simply transparent to the decision-making process.

In the third model, the district managers attempt to maximize the benefits of the members subject to a distribution based on the relative political strengths of each member (Rausser and Zusman 1991; Zusman and Rausser 1994). This model examines the motives of both the managers and members and creates a two-stage optimization model.

McDowell, (M&U) examine whether government-enterprise managers respond to the sometimes divergent interests of "voter-consumers" in a manner different from those of private enterprises (McDowell and Ugone 1982). Public managers must balance maintaining political support that ensures their tenure with maximizing net benefits to consumers of the districts' services. The analytic framework uses the median-voter paradigm (Peltzman 1971). M&U hypothesize that if political support is not proportional to revenue responsibility, i.e., the district

has many voters of whom few pay related fees or taxes, then interests diverge between the disparate groups within the district. They further ask whether cross-subsidies through pricing are more likely in the case of government enterprises.

M&U build on Peltzman's (1971) model in which the district manager attempts to maximize voter support subject to the constraint that total district benefits exceed a certain level (McDowell and Ugone 1982 p.458). The dual of this problem is to minimize the economic benefits forgone to achieve a majority vote. The result is finding the tangency of the isovote and isoprofit curves in the multiple-group/price space. The isovote curve represents the combination of prices to the relevant groups within the district that maintain the same level of political support. The isoprofit curve represents the combination of prices to the relevant groups within the district that maintain the same level of total net benefits to the district. If the political process transmits voter support in proportion to the revenues generated by the consumers in each group, then the tangency should lie along the 45 degree line from the origin, i.e., the relative prices for each group should be the same. If the potential support is not proportional to revenues, then the tangency will deviate so that the group with more political clout receives lower prices. Both of these situations can deviate from the case of the discriminating monopolist which would charge prices based solely on the relative costs of providing service to each group.

The district manager, instead of equating marginal costs and marginal revenues, equates the ratio of marginal vote gains to marginal losses in profits among the various groups. M&U proposes to test their hypothesis by whether the price ratio of water for large farms to small farms is greater for districts using a popular vote method versus ones using an acreage-based method:

$$(P_L/P_S)_{pop} > (P_L/P_S)_{acre}$$

M&U do not directly test this hypothesis or the ones comparing public with private ownership. Instead, they estimate the parameters for three models across twenty-four special districts across seven states that examine the relationships of operational expenses, operational revenues and district rates of return to scale of water deliveries, proportion of agricultural service, board selection methods and whether electric utility service is also provided. They report results that they claim supports their hypothesis that acreage-based electoral systems provide more direct benefits to the consumers of district services. However, the linkage does not appear evident for several reasons. The relative levels of district revenues and expenses are more likely to be influenced by other physical and institutional factors such as:

- the age of the district and its facilities,
- the sources of water supplies and whether these sources are federally-subsidized,
- the nature of the water rights that the district might hold and whether the district might be under or over investing based on the priority of those rights (Burness and Quirk 1979),
and
- the general types of agricultural activity and their net returns per acre.

M&U also misspecify the measure of farm size in their models, instead measuring the intensity of water applied per acre of land in the district.

Rosen, (**R&S**) develop a cooperative game model that examines how coalitions might be built for water markets within a district (Rosen and Sexton 1993). This model uses an approach developed by Sexton to assess the voting patterns of agricultural production cooperatives (Sexton 1986). In this cooperative setting, R&S examine if a policy which maximizes the net benefits for

a number of individuals that represents the majority in the district will be chosen over another which maximizes the *total* net monetary benefits to the members of the district. R&S assume that a single popular vote institution is used to transmit political influence to the district's board and managers.² The implicit assumption is that political power is in proportion to the institutional allocation of votes.

R&S examined the Imperial Irrigation District-Metropolitan Water District sales transactions and how IID farmers decided to accept or reject various sales terms and revenue allocations. R&S surveyed 31 farmers about their farm operations to estimate the net benefits from alternative trading scenarios. They then created a voter-decision model using a pair-wise voting procedure that simulated farmers' choices based on the expected net benefits to each individual. The result was that the policy which would have generated the greatest total benefits to district members—a *de facto* assignation of water rights to individual land owners before transfer—lost to a policy which gave the greatest net benefits to a majority of eligible voters—a combination of conservation measures to preserve water supplies to farms and a distribution of

²Rosen, state that most California irrigation districts use a one-person/one-vote mechanism [p. 40]. While this statement is true in the narrow context of state law as defined by the term “irrigation district,” it is misleading about the more general nature of state’s agricultural water-supply districts. In districts where a popular-vote method is used, voter qualification requirements vary regarding land ownership and residency. More importantly, electoral rules relying on eligibility and vote weighting by land ownership or value are equally prevalent, and representative of the most recently formed districts [Goodall, 1978]. However, the results from R&S are generalizable to these other institutional structures with the proper adjustments.

sales revenues after the conservation costs were covered. This conformed with the actual outcome of the transaction. R&S found that the interests of tenants and owners diverged between these policy options, with tenants prevailing because of the voting structure.

Zusman and Rausser (Z&R) create a non-cooperative bargaining model in which the managers are at the center of a institutional “wheel” with the district members as peripheral agents attempting to politically influence the managers' decisions (Zusman and Rausser 1994). Each member has a certain level of political strength that can be exerted at some cost. The member's objective function is to maximize the net economic benefits from the district's services. The center's objective function is to maximize the sum of the group's objective function plus the sum of the political support exerted to influence the center. Z&R show that using this model that any collective action to manage a resource will result in a socially-suboptimal outcome, defined as maximizing net wealth, unless none of the agents attempt to influence the center's decisions.

The solution concept to the bargaining problem is the product of the net benefits to each individual member, or the total benefits are maximized subject to minimizing the differences between members' benefits. To find the parameters of the model, the individual payoffs must be specified at the decision outcome and compared to the optimal district-wide solution if one assumes that the marginal cost of political influence is equated among members.

In a companion paper, Rausser and Zusman create a water-resource management model using these concepts (Rausser and Zusman 1991). They look at a situation similar to that described in Coontz (1991), where water districts try to influence the behavior of a central water-supply authority. The power relationship in this model is somewhat less formal than looking at the water districts themselves because the governance structure is not specified in a formal

constitution. Nevertheless, the "hydrological-political-economic" equilibrium found in the model shows that a narrowly-rational districts will apply political pressure on the authority to lower water prices leading to increased water application.

1.2 How Might Differing Motives Affect Agricultural Water District Management Decisions

A useful institutional perspective is to compare how the operations and financing of water districts reflect the principles of cooperatives (Bain, Caves, and Margolis 1966; Rosen and Sexton 1993, p. 41): these districts provide service "at cost" as non-profit organizations; benefits generally are distributed in proportion to use of the managed resource; returns to equity capital are limited and generally gained through directly-related activities, such as selling irrigated crops; and the district is controlled by the member-users, which meshes with the concept of vertical integration of the water supply with agricultural production.

Several advantages exist in the cooperative management of input resources (Sexton 1986). The joint allocation of resources avoids the transaction costs and risks associated with market-type exchange institution, e.g., post-contract opportunism by a party (Alston and Gillespie 1989; Williamson 1979; Williamson 1983). By extending or avoiding market power, it can encourage development of asset-specific relationships by removing risk of contract breach (Williamson 1983). And it provides a mechanism for avoiding, mitigating, spreading and sharing risk among members (Thompson and Wilson 1994). The internalization of allocation decisions can avoid government interference in the exchange institution, e.g., federal reclamation law acreage limitations (Wahl 1988).

The model presented here builds on the three political-economy models that explain district behavior from different perspectives, but rely on a common assumption. *The assumption is that members try to influence district managers to choose management policies that distribute benefits in proportion to political power while maximizing aggregate benefits subject to that constraint.* The district's objective, acting as a cooperative, is to maximize net benefits to all members, but the non-profit constraint means that the district's "rents" must be distributed among its members indirectly, perhaps through changes in water rates or allocations. This distribution is the function of political power within the district, measured in terms of voting share in this case.

Politically, water districts in California are marked by a variety of governance-selection schemes (Bain, Caves, and Margolis 1966; Goodall, Sullivan, and DeYoung 1978). Most of these are directed through state general district acts, of which there are 38 types; in addition, over one hundred special-district enabling acts were in place by 1994 (California Department of Water Resources 1994). Selection of the governing board may be through a vote of eligible persons or appointment by the county board of supervisors. Eligible voters may be residents of the district and/or property owners. Votes may be counted as one-person/one-vote (popular) or be weighted by property acreage or assessed value per acre. California law tends to favor landowners in governance procedures (Smith 1992). While the popular vote is predominate in older districts in the Sacramento and east San Joaquin Valleys, the property-weighted scheme has grown in use, especially in the west and south San Joaquin Valley served by the newer state and federal water projects where corporate farms, rather than family-owned farms, are more common (Goodall,

Sullivan, and DeYoung 1978). Even older districts have switched to land-owner enfranchisement.³

Each of the districts' management-selection procedures give different incentives to district members and managers. Economic theory leads to an expectation that an assessed-property-value weighted voting scheme would most closely mimic that of a vertically-integrated firm. Agricultural property values reflect the net returns to crops, and to the degree that water application is correlated with land values, the votes would be allocated in proportion to implicit ownership and utilization of the water resource. However, because land values reflect other factors such as soil type and relative market location, value-based voting should not simply follow the same pattern as that for single-product firms. District "ownership" shares are not necessarily in direct proportion to the value-added from water application, as would be case in a private enterprise where ownership would be based on output value, not input quantities. Acreage-weighted schemes reflect a presumption that the amount of water applied per acre is roughly constant across farms and that marginal land values attributable to water use do not vary substantially across a district. This scheme is less likely to match the profit-maximizing interests of the landowners than value-based methods. A popular-vote method tends to divest the district from a solely profit-maximizing objective. Equitable distribution of benefits from district operations become more important. The interests of individual landowner farmers can diverge from that of the district, e.g. in the extradistrict sale of water rights. Finally, board-appointed districts represent an interesting enigma. In theory, because the district board supposedly represents the interests of the entire county, the decision-making process for the district should be

³For example, Glenn-Colusa ID switched in 1992 and Richvale ID in 1996.

quite divergent from maximizing the profits of those receiving water supplies. However, these agencies are relatively obscure except to those directly impacted, and these boards more likely are "captured" by their customers and reflect their informally-transmitted desires. In summary, it is evident that the motives for the districts can be quite different than the classic assumption of "profit-maximization."

The various governance rules used by different types of districts, such as voting eligibility and weighting, can undermine some of the principles in cooperative management in achieving efficiency. Stated simply, *managers are likely to distribute benefits from operations of the district in proportion to the political strength of its members rather than to economic contribution.* Reliance on popular vote rather than property-weighted vote can create a wedge between those defined as members versus users, and benefits may be rebated on a basis different from use. These benefits might extend beyond simply delivering water to reassigning responsibility for water rights, deciding if water sales need approval to protect certain interests within the district, and setting district charges and taxes to achieve economic goals other than efficiency. In general, we might expect if the votes are distributed in proportion to the value of agricultural land, then the district will act to maximize the value to landowners. If on the other hand, the electoral selection process uses a one-person/one-vote rule, we might expect that the district will attempt to maximize the value of water-related economic activity regardless of its ties to the land. These action can include maintaining the water resource for tenant farmers who do not hold title to the land but may have significant fixed investments in their farm, and considering local farm-service businesses if they are eligible to vote. An assessed-value-weighted voting scheme appears more likely than a popular-vote system to mimic the prototypical "firm" in

economic modeling due to the closer correlation between the governance process and the distribution of benefits from water use. Water sales tend to benefit landowners because the districts' rights are most frequently tied to the land. Thus, we expect property-weighted districts to be more receptive to selling into a water market than districts with other types of governance structures.

Using some assumptions about how the motives for various district members might differ, we can build a model that assesses how the various political structures might influence the districts' management decisions. In a property-based voting system, we can assume that the preferred policies will tend to lead to accrual of district benefits in land values. For the popular-vote structure, we must identify a proxy for those actions that target benefits towards water-related activities.

As the voting structure moves away from being directly proportional to the value of water use, we might find that the district's manager will pursue policies that benefit non-landowners. Landowners are more likely to be focused on the bottom line—for example, which generates more revenues per acre, growing crops or selling the water. On the other hand, tenant farmers require water to work their land—they are unlikely to receive payment for water sold by the landowner through a district. Local businesses also rely on farming activity, not just income flows to local landholders that might result from water sales. In a popular-vote system, the district may choose to both limit outside water sales so as to maintain farming activity, and to price water in a way that maximizes other related economic activity, e.g., fertilizer and equipment sales. Observing the former is difficult when water markets do not exist for many other reasons such as state policy. However, we may be able to find a suitable proxy for the latter.

In the case of tenant farmers, they may be reluctant to plant high-value, water-saving crops due to uncertainty about their tenure on the land. Orchard crops require several years before they reach maturity and must produce for up to two decades to recover the initial investment. Tenants tend to show higher discount rates than owners, leading to less investment in resource-conserving technologies that are capital intensive (Hartman and Doane 1986). More efficient irrigation technologies generally require sunk investment that can be lost by a tenant if the landowner takes action to stop farming on the land. In response to these risks, tenant farmers would be more likely to grow water-intensive field crops with less-efficient irrigation technologies. To support these practices, the district would lower the per unit price of water so that higher application rates do not cause higher costs, and rely on other revenue sources such as per-acre fees or taxes and electricity sales. Higher property taxes have the added advantage for tenants that the elasticity of demand for land limits the incidence of the tax on rents, i.e., landlords must absorb part of the tax in their rents to stay competitive in the agricultural land market. The existence of sharecropping arrangements reinforces this tendency because landowners often must pay the delivered water charge, which comes out of their rent earnings.

Local businesses may prefer two types of outcomes.⁴ The first is that crops be grown that require a high level of purchased inputs, e.g., fertilizer or equipment. Field crops generate less employment per acre-foot of water than other crops (Mitchell 1993, p. 5), which might imply that other local inputs such as farm equipment are utilized to a higher degree in production. The second is that business activity remain at a fairly constant or growing level, and that it be of the

⁴Because farm laborers in California frequently are foreign nationals, and are less likely to vote anyway due to having lower incomes, labor employment is not considered in this perspective.

same nature year-to year (Pindyck 1991). This gives businesses a greater assurance that they will recover their investment in equipment, knowledge and good will. To serve both of these desires, the district will tend to establish pricing structures that do not penalize water use, particularly if the water is for long-established crops. Again, this perspective encourages support for a two-part pricing tariff in which the per water unit charge is relatively small compared to the fixed or property-based portion.

1.3 Analytic Approach

This study compares management decisions among various classes of water districts. This is done in a broad framework that encompasses a large number of districts. For this reason, the model developed here takes the perspective of a district as the decision-making unit. In this way, we can draw inferences about a broad range of districts while controlling for other factors that may influence their behavior, e.g., source of water, dominant crop type, the types of farming operations.

A modeling approach that relies on analyzing the individual farm operation as the unit of interest, as proposed in the types of models described in Rosen and Sexton, and Zusman and Rausser, has two problems. The first is that it misses the influence of non-farm voters on district decisions, particularly in popular-vote and board-appointed selection systems. The second is that the data requirements for a sufficiently broad empirical analysis quickly overwhelm the available resources for most studies of this type.

The model presented here specifies an objective function for the district managers in which they attempt to maximize their likelihood of being elected by adopting policies that maximize the welfare of certain voting interest groups. We examine theoretically how specific district policies would effect certain types of constituents rather than simulating how each farm operation might respond to different management schemes.

2. DEFINING THE POLITICAL STRUCTURE OF A DISTRICT

This analysis addresses three questions as to how the institutional structures of California's agricultural water districts affect decisions by elected board members and farmer in these districts. The focus is on the governance rules and political structure of those institutions--voter eligibility and vote counting. These questions are:

- How do farmers' decision rules differ under different institutional structures, including an "optimal" cooperative,
- What are the decision rules for district board members under different rules for existing institutions; and
- How do the rules in the existing districts cause key management decisions to diverge from those in "optimal" or other types of districts.

We begin by comparing the "optimal" or efficient cooperative, as classically defined by economists, to the institutions which actually manage agricultural water resources at the retail level in California. We derive the decision rules for determining the levels of inputs--land, water and other types--under the theoretical structure versus the existing structures. We then turn to deriving decision rules for district managers under existing voting rules assuming that they are striving to maintain their political base. Finally, we compare how farmers' and other constituents' decisions vary among these various institutions and how managers might design their policies to cater to the key voter groups in their districts.

2.1 Farmers' Choices and Objectives

A farmer proceeds through several decision-making stages in deciding what to plant, production levels, investment and water use. The initial choice is the size of the operation. The decision as to how much land to put under cultivation and irrigation is dependent on many factors such as how it is acquired (e.g., purchased versus inherited), available financial resources, which crops are appropriate, past resource usage, variation in land quality, and distance to markets. Once this choice is made, a farmer chooses to plant and irrigate on their most "fixed" asset, land, to the maximum extent possible and selects that appropriate crops, water use and irrigation technologies on that basis.

Next the farmer selects the crops to be grown on this land. This choice drives other factor choices, particularly for water. Most crops require a fairly narrow range or "effective" water application as determined by local evapotranspiration requirements and land quality factors such as permeability, drainage and nutrient levels (Caswell and Zilberman 1986; Green et al. 1996). The amount of effective water, e , is a product of the amount applied, a , and the technical efficiency of the irrigation method, h . The farmer then adjusts either irrigation technology/source or amount of applied water to compensate for changes in the other factor. As a result, the farmer faces a two-stage problem—first choose either water applied *or* irrigation efficiency, then select the other given conditions that dictate effective water requirements (Caswell, Lichtenberg, and Zilberman 1990). Thus, the farmer first chooses optimal input levels for a particular mode and efficiency of irrigation, h , and selects the irrigation method that provides the largest net profits to the farm.

