# Economic Organization and the Lease-Ownership Decision in Water

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**Abstract**

This paper analyzes the lease-own decision for water using data on water transactions. Water is transferred through short-term and long-term leases as well as permanent ownership contracts. Water is a unique asset in that its supply is highly variable and its transfer and use affect third parties. We apply an ordered probit analysis to investigate the empirical determinants of contract type. We confirm that long-term and permanent contracts are more likely when investments in specific assets are required for conveyance. We also find that longer term arrangements are common when buyers with uncertain water supplies are purchasing from sellers with more certain rights. We do not find robust evidence supporting the hypothesis that short-term agreements are more likely when the costs of a transfer to third parties are potentially high.



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# 1 Introduction

The decision of whether an asset should be contracted for on a short-term or long-term basis is a classic economic organization problem (Coase, 1937; Williamson, 1979). It is akin to the decision to use the market or the firm to organize production. The incentives of both buyers and sellers when negotiating a contract are influenced by asymmetric information, asset specificity, and numerous other economic and political variables. Transaction cost economics predicts that the factors influencing contract choice will include much more than the simple economic variables affecting gains from trade under different types of contracts. Namely, contract choice is influenced by the potential for opportunistic behavior on the part of either buyers or sellers.

In this paper we examine the economic organization of water use by studying the lease-own decision. Water is most commonly transferred between users through three types contracts. First, short-term leasing is a common method of temporarily reallocating water. A short-term lease is a voluntary agreement between an owner of the water right and a willing lessee where a negotiated quantity is transferred at a single point in time. Second, longer term leasing is a contractual relationship where water is transferred each year up to the expiration of the contract. Both short-term and long-term leases do not involve transfer of the specific water right. The right is maintained by the seller throughout the contract period. Third, ownership (or sales) contracts are permanent agreements where a buyer purchases the legal right to divert a certain quantity each year into the future. Unlike leases, ownership contracts do transfer the actual water right.

At its heart, the lease-ownership decision in water is no different from choosing whether to contract for short-term or long-term use of an asset; a problem which has been widely studied in markets for coal (Joskow, 1985, 1987), inputs in the aerospace industry (Masten, 1984), agricultural assets (Allen and Lueck, 2002; Ford and Muser, 1994), trucking (Baker and Hubbard, 2001, 2003), and franchising contracts (Brickley, Misra, and Van Horn, 2006). The choice of short-term contracting or permanent ownership

of an asset is affected by many dimensions. Our empirical analysis of the lease-own decision for water transfer contracts serves as an application of economic organization theory to a unique type of asset. We look at asset specificity as a critical determinant of the choice of contract type. Some transfers are more likely to require dedicated assets in order for the water to be conveyed (transported) between sellers and buyers. Classic economic organization theory predicts that these transactions are more likely to result in longer term arrangements.

There are several characteristics of water which make the lease-own decision between buyers and sellers unique compared to studies of coal mines and trucks. Water is not a fixed asset, such as a coal mine or truck, but instead an asset whose size and quality are subject to substantial uncertainty depending on weather and hydrologic conditions. Water law reflects this uncertainty and thus also impacts western water transactions. Water rights are governed by a seniority system in which the right of an owner depends on a priority ranking (based on the date of the original claim) so that a 'senior' right has priority over a 'junior' right in a low water year (Getches, 1997).[1] A more senior right means the owner faces less uncertainty as to how much of the asset will actually be available for use. The uncertainty of water supply creates risk for transacting parties. Our empirical model considers the effects of an uncertain water supply on the choice of contract type.