The decision on how much water to apply can be a long-term commitment. Historically, only a few opportunities have arisen to acquire surface water supplies with the initiation or expansion of water projects (e.g., the Central Valley Project in the 1940s and 1950s, and the State Water Project in the 1960s) (Bain, Caves, and Margolis 1966). These water "markets" only opened for short periods and only offered long-term contracts. Water diversion is capital intensive and can require commitments up to 40 years with payments relatively invariant with actual usage. While water market opportunities now are expanding and environmental regulations are constraining supplies, even in these cases farmers face long-term choices. Because of this time frame, the amount of water to apply from water district sources appears to be the dominant variable in choosing how to meet effective water requirements, and efficiency is a residual of these choices; thus we can leave a choice variable, h , to the second stage. The amount of effective water as a result is based on an expectation about the amount of land under cultivation, the price of water and of irrigation technologies, and the price and availability other inputs.

The water-use efficiency variable, h , can be interpreted in several ways, either as improved irrigation technologies or as greater reliance on water sources autonomous from district supplies, such as groundwater pumping. This decision of selecting the appropriate irrigation technology and/or water source has a long lead time as well (annual at minimum) and requires year-to-year planning to change. The expense of selecting a different technology is captured in the investment cost of the technology, $I(h,L)$, and the cost of pressurizing the irrigation system or for local groundwater pumping, $v(h)$. However since $h = A/E$, these costs are actually dependent only on the amount of water applied, α .⁵ Thus v and I become functions of α as well.

⁵To a certain extent, the quality of delivery service (e.g., scheduling and lead time on

Other inputs, x_j , are chosen in different time frames before and within each growing season. To simplify the problem, x represents a composite index of all other inputs. In fact, we would expect to see shifts among these inputs with changes in water usage and irrigation investment as well. This variable is included to measure the impact on non-farmer district members and residents from changes in district policies.

2.2 The Storage Infrastructure Investment Decision

Perhaps the most important reason for forming any water district is the provision of a *reliable* water supply. The issues of overall supply and service quality must be addressed collectively because they have clear “common property” traits. Adding capacity to a reservoir is likely to improve everyone’s supply reliability within the district if the water rights are effectively “correlative” (Burness and Quirk 1980). Defining the property rights to this added capacity would undermine the cooperative nature of the district. The district is then searching for the “optimal” choice for these variables based on a set of rules. These rules begin with deriving the opportunity cost or “shadow value” of the water supply.

The choice of the supply capacity, S , directly influences reliability--the greater the storage capacity and transfer capability, the longer the district is able to carry over storage during drought periods. In other words, the probability that full water deliveries will be available, $F(S)$, increases with the size of storage capacity, S . The average supply availability below full deliveries is the _____ deliveries, amount of pressurized system, conveyance losses), also affects the efficiency of water application . However, we are ignoring this aspect in our current discussion.

sum of the probabilities of these lesser flows (Burness and Quirk 1979). However to simplify this problem, we can present it as a dichotomous probability case of either full deliveries or drought-constrained deliveries without any supply capacity, s_d , which equal approximately the average of the less-than-full delivery conditions. Thus we can estimate an expected level of delivery, \bar{s} , as a function of the supply capacity.

$$\begin{aligned}
 \bar{s}_i &= \int_0^{S_i} s_i(1-f(s_i))ds_i + S_i \cdot F(S_i) \\
 (1) \quad &\approx s_d(1-F(S_i)) + S_i \cdot F(S_i) \\
 &\approx s_d + (S_i - s_d) \cdot F(S_i)
 \end{aligned}$$

- S_i =water delivery capacity per acre from district supplies, and district's delivery service quality to farm I measured by (1) relative miles of unlined/lined canals and pipelines, and (2) delivery conditions, requirements and lead time.
- s_d = the minimum water delivery service and capacity which exists without district investment. For example, the minimum water delivery under drought conditions without storage facilities.
- \bar{s}_i = average water supplied to farmer during the year per acre.
- $F(S_i)$ = cumulative probability density function of full water supply conditional on district supply capacity.

A district not only must supply water to its customers, but it also must deliver that water on schedule, without large conveyance losses, and of sufficient quality (e.g., low salinity). To this end, the district will have scheduling arrangements and constraints with customers, may line canals or install pipeline to reduce losses, and take measures to ensure that water quality is not degraded during transportation. All of these measures have costs beyond simply releasing stored water into district canals. Farmers' costs are affected by these quality factors, such as the use of laborers to irrigate fields at certain times, managing drainage, and losing yield to poorer quality

water. A fully-cooperative district compares its marginal costs of improving quality to the marginal gains to farmers from such improvements.

2.3 Providing a Benchmark: A District as an Efficient Cooperative

Often the terms “efficient,” “social-welfare maximizing” and “wealth maximizing” are often used interchangeably by economists as though they represent much the same measure. However, attaining the maximum wealth for a group may not be the most efficient outcome because two individuals still might want to trade among themselves. This results from their respective preferences changing at nonlinear rates. Perhaps even more confounding is that the distribution of wealth may also be important in attaining the preferred level of social welfare. Because the classical model often uses monetary measures of well-being, through profits, it reduces the definition of efficiency to maximizing wealth. The problem with defining efficiency solely in terms of net monetary benefits is that the “cooperative” has key difference from the “firm” in the neoclassical sense—cooperative members maximize over their individual preferences which may include non-monetary outcomes, while a firm’s shareholders only derive monetary returns. For comparative purposes though, we define our efficiency measure in this reduced simplistic form, which in turn may be somewhat misleading in a political-economic analysis.

If an agricultural water district was managed as a wealth-maximizing cooperative, it would choose the mixture of investment in water-supply capacity and agricultural production that would generate the greatest net benefits for its members. Water would be priced at its marginal cost internally to signal the most efficient uses to members, and any net profits or losses from water-

supply operations would be returned to district members in a fashion which would not distort water-use decisions. In fact, this model is institutionally quite different from the way public-enterprise district operate.

Existing districts have several characteristics distinct from this model. The most important is the so-called "non-profit" requirement, i.e., that expenditures and revenues must be in approximate balance. Revenues are often limited to sources directly linked to water-use, e.g., prices, charges or property taxes, and thus pricing must approximate average, not marginal, costs. Water is not priced to signal the most-efficient uses these cases. The net benefits from the district also may be allocated in any number of ways, some of which distort water-use choices by farmers. Finally, water district board members tend to choose policies which allow them to continue to hold office. This means pleasing enough constituents to gain a majority of votes. Policies that increase total district wealth may benefit only a few district members and not generate sufficient political support.

Even though the "efficient cooperative" model may not be appropriate institutionally, it is useful as a benchmark to measure performance by other institutional forms. One can assess how a district's manager might choose to maximize total wealth if the manager could control all internal resource management decisions either through directives or complete internal pricing mechanisms. Thus, this is more appropriately called the "wealth-maximizing" model. This model assumes that farmers see the full and direct costs for the water resources that they use and receive back the net profits from the operations of the district. The institutions that manage and price such water resources are "transparent" in this case. The district does not face a non-profit constraint, nor must it decide how to return any excess profits to district members. Distribution of total benefits

is not addressed in this model. However the model provides a useful measure for comparing the different institutional arrangements that water districts use in California.

In the efficient cooperative model, we assume that an “omniscient central planner” allocates all resources to produce the highest level of total district net wealth. Of course, in reality these functions are institutionally segregated between an elected or appointed governing board and the individual farmers. In the latter case, the issue becomes coordinating the actions between the farmers and board members through “signaling” such as pricing and voting. This is confounded by the effects on these signals of distribution of that wealth among district members—the “political economy” of the district.

2.3.1 The “Transparent” Efficient Cooperative Water District Model

In the “efficiently”-run cooperative, the objective for farmers and board members is to choose the total yield that maximizes net revenues after accounting for costs.⁶ This a fully vertically-integrated system. Farmers see the direct or “transparent” cost of providing water supplies, as represented by the investment in capacity, $K(S)$,⁷ and the variable cost of supply, c .

⁶This is a static model representing one-year's decision rather than looking at this problem as a dynamic problem. We believe that we do not lose the important initial insights by assuming that the dynamic programming problem would not look substantially different from the static problem here.

⁷In addition, the cooperative may be supplying a joint product from hydropower generation, and it may be covering some of the system capacity costs through these revenues. However, the number of districts with this option are relatively small and we ignore them for this discussion.

Because the cooperative reflects the singular preferences of the farmers/members to maximized total district wealth, the farmers also choose the level of supply capacity and delivery “quality”(i.e., timing, flexibility and conveyance losses), S , given the capital investment costs, K . In addition, the cooperative may buy or sell a portion of its supply in the water “market” at the going price, m . This can be thought of as the outside contract rate for project water acquired during the short “windows” that opened in the California water market (Bain, Caves, and Margolis 1966). These costs include the opportunity or “rental” cost, ry of land, L , for applied water, α , irrigation investment, $I(h,L)$ and pressurization costs associated with more efficient or alternative water irrigation systems, $v(h)$, and other input (e.g., labor, fertilizer, equipment) costs,

b. The choice variables can be separated into two categories:

- those that affect district-wide capacity and operations and must be decided collectively—supply capacity, service and delivery quality, S , and
- those that affect the operations of individual farms and do not have direct impacts on other farmers in the district—acreage to be irrigated, L_i , applied water, α_i , and use of other inputs, x_{ij} , such as labor, fertilizer, and equipment.

The district’s objective function becomes:

$$(2) \quad \max_{L_i, \alpha_i, x_{ij}, S_i} \Pi_{coop} = \sum_{i=1}^N [p \cdot q(h_i, \alpha_i, x_i) \cdot L_i - I(h_i, L_i) - (v(h_i) \cdot \alpha_i + bx_i + ry_i) \cdot L_i] - \left[K \left(\sum_{i=1}^N S_i \cdot L_i \right) + \sum_{i=1}^N c \alpha_i \cdot L_i \right] + \sum_{i=1}^N m \cdot (\bar{s}_i - \alpha_i)$$

and the variables are defined as:

- \bar{L}_i = acreage owned or rented by a farmer or business or resident within the district, enrolled in a district's assessments, but not necessarily irrigated.
- L_i = acreage irrigated by farmer I in acres
- S_i = water delivery capacity per acre from district supplies, and district's delivery service quality to farm I measured by (1) relative miles of unlined/lined canals and pipelines, and (2) delivery conditions, requirements and lead time.
- s_d = the minimum water delivery service and capacity which exists without district investment. For example, the minimum water delivery under drought conditions without storage facilities.
- \bar{s}_i = average water supplied to farmer during the year per acre.
- K = annual cost recovery for capital investment as a function of water supply capacity ($\sum S_i L_i$).
- q = yield from an acre of crops on farm I as a function of effective water, land and other inputs.
- p = price per unit of output of crops, exogenously set in the agricultural marketplace.
- h_i = technical irrigation efficiency of applied to effective water
- a_i = delivered and applied water in acre-feet per acre
- e_i = "effective" water actually used by the crop or lost through evapotranspiration. Effective water is the product of applied water times the irrigation efficiency rate, $e_i = h_i \cdot a_i$
- m = "market" price for water supply either acquired from sources such as water projects (e.g., the State Water Project or the Central Valley Project) or sold outside of the district
- I = investment cost per acre of irrigation technology used by farmer as a function of land and efficiency.
- c = district-average variable or "volumetric" delivery costs per acre-foot per acre delivered to the main canal.
- v = n-farm groundwater and surface pumping and irrigation pressurization costs per acre-foot per acre as a function of use-efficiency as a function of efficiency.
- ρ = risk premium applied to fixed investments by tenant farmers relative to owner/operators due to the potential loss of tenancy through lease cancellation or sale of land or water rights by the landlord.
- x_i = composite index of other farm inputs (e.g., labor, fertilizer, energy, equipment)
- b = composite price of other farm inputs
- r = land "rental" or opportunity rate per acre
- y_i = assessed land value for property tax and district voting purposes

First Order Conditions:

$$\begin{aligned} \frac{\partial \Pi}{\partial L_i} &= \sum_{i=1}^N \left(p \cdot q_i - \frac{\partial I}{\partial L_i} - (v_i + c) \cdot a_i - r \cdot y_i - b x_i - S_i \cdot \frac{\partial K}{\partial L_i} + m \cdot (\bar{s}_i - a_i) \right) = 0 \\ \frac{\partial \Pi}{\partial a_i} &= \sum_{i=1}^N L_i \cdot \left(p \cdot h_i \cdot \frac{\partial q_i}{\partial a_i} - (v_i + c + m) \right) = 0 \\ \frac{\partial \Pi}{\partial x_i} &= \sum_{i=1}^N L_i \cdot \left(p \cdot \frac{\partial q}{\partial x_i} - b \right) = 0 \\ \frac{\partial \Pi}{\partial S_i} &= \sum_{i=1}^N L_i \cdot \left(\frac{\partial K}{\partial S_i} - m \cdot \frac{\partial \bar{s}_i}{\partial S_i} \right) = 0 \end{aligned}$$

By assumption, the relevant functions have the following properties:

$$\begin{aligned} q_i &\geq 0 \quad q_{ii} \leq 0; \text{ for } i = L, p, a, x, y \\ q_h a &= q_a h = q_e \text{ where } e = h a \\ I_h &\geq 0 \quad I_{hh} \geq 0; \quad I_L \geq 0 \quad I_{LL} \leq 0 \\ v_h &> 0 \quad v_{hh} > 0; \quad v_h a = v_e \\ K_S &> 0; \quad K_L > 0 \\ 0 &\leq F(S) \leq 1, \quad F_S > 0, \quad F_{SS} < 0 \end{aligned}$$

We assume the usual concavity and differentiability properties for the farm production functions, q (Berck and Helfand 1990). We also assume the usual properties for cross partials hold between applied water and irrigation efficiency so that we can find the derivative of effective water application on yield. Irrigation technology increases in cost with increased efficiency, a phenomenon commonly seen as farmers move from flood to furrow to sprinklers to drip systems (Caswell, Lichtenberg, and Zilberman 1990). The marginal investment costs are also increasing consistent with approaching an ultimate efficiency limit of 100%. Pressurization costs also increase, also at an increasing rate consistent with physics. In the case of land, total farm

irrigation investment increases with size, but at a decreasing rate consistent with economies of scale.

2.3.2 Water “Market” Price and the Shadow Value of Water Supply

A useful benchmark is assessing the relationship between the value for m and the shadow value of adding supply capacity. The variable m has two interpretations. The first is as the “market price” for water, whether to acquire new resources beyond existing district capacity or to sell in a water market. In this case, m represents what the cooperative might pay or receive for the difference between its expected supply, \bar{s} , and applied water, a . The second interpretation is as the shadow value of water in the district's allocation of resources. It reflects the value of changing either the expected average water supplies from the district's system or the changing the amount of water allocated to district farmers for cultivation. Thus, m can be either imposed externally through markets or derived internally from the cost of changing resource management.

$$(5) \quad m = \frac{\partial K / \partial S_i}{\partial \bar{s} / \partial S_i} = \frac{\partial K}{\partial \bar{s}}$$

If m represents an external market price, it dictates the district's supply capacity decision, S . If m is interpreted as the shadow value of adding supply capacity (or reducing water allocated to district farms), then as shown in equation (5), the shadow value of water is dependent on the cost and effectiveness of expanding supply capacity. The shadow value equals the marginal capacity cost divided by the marginal increase in expected supplies from that added capacity (or the marginal capital cost for an increase in *expected* supply). In other words, the district will choose to invest up to the point where the marginal cost per *expected or average* acre-foot equals the

perceived water market price. This price might be the contract rate from the Bureau of Reclamation or Department of Water Resources (Bain, Caves, and Margolis 1966), or what the district believes is the going price for long-term water sales.

A second interpretation of m can be derived from the model. The value of marginal product of effective water equals the total of the on-farm pressurization costs plus district conveyance costs plus the “market price” or shadow value of expected system supplies per acre.

$$(6) \quad p \cdot h_i \frac{\partial q_i}{\partial a_i} = p \cdot \frac{\partial q_i}{\partial e_i} = VMP_e = m + c + v = \frac{\partial K}{\partial \bar{s}_i} + c + v$$

As the value of marginal product increases, at least one of two things would likely occur: on-farm pressurization costs would increase, implying improved irrigation efficiency (or perhaps more or deeper groundwater pumping which is only indirectly addressed here); or the district would realize a higher value for m and either acquire new higher-cost supplies or increase investment in supply capacity to improve expected supplies.

2.3.3 Value of Marginal Product of Land

Rearranging terms from the first-order conditions and substituting for m from equations (5) and (6):

$$(7) \quad p \cdot q_i = VMP_L = \frac{\partial I}{\partial L_i} + (v + c + m) \cdot a_i + r \cdot y_i + b \cdot x_i + S_i \cdot \frac{\partial K}{\partial L_i} - m \cdot \bar{s}_i \\ = S_i \cdot \frac{\partial K}{\partial L_i} + \frac{\partial I}{\partial L_i} + r \cdot y_i + b \cdot x_i + (VMP_e \cdot (a_i - \bar{s}_i) + \bar{s}_i \cdot (c + v))$$

The value of marginal product for land equals the marginal investment cost for supply capacity per added acre, plus the marginal irrigation investment cost per acre plus the rent and added input costs per acre, plus the value of marginal product of effective water times the net applied water above district supplies, plus the conveyance and pressurization costs of the expected district supply per acre. The first two terms represent the additional investment, both by the district and the farmer, necessary to put an acre into production and under irrigation. The next two terms are usual costs of production. The last two terms represent the tradeoff in using more of the district's water supply—the net value of marginal product for water accrues to the added acre, but the district and farmer incur additional conveyance and pumping costs.

2.3.4 Other On-farm Inputs

The classical result that the value of marginal product equals the input price holds in this case.⁸

$$(8) \quad b = p \cdot \frac{\partial q}{\partial x_i} = VMP_x$$

2.4 The Efficient Cooperative Water District Model with A Non-Profit Constraint

⁸This result becomes more important when assessing how district managers respond to the non-farmer electorate under different governance rules however.

Imposing a non-profit constraint on the optimal cooperative district implies that the difference between aggregate marginal costs and average costs accrue to the cooperative members directly through rates, rather than to the district itself. The process becomes a two-stage game, where the farmers first choose their optimal-output rules, and the district then establishes the optimal level of supply and electricity generation capacity. The water and land charges, w , l and t , then fall out of the results.

This model is structured as a neo-classical central-planner model for both ease of exposition and to show that even in this framework, institutional characteristics can be incorporated to create political-economic effects. The model is informally akin to a Stackelberg-leader game where the district managers anticipate the actions by individual farmers in setting district policy and trying to assure the maximum probability that the managers will be re-elected.

$$(9) \quad \begin{aligned} \max_{L_i, \alpha_i, x_i, S_i} \Pi_{constraint} &= \sum_{i=1}^N \pi_F \\ \text{subject to} \quad \sum_{i=1}^N (w \cdot \alpha_i + l + t y_i) \cdot L_i &= K \left(\sum_{i=1}^N S_i \cdot L_i \cdot E \right) + \sum_{i=1}^N c \alpha_i \cdot L_i - \sum_{i=1}^N m \cdot (\bar{s}_i - \alpha_i) \cdot L_i \end{aligned}$$

where the owner/farmers' problem is represented as:

$$\max_{L_i, \alpha_i, x_i} \pi_F = p \cdot q(h_i, \alpha_i, x_i) \cdot L_i - I(h_i, L_i) - ((v(h_i) + w) \cdot \alpha_i + l + (r+t) \cdot y_i + b x_i) \cdot L_i$$

where:

- w = district's water charge per delivered acre-foot
- l = district's per acre land assessment for water delivery
- t = district's ad valorem property tax rate

The Lagrangian problem becomes:

$$(10) \quad \mathcal{L} = \sum_{i=1}^N \pi_{F_i} - \lambda \cdot \left[\sum_{i=1}^N (w \cdot \alpha_i + l + t y_i) \cdot L_i - \left(K \left(\sum_{i=1}^N S_i \cdot L_i \cdot E \right) + \sum_{i=1}^N c \alpha_i \cdot L_i \right) + kE + \sum_{i=1}^N m \cdot (\bar{s}_i - \alpha_i) \cdot L_i \right]$$

First Order Conditions:

$$\begin{aligned} - &= \sum_{i=1}^N \left(p \cdot q_i - \frac{\partial I}{\partial L_i} - (v_i + w) \cdot \alpha_i - l - (r + t) \cdot y_i - b x_i \right) - \lambda \cdot \sum_{i=1}^N \left[w \alpha_i + l + t y_i - S_i \cdot \frac{\partial K}{\partial L_i} - c \alpha_i + m \cdot (\bar{s}_i - \alpha_i) \right] \\ - &= \sum_{i=1}^N L_i \cdot \left(p \cdot h_i \cdot \frac{\partial q_i}{\partial \alpha_i} - (v_i + w) \right) - \lambda \cdot \sum_{i=1}^N L_i \cdot (w - c - m) = 0 \\ - &= \sum_{i=1}^N L_i \cdot \left(p \cdot \frac{\partial q}{\partial x_i} - b \right) = 0 \\ - &= \sum_{i=1}^N \lambda \cdot L_i \cdot \left(\frac{\partial K}{\partial S_i} - m \cdot \frac{\partial \bar{s}_i}{\partial S_i} \right) = 0 \end{aligned}$$

2.4.1 Shadow Value of Expected Water Supplies

As with the unconstrained efficient cooperative, the market price for water equates to the marginal cost of increasing the district's average water supply. The non-profit constraint does not affect this result.

$$(11) \quad m = \frac{\partial K / \partial S_i}{\partial \bar{s}_i / \partial S_i} = \frac{\partial K}{\partial \bar{s}_i}$$

2.4.2 Value of Other On-Farm Inputs

As with the unconstrained efficient cooperative, the value of marginal product for other inputs equals the price of those inputs. As with the shadow value of average supply, the non-profit constraint does not influence the result.

$$(12) \quad b = p \cdot \frac{\partial q}{\partial x_i} = VMP_{x,\Pi}$$

2.4.3 The Effect of the Non-Profit Constraint on Revenue Sources

The non-profit constraint is a classic regulated monopoly problem (Carlton and Perloff 1990, p. 798.). Using the Lagrangian multiplier, λ , the resulting pricing rule is:

$$\frac{1}{1-\lambda} = \epsilon \cdot \frac{Revenues - Costs}{VMP_a}$$

where ϵ is the elasticity of demand for applied water by district customers and VMP_a is the value of marginal product for applied water. For the non-profit constraint to hold, λ equals one, since revenues must equal costs at the given level of input demand. We assume that this condition holds throughout this analysis, although in reality district managers may diverge from these pricing policies. Without the constraint, λ equals zero.

From the first-order conditions, we can derive two expressions for λ :

$$\begin{aligned}
(13) \quad \lambda &= \frac{\sum_{i=1}^N p \cdot q_i - \partial I / \partial L_i - (v_i + w) \cdot a_i - l - r_i - t y_i - b x_i}{\sum_{i=1}^N (w - c - m) \cdot a_i + l + t y_i - S_i \cdot \frac{\partial K}{\partial L_i} + \bar{s}_i \cdot m} \\
&= \frac{\sum_{i=1}^N \partial \pi_f / \partial L_i}{\sum_{i=1}^N (w - c - m) \cdot a_i + l + t y_i - S_i \cdot \partial K / \partial L_i + \bar{s}_i \cdot m}
\end{aligned}$$

$$\begin{aligned}
(14) \quad \lambda &= \frac{\sum_{i=1}^N L_i \cdot p \cdot h_i \cdot \partial q_i / \partial a_i - (v_i + w)}{\sum_{i=1}^N L_i \cdot (w - c - m)} \\
&= \frac{\sum_{i=1}^N L_i \cdot \partial \pi_f / \partial a_i}{\sum_{i=1}^N L_i \cdot (w - c - m)}
\end{aligned}$$

The Lagrangian multiplier can be interpreted as the shadow value to the district of changing a district fee or charge. In equation (14), increasing the per acre charge, l , will decrease λ through both the numerator and denominator. The water-sue charge, w , and the property tax rate, t , similar effects as l .

We can use these equations to find the preferred levels for the district charges, l , t and w . Setting equations (13) and (14) equal and rearranging the terms:

$$(15) \quad \frac{\sum_{i=1}^N \partial \pi_F / \partial L_i}{\sum_{i=1}^N \partial \pi_F / \partial a_i \cdot L_i} = \frac{\sum_{i=1}^N a_i}{\sum_{i=1}^N L_i} + \frac{\sum_{i=1}^N (l + t y_i - S_i \cdot \partial K / \partial L_i + \bar{s}_i \cdot m)}{(w - c - m) \cdot \sum_{i=1}^N L_i}$$

Equation (15) shows the ratio between the land-based charges, l and t in the numerator, and the water charge, w , in the denominator, compared to the per-acre ratios of the marginal profits for land and applied water.

Proposition 1: In the optimal cooperative with a non-profit constraint, the optimal per-acre charge ($l^ + t^* y$) equals marginal cost of storage capacity with respect to acreage times capacity per acre ($S_i \cdot \partial K / \partial L_i$) minus the marginal cost of storage with respect to changes in average water supply times the average water supply per acre ($\bar{s}_i \cdot \partial K / \partial \bar{s}_i$).*

At the optimal level of output for the cooperative, by using the envelope theorem, we can show that the aggregate effect from infinitesimal change in one input will equal the aggregate effect from an infinitesimal change in another input times the inverse ratio of the optimal levels of the inputs. If all of the individual farms were identical, by Chebyshev's inequality (Berck and Sydsaeter 1991), the ratio would be:

$$\frac{\partial \pi_F / \partial L_i^*}{\partial \pi_F / \partial a_i^* \cdot L_i^*} = \frac{a_i^*}{L_i^*}$$

However, the efficient cooperative is optimizing across the population of farms, and thus chooses policies across farms to derive maximum wealth without regard to distribution. The district then achieves this optimum at the ratio of the sum of applied water to the sum of irrigated land:

$$(16) \quad \frac{\sum_{i=1}^N \partial \pi_f / \partial L_i^*}{\sum_{i=1}^N \partial \pi_f / \partial a_i^* \cdot L_i^*} = \frac{\sum_{i=1}^N a_i^*}{\sum_{i=1}^N L_i^*}$$

which implies,

$$\frac{\sum_{i=1}^N (l + t y_i - S_i \cdot \partial K / \partial L_i + \bar{s}_i \cdot m)}{(w - c - m) \cdot \sum_{i=1}^N L_i} = 0$$

If we assume that each farm's acreage charge equals its net cost of providing supply per acre and substituting for m , then we arrive at

$$(17) \quad \sum_{i=1}^N l^* + \sum_{i=1}^N t^* y_i = \sum_{i=1}^N \left(S_i \cdot \frac{\partial K}{\partial L_i} - \bar{s}_i \cdot \frac{\partial K}{\partial \bar{s}_i} \right)$$

Proposition 2: In the constrained efficient cooperative, the per-acre-foot water charge, w^* , equals the cost of conveying water to the district, c , plus the marginal cost of storage with respect to increased average supply, $\partial K/\partial \bar{s}$, times the average or expected supply per acre, \bar{s} .

Inverting equations (13) and (14) which define λ , and equating,

$$\frac{\sum_{i=1}^N (w - c - m) \cdot a_i + l + ty_i - S_i \cdot \partial K / \partial L_i + \bar{s}_i \cdot m}{\sum_{i=1}^N \partial \pi_F / \partial L_i} = \frac{\sum_{i=1}^N L_i \cdot (w - c - m)}{\sum_{i=1}^N \partial \pi_F / \partial a_i \cdot L_i}$$

$$(w - c - m) \cdot \left[\frac{\sum_{i=1}^N L_i}{\sum_{i=1}^N \partial \pi_F / \partial a_i \cdot L_i} - \frac{\sum_{i=1}^N a_i}{\sum_{i=1}^N \partial \pi_F / \partial L_i} \right] = \frac{\sum_{i=1}^N l + ty_i - S_i \cdot \partial K / \partial L_i + \bar{s}_i \cdot m}{\sum_{i=1}^N \partial \pi_F / \partial L_i}$$

From Proposition 1, the right-hand side of this equation equals zero. Thus, after substituting for m ,

$$(18) \quad w^* = c + \bar{s}_i \cdot \frac{\partial K}{\partial \bar{s}_i}$$

Thus, the optimal water charge equals the conveyance cost plus the marginal investment cost per average acre-foot times the expected acre-feet of supply per acre irrigated.

These decision rules for the constrained wealth-maximizing cooperative now can be used as benchmarks for comparing other institutional district forms.

3. EXAMINING EXISTING INSTITUTIONS

The water supply and agricultural production institutions as they exist today are quite different from the efficient-cooperative model. The agencies that supply water and the farms which use the water for growing crops or raising livestock are not as fully vertically integrated as is implicitly assumed in the “wealth-maximizing” district model. No board centrally plans and allocates resource use and production levels. The institutional incentives differ from the theoretical model in two important ways:

- (1) While the efficient cooperative managers are only concerned with generating the maximum net income for the district’s members, the managers in existing districts are most concerned with maintaining their political power. This means that they must assemble a majority of votes through their policy choices.
- (2) The efficient model assumes that land is used to the maximum benefit of the district’s members regardless of ownership form and size. In fact many different forms of ownership exist, including different types of tenancy, and often non-farmers also have a stake in the electoral process. Individuals have different objective functions rather than the common one used in the theoretical model.

Fundamentally, the various district institutions are bifurcated between control of water rights and land rights. The district managers and voters control the water rights, and the farmers control the land property rights. The issue is how this bifurcation affects the efficiency of the use of these resources, and how the variations in institutional rules affect the different forms of the districts. As a cooperative, the district and the farms are partially integrated, but the exchange of

information between the two levels—the district and the farmers—is externally manifested through prices and voting, and decision-making is decentralized. Farmers use water in amounts and in a manner that balance the benefits of revenues generated against the costs of this and other inputs. The district provides at least a price signal as to the “appropriate” use of the water. The district also responds to the wishes of the farmers through the electoral process. The responses to signals from both sides will be imperfect for a number of reasons, including transactions costs, the structure of the tariffs, externally-imposed legal requirements, and the voting rules for the cooperative.

3.1 Choices by District Board and Managers in Existing District Structures

District board members (by implication, the line managers) try to stay in office by pleasing a sufficient number of constituents through their policy choices. They attempt to win a majority of votes by addressing the issues that most affect district members. This is the basis of the median-voter model (Peltzman 1971). This idea can be extended to incorporate the "interest group" concept by assessing how voters grouped by key characteristics might respond to different policy choices, and determining whether board members can assemble a majority vote by appealing to these various groups (Olson 1965). The existence of different voting rules in California's agricultural water districts allows us to test this hypothesis.

Several different methods are specified in state law to identify qualified electors and how to weigh votes for electing governing boards. The two dominant methods are the property-qualification, assessed value-weighted method and the universal-franchise, popular vote method

(California Department of Water Resources 1994).⁹ The former allows only those who own property to vote, and each owner is given a vote in proportion to the assessed value of their land. This method might be interpreted as allocating votes in proportion to the value of net output from an agricultural district. The latter method enfranchises any registered voter and simply tallies one-person/one-vote. This is also the most common method for electing officials in other governmental jurisdictions.

While a board cannot guarantee that a particular voter will vote for them, they can affect the likelihood that they will receive a positive vote. The board has five variables to consider: who the eligible voters are in the district, the well-being of the district's individual voters, the cost of the district's water supply, the variability and reliability of the district's supply, and the mode of collecting the district's required revenues. We focus on the district board's objective function which is to maximize the number of voters subject to meeting a non-profit budget constraint.

The function γ specifies the relationship of individual net benefits for district voters and the likelihood of those voters voting for the incumbent board. γ can be interpreted as a single utility function in which the output is a "yea" or "nay" vote on the current district management. For purposes here, we need not specify the exact function, but only note that γ increases as net benefits increase for members within each interest group.

⁹In addition, property-qualification, popular vote, appointed boards and acreage-based voting systems are used but not nearly as common. These are not included in the further analysis for ease of exposition. The two dominant electoral methods discussed here largely represent the polar cases anyway.

In water districts, managers choose the levels of investment in water-supply infrastructure and face per-unit costs for transporting that water to members in the district. To meet these expenditures managers may choose from various instruments, including volumetric and per-acre water charges, property taxes, other enterprise activity sales (particularly electric power sales), or sales of water to other entities. These districts also face a non-profit constraint that revenues and expenditures must balance. Board members choose the level of supply capacity and the “quality” of delivery service, S , property tax, t , and water charges on volume, w , and acreage, l , and the property tax rate, t .

3.2 Farmers’ Choices under Existing District Institutions

Under the existing institutional structures farmers do not see the true marginal cost of their water supply captured in a single price or linked capacity/use tariff as derived in the “wealth-maximizing” cooperative model. The non-profit constraint and the ability to levy taxes unrelated to use leads a multi-part pricing system. To pay for water supplies from the district, a farmer may pay a volumetric charge, w , a per-acre charge, l , or ad valorem or benefit assessments, t . These district charges and policies are taken as given initially, but can be modified to attract votes for the district managers. The objective for farmers within a district is to choose the total yield that maximizes net revenues after accounting for costs. These costs include the opportunity cost, ry , of irrigated land, L , the cost of applied water, a , the investment, I , and pressurization, v , costs associated with more efficient or alternative water irrigation systems, h , and other input (e.g., labor, fertilizer, equipment), x , costs, b .

The objective function for a tenant farmer differs from an owner/operator in two ways from that of an owner. First, tenant farmers are more likely to incorporate a risk premium, ρ , on fixed irrigation technology investment due to the nature of tenancy versus ownership (Hartman and Doane 1986). Tenants risk not being able to fully recover investment costs since they do not control land use and cannot regain fixed investment in the land value. In other words, their risk of sunk costs in investment stand to be substantially higher. This effectively increases the apparent cost of upgrading irrigation efficiency if we assume improvements require higher fixed investment (Pindyck 1991). Second, a property tax has only a secondary effect through the rent on land costs to tenants. A portion of the property tax incidence is on landlords. Thus tenants do not fully realize the brunt or benefit from changes in this type of tax.

Models for two different types of water districts are evaluated in the next two sections. Each model is constructed in parallel to the constrained efficient cooperative to allow direct comparison. The first district model addresses the property-enfranchised, assessed-value governance rules that guide most "California water districts." Board members in these districts respond to political influence based on the assessed-value held by an elector in the district. The second model uses the universal-franchise, popular-vote governance rules that generally direct "irrigation districts." Board members receive direct political signals of equal weight from each farmer regardless of farm size or tenancy, plus each non-farmers has an equal vote. These differences governance rules lead to predictions about how district resources are managed.