Another unique feature of water are the third party effects which are tied to its use. Approximately 80% of water supply in western states is allocated to agriculture. Agriculture is therefore the dominant supplier for water transactions. Both rural agricultural communities and downstream irrigators benefit from agricultural water use. Rural communities are dependent on agricultural labor, input purchases, etc. Downstream irrigators benefit when water is applied to crops, as a portion of applied agricultural water returns to streams and is available for downstream use. Previous work on third

[1]There are numerous intricacies to the prior appropriation system which are beyond the scope of this paper. Getches (1997) is a good source for interested readers.

party impacts of water markets highlights some of the factors which create opposition to transfers by local community residents and downstream appropriators (Vaux and Howitt, 1984; Young, 1986; Hanak, 2005). Some third party effects are true externalities. For instance, transferring water out of a basin has the impact of reducing return flows to downstream users (Anderson and Johnson, 1986). Other externalities are pecuniary. A fall in wages that results from decreased demand for agricultural labor is an example of a pecuniary externality resulting from a transfer. In addition to rural agricultural communities, environmental users are dependent on instream flows for recreation purposes. A transfer has the potential to reduce instream flows and therefore reduce water supply available for environmental purposes. In many states participants in a transfer must prove that no environmental interests will be damaged as a result of the transfer.

The remainder of the paper is organized as follows. Section 2 gives an overview of water supplies and water institutions in the western states. We place particular emphasis on California since our dataset consists solely of transfers from California. Section 3 discusses the literature on the lease-own decision in water and outlines the testable implications that we consider in our empirical analysis. Section 4 describes the data and presents the results. Section 5 summarizes and concludes.

# 2 California Water Use and Transfers

We briefly overview water use and institutions in California and the structure of water transfers. The allocation of water is not a simple phenomenon. Technology is generally sophisticated and both institutions and transfers can be quite complex. While it is not possible to provide full detail on these aspects of water allocation, we provide a simplified discussion in order to help understand the questions addressed in this paper.

## 2.1 Water Use and Institutions

Water is a scarce resource in most western states. Limited precipitation makes water supply a common topic of debate. Agriculture has used the greatest share of the available water supply over the last century. The creation of the federal Bureau of Reclamation in 1902 was followed by a near century-long period of construction projects on dams and canals to bring water to agricultural regions which would have been unproductive without imported water. The current irrigation system provides for the irrigation of over 10 million acres of land in the western states. In addition to irrigation, urban growth has facilitated the need for significant investments in municipal water facilities. Much of municipal water comes from historic supply projects. However, transfers from agricultural users have become more common as rapid growth has caused existing municipal supply and storage facilities to become insufficient.

California is the largest of the western states in terms of both agricultural and municipal water use. Given that California has the largest agricultural economy of all states, it is not surprising that 75-85% of water use is accounted for by agriculture. The fertile soils in the central part of the state are generally unproductive without sufficient irrigation. On average, the state uses 34 million acre-feet of water per year.[2] An acre-foot of water is defined as the total amount required to flood an acre of land to a height of one foot. It is generally considered to be enough water to satisfy the demand of an urban family for an entire year. The magnitude of agricultural water use is a common topic of debate given growing urban demands fueled by population growth.

The allocation of irrigation water is governed by a complex legal system and various federal and state entities. The United States Bureau of Reclamation created the Central Valley Project (CVP) in the late 1930s as a way of capturing water from the relatively wet northern counties and transporting it to agriculturally productive areas in the central part of the state. The California State Water Project (SWP) also supplies irrigation

[2]See California Department of Water Resources homepage, www.water.ca.gov.

water to farmers. The SWP is a system of lakes and reservoirs, canals, pumping plants, and storage facilities that transport water from north to south for both agricultural and municipal purposes. In addition to these two major supply projects, water users hold rights to divert water directly from local streams and rivers.