3.3 Assessed-Value Weighted-Voting Water Districts

In California, a prevalent form of water-district organization is the “California water district” (Davis 1993). At the center of its governance rules is that only landowners are enfranchised and that one vote equals one dollar of assessed value (California Department of Water Resources 1994). By state law, this type of district is restricted to retail service for predominantly agricultural users; once districts reach a certain threshold of residential and commercial service, the district must modify its voting procedures to use a popular-vote system (Marchini et al. 1996). Given the linkage between agricultural land values, productivity and the value of marginal productivity from applied water within a specific region, we might expect that this voting structure most closely mirrors that of an efficient cooperative.

The objective function for managers in a district with landowner-enfranchised, assessed-value weighted voting, and a non-profit revenue constraint is:

$$(20) \quad \begin{aligned} \max_{L_i, \alpha_i, x_i, S_i} \Gamma_{weighted} &= \sum_{i=1}^N \bar{L}_i \cdot y_i \cdot \gamma(\pi_F) \\ \text{subject to } \sum_{i=1}^N (w \cdot \alpha_i + l + t y_i) \cdot L_i &= K \left(\sum_{i=1}^N S_i \cdot L_i \right) + \sum_{i=1}^N c \alpha_i \cdot L_i - \sum_{i=1}^N m \cdot (\bar{s}_i - \alpha_i) \cdot L_i \\ \pi_F &= (p \cdot q(h_i, \alpha_i, x_i) \cdot L_i - I(h_i, L_i) - ((v(h_i) + w) \cdot \alpha_i + l + (r+t) \cdot y_i + b x_i) \cdot L_i) \end{aligned}$$

where the enfranchised owner/farmer is represented as:

γ = a probability density function expressing the probability of voting for the current district board members based on economic benefits from district operations, and $0 \leq \gamma \leq 1$.
 Γ = votes, if the district's voting rules are based on property value and ownership

The Lagrangian problem is represented as:

$$(21) \quad \mathcal{L} = \sum_{i=1}^N \bar{L}_i y_i \gamma(\pi_F) - \lambda \cdot \left[\sum_{i=1}^N (w \cdot a_i + l + t y_i) \cdot L_i - \left(K \left(\sum_{i=1}^N S_i \cdot L_i \right) + \sum_{i=1}^N c a_i \cdot L_i \right) + \sum_{i=1}^N m \cdot (\bar{s}_i - a_i) \cdot L_i \right]$$

First Order Conditions:

$$\begin{aligned} \frac{\partial \Gamma}{\partial L_i} &= \sum_{i=1}^N \bar{L}_i y_i \cdot \frac{\partial \gamma}{\partial \pi_F} \cdot \left(p \cdot q_i - \frac{\partial I}{\partial L_i} - (v_i + w) \cdot a_i - l - (r + t) \cdot y_i - b x_i \right) \\ &\quad - \lambda \cdot \sum_{i=1}^N \left[w a_i + l + t y_i - S_i \cdot \frac{\partial K}{\partial L_i} - c a_i + m \cdot (\bar{s}_i - a_i) \right] = 0 \\ \frac{\partial \Gamma}{\partial a_i} &= \sum_{i=1}^N \bar{L}_i y_i \cdot \frac{\partial \gamma}{\partial \pi_F} \cdot L_i \cdot \left(p \cdot h_i \cdot \frac{\partial q_i}{\partial a_i} - (v_i + w) \right) - \lambda \cdot \sum_{i=1}^N L_i \cdot (w - c - m) = 0 \\ \frac{\partial \Gamma}{\partial x_i} &= \sum_{i=1}^N \bar{L}_i y_i \cdot \frac{\partial \gamma}{\partial \pi_F} \cdot L_i \cdot \left(p \cdot \frac{\partial q}{\partial x_i} - b \right) = 0 \\ \frac{\partial \Gamma}{\partial S_i} &= \sum_{i=1}^N \lambda \cdot L_i \cdot \left(\frac{\partial K}{\partial S_i} - m \cdot \frac{\partial \bar{s}_i}{\partial S_i} \right) = 0 \end{aligned}$$

3.3.1 Value of Other On-Farm Inputs

As with the unconstrained efficient cooperative, the value of marginal product for other inputs equals the price of those inputs. As with the shadow value of average supply, the non-profit constraint does not influence the result.

$$(22) \quad b = p \cdot \frac{\partial q}{\partial x_i} = VMP_{x_i \Gamma}$$

3.3.2 Shadow Value of Expected Water Supplies

We can derive the shadow value of additional water supply, as represented by m :

$$(23) \quad m = \frac{\partial K / \partial S_i}{\partial \bar{s}_i / \partial S_i} = \frac{\partial K}{\partial \bar{s}_i}$$

The important point here is that the rule for the shadow value is identical between the theoretical and existing district forms. As we show in the previous section on the wealth-maximizing cooperative, the optimal choice rule for district supply capacity can be derived from this equation. This implies that the choice of supply capacity is independent of the electoral rules of a district.

3.3.3 Evaluating Changes in Revenue Sources and Other Policy Instruments

In the efficient cooperative, λ represented the proportionate price adjustment to true marginal district supply costs required to balance revenues and expenditures. We assumed that λ was chosen in an efficient manner to create the least distortionary effects (Carlton and Perloff 1990, p. 798).

District boards must balance the relative effects from relying on available revenue sources to maintain political support. The shadow values, λ , describe how such support varies with changes in these revenue sources, and it may no longer be chosen simply to minimize price distortions. These shadow values can be used to evaluate the effect of changing revenue sources compared to the benchmark measure provided by the efficient cooperative.

$$\begin{aligned}
(24) \quad \lambda &= \frac{\sum_{i=1}^N \bar{L}_i y_i \frac{\partial \gamma}{\partial \pi_F} \cdot (p \cdot q_i - \frac{\partial I}{\partial L_i} - (v_i + w) \cdot a_i - l - r_i - t y_i - b x_i)}{\sum_{i=1}^N \left((w - c - m) \cdot a_i + l + t y_i - S_i \cdot \frac{\partial K}{\partial L_i} + \bar{s}_i \cdot m \right)} \\
&= \frac{\sum_{i=1}^N \bar{L}_i y_i \frac{\partial \gamma}{\partial \pi_F} \cdot \frac{\partial \pi_F}{\partial L_i}}{\sum_{i=1}^N \left((w - c - m) \cdot a_i + l + t y_i - S_i \cdot \frac{\partial K}{\partial L_i} + \bar{s}_i \cdot m \right)}
\end{aligned}$$

$$\begin{aligned}
(25) \quad \lambda &= \frac{\sum_{i=1}^N L_i \bar{L}_i y_i \frac{\partial \gamma}{\partial \pi_F} \cdot (p \cdot h_i \cdot \frac{\partial q_i}{\partial a_i} - (v_i + w))}{\sum_{i=1}^N L_i \cdot (w - c - m)} \\
&= \frac{\sum_{i=1}^N \bar{L}_i y_i \frac{\partial \gamma}{\partial \pi_F} \cdot \frac{\partial \pi_F}{\partial a_i} \cdot L_i}{\sum_{i=1}^N L_i \cdot (w - c - m)}
\end{aligned}$$

and similarly to the optimal cooperative district:

$$(26) \quad \frac{\sum_{i=1}^N \bar{L}_i y_i \frac{\partial \gamma}{\partial \pi_F} \cdot \frac{\partial \pi_F}{\partial L_i}}{\sum_{i=1}^N \bar{L}_i y_i \frac{\partial \gamma}{\partial \pi_F} \cdot \frac{\partial \pi_F}{\partial a_i} \cdot L_i} = \frac{\sum_{i=1}^N a_i}{\sum_{i=1}^N L_i} + \frac{\sum_{i=1}^N (l + t y_i - S_i \cdot \frac{\partial K}{\partial L_i} + \bar{s}_i \cdot m)}{(w - c - m) \cdot \sum_{i=1}^N L_i}$$

Proposition 3: *If the enrolled acreage, \bar{L}_i , and the assessed value, y_i , for each farm are identical, then the optimal acreage-based charges, l and t , and per-*

acre-foot water charge, w , are the same as for both the constrained optimal cooperative district and the assessed-value-weighted-voting district.

If we equate the “value” of marginal productivity ratios for the two types of districts,

$$(27) \quad \frac{\sum_{i=1}^N \partial \pi_F / \partial L_i}{\sum_{i=1}^N \partial \pi_F / \partial \alpha_i \cdot L_i} = \frac{\sum_{i=1}^N \bar{L}_i \cdot y_i \cdot \partial \gamma / \partial L_i}{\sum_{i=1}^N \bar{L}_i \cdot y_i \cdot \partial \gamma / \partial \alpha_i \cdot L_i}$$

Assuming that the relative functional relationships of L_i and α_i to γ and π_F are the same, then the ratios of the terms should be equal. Expanding (27):

$$\frac{\sum_{i=1}^N \partial \pi_F / \partial L_i}{\sum_{i=1}^N \partial \pi_F / \partial \alpha_i \cdot L_i} = \frac{\sum_{i=1}^N \bar{L}_i \cdot y_i \cdot \partial \gamma / \partial \pi_i \cdot \partial \pi_F / \partial L_i}{\sum_{i=1}^N \bar{L}_i \cdot y_i \cdot \partial \gamma / \partial \pi_i \cdot \partial \pi_F / \partial \alpha_i \cdot L_i}$$

The relationships in equations (16) and (27) can only be true if:

$$\begin{aligned} \sum_{i=1}^N \bar{L}_i \cdot y_i \cdot \frac{\partial \gamma}{\partial \pi_i} \cdot \sum_{i=1}^N \frac{\partial \pi_F}{\partial L_i} &= \sum_{i=1}^N \bar{L}_i \cdot y_i \cdot \frac{\partial \gamma}{\partial \pi_i} \cdot \frac{\partial \pi_F}{\partial L_i} \text{ and} \\ \sum_{i=1}^N \bar{L}_i \cdot y_i \cdot \frac{\partial \gamma}{\partial \pi_i} \cdot \sum_{i=1}^N \frac{\partial \pi_F}{\partial \alpha_i} \cdot L_i &= \sum_{i=1}^N \bar{L}_i \cdot y_i \cdot \frac{\partial \gamma}{\partial \pi_i} \cdot \frac{\partial \pi_F}{\partial \alpha_i} \cdot L_i \end{aligned}$$

which only holds for Chebychev’s inequality, (Berck and Sydsaeter 1991), if

$$\bar{L}_i \cdot y_i \cdot \frac{\partial \gamma}{\partial \pi_i} = \bar{L}_j \cdot y_j \cdot \frac{\partial \gamma}{\partial \pi_j}$$

Proposition 4: *In an assessed-value weighted-vote district, if the district managers set rates optimally, the preferred land-based charge ($l^\Gamma + t^\Gamma y$) decreases as the amount of land irrigated on a farm (L_i) increases.*

Proposition 3 states that under certain conditions¹⁰ the district will set its land-based charges as:

$$N \cdot l^\Gamma + t^\Gamma \sum_{i=1}^N y_i = \sum_{i=1}^N S_i \cdot \frac{\partial K}{\partial L_i} - \bar{s}_i \cdot \frac{\partial K}{\partial S_i}$$

Taking the total derivative of this equation with respect to l , t , and L_i :

$$(29) \quad \frac{N \cdot dl^\Gamma + dt^\Gamma \sum_{i=1}^N y_i}{\sum_{i=1}^N dL_i} = \sum_{i=1}^N S_i \cdot \left(S_i \cdot \frac{\partial^2 K}{\partial L_i^2} - \bar{s}_i \cdot \frac{\partial^2 K}{\partial S_i \partial L_i} \right)$$

Storage and conveyance costs generally show economies of scale, at least with respect to the size of service territory (Bain, Caves, and Margolis 1966). This property implies $\partial^2 K / \partial L^2 \leq 0$.

Convexity requires that $|\partial^2 K / \partial L^2| \geq |\partial^2 K / \partial S \partial L|$. Also, by equation (2), $\bar{s} \leq S$. Thus, we find

$$(30) \quad \frac{N \cdot dl^\Gamma + dt^\Gamma \sum_{i=1}^N y_i}{\sum_{i=1}^N dL_i} \leq 0$$

¹⁰Conditions which are likely to hold if California farmers generally irrigate their land as extensively as possible, and if assessed values are largely a function of agricultural productivity values.

and an additional variable is:

$$\Upsilon = \text{vote if the district's voting rules are based on popular "one-person, one-vote"}$$

The Lagrangian problem can be expressed as:

$$(31) \quad \mathcal{L} = \sum_{i=1}^{N-T} \gamma(\pi_F) + \sum_{i=1}^T \gamma(\pi_T) + \sum_{j=1}^B \gamma(\pi_B) - \lambda \cdot \left[\sum_{i=1}^N (w \cdot a_i + l + ty_i) \cdot L_i - \left(K \left(\sum_{i=1}^N S_i \cdot L_i \right) + \sum_{i=1}^N ca_i \cdot L_i \right) + \sum_{i=1}^N m \cdot (\bar{s}_i - a_i) + \sum_{j=1}^B ty_j \cdot \bar{L}_i \right]$$

First Order Conditions:

$$\begin{aligned} \frac{\partial \Upsilon}{\partial L_i} &= \sum_{i=1}^{N-T} \frac{\partial \gamma}{\partial \pi_F} \cdot \frac{\partial \pi_F}{\partial L_i} + \sum_{i=1}^T \frac{\partial \gamma}{\partial \pi_T} \cdot \frac{\partial \pi_T}{\partial L_i} + \sum_{i=1}^B \frac{\partial \gamma}{\partial \pi_B} \cdot \frac{\partial \pi_B}{\partial L_i} \\ &\quad - \lambda \cdot \sum_{i=1}^N \left(wa_i + l + ty_i - S_i \cdot \frac{\partial K}{\partial L_i} - ca_i + m \cdot (\bar{s}_i - a_i) \right) = 0 \\ \frac{\partial \Upsilon}{\partial a_i} &= \sum_{i=1}^{N-T} \frac{\partial \gamma}{\partial \pi_F} \cdot \frac{\partial \pi_F}{\partial a_i} + \sum_{i=1}^T \frac{\partial \gamma}{\partial \pi_T} \cdot \frac{\partial \pi_T}{\partial a_i} + \sum_{i=1}^B \frac{\partial \gamma}{\partial \pi_B} \cdot \frac{\partial \pi_B}{\partial a_i} - \lambda \cdot \sum_{i=1}^N L_i \cdot (w - c - m) = 0 \\ \frac{\partial \Upsilon}{\partial x_i} &= \sum_{i=1}^{N-T} L_i \cdot \left(p \cdot \frac{\partial q}{\partial x_i} - b \right) + \sum_{i=1}^T L_i \cdot \left(p \cdot \frac{\partial q_i}{\partial x_i} - b \right) + \sum_{i=1}^B \sum_{i=1}^N L_i \cdot \frac{(b - z)}{B} = 0 \\ \frac{\partial \Upsilon}{\partial S_i} &= \sum_{i=1}^N \lambda \cdot L_i \cdot \left(\frac{\partial K}{\partial S_i} - m \cdot \frac{\partial \bar{s}_i}{\partial S_i} \right) = 0 \end{aligned}$$

3.4.1 Value of Other On-Farm Inputs

In both the “efficient cooperative” and assessed-value-weighted district, the value of marginal product for other inputs equals the price of those inputs, as shown in equation (22).

However, in the case of popular-vote district, the rule used by the district managers equates the

value of marginal product to z , the suppliers' opportunity cost, and not the farmers', in providing the other inputs, x .

$$(32) \quad z = p \cdot \frac{\partial q}{\partial x_i} = VMP_{x_i, \Upsilon}$$

Proposition 5: In a popular-vote district, the district manager will set rates so that the use of other inputs, x_p , will be equal to or greater than in either the assessed-valuation weighted voting or optimal cooperative districts.

Based on equation (22), the ratio of the value of marginal product for x_i for each of the district types is

$$(33) \quad \frac{b}{z} = \frac{\partial q_i / \partial x_{i, \Pi}}{\partial q_i / \partial x_{i, \Upsilon}} \geq 1$$

since the factors used to produce x would be used elsewhere if they could not command at least their opportunity cost, z . With a convex production set with respect to its inputs, the marginal product declines as the use of the input increases. Thus,

$$(34) \quad \frac{\partial q_i}{\partial x_{i, \Pi}} \geq \frac{\partial q_i}{\partial x_{i, \Upsilon}} \Rightarrow x_{i, \Pi} \leq x_{i, \Upsilon}$$

and other inputs will be used to a greater degree than in a similarly situated "efficient cooperative" or assessed-value weighted voting district.

3.4.2 Shadow Value of Expected Water Supplies

We can derive the shadow value of additional water supply, as represented by m :

$$(35) \quad m = \frac{\partial K / \partial S_i}{\partial \bar{s}_i / \partial S_i} = \frac{\partial K}{\partial \bar{s}_i}$$

The important point here however is that the rule for the shadow value is identical between the assessed-value and popular-weight vote district forms. As we show in the previous discussion about the efficient-cooperative district, the choice rule for district supply capacity can be derived from this equation. This implies that the choice of supply capacity is independent of the electoral rules of a district.

3.4.3 Evaluating Changes in Revenue Sources and Other Policy Instruments

Again the district boards must balance the relative effects from relying on available revenue sources to maintain political support. The shadow values, λ , describe how such support varies with changes in these revenue sources. These shadow values can be used to evaluate the effect of changing revenue sources compared to the levels chosen by an efficient cooperative or assessed-value weighted-vote district. Solving from the first-order conditions,

$$(36) \quad \lambda = \frac{\sum_{i=1}^{N-T} \frac{\partial \gamma}{\partial \pi_F} \cdot \frac{\partial \pi_F}{\partial L_i} + \sum_{i=1}^T \frac{\partial \gamma}{\partial \pi_T} \cdot \frac{\partial \pi_T}{\partial L_i} + \sum_{i=1}^B \frac{\partial \gamma}{\partial \pi_B} \cdot \frac{\partial \pi_B}{\partial L_i}}{\sum_{i=1}^N ((w - c - m) \cdot a_i + l + ty_i - S_i \cdot \partial K / \partial L_i + \bar{s}_i \cdot m)}$$

$$(37) \quad \lambda = \frac{\sum_{i=1}^{N-T} \frac{\partial \gamma}{\partial \pi_F} \cdot \frac{\partial \pi_F}{\partial a_i} + \sum_{i=1}^T \frac{\partial \gamma}{\partial \pi_T} \cdot \frac{\partial \pi_T}{\partial a_i} + \sum_{i=1}^B \frac{\partial \gamma}{\partial \pi_B} \cdot \frac{\partial \pi_B}{\partial a_i}}{\sum_{i=1}^N L_i (w - c - m)}$$

We arrive at the expression comparable to equations (15) and (26):

$$(38) \quad \frac{\sum_{i=1}^{N-T} \frac{\partial \gamma}{\partial \pi_F} \cdot \frac{\partial \pi_F}{\partial L_i} + \sum_{i=1}^T \frac{\partial \gamma}{\partial \pi_T} \cdot \frac{\partial \pi_T}{\partial L_i} + \sum_{i=1}^B \frac{\partial \gamma}{\partial \pi_B} \cdot \frac{\partial \pi_B}{\partial L_i}}{\sum_{i=1}^{N-T} \frac{\partial \gamma}{\partial \pi_F} \cdot \frac{\partial \pi_F}{\partial a_i} + \sum_{i=1}^T \frac{\partial \gamma}{\partial \pi_T} \cdot \frac{\partial \pi_T}{\partial a_i} + \sum_{i=1}^B \frac{\partial \gamma}{\partial \pi_B} \cdot \frac{\partial \pi_B}{\partial a_i}} = \frac{\sum_{i=1}^N a_i}{\sum_{i=1}^N L_i} + \frac{\sum_{i=1}^N (l + ty_i - S_i \cdot \partial K / \partial L_i + \bar{s}_i \cdot m)}{(w - c - m) \cdot \sum_{i=1}^N L_i}$$

Proposition 6: *In comparison to assessed-value voting districts, district managers in popular-vote districts will tend to set land-based charges ($l^r + t^r y$) higher and water charges (w^r) lower because of the electoral influence of tenant farmers and local businesses/suppliers.*

Note that the right-hand sides of equations (15), (26) and (38) are identical, and that Propositions 1 and 2 show that these expressions can be used to derive the land-based and water-based charges. Thus by comparing the left-hand sides of equations (26) and (38), we can determine the relative magnitudes of $(l + ty)$ and w in each case. First, we can expand the left-hand sides of equations (26) and (38):

$$(39) \quad \frac{\sum_{i=1}^N \bar{L}_i y_i \cdot \frac{\partial \gamma}{\partial \pi_F} \cdot \frac{\partial \pi_F}{\partial L_i}}{\sum_{i=1}^N \bar{L}_i y_i \cdot \frac{\partial \gamma}{\partial \pi_F} \cdot \frac{\partial \pi_F}{\partial a_i}} = \frac{\sum_{i=1}^N \bar{L}_i y_i \cdot \frac{\partial \gamma}{\partial \pi_F} \cdot (pq_i - (v_i + w) \cdot a - l - bx_i) - \sum_{i=1}^N \bar{L}_i y_i \cdot \frac{\partial \gamma}{\partial \pi_F} \cdot \left(\frac{\partial I}{\partial L_i} + (r+t) \cdot y_i \right)}{\sum_{i=1}^N \bar{L}_i y_i \cdot \frac{\partial \gamma}{\partial \pi_F} \cdot \left(ph \frac{\partial q_i}{\partial a_i} - (v+w) \right)}$$

$$(40) \quad \frac{\sum_{i=1}^{N-T} \frac{\partial \gamma}{\partial \pi_F} \cdot \frac{\partial \pi_F}{\partial L_i} + \sum_{i=1}^T \frac{\partial \gamma}{\partial \pi_T} \cdot \frac{\partial \pi_T}{\partial L_i} + \sum_{i=1}^B \frac{\partial \gamma}{\partial \pi_B} \cdot \frac{\partial \pi_B}{\partial L_i}}{\sum_{i=1}^{N-T} \frac{\partial \gamma}{\partial \pi_F} \cdot \frac{\partial \pi_F}{\partial a_i} + \sum_{i=1}^T \frac{\partial \gamma}{\partial \pi_T} \cdot \frac{\partial \pi_T}{\partial a_i} + \sum_{i=1}^B \frac{\partial \gamma}{\partial \pi_B} \cdot \frac{\partial \pi_B}{\partial a_i}} = \frac{\sum_{i=1}^N \frac{\partial \gamma}{\partial \pi_i} \cdot (pq_i - (v_i + w) \cdot a - l - bx_i) - \sum_{i=1}^{N-T} \frac{\partial \gamma}{\partial \pi_F} \cdot \left(\frac{\partial I}{\partial L_i} + (r+t) \cdot y_i \right) - \sum_{i=1}^T \frac{\partial \gamma}{\partial \pi_T} \cdot \left(\rho \cdot \frac{\partial I}{\partial L_i} + r(t) \cdot y_i \right) + \sum_{j=1}^B \sum_{i=1}^N \frac{\partial \gamma}{\partial \pi_B} \cdot \frac{b-z}{B} \cdot x_i}{\sum_{i=1}^N \frac{\partial \gamma}{\partial \pi_i} \cdot \left(ph \frac{\partial q_i}{\partial a_i} - (v+w) \right)}$$

Note that if we assume (I) each farm is of identical size and assessed value per acre and (ii) the probability of voting function, γ , is invariate across types of farms, that the denominators on the right-hand side of both equations are equivalent, and so are the first terms in the numerators.

Thus we can determine the relative relationships of the two equations by focusing on the latter portions of the numerators. We first assume that the property tax incidence on rent, $r(t)$, must be one or less, i.e., that less than the whole amount of the property tax can be passed on to tenants.

This implies $(r+t)y_i \geq r(t)y_i$. We also assume that tenants place a risk premium, ρ , on a fixed investment such as irrigation technology. This implies that $\partial I / \partial L \leq \rho \partial I / \partial L$. Using these parameters, we can relate the portions of the numerator attributable to farmers' objective functions:

$$(41) \quad \sum_{i=1}^N \frac{\partial I}{\partial L_i} + (r+t) \cdot y_i >< \sum_{i=1}^{N-T} \left(\frac{\partial I}{\partial L_i} + (r+t) \cdot y_i \right) + \sum_{i=1}^T \left(\rho \cdot \frac{\partial I}{\partial L_i} + r(t) \cdot y_i \right)$$

$$as \quad \sum_{i=1}^{N-T} \frac{\partial I}{\partial L_i} + \sum_{i=1}^T \rho \cdot \frac{\partial I}{\partial L_i} <> \sum_{i=1}^{N-T} (r+t) \cdot y_i + \sum_{i=1}^T r(t) \cdot y_i$$

However, this relationship is basically indeterminate because we can not adequately define this relationship between the magnitude of the risk premium and the property tax incidence. Each of these probably varies significantly and is empirically difficult to measure.

Turning to the businesses and suppliers portion of the numerator, this adds a strictly positive factor to the popular-vote district's numerator. Assuming that this factor outweighs the indeterminate relationship of the farmers' objective function in equation (30) (which is certainly true for districts with large non-farm electorates), then the numerator for the popular-vote districts is larger.

Returning to equations (26) and (38), the relative magnitudes of terms in equation (38) implies

$$(42) \quad \frac{\sum_{i=1}^N a_i}{\sum_{i=1}^N L_i} + \frac{\sum_{i=1}^N (l^{\Pi} + t^{\Pi} \cdot y_i - S_i \cdot \partial K^{\Pi} / \partial L_i + \bar{s}_i \cdot m^{\Pi})}{(w^{\Pi} - c^{\Pi} - m^{\Pi}) \cdot \sum_{i=1}^N L_i} < \frac{\sum_{i=1}^N a_i}{\sum_{i=1}^N L_i} + \frac{\sum_{i=1}^N (l^{\Upsilon} + t^{\Upsilon} \cdot y_i - S_i \cdot \partial K^{\Upsilon} / \partial L_i + \bar{s}_i \cdot m^{\Upsilon})}{(w^{\Upsilon} - c^{\Upsilon} - m^{\Upsilon}) \cdot \sum_{i=1}^N L_i}$$

which in turn leads to the conclusion that,

$$(43) \quad (l^{\Pi} + t^{\Pi} \cdot y_i) < (l^{\Upsilon} + t^{\Upsilon} \cdot y_i) \text{ and } w^{\Pi} > w^{\Upsilon}$$

The land-based charges, l and t , are higher and the water-use charge lower for the popular-vote districts than for the alternative district forms.

Proposition 7: *As the per farm efficiency of irrigation technology increases in a popular-vote district and if the property-tax incidence in rents remains constant, then the tendency of district managers to rely on land-based charges increases.*

Taking the derivative of equation (41) with respect to irrigation efficiency, h ,

$$\sum_{i=1}^N \frac{\partial^2 I}{\partial L_i \partial h_i} \leq \sum_{i=1}^{N-T} \frac{\partial^2 I}{\partial L_i \partial h_i} + \sum_{i=1}^T \rho \cdot \frac{\partial^2 I}{\partial L_i \partial h_i}$$

with $\partial I / \partial L_i > 0$, implies $\rho \partial I / \partial L_i \geq \partial I / \partial L_i$. This occurs because tenant farmers are more sensitive to the risk exposure of higher levels of irrigation investment than owner/operators.

From equation (41), this implies that as the irrigation investment in a popular-vote district increases and if the property-tax incidence in rents remains constant, then the numerator on the right-hand side of equation (42), representing the popular-vote district, increases. This in turn implies that the tendency of popular-vote district managers to rely on land-based charges increases.

Proposition 8: *(1) If the construction costs of storage and conveyance facilities exhibit “strong” intensive economies of scale (i.e., with increasing facilities per acre), a popular-vote district will construct smaller storage and conveyance facilities than an assessed -value-weighted voting district. (2) If storage and conveyance facilities do not exhibit strong economies of scale, then an assessed-*

value-weighted-voting district will construct smaller storage and conveyance facilities than a popular-vote district.

Economies of scale in developing and operating water supply storage and conveyance facilities is often cited as a primary reason for the creation of agricultural water-supply cooperatives, many of which evolved into or were created as governmental entities (Bain, Caves, and Margolis 1966). In the case of water districts, these economies of scale can be broken into two dimensions: “intensive” and “extensive.” Intensive economy of scale relates to increased water usage relative to other inputs. This requires more storage and conveyance spread over the same land area, and the increased need for storage does not come with the acquisition new water sources. Extensive economy of scale occurs as water use increases in tandem with another input, e.g. land. As more land is irrigated, the need for more storage and conveyance facilities increases, but the costs and use are also spread over more acreage. Often new storage facilities and water sources become available with the added land as well. Because water use per acre is constant under extensive increases, and new water sources generally become available as land is annexed to a district, the extensive economy of scale for storage is more likely than intensive economy of scale. On the other hand, the cost of expanding a conveyance system over more acreage is likely to be more costly than increasing the volumetric capacity of the system without adding new acreage. Thus, the intensive economy of scale for conveyance is more likely than extensive economy of scale.

These economies of scale are affected by the changing probability of full water supply as reflected in the function \bar{s} . While the cost per added acre-foot of storage may fall as a reservoir

increases in size, the marginal improvement in *expected* supply will eventually diminish as the reservoir approaches the expected runoff of the watershed.

One important note: Long-term economies of scale should not be confused with “lumpiness” of investment. Lumpiness reflects intensive economies of scale within a range of selected investment level due to high short-term fixed costs. This one-time economy of scale effect disappears when the district goes back to add additional storage or conveyance facilities, and the incremental costs are higher than the original investment per unit of water.

From equation (16), and substituting for \bar{s}_i ,

$$(44) \quad (w^* - c) = \bar{s}_i \cdot \frac{\partial K / \partial S_i}{\partial \bar{s}_i / \partial S_i} = \frac{\partial K}{\partial S_i} \cdot \frac{s_d + (S_i - s_d) \cdot F(S_i)}{F(S) + (S_i - s_d) \cdot f(S_i)}$$

Totally differentiating with respect to w and S and inverting,

$$(45) \quad \frac{dS_i}{dw^*} = \frac{- \left(2 \cdot f(S_i) + (S_i - s_d) \cdot \frac{\partial^2 f(S_i)}{\partial S_i^2} \right)^2}{\frac{\partial^2 K}{\partial S_i^2} \cdot F(S) + (S_i - s_d) \cdot f(S_i)}$$

The terms $F(S_i)$, $f(S_i)$ and $(S_i - s_d)$ are positive, and the numerator is negative. To sign dS/dw , we must evaluate the conditions under which the denominator might be negative or positive, which depend solely on $\partial^2 K / \partial S^2$, the rate of change in marginal capacity cost:

$$(46) \quad \begin{aligned} \text{Condition 1: } & \text{If } \frac{\partial^2 K}{\partial S_i^2} < 0 \text{ and } \left| \frac{\partial^2 K}{\partial S_i^2} \right| > (S_i - s_d) \cdot \frac{f(S_i)}{F(S_i)} \text{ then } \frac{dS_i}{dw^*} > 0 \\ \text{Condition 2: } & \text{If } \frac{\partial^2 K}{\partial S_i^2} > 0 \text{ and/or } \left| \frac{\partial^2 K}{\partial S_i^2} \right| < (S_i - s_d) \cdot \frac{f(S_i)}{F(S_i)} \text{ then } \frac{dS_i}{dw^*} < 0 \end{aligned}$$

Condition 1 is the mathematical representation of “strong” intensive economies of scale. The marginal costs of adding storage and conveyance facilities are falling on a per acre basis, and the absolute value of the changes in marginal cost are greater than change in added expected water supply from the increase in capacity. Using equation (48), we can compare how popular-vote districts will invest in storage and conveyance facilities versus the assessed-value-weighted-voting districts. Since $w^r < w^a$, then $S_i^r < S_i^a$ if Condition 1 holds; otherwise, Condition 2 holds and $S_i^r > S_i^a$. In other words, if the strong condition for economies of scale holds, then the popular-vote districts will invest less in storage and conveyance facilities than the other types of districts.

4.0 EMPIRICAL ANALYSIS OF DISTRICT MANAGERS' BEHAVIOR

To test the propositions put forward in the previous section of this study, a data set of agriculturally-oriented water districts located throughout California was compiled. An initial set of 128 districts were selected from a survey conducted on responses to the recent five-year drought (Zilberman et al. 1992; Zilberman, MacDougall, and Shah 1994). These districts were matched with additional information from the Association of California Water Agencies (ACWA) and financial data from the California State Controller (Davis 1993). In addition, the legal and financial requirements for each of these districts was drawn from a summary of the California Water Code produced by the California Department of Water Resources (California Department of Water Resources 1994). These data were summarized and analyzed using standard econometric techniques. The regression analysis found that the key proposition that electoral rules have a small but significant influence on whether district managers rely more on operating or non-operating revenue sources to finance district operations and capital expenditures. This study also indicates that further analysis might be fruitful in exploring how water pricing, debt financing and other factors varies by district and over time using and expanding the current data set.

4.1 Description of California's Agricultural Publicly-Owned Water Utilities

California has developed a wide variety of institutions to manage and deliver water supplies to agricultural customers. Several large water storage and conveyance projects have been developed by federal, state and consortiums of local agencies. For example, the Central Valley Project was built

by the U.S. Bureau of Reclamation (USBR), the State Water Project by the California Department of Water Resources (CDWR), and the Colorado Aqueduct by the Metropolitan Water District of Southern California (MWDSC). Other large local projects have been developed as well, such as Don Pedro Reservoir operated jointly by the Modesto and Turlock Irrigation Districts. Water from these projects is often delivered to wholesale agencies, such as the Kern County Water Agency (KCWA), which in turn sells the water to retail agencies.

California calls the local agencies that provide water delivery services “special districts.” Such water districts are among a host of others that provide specialized government services beyond those that might be offered by counties or cities, such as flood control, mosquito abatement and waste collection. Special districts that provide services which are charged for directly, such as water utilities or waste collection, are called “enterprise districts.”