The remaining question is how do farmers obtain water? Local supply agencies such as irrigation districts and water supply districts are the most common source of water for farmers. These are public entities that are responsible for holding water rights and allocating water to individual farmers within their districts. For Instance, the Imperial Irrigation District in Southern California owns rights to divert water from the Colorado River. Imperial then sells this water to farmers at a price approximately equal to cost. Irrigation districts are also responsible for developing and maintaining the facilities necessary to convey water to irrigators. These include ditches, canals, and storage facilities. Board members are elected by landowners in order to manage district activities.[3]

Municipal users are the other major water user group in California. Most municipal customers are served by public municipal water providers. Cities and towns have water departments that are responsible for distributing water to those living within the boundaries of the city. In addition to distribution, municipal water utilities are also responsible for acquisition of water rights, treatment and storage, and seeking additional water supplies when necessary. A municipal water district is similar to an irrigation district; with the main difference being the final use of its customers.

Environmental water use is an important element of water allocation in California. Unlike agricultural and urban uses, environmental use is generally not consumptive. Environmental users are most interested in maintaining water in streams for recreation and fish/wildlife habitat. Environmental users have been allowed to purchase water for

[3]It should be noted that some agricultural producers also hold rights directly without the involvement of irrigation districts. We don't discuss this situation directly, as our empirical analysis considers only transactions between identifiable holders of water rights. We do not consider transactions between individuals, as many of our legal and economic variables are unknown for such transactions.

instream flows since 1991. The U.S. Fish and Wildlife Service, California Department of Water Resources, and the California Department of Fish and Game are the major public entities that secure water for environmental purposes. Private entities such as wildlife refuges and fishery conservation groups are also common buyers of water for instream flows. Environmental users are generally the most junior holders of water rights and therefore rely on markets to satisfy their demands.

## 2.2 Water Rights and Transfer Agreements

Water rights are defined to allow holders of the right to divert a given quantity during a given time period, most often one year. While previous work indicates that defining rights on the basis of consumptive use has the potential to improve efficiency while protecting downstream users, diversion rights are the standard (Johnson, Gisser, and Werner, 1981). The diversion of water in California by irrigation districts, municipal water districts, and private rights holders is governed mostly by a hybrid of the prior appropriation and riparian doctrines. Appropriative rights allocate water based on the date of initial water use. A user is required to establish use rights by diverting water and putting it to beneficial use. Owners with rights that were established further back in time are referred to as senior appropriators. Junior appropriators are those which have established rights in more recent history. Riparian rights allocate water based on ownership of land adjacent to rivers and lakes. Because of the separation between land ownership and water rights holdings, appropriative rights are generally easier to transfer than riparian rights.[4]

It is clear that water allocation is governed by a set of legal requirements based on land ownership and seniority. Water has been historically allocated by such legal institutions rather than by markets. The users of water are also diverse, ranging from farmers to urban residents to fishermen. It has been widely noted that the marginal

[4]Transfers of appropriative rights are governed by laws which are highly variable by state. For a more detailed description of state regulations, see Getches (1997), pp 155-176.

values of water vary widely between user groups. The potential for mutual gains from the establishment of water markets has been widely discussed in the early literature on water transfers (Vaux and Howitt, 1984; Young, 1986). In many areas water used for municipal purposes is valued at upwards of 10 times the value of agricultural water. Brewer et al. (Brewer, Glennon, Ker, and Libecap, 2007) point out a number of cases across western states where urban water values far exceed agricultural values. Contracting is required for transfer participants to realize these gains from trade. The contractual forms have yet to be investigated by the literature. Our empirical analysis focuses on transaction cost economics and the duration of transfer agreements.

Contracts for water transfers range from simple two page agreements to complex agreements with numerous different contract terms. Many transfer agreements are complex and involve elements of risk, uncertainty, timeliness, and third party concerns. A typical contract specifies duration, price and quantity schedules, conveyance procedures, and timing and location of diversion. Other more involved contracts include land fallowing commitments, conservation measures by sellers, terms on how environmental impact reports will be prepared, environmental mitigation cost sharing, water quality requirements, transfer quantities that are contingent upon availability, arbitrage clauses, and termination clauses. As shown in Brewer et al. (2007), there is tremendous variability in prices, quantities, and contract forms for western transfers. Complex agreements for water transfers are far more involved than contracts for other assets, such as agricultural land or trucking equipment. An example of a more complicated transfer is the recent long-term leasing agreement between the Imperial Irrigation District (IID) and San Diego County Water Authority (SDCWA). The agreement involves transferring the water conserved from lining irrigation canals to San Diego. While reducing consumptive use in agriculture made water available to transfer, reduced return flows were judged to be potentially harmful to the Salton Sea, which is a downstream body of water dependent upon return flows from irrigation by Imperial. The no harm clause to third