The retail agencies, which are the focus of this study, are governed by a wide variety of state laws and regulations, contained mostly in the state Water Code. Many aspects of these districts have been described in several other publications (e.g., (Bain, Caves, and Margolis 1966; Chatterjee 1994; Goodall, Sullivan, and DeYoung 1978; Rosen 1992). Table 1 compares the districts captured in the survey and reviewed in this analysis and several key characteristics (California Department of Water Resources 1994). These districts have a variety of functions and rules. While community services districts are numerous, they are relatively small players in the agricultural water supply industry, and often do not even provide water service. County water and California water districts are the most numerous of the specialized water utilities, and the latter are designed specifically to provide agricultural water service. Reclamation districts, the next most prevalent group; however, the

District Type	Code #	Statute Date	Electoral Rules	Governing Board		Bonding Requirements	Revenue Sources	Taxation Powers	Outside Water Sales		
				Franchise; Weight	Members; Decision Rules					Types, Limits & vote Approval	
				Reg. voter	3-5, majority vote					GO: 2/3, Rev: 1/2; 5yr notes < GO < 20% value	Rates/standby, leases, prop sale
Community Services District	5	1951	Reg. voter	3-5, majority vote	GO: 2/3, Rev: 1/2; 5yr notes < GO < 20% value	Rates/standby, leases, prop sale	AdVal* (land: irr.) < 1%, special tax: 2/3	No provision			
Antelope V.-E. Kern Water Agency	45.3	1959	Reg. voter	7; uncontested appt. by county	GO: 2/3, rev: 1/2; 5yr notes < \$2m/2% value	Rates/standby, lease/sales	AdVal, admin < 0.1%, rev. capacity fees	Surplus			
Placer County Water Agency	45.12	1957	Reg. voter	5, power sale by county	GO: 2/3 zone, rev: 1/2	Rates/standby, lease/sales, power	AdVal* < 0.1%, zone < 0.5%	Surplus			
San Diego County Water Authority	45.19	1943	County electors	1 vote/\$5m value	GO: 2/3, Rev: 1/2; < 15% value; notes < 1/4% value	Rates/standby, leases, prop sale, power	AdVal < 0.5% excl. bonds	Member agencies pref. surplus w/ 1yr recapture			
County Water District	42	1913	Reg. voter (some owners)	5, (some specific requirements)	GO: 2/3, Rev: 2/3 or 1/2; neg. notes	Rates, leases, prop. sale, power, other	AdVal* (land: US debt), special tax: 2/3, < \$10/ac standby	Surplus			
Irrigation District	52	1887, 1897	Reg. voter (some owners)	3-5, voter / freeholder	GO/Rev: 2/3 dir / 1/2 vote; < 4% value; notes/warrants	Rates, leases, prop. sale, power, other	AdVal*: land, special tax: 2/3	Surplus, limits w/acquired rights			
Municipal Water District (1911)	44	1911	Reg. voter, imp. dist: 1/\$1 value	5, dist residents	GO: 2/3, Imp: 1/2 value; 5yr notes < \$3m/3% value, 10yr notes < \$3m/1%	Rates/standby, leases, prop. sale, power	AdVal*, spec. tax: 2/3, revenue in lieu, gw charge	Surplus			
Public Utility District	40	1921	Reg. voter	3-5	GO/Rev: 2/3, < 20% value	Rates/standby, leases, prop. sale, power	AdVal except farm prod., spec. tax: 2/3	No limitation			
Reclamation District	26	1867	1 vote/\$1, proxy	3-7, owners	GO/Rev: 1/2; warrants	Rates/standby, leases, prop. sale	Benefit/other basis	Contiguous land			
Water Conservation District (1927)	46.3	1927	1 vote/acre, proxy	3-7	Rev: 1/2	Rates, approp. permit, prop. sales	AdVal < 0.25%	Distribute to dist land, but not ratably			
Water Conservation District (1931)	46.4	1931	Reg. voter	3-7, by div.	GO: 2/3, Rev: 1/2; 5yr notes < \$5M/2% value; warrants: spec. assess.	Rates, water rights, prop. sale/lease, zonal ag/gw rates, electricity	AdVal: land < 0.25%, benefit assmt: 51%/60% owners, gw charges	No provision			
California Water District	41	1911, 1951	1 vote/\$1; Reg voter if muni > 50%	< 11, owners	GO: 2/3 or no 1/2 protest; Rev: 1/2; warrants < 1/4% value w/4/5 board/1/2%	Rates, sales, prop. sale/lease, power	AdVal*: land w/ standby, specific tax / acre	Apportioned by acre, surplus. No water rights sales.			
Water Storage District	48	1921	1 vote/<\$100 assessed; proxy	5-11, owner	GO: 1/2 value or 2/3 board; warrants	Rates/sales, leases, prop. sale, power	Benefit assessments; interim project < \$5/acre	Water & rights not necessary to district			

* - Ad valorem taxes may be used to meet all deficits in these districts; otherwise may only be used for debt and fixed obligations.

agencies are more often engaged in flood control than water service based on a review of the Controller's Annual Report. Irrigation districts are the next most numerous institutional form, and the second most numerous agricultural water provider. The remaining district forms are either few in number (e.g. water storage and water conservation districts) or more often dominated by municipal users (e.g. municipal water and public utility districts).

Table 1 lists several aspects of the political structure, governance rules and financial considerations. Listed first are the *electoral rules*. Generally these types of special districts enfranchise either registered residents or landowners. Votes may be one-person/one-vote, one per landowner, per acre owned or per dollar assessed value. Next are the *governing board* requirements including membership and decision rules. *Bonding requirements* describe the vote thresholds necessary to approve general obligation (GO) and revenue (Rev) bonds, and the limitations on indebtedness, usually relative to assessed value within the district's borders. *Revenue sources* generally describe the types of revenues that a district might raise from charges, fees and tariffs. *Taxation powers* describes the limits on ad valorem and benefit-assessment property taxes, and the voting requirements for imposing these types of taxes. Limitations on standby charges also are listed. Finally, availability and restrictions on *outside water sales* are shown. In most cases, only sales of water "surplus" to district customers' needs are allowed.

4.1.1 Electoral Rules

As with most general and special district governments in California, water districts generally rely on a universal-franchise, one-person/one-vote system or “residential voting.”¹¹ Types of districts relying these rules (with some exceptions) include: community services, county water, irrigation, municipal water, public utility, and 1931 water conservation. In addition, specified water agencies¹², and California water districts which have a threshold where 50% of the assessable area is in non-agricultural use (California Water Code, Section 35041) also rely on this rule.¹³ For some irrigation (California Water Code, Section 20527.1, *et seq*) and county water districts (California Water Code, Section 30700.5, *et seq*), the franchise may be limited to only those owning land within the district.¹⁴

Another common method used by reclamation, water storage and agricultural-dominated California water districts enfranchises land owners, weights their votes by assessed value for the parcel (usually one vote per dollar value), and allows proxy voting in district elections. This type of voting is more reflective of that found in mutual water companies or corporations where voting rights and ownership in core assets are linked.

¹¹The passage of Proposition 218 in 1996 changes to voting rules on specific types of tax increases for many general and special district governments, including water and flood control districts, to account for either property ownership or expected service benefits.

¹²Antelope Valley-East Kern and Placer County Water Agencies in the survey data set.

¹³Five California water districts in the data set rely on this type of voting.

¹⁴No districts of this type were included in the data set, however Glenn-Colusa Irrigation District switched to this system in 1992 after the data was collected.

Only the 1927 water conservation districts limit voting to land owners and weight the votes on a per-acre basis. County water authorities, which are largely wholesale agencies, have appointed board members selected by the member agencies.¹⁵

4.1.2 Governing Board Members and Decision Rules

The number of board members ranges from three to eleven. Typically membership limitations mirror those of the voting requirements. In most cases, election may be at-large or by division, although the 1931 water conservation districts are restricted to election by division. Decisions generally can be made by majority vote.

4.1.3 Requirements on Bond Approval and Debt Limitations

In general these districts may issue either general obligation (GO) or revenue bonds. The former are financed from general tax revenues without linkage to any specific activity; revenue bonds are repaid from a specific revenue source such as water-use charges or property leases. Only the 1927 water conservation districts are restricted to issuing only revenue bonds. Other types of debt-financing instruments, such as short-term notes and warrants, are also specifically authorized for many of these districts.

GO bonds generally require a two-thirds majority from voters for approval. Districts which use assessed-value weighting (i.e., reclamation, and water storage districts) require only a 50% majority of voted assessments, and California water district boards may issue GO bonds if a majority of voters do not submit written protests.

¹⁵Only the San Diego County Water Authority is included in the data set with these characteristics.

Revenue bonds generally require only a majority vote for approval. In some cases, county water districts do require a two-thirds vote. Water storage districts are not specifically authorized to issue revenue bonds, although they are allowed to issue GO bonds, which are usually considered to be of superior investment-grade, with a majority vote in line with other districts' approval of revenue bonds.

Numerous limitations are placed on the districts' abilities to encumber assessed value, usually as a percentage or dollar-amount cap on total debt attributed to a specific type of instrument. For example long-term bond limits typically range from 3% to 20% of assessed value within a district. Limits may be higher for projects financed in a specific improvement district.

4.1.4 Revenue Sources

These are revenues sources available to a district beyond tax revenues, such as charges, fees, tolls and sales. All districts are authorized to collect rates for water service and sales, although some districts are not authorized to charge for "standby" service (i.e., water conservation, irrigation, county water, California water and water storage districts). Several districts may also lease or sell water (e.g. irrigation and California water districts). Property sales and leases also are generally allowed. Many districts may sell wholesale electric power (i.e., water agencies and authorities, municipal water, public utility, water conservation, California water and water storage districts), but only irrigation districts may make direct retail sales.

4.1.5 Taxation Power and Limits

Special districts rely almost solely on different types of property taxes. Ad valorem, which are based on a percentage of assessed value, and benefit-assessment, which allocates tax burdens based on projected benefits, taxes are the two most common. Ad valorem taxes, often with

assessment limits ranging from 0.25% to 1%, are available to all but the reclamation and water storage districts. These two districts must rely on benefits-assessment taxes. 1931 water conservation districts also may use benefit-assessment taxes. Many districts also may raise special assessment taxes, often with a two-thirds vote.

Assessed valuation may be limited to land only without improvements, which is often the case in agriculturally-oriented districts such as irrigation, county water, California water, water conservation districts. Public utility and community service districts treat agricultural land in this manner as well. Other districts may include various amounts of improvements as well.

4.1.6 Outside Water Sales

Generally sales of water outside district boundaries are limited to “surplus” water. However, at least four types of districts may make outside sales. Public utility districts apparently have no limitations on sales and sales are specifically authorized. The 1927 water conservation districts may distribute water to the land within the district to be disposed of by the land owners. Water storage districts may sell water and rights not necessary for the uses and purposes of the district. And reclamation districts may sell to contiguous lands. On the other hand, irrigation and California water districts may only sell surplus water within the limits of acquired water rights. Community service and 1931 water conservation districts have no provisions for outside sales. The provisions for water sales appear to have little or no correlation with the district’s electoral rules.

4.2 The District Data Set

The base data set for the empirical analysis is drawn from a survey conducted by the University of California at Berkeley, Department of Agricultural and Resources Policy and Economics. The survey covered 128 districts. The survey methodology and a partial summary of results is included in a department working paper (Zilberman et al. 1992), and an analysis of how the districts altered their behavior during the drought was later published (Zilberman, MacDougall, and Shah 1994).

The survey data set was supplemented with district-specific information from two other sources. The first was the ACWA membership list, which supplied further addresses and contacts, all activities undertaken by the districts, and information on agricultural and municipal customer usage and rates. One-hundred eight districts on the ACWA list were also included in the survey data set. The second was the State Controller data on special districts' financial transactions for the 1991-1992 fiscal year. One-hundred twenty-seven districts in the survey data set had supplied the State Controller with financial data. This source was also used to pinpoint the primary county and regional location

A third source was used to add data on electoral rules. Which voters are eligible in local elections, and how votes are weighted and counted was compiled by district type from the CDWR Bulletin 155-94 (California Department of Water Resources 1994). The data set was modified where the Water Code either had provisions specifically relating to a district or making exceptions dependent on the composition of the district (e.g., in Section 35041 for California Water Districts).

4.2.1 Geographical Distribution of Districts by County and Region

Table 2 shows how the districts in the data set are distributed among twenty-nine counties¹⁶ and seven regions in California. The largest concentrations of districts are in San Diego (13), Tulare (12), Fresno (11) and Kern (11) counties. All other counties have six or less. Most of the districts are located in four regions—the Sacramento and San Joaquin Valleys, the Tulare Lake Basin and Southern California, with 84% of respondents in these regions. Over 60% are located in the Central Valley. This distribution reflects the agricultural orientation of the initial survey since the majority of California's agricultural activity is located there.

Table 3 shows the distribution of land-owner-enfranchised districts in the data set. All but one of the forty-two districts of this type are located in the three Central Valley regions. The Sacramento Valley at the north end has almost the same number as the Tulare Lake Basin at the southern end. Kern county has the largest number, ten, which reflects the seven water storage districts located there. Tulare and Fresno county have five each. The concentration in the Central Valley of both types is apparent, along with the dominance by the region of land-owner-based electoral rules. Due to large and widespread urban activity in Southern California, land-owner-based electoral rules have difficulty surviving legal and political tests and none are shown in the data set despite the relatively high proportion of all districts located in the region.

¹⁶California has fifty-eight counties total.

Table 2
Survey Data by County

No. County	Data Set	All Districts						
		Mountain	Central Coast	Sacramento Valley	San Joaquin Valley	Tulare Lake Basin	Southern California	Inland Empire
4 Butte	5	-	-	5	-	-	-	-
6 Colusa	4	-	-	4	-	-	-	-
7 Contra Costa	3	-	3	-	-	-	-	-
9 El Dorado	1	1	-	-	-	-	-	-
10 Fresno	11	-	-	-	11	-	-	-
11 Glenn	4	-	-	4	-	-	-	-
13 Imperial	2	-	-	-	-	-	-	2
15 Kern	12	-	-	-	-	11	1	-
16 Kings	4	-	-	-	-	4	-	-
19 Los Angeles	2	-	-	-	-	-	2	-
20 Madera	1	-	-	-	1	-	-	-
24 Merced	4	-	-	-	4	-	-	-
29 Nevada	1	1	-	-	-	-	-	-
30 Orange	5	-	-	1	-	-	4	-
31 Placer	1	1	-	-	-	-	-	-
33 Riverside	6	-	-	-	-	-	-	6
34 Sacramento	3	1	-	2	-	-	-	-
35 San Benito	1	-	1	-	-	-	-	-
37 San Diego	13	-	-	-	-	-	13	-
39 San Joaquin	6	-	-	-	6	-	-	-
42 Santa Barbara	6	-	-	-	-	-	6	-
45 Shasta	3	3	-	-	-	-	-	-
47 Siskiyou	2	2	-	-	-	-	-	-
48 Solano	2	-	-	2	-	-	-	-
50 Stanislaus	4	-	-	-	4	-	-	-
51 Sutter	2	-	-	2	-	-	-	-
54 Tulare	12	-	-	-	-	12	-	-
56 Ventura	3	-	-	-	-	-	3	-
57 Yolo	4	-	-	4	-	-	-	-
Regional Totals	127	9	4	24	26	27	29	8
		7.0%	3.1%	18.9%	20.5%	21.3%	22.8%	6.3%

Table 3
Survey Data by County

Land Owner-Enfranchised Districts

No.	County	Data Set	Mountain	Central Coast	Sacramento Valley	San Joaquin Valley	Tulare Lake Basin	Southern California	Inland Empire
4	Butte	3	-	-	3	-	-	-	-
6	Colusa	2	-	-	2	-	-	-	-
7	Contra Costa	-	-	-	-	-	-	-	-
9	El Dorado	-	-	-	-	-	-	-	-
10	Fresno	5	-	-	-	5	-	-	-
11	Glenn	3	-	-	3	-	-	-	-
13	Imperial	1	-	-	-	-	-	-	1
15	Kern	10	-	-	-	-	10	-	-
16	Kings	2	-	-	-	-	2	-	-
19	Los Angeles	-	-	-	-	-	-	-	-
20	Madera	-	-	-	-	-	-	-	-
24	Merced	2	-	-	-	2	-	-	-
29	Nevada	-	-	-	-	-	-	-	-
30	Orange	-	-	-	-	-	-	-	-
31	Placer	-	-	-	-	-	-	-	-
33	Riverside	-	-	-	-	-	-	-	-
34	Sacramento	1	-	-	1	-	-	-	-
35	San Benito	-	-	-	-	-	-	-	-
37	San Diego	-	-	-	-	-	-	-	-
39	San Joaquin	1	-	-	-	1	-	-	-
42	Santa Barbara	-	-	-	-	-	-	-	-
45	Shasta	-	-	-	-	-	-	-	-
47	Siskiyou	-	-	-	-	-	-	-	-
48	Solano	1	-	-	1	-	-	-	-
50	Stanislaus	-	-	-	-	-	-	-	-
51	Sutter	2	-	-	2	-	-	-	-
54	Tulare	5	-	-	-	-	5	-	-
56	Ventura	-	-	-	-	-	-	-	-
57	Yolo	4	-	-	4	-	-	-	-
	Regional Totals	42	0	0	16	8	17	0	1
			0%	0%	38.1%	19.0%	40.5%	0%	2.4%

Table 4 shows the distribution by district type across the regions. The total population of districts, as of the 1991-1992 fiscal year, is shown next to the number in the sample data set. A high proportion of a district-type's population was captured in the case of the California water (21%) and irrigation (46%) districts.¹⁷ The community services districts are all in the Mountain region of northern California, reclamation districts are all in the Sacramento Valley, and water storage districts are all in the Tulare Lake Basin. Municipal water districts are concentrated in the two most southern regions, reflecting a preponderance in San Diego county. 1931 water conservation districts are mostly in Southern California, as are the county water agencies. The three dominant types in the data set—California water, county water and irrigation districts—appear to be well distributed across the state. However, note that all but one of the California water districts located outside of the Central Valley rely on universal franchise or “residential voting” because the district’s assessed area is more than 50% dedicated to non-agricultural uses.

¹⁷This high sample proportion leads to an adjustment in the sample variance for small populations.

Table 4
Survey Data by District

Code By District	Pop.	Data Set	All Districts						
			Mountain	Central Coast	Sacramento Valley	San Joaquin Valley	Tulare Lake Basin	Southern California	Inland Empire
5 Community Services	305	2	2	-	-	-	-	-	-
26 Reclamation	156	6	-	-	6	-	-	-	-
40 Public Utility	54	1	-	-	-	-	-	1	-
41 California Water	157	33	1	-	10	8	9	3	2
42 County Water	189	14	-	2	2	1	1	7	1
44 Municipal Water (1911)	41	11	-	-	-	-	-	8	3
45 Water Agency	33	3	1	-	-	-	-	2	-
46.3 Water Conservation (1927)	14	1	-	-	-	-	1	-	-
46.4 Water Conservation (1931)	14	4	-	-	-	1	-	3	-
48 Water Storage	8	7	-	-	-	-	7	-	-
52 Irrigation	98	45	5	2	6	16	9	5	2

4.2.2 State Controllers' Financial Transaction Data

The basis of the subsequent analysis is financial data provided from the State Controller (Davis 1993). Most of the data on individual districts was drawn from Table 23 in the State Controllers' Report, "Water - Operating Statement and Changes in Fixed Assets." For districts which also act as electric utilities, data were taken from Table 19, "Electric - Operating Statement and Changes in Fixed Assets." Additional information on the number of districts, relevant statutory authorization, and primary county location was also used.

Table 23 in the Report separates revenues and expenditures into six general categories: (1) operating revenues; (2) operating expenses; (3) non-operating revenues; (4) non-operating expenses;

(5) fixed assets; and (6) accumulated depreciation. The first four categories were used in this analysis.

Operating revenues include water sales, categorized by end-user including “irrigation” and water services including fire prevention and groundwater replenishment. The “other” category often is the largest revenue source, however, rendering these revenue breakdowns imprecise.

Operating expenses include water supply purchases and pumping, treatment, distribution, and general expenses for customers and management. Districts appear not to follow a standard practice in assigning these costs to various categories, particularly between customer service and administrative.

The Controllers’ Report also includes depreciation under this category. Because depreciation of a fixed-capital expenditure is an accounting convention which does not vary with operations, and since depreciation is representative of the principal included along with interest in debt repayment, this expense category was moved to non-operating expenses in later calculations.

Non-operating revenue includes outside income such as investment interest and leases as well as various tax revenue sources such as ad valorem and benefit assessment taxes, and specific debt repayment taxes.

One ambiguous category which is actually quite significant is “other non-operating revenues.” This source can be quite significant, for example, Imperial Irrigation District received 58% of its total revenues in this category—\$50 million out of \$86.5 million. Unfortunately, no notes are included on possible sources of these apparent windfalls. These revenues were excluded in the final calculation of total revenues.

Non-operating expenses include interest on short and long-term debt, judgements, and various taxes. The depreciation expenses were moved to this category for this study, as discussed above.

Net income equals total revenues minus total expenses. In calculating total revenues in the analysis, net income was treated as a non-operating revenue source if net income was less than zero. This treatment reflects the fact that the district would have to draw from its financial assets to cover expenses in this situation. In the case where net income was positive, revenues were not adjusted.

4.2.3 Data Set Statistics

Table 5 summarizes several key statistics by district type from the Controller's Report. It also summarizes by electoral rules. The averages and standard deviations for the sample population is shown. After the type, code number and sample size, the ratios of operating revenues and expenditures to total expenditures, the amount of operating revenues recovered from irrigation, and the net income ratios are shown.

Table 5							
Water District Survey Summary - Controllers' FY 1991-92 Financial Data							
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
By District Type	Controller Dist Type	Sample	Oper. Rev / Expend.	% Oper. Expend. / Total Exp	%Ag. Rev / Oper Rev	%Net Inc / Exp.	% Adj Net Inc / Exp
<i>Averages</i>							
Community Services	5.1	2	98.9%	76.0%	21.5%	11.2%	10.5%
Public Utility	40.1	1	105.1%	82.2%	42.3%	7.5%	-0.4%
California Water	41	33	110.0%	74.7%	69.1%	16.3%	8.6%
County Water	42	13	122.7%	77.8%	31.8%	34.3%	21.6%
Municipal Water	44	11	104.8%	80.6%	40.7%	46.9%	14.9%
Water Storage	48	7	90.0%	89.1%	71.1%	2.7%	0.5%
Irrigation	52	45	84.2%	82.2%	71.9%	6.5%	-3.1%
<i>Standard Deviation</i>							
		Pop.					
Community Services	5.1	305	17.0%	0.2%	0.2%	18.8%	19.8%
Public Utility	40.1	54	0.0%	0.0%	0.0%	0.0%	0.0%
California Water	41	157	92.3%	5.2%	13.5%	74.5%	74.4%
County Water	42	189	14.3%	1.6%	16.0%	10.8%	6.0%
Municipal Water	44	41	2.8%	0.5%	5.8%	26.8%	3.2%
Water Storage	48	8	6.0%	0.1%	8.2%	2.4%	2.8%
Irrigation	52	98	10.3%	2.3%	10.4%	11.4%	7.9%
<i>Average</i>							
By Voting Franchise / Weight	Franchise	Sample					
Land Ownership / Assessed Value	Land	39	101.3%	77.7%	76.6%	10.9%	2.8%
Registered / Popular	Reg.	84	94.9%	79.2%	52.4%	21.0%	6.9%
<i>Standard Deviation</i>							
		Total					
Land Ownership / Assessed Value	Land	313	85.3%	5.2%	13.0%	68.7%	69.0%
Registered / Popular	Reg.	382	12.6%	2.6%	14.6%	16.8%	9.5%

Column (4) shows the ratio of operating revenues to total expenditures after the adjustments described above (Op Rev / Expend). These values are the dependent variable in the subsequent analysis because it measures the amount of sales-derived revenue that a district relies on to meet its total obligations. Note that this variable is not bounded by either zero or one. A district may provide

refunds to its members from other revenues, thus producing negative operating revenues.¹⁸ And as clearly shown by the averages for some districts, operating revenues can exceed expenditures. County water districts have the highest average operating revenue ratio, followed by California water districts. Irrigation districts show the lowest average ratio. The average for districts using land-owner-enfranchised electoral rules is higher than the popular-vote districts.

Column (5) shows the percentage of total expenditures accounted for by operating expenditures ($Op\ Exp / Exp$) as redefined above. The standard deviations within district types are remarkably small indicating that the relative costs among districts do vary substantially. Even the averages among districts and between electoral rules are spread over a relatively small range.

Column (6) shows the proportion of operating revenues collected from irrigation customers ($Irrig\ Rev / Op\ Rev$). This category reflects at least partially the relative dominance of agriculture within a district. Irrigation, water storage and California water districts show substantially higher irrigation revenue proportions than the remainder of the data set. This is also true for the land-owner-enfranchised districts, which by California law must be agriculturally dominated. For this reason, a separate econometric analysis was conducted for irrigation and California water districts, as discussed below, to distinguish the effects of agricultural-dominance on the dependent variable.

However, this measure is probably not fully reflective of the proportion of customers for two reasons. First, not all districts properly categorize their revenues, as evidenced by the number of responses showing “other sales.” We have no way of knowing if these districts have similar or different distributions of customers. Second, districts depend differentially on operating revenues, as this discussed in this study. The proportion of agricultural customers may be correlated with the

¹⁸In the Controller’s Report, some districts show negative revenues in some categories.

relative dependence on operating revenues. Thus, this variable is not used as an independent variable in the econometric analysis.

Columns (7) and (8) show two measures of net income. The first is the net income as reported in the Controller's Report. The second is adjusted after subtracting the "other non-operating revenue" category which is undefined and often quite large for particular districts. This adjustment shows a rather large effect for California water, irrigation, county water and municipal water districts, and reduces the standard deviation substantially in the latter two cases.

4.3 Statistical Relationships Among Key Variables

The data set contains a number of variables that describe a range of activities and characteristics of the districts. The 1992 district survey gathered data on farm size, water supply sources and infrastructure development, water deliveries over the 1987 to 1991 period, irrigation methods, cropping patterns over the five-year period, and water charges. These data were manipulated and combined with the financial data from the State Controller to develop the final data set for the 127 districts.

4.3.1 Relationships Among Financial and Institutional Characteristics and Farm Size

Table 6 shows the correlation between key financial and institutional characteristics of the districts in the data set and the average size of the farms within each district. The institutional characteristics include dummy variables for whether a district relies land-owner franchise and whether it sells either wholesale or retail electricity. The next three variables are the total district expenditures on water utility services as a measure of district size, the ratio of operating revenues to total

expenditures, and the percentage of total expenditures attributable operations. The last two variables show the average irrigated and total acreage per farm in each district

The correlation analysis indicates that popular-vote districts are more likely to provide electric sales and to be somewhat larger than land-owner-vote districts. Also larger districts also are more likely to sell electricity, which is consistent with need for water projects to be sufficiently large to generate hydropower economically, and the need for a larger administrative staff to manage an electric utility. The next two variables measure financial performance ratios are largely uncorrelated with most other district characteristics, although the percentage operating expenditures is negatively related to district size. This is probably reflective to district scale—as infrastructure investment increases, operational costs increase at less than a proportional rate. In contrast though, operating revenues are slightly negatively correlated with operating expenses, indicating that districts do not necessarily link revenues and expenses in establishing rates and charges.

Table 6 Correlation Coefficients Among District Financial Measures and Average Farm Size									
<i>Variables</i>	<i>N</i>	<i>Mean</i>	<i>S.D.</i>	Land-Own. Vote	Electric Utility	Expend.	Op Rev / Exp	Op Exp / Exp	Irr Acres / Farm
Land-Own. Vote	105	35.2%	NA	1					
Electric Utility	105	13.3%	NA	-.172	1				
Expenditures	105	\$0.995M	\$2.34M	-.187	.392	1			
Op Rev/Exp	105	95.2%	66.4%	.056	-.091	-.013	1		
Op Exp/Exp	105	79.1%	18.4%	.015	.014	-.204	-.088	1	
Irr. Ac./Farm	105	539.9	1462.1	.376	-.103	-.004	-.076	.189	1
Acres/Farm	105	815.5	2101.1	.304	-.107	.074	-.064	.114	.932

Average size farm and the acreage irrigated per farm is strongly correlated. Because data on irrigated acreage is probably better than on actual farm size, the irrigated acreage is used the proxy for farm size.

Farm size tends to be large in districts with land-owner franchise. This relationship may reflect one of several possibilities. The first could be the desire of larger land owners to better influence district policies. However, the second one is that the more urbanized districts, which tend to have smaller farm operations, are required to use popular-vote electoral rules. Thus, the districts which can use land-owner enfranchisement will tend to have larger farms. Or the relationship may be simply geographical, reflecting the tendency of larger farms to be located in the Central Valley where almost all of the land-owner-enfranchised districts are located.

One way to assess the possible source of this relationship is to isolate the analysis to the most agriculturally-dominated districts, irrigation and California water districts, and those located in the three Central Valley regions and the Inland Empire (i.e., Imperial and eastern Riverside counties). Table 7 compares the means and correlation coefficients from all districts in the data set to those for irrigation and California water districts located in the Central Valley and Inland Empire. The results differ only slightly with the narrowing of the analysis, indicating the relationship between electoral rules and average farm size appear to be invariant with urbanization or location. This relationship appears to be most consistent with the first proposition that large land owners prefer an electoral system in which they can wield greater direct political influence.

Table 7
Correlation Coefficients Between Electoral Rules and Average Farm Size
for All Districts vs. Central Valley and Inland Empire
Irrigation and California Water Districts

<i>Variables</i>	<i>Mean</i>		Land-Owner Vote		Irrigated Acres/ Farm	
	<i>All</i>	<i>CV & IE</i>	<i>All</i>	<i>CV & IE</i>	<i>All</i>	<i>CV & IE</i>
N	105	58	105	58	105	58
Irrigated Acres/Farm	539.9	668.0	.376	.330	1	1
Acres/Farm	815.5	778.1	.304	.325	.932	..995

4.3.2 Relationship Among Institutional Characteristics and Water Supply Sources and Infrastructure

Table 8 shows the correlation coefficients among district characteristics such as voting rules, size and farm size, and storage and delivery infrastructure and surface water sources. Popular-vote districts tend to have a higher level of investment in storage, pipeline and lined canals. These districts also tend to rely more on appropriative rights for their water sources. Reliance on stream diversion naturally leads to the conclusion that storage facilities would be larger in these districts. However, the amount of pipeline is also strongly correlated with storage as well. On the other hand, while lined canal systems are relatively larger in popular-vote districts, the levels are uncorrelated with either of the other infrastructure measures. The tendency toward lined canals by popular-vote districts indicates that strong intensive economies of scale may not exist in conveyance facilities, consistent with the second condition in Proposition 8.

Table 8									
Correlation Coefficients Among District Characteristics and Water Supply Infrastructure and Sources									
<i>Variables</i>	<i>N</i>	<i>Mean</i>	<i>S.D.</i>	Land-Own. Vote	<i>Expend.</i>	<i>Irr. Ac. / Farm</i>	<i>Storage</i>	<i>Pipe line</i>	<i>Lined Canal</i>
Land-Owner Vote	69	39.1%	NA	1					
Expenditures	69	\$0.862	\$2.17M	-.137	1				
Irrigated Acres/Farm	69	517.9	1333.1	.339	-.077	1			
Storage AF/Acre	69	1.37	8.24	-.115	-.024	-.062	1		
Pipeline Mile /100 Acres	69	0.027	0.110	-.182	-.003	-.090	.949	1	
Lined Canal Mile /100 Acres	69	0.068	0.188	-.147	.048	.021	-.013	.093	1
CVP Class 1	69	38.1%	45.0%	.109	-.122	-.198	-.131	-.121	-.216
CVP Class 2	69	7.6%	21.6%	-.160	-.088	-.103	-.059	-.057	.107
CVP Exchange	69	2.8%	14.3%	-.091	-.047	-.041	-.033	-.047	-.031
SWP	69	14.5%	34.1%	.118	.068	.570	-.051	-.068	-.035
Appropriative Rights	69	29.3%	44.1%	-.226	.172	-.144	.242	.261	.230

The relationship of popular-vote districts and appropriative rights probably is indicative of the fact that these districts were formed before land-owner enfranchised districts since these districts would be better able to access appropriative rights. That Central Valley Project Exchange contractors, who relinquished their appropriative and pre-1914 rights to the U.S. Bureau of Reclamation in exchange for favorable water supply contracts, also slightly tend to be popular-vote districts is consistent with this observation.

Receiving water project supplies, either from the CVP or SWP is negatively correlated with infrastructure size. This might reflect the fact that much of the delivery infrastructure for these contractors is paid for through project charges rather than by direct district investment.

An interesting relationship is irrigated acreage to CVP Class 1 and SWP water deliveries. The negative relationship in the first case is consistent with CVP “hammer clause” rules requiring that farm “units” be less than 960 acres to be eligible for these contracts (Wahl 1988). This limitation does not hold for either the Exchange contracts or more expensive Class 2 deliveries. However, these districts tend slightly to use the land-owner franchise, contrary to the overall tendency of districts with larger farms to rely on this electoral rule. In contrast, districts with SWP contracts strongly tend to have larger farms. This reflects the lack of rules on farm size and eligibility for this water project. However, these districts are not any more likely to use land-owner franchise rules than the districts with CVP Class 1 deliveries.

4.3.3 Relationship of Institutional Characteristics to Irrigation Efficiency and Cropping

Table 9 shows the correlation coefficients among the three institutional characteristics shown in Table 8, irrigation efficiency, and the proportions of crops planted in each district. Efficiency is the weighted average for each of four methods—drip, sprinkler, furrow and burrow (Caswell, Lichtenberg, and Zilberman 1990). The five crop types are classified from the individual crops identified in the survey responses.

<p style="text-align: center;">Table 9 Correlation Coefficients Among District Characteristics, Irrigation Efficiency and Crop Patterns</p>							
<i>Variables</i>	<i>N</i>	<i>Mean</i>	<i>S.D.</i>	Land- Owner Vote	<i>Expend.</i>	<i>Irrig Acres. / Farm.</i>	<i>Irrig. Efficiency</i>
Land Vote	90	34.4%	NA	1			
Expenditures	90	\$1.09M	\$2.51M	-.194	1		
Irrig. Acres/Farm	90	474.0	1258.2	.375	.014	1	
Irrig. Efficiency	53	69.4%	12.6%	-.290	.063	-.021	1
Orchards	90	45.6%	39.5%	-.365	.040	-.069	.756
Field Crops	90	28.3%	32.2%	.505	-.194	.222	-.588
Pasture	90	14.8%	20.8%	.063	.184	-.093	-.647
Produce	90	6.1%	11.8%	-.037	.120	-.082	-.052
Nursery	90	3.2%	11.0%	-.142	-.010	-.078	.322

Irrigation efficiency generally has the expected strong positive correlations with orchard and nursery crops, which have the highest product value per acre (Mitchell 1993), and negative with field and pasture crops. Produce crops, such as vegetables, berries and melons, show no relationship with irrigation efficiency, which is somewhat surprising given the relative output value per acre.

The relationship of crop patterns and irrigation efficiencies to electoral rules also is interesting. Orchard crops tend to be located in districts using popular-vote rules while field crops tend to be in land-owner enfranchised districts. In addition, larger farms tend to grow more field crops, consistent with the fundamental economics of these various crops. As a result of these two relationships, irrigation efficiency is positively correlated with popular-vote rules. At first glance, this would seem to be inconsistent with Proposition 6 which states that popular-vote districts will tend to set lower water-use charges, which in turn should encourage lower, not higher, efficiencies. However, Green,

et al (1996), found that water pricing had a relatively small effect on irrigation choices. According to Proposition 5, if orchard farming requires the use of more local inputs such as equipment, fertilizer and labor relative to field crops, then district managers will tend to set rates which encourage this crop choice. This is consistent with past findings that orchard crops have substantially higher employment rates per acre-foot of water applied (Mitchell 1993) and a regional economic analysis of the Sacramento Valley found a higher ratio of in-region purchases for the “fruit and nuts” subsector than for “feed grains” (Moss et al. 1993, Appendix C). The improvement in irrigation efficiency would simply be a byproduct of this tendency toward local-input-intensive crops in popular-vote districts.