parties forced the contract between IID and SDCWA to also include mitigation efforts.[5] The IID-SDCWA transfer shows that varying environmental and economic conditions can cause transfer contracts to vary substantially in complexity. The contract includes contingencies in both prices and quantities, price adjustments over time, resale terms, and predetermined delivery schedules during each year of the agreement.

A decision that is likely one of the first to be made during negotiations is the length of the agreement. Contracts range from short-term lease agreements to long-term leases to permanent ownership.[6] Short-term leases are one year agreements which allow lessees to alleviate short-term supply instability. Longer term arrangements result when buyers anticipate long term need and economic conditions cause agricultural rights holders to be willing to permanently sell at least a portion of their water rights. In addition to the simple demand effects, transaction cost economics predicts that the micro-level features of economic behavior will have definite impacts on contract structure. Our empirical analysis considers the impact of specific assets, uncertainty, and negative externalities on contract form. It is first useful to develop our predictions within the context of the economic organization literature.

# 3 Economics of the Lease-Own Decision in Water

The theory of the lease-own decision for an asset has been studied for both general capital assets (Schall, 1974; Miller and Upton, 1976; Wolfson, 1985) and agricultural

[5]Opposition to transfers by rural communities is not unique to the IID-SDCWA agreement. Rural areas are often wary of water transfers out of agriculture. Direct and pecuniary externalities are the source of this opposition. Much of the wariness results from the historic case of the land purchases by the city of Los Angeles in the Owens Valley. The city purchased agricultural land in the valley during the early part of the twentieth century in order to secure the water to be transferred through the Los Angeles aqueduct. The decrease in the viability of the valley as an agricultural region created abundant opposition by valley residents to the transfer. The Owens Valley - Los Angeles transfer is the most commonly cited case by opponents of transfers.A detailed description of the water controversy between Los Angeles and the Owens Valley is certainly beyond the scope of the present paper. For a detailed description of the historic case see Libecap (2008).

[6]Since water rights holders own only the right to use and transfer water, when referring to ownership we are referring to ownership of use rights rather than ownership of the water itself.

assets (Ford and Muser, 1994). In addition to these studies, the economic organization literature predicts that the length of economic agreements will depend critically on opportunism. We next consider transfer duration from an economic organization perspective. Such a framework accounts for the micro-level incentives of the agents participating in the transaction. We look at implications from the literature on asset specificity and uncertainty. We also consider the impacts of third party effects on water organization. The consideration of third parties makes water negotiations unique. Third party impacts create a series of incentives that are only relevant for water negotiations.

## 3.1 Asset Specificity

An asset is 'specific' if its value is reduced substantially if a complementary asset which is contracted for is unable to be secured. The general result from the literature is that vertical integration is likely to dominate temporary contracting when either of two agents in a relationship make relationship-specific investments (Klein, Crawford, and Alchain, 1978; Williamson, 1979; Riordan and Williamson, 1985). If a buyer(seller) makes investments in assets which are specific to a relationship with a particular seller(buyer), then there is scope for opportunistic behavior in short-term contracts. The party not making the investments gains substantial bargaining power as the investing party stands to lose more if repeated negotiations fail. Vertical integration serves as the mechanism to avoid opportunistic behavior as a result of specific investments. While vertical integration may seem different than the lease-own decision, the theory pertains to the duration of a contractual relationship between economic agents. Long-term contractual relationships are therefore expected when a transaction involves investments in specific assets.