4.4 Testing A Political-Economy Model of District Management Decisions.

A set of eight propositions are developed from analyzing the theoretical model presented here. Propositions 1 and 2 define decisions rules for a theoretical constrained optimal cooperative. Proposition 3 compares the conditions under which an assessed-value-weighted voting district will arrive at the same decision rules as constrained optimal cooperative. The subsequent five propositions present hypotheses which could be tested with empirical data and analysis. However, the presently available data is only sufficient to test to of the propositions, Propositions 5 and 6. Some preliminary inferences can be drawn for Propositions 4 and 8, and the data is sufficiently confounding preclude any assessment of Proposition 7.

4.4.1 Proposition 6: Relative Reliance on Water Sales Revenues

The first proposition to be tested is Proposition 6 as to whether universal franchise/popular-vote (PV) districts are less likely to rely on water-use charges than land-owner-franchised/assessed-value-weighted (AVV) districts. Another way to state this proposition is: PV districts meet a lower proportion of their total expenditures with operating revenues than AVV districts. This assumes a close link between the use of water charges and operating revenues, and between fixed charges and taxes and non-operating revenues.

Proposition 6 presents a simple test comparing the ratio of water-use and acreage-based charges. The hypothesis can be stated as:

$$H_0: \frac{w^\Gamma}{l^\Gamma + t^\Gamma \cdot y_i} = \frac{w^\Upsilon}{l^\Upsilon + t^\Upsilon \cdot y_i}$$
$$H_1: \frac{w^\Gamma}{l^\Gamma + t^\Gamma \cdot y_i} > \frac{w^\Upsilon}{l^\Upsilon + t^\Upsilon \cdot y_i}$$

We have assumed in this analysis that “water-use charges” are equivalent to “water sales” and “water service” as defined in the State Controller’s Report. We can then test equivalently what proportion of total district revenues are derived from “operating revenues” as shown in the State Controllers’ Report. As discussed above, we have included negative net income as a fixed revenue source equivalent to draws on “non-operating income.” The resulting dependent variable is the ratio of operating revenues to total expenditures (*OR/Exp*).

Note that this dependent variable is independent of regional variations in water pricing. A high-cost district can have the same ratio as a low-cost district. This avoids the problem of having to trace the numerous local and institutional factors which create pricing differentials. McDowell and

Ugone developed a similar model but assessed the absolute dollar spending on operating expenses, and thus had to account for regional disparities across the Southwest U.S.

Nevertheless, both economic theory and an analysis of the correlation coefficients leads to the conclusion that several other key variables may affect this ratio. The first is whether the district also delivers wholesale or retail electricity service. These districts may be able to cross subsidize between electric and water utility service (Chatterjee 1994), and these districts are likely to be larger than comparable non-electric districts. Whether a district is also an electric utility (E) is represented as a (0,1) intercept dummy variable and added as a slope dummy to the parameter (Judge et al. 1988, p. 429) on district size to account for economy of scope. The second factor is the economy of scale inherent in district operations (Bain, Caves, and Margolis 1966). Larger districts are likely to have a lower costs per acre-foot delivered. However, we do not expect a linear relationship due to the law of diminishing returns; rather, we expect the magnitude of the effect to diminish with increasing district size. In this case, the natural log of total expenditures ($Log(Size_t)$) is used to represent economy of district scale. The third is the relative size of farms in the district. Proposition 4 hypothesizes that larger farm operations will prefer a greater reliance on water-use charges. Again, we do not expect the effect to be linear, and the natural log of average irrigated acreage per farm is used ($Log(AIAF)$). Based on Proposition 4, a slope dummy is added to assess the effect of larger farm size within land-owner-franchised / assessed-value-weighted voting districts. Finally, a (0,1) dummy variable is added to distinguish districts using a land-owner-franchised / assessed-value-weighted voting scheme (AVV_t) from those using a universal-franchise / popular-vote system. The model used to test Proposition 6 is:

$$(47) \frac{OR_i}{Exp_i} = \beta_1 + \beta_2 * AVV_i + \beta_3 * Log(Size_i) + \beta_4 * (E_i * Log(Size_i)) + \beta_5 * (AVV_i * Log(AIAF_i)) + e_i$$

Table 10 shows the results for two models, along with the test statistic probability values.¹⁹ The first model evaluates Proposition 6 for most districts with usable data in the sample.²⁰ A second model isolates the effect for two different district forms. While both types are districts are generally dominated by agricultural activities, California water districts use assessed-value voting and irrigation districts use the popular vote method. The second model eliminates those California water districts now using residential-voting rules.

¹⁹The models were estimated using the SHAZAM Econometrics Computer Program, Version 7.0.

²⁰Certain district types were removed from the regression model data set. Community service (two) and public utility (one) districts were removed due to the multitude of functions they perform and their small number in the data set. Reclamation districts (six) were removed due to their apparent focus on flood control and the lack of financial data in Table 23 of the Controller's Report in many instances. Water agencies (three) were removed due to small numbers in the data set and their nature as a wholesaler overlaid on other retail districts.

Table 10 Operating Revenue Ratio Models								
Model	β_1	β_2	β_3	β_4	β_5	DF	R ²	F-stat.
<i>Model (1) Parameters</i>	-0.080	1.218	0.072	-0.018	-0.176	106	0.1029	3.04
t-stat.	0.438	0.002	0.020	0.066	0.003			
p-value								
F-stat.		0.003	0.040	0.131	0.006			0.028
p-value								
<i>Model (2) Parameters</i>	-0.447	2.028	.0941	-0.021	-0.283	73	0.1465	3.13
t-stat.	0.265	0.001	0.030	0.081	0.003			
p-value								
F-stat.		0.001	0.060	0.162	0.005			0.027
p-value								

Except for the intercept parameter, β_1 , all of the model parameters exhibit relative high probabilities of being different from zero. The intercept is probably collinear with the district size because the size is relatively large and constant value relative to the other variables in the model. As a result, the t-statistic on β_3 understates the probability that this parameter differs from zero. The R² and F-statistics indicate that each model is statistically significant at the 5% level.

In addition, a joint null hypothesis is tested for each model that the slope parameters $\beta_4 = \beta_5 = 0$ (Judge et al. 1988, p. 434; White 1992, p. 91). For Model (1) with 5 parameters and 106 degrees of freedom, the F-statistic probability value equals 0.0097. For Model (2) with 5 parameters and 96 degrees of freedom, the F-statistic probability value equals 0.012. These probability values indicate a strong probability that both of these parameters are significantly different from zero in both models.

Both Models (1) and (2) support Proposition 6 that electoral rules do affect district decisions on how to collect revenues. The direction of β_2 is consistent with the hypothesis that land-owner-enfranchised districts will tend to rely more on water sales revenues to meet total expenditures. Model (2) indicates that the electoral effect may be stronger in agriculturally-dominated districts such as irrigation and California water districts.

In both models, larger districts tend to rely more on operating revenues. As previously mentioned the operating revenues and operating expenditures are somewhat negatively correlated. The theory presented in this analysis makes no conclusions about how district size should affect the balance between water-use rates and land-based charges and taxes.

On the other hand, economies of scope that allow cross subsidies from electricity operations to water service are evident. The addition of electricity sales reduces the size effect and is consistent with other previous analyses (Chatterjee 1994).

Finally, increasing farm size in land-owner-enfranchised districts exerts a depressing effect on the use of water sales revenues in a district. This is inconsistent with Proposition 4. However, this may be in part an artifact of the data set being dominated by CVP-contractor districts. Table 7 shows that CVP Class 1 contracts tend to reduce the size of farms in a district, consistent with USBR rules, but that these districts also tend to use land-owner-enfranchisement rules. Another possibility is that the economies of scale in the conveyance system are sufficient that the costs typically allocated to an individual customer are decreasing faster than the desire for large land-owners to pay more through water sales than in land-based charges. These latter charges may be allocated in greater proportion to centralized district facilities and operations.

4.4.2 Proposition 5: District Manager Biases Toward Crop Choices

Proposition 5 states that managers of popular-vote districts will tend to set water rates that encourage the use of local resources in farming activity. An indicator of these policies would be a greater preponderance of local-input-intensive crops in these districts. A previous regional economic analysis indicated that orchard crops generate substantially more direct spending on agricultural support services than field crops (Moss et al. 1993). The resulting hypothesis is:

$$H_0: \frac{Orchard^{\Gamma}}{Field^{\Gamma}} \geq \frac{Orchard^{\Upsilon}}{Field^{\Upsilon}}$$
$$H_1: \frac{Orchard^{\Gamma}}{Field^{\Gamma}} < \frac{Orchard^{\Upsilon}}{Field^{\Upsilon}}$$

Two sets of models were developed to test Proposition 5. The models are again distinguished between assessing the entire data set and two district forms dominated by agricultural, irrigation and California water districts. The first set of models evaluates whether electoral rules influence the proportion of orchard crops within a district.. The second set evaluates whether electoral rules influence the proportion of field crops within a district.

According to Table 9, orchard crops are strongly associated with irrigation efficiency. The only potentially exogenous variable in the data set positively correlated with efficiency is the proportion of surface water supplies received from the State Water Project (*SWP*). The resulting model also includes an intercept dummy for whether the district uses a land-owner-enfranchisement rule (*AVV*).

$$(48) \quad Orchard_i = \beta_1 + \beta_2 * AVV_i + \beta_3 * SWP_i + e_i$$

Table 11 shows the parameters and test statistics for Models (3) and (4).

Table 11						
Orchard Crop Influence Models						
Model	β_1	β_2	β_3	DF	R ²	F-stat.
<i>Model (3)</i>	0.588	-0.308	0.000	47	0.161	4.51
<i>Parameters</i>						
t-stat.	0.0	0.004	0.362			
p-value						
F-stat.		0.008	0.724			0.023
p-value						
<i>Model (4)</i>	0.414	-0.144	0.000	34	0.045	0.80
<i>Parameters</i>						
t-stat.	0.001	0.151	0.339			
p-value						
F-stat.		0.302	0.678			0.353
p-value						

Model (3) appears to be significant at the 2.5% probability level, but Model (4) which focuses on just the two district forms does not appear to give significant results. The parameter estimate for the influence of electoral rules in Model (3) is consistent with Proposition 5 and statistically significant at the 1% level. Whether the district is a SWP contractor appears to have little influence over whether farmers in the district choose orchard crops.

The second set of models assesses the influence on the choice to grow field crops. Table 9 indicates a positive relationship between average farm size and the share of field crops. Given the relatively low revenue and value per acre, this relationship is consistent with economic theory that economies of scale would prevail in these operations. As with the models of district revenue sources, we expect that this scale effect diminishes with the size of the farm, so the natural logarithm of

average irrigated acreage ($L(AIAF)$) is used. The resulting model also includes an intercept dummy for whether the district uses a land-owner-enfranchisement rule (AVV).

$$(49) \text{ Field}_i = \beta_1 + \beta_2 * AVV_i + \beta_3 * L(AIAF_i) + e_i$$

Table 12 shows the parameters and test statistics for Models (5) and (6).

Table 12						
Field Crop Influence Models						
Model	β_1	β_2	β_3	DF	R ²	F-stat.
<i>Model (3)</i>	-0.162	0.147	0.083	51	0.385	15.96
<i>Parameters</i>						
t-stat.	0.070	0.061	0.001			
p-value						
F-stat.		0.122	0.002			0.000
p-value						
<i>Model (4)</i>	-0.113	0.119	0.084	37	0.324	8.87
<i>Parameters</i>						
t-stat.	0.205	0.146	0.004			
p-value						
F-stat.		0.292	0.008			0.000
p-value						

Both models appears to be significant at the 0.01% probability level, which probably reflects the inclusion of more than just a dummy variable as a significant explanatory variable. As in Model (3), the parameter estimates for the influence of electoral rules are consistent with Proposition 5 and statistically significant at the 10% level in Model (5) and 15% level for Model (6). As expected, farm size positively influences the proportion of district acreage devoted to field crops.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Findings

This study sets out a series of propositions about how governance rules affect the management incentives and decisions in special districts that supply water to agricultural customers. The first two propositions set out decision criteria that a aggregate net-wealth maximizing cooperative facing a non-profit budget constraint would use to determine the optimal level of water-use charges and property-based taxes and assessments. A third proposition says that a water district which uses land-owner-franchise / assessed-value-weighted voting (AVV) rules, under conditions consistent with empirical economic data, will also tend to use these rules because this voting scheme is consistent with incentives and benefit distribution in the constrained cooperative.

A fourth proposition states that larger landholders will tend to prefer relatively higher water-use charges than smaller landowners. The empirical analysis contradicted this statement, but this may have resulted from one of two causes. The data set was disproportionately drawn from districts which contract with the CVP for water supplies. USBR rules require that “farms” be smaller than 960 acres to receive the lowest-prices supplies, so these districts show smaller farms, which in fact may be managed jointly in larger “management units.” A second cause might be from an economy of scale for conveyance to larger farms. This scale economy may be decreasing per farm delivery costs faster than the desire of larger landowners to see water-use rates rather than property taxes.

The next two propositions compare incentives for managers between AVV and universal-franchise / popular-vote (PV) rule districts. The fifth proposition says that managers in PV districts

will tend to set water rates to encourage greater use of local inputs for farming, and as a result foster the growth of local-resource-intensive crops, such as fruit and nut trees. Econometric analysis supports this proposition. The sixth proposition makes a fundamental comparison of how much district managers rely on water sales to cover district expenditures. Empirical analysis of the hypothesized model supports the proposition that PV districts will tend to rely less on water sales than AVV districts.

The seventh proposition states that as irrigation efficiency increases in a PV district, managers will tend to rely more on property taxes and assessments. The complicated relationship of irrigation choice and institutional structure could not be disentangled using the data available here.

In the last proposition, two conditions were set out for when a PV district might have more or less investment in water-supply infrastructure than an AVV district. The nature of the scale economies for such infrastructure establishes the decision rules. While not analyzed empirically, the data could be supplemented to assess the likely type of scale economies that these decision rules imply.

5.2 Conclusions and Policy Recommendations

In general the empirical analyses support the propositions that the rules governing district elections influence the decisions that district board members and managers make. These differences in institutionally-derived incentives have several important policy implications.

First, AVV districts are more likely to rely on water sales and water-use charges. Given that the recent trend to encourage agricultural water conservation through increased water rates, (e.g.,

the USBR Best Management Practice Guidelines), this means that AVV districts will be more likely to adopt these types of measures. That Westlands and Broadview Water Districts, which are AVV districts, are at the forefront in adopting agricultural BMPs is consistent with this finding. Conversely, PV districts, such as irrigation districts, are likely to be more resistant to adopting BMPs, particularly ones that shift district revenues toward water sales.

Another implication is that AVV districts are likely to be willing to participate in water transfers outside of the district boundaries. These districts' members view water sales revenues, no matter the source, as beneficial.

PV districts are more likely to encourage input-intensive orchard crops. This means that local communities are more dependent on agricultural activity for their livelihood. These crops also tend to use more efficient irrigation technologies. These two effects tend to amplify the local influences from water transfers out of the district. These operations cannot easily reduce their water use due to the already high levels of efficiency without either fallowing or turning to groundwater. If either the land is fallowed or water costs increase, use of local resources is likely to decrease. Because of the tighter local linkage, this reduction will be felt more severely in these PV district communities.

5.3 Recommendations for Further Analyses

The empirical analysis presented here is somewhat limited in scope. It assesses only one of the propositions developed in this study and it looks at data from only one year, the 1991-1992 fiscal year. The survey data set provides data over a five-year period from 1987 to 1991, and State Controller financial data is available over this same time period. A pooled-time series analysis would

likely provide a richer view of how districts manage their finances over a longer period, particularly given the apparent large fluctuations in net income and availability of “other non-operating income.” Changes in cropping patterns, water use and water rates over this period also is available in the survey data set.

The State Controller data set also contains information on district debt loads and infrastructure investment, and financial data on other district activities such as flood control and electricity production. How electoral rules might influence these decisions might affect at least indirectly the differential reliance on operating versus non-operating revenues.

The data set could be supplemented with at least three more pieces of information. The first set is the year in which the district was founded, and the dates that the district began receiving water service from either of the large water projects, i.e., the Central Valley Project or the State Water Project. These date could be useful in sorting out whether the differences seen between districts is more reflective of electoral rules or of the contractual arrangements offered by the project managers, i.e., the U.S. Bureau of Reclamation and the California Department of Water Resources. The question is whether a particular political form conforms best with the contractual needs or that a contractual and investment arrangement dominates whatever electoral form was chosen. The problem is likely to be endogenous and require a more sophisticated econometric analysis than presented here.

The second set would come from overlaying locally-specific groundwater usage and depth data available from the CDWR’s CVPM mathematical-programming model. Data on “discrete analytic units” (DAUs) shows estimated groundwater usage rates and depth by local regions that usually encompass several districts in the Central Valley (Dale 1994; Hatchett 1994). Combined with the surface-water source data, the total water usage within a district could be estimated and

compared. A closer review of CVP and SWP deliveries to these specific districts also would be useful to derive a more accurate estimate of water consumption.

A third set would incorporate the soil type information also included in the CVPM model (Hatchett, Horner, and Howitt 1991; Howitt and Horner 1993) and shown to have a significant effect on the choice of irrigation technology and water application rates (Green et al. 1996). This information would help further distinguish between district characteristics.

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