The empirical evidence generally confirms the predictions on asset specificity and the duration of contracts (for a complete review see Shelanski and Klein (1995)). Studies using cross-sectional data from different industries and explaining the emergence of vertical integration as a function of variables measuring specific assets generally find evidence

in support of the economic organization hypothesis (Levy, 1985; Caves and Bradburd, 1988; Lieberman, 1991; Minkler, 1994; Baker and Hubbard, 2001, 2003). Other studies use micro-level data for a specific industry to explain either contract duration or vertical integration. Joskow (1987) finds that duration of coal contracts is positively associated with variables meant to proxy for investment in specific assets. Recent work by Brickley, Misra, and VanHorn (2006) finds that long-term franchising contracts are more likely when a franchisee makes investments in relationship-specific assets. Masten (1984) finds that downstream firms in the aerospace industry are more likely to produce specialized inputs themselves rather than contract for their use from upstream manufacturers. Both results confirm the prediction from the economic organization literature that long-term relationships and vertical integration are more likely to result when asset specificity is present. Allen and Lueck (2002) find that agricultural buildings are more likely to be leased when agricultural land is rented. Since land is a complimentary asset to agricultural buildings, owning land is a relationship specific investment.

Physical asset specificity can be important in water organization as well. Existing conveyance facilities may be inadequate to transport water between geographically separated buyers and sellers. Investment in assets which are specific to the particular transaction are then needed for appropriate conveyance. Buyers which make investments in conveyance facilities which are specific to a particular seller are unlikely to desire a short-term leasing arrangement with that seller. Making these investments also creates the opportunity for strategic behavior in contractual negotiations for short-term leases. Ownership allows buyers to avoid potentially large losses that can result from opportunistic behavior on the part of sellers.

## 3.2 Uncertainty

In their most simplified form, transaction costs can all be related to uncertainty. Water is unique in that the asset being traded is not fixed. Two parties negotiating a transfer

are uncertain as to how much of the water is truly going to be available during a given year. For appropriative rights, more senior rights are certainly accompanied by less uncertainty. The more senior a right, the less uncertainty as to whether the full amount will be available for diversion during a low streamflow year. Junior rights are more uncertain. During low streamflow years junior rights may not be satisfied as more senior rights holders are likely to use the entire water supply. The water rights system and hydrologic conditions therefore create a natural form of uncertainty which would be expected to impact the choice of contract duration for transfers.

We must also consider the uncertainty of existing water rights held by participants in a transaction. Buyers of water are unsure about whether their existing rights will be sufficient during dry years. Sellers with more senior rights may expect to have excess water. The length of the agreement is expected to reflect these relative preferences toward risk. Risk averse buyers with uncertain water supplies are expected to counteract risk by negotiating for longer term transfers when the asset being contracted for is associated with high degrees of certainty (senior rights).

An interesting empirical test of uncertainty and contract duration comes from the labor economics literature. Several studies have observed an inverse relationship between inflation uncertainty and contract duration (Gray, 1978; Vroman, 1989; Rich and Tracy, 2004). Labor contracts are certainly different from contracts for physical assets. The directional effect of uncertainty on contract duration depends critically upon the type of uncertainty and the risk aversion of the agents.

## 3.3 Third Party Effects

The effects of third party impacts on the organization of transactions are not a significant component of the economic organization literature. Indeed, many transactions between private parties have little or no third party impacts and the parties have relatively limited collective action problems themselves. The places where the empirical literature

is thickest (e.g., trucking, farming) are cases in which externalities are likely to be minimal. In other cases, however, and for water in particular, third party impacts seem to be important, so the structure of the transaction may depend not only on the incentives of the direct participants, but also on the incentives of the individuals that are affected by a transfer. A combination of externalities and the often diverging opinions of heterogeneous third parties makes negotiating a transaction more complex and provides another source of variation in the length of agreements.

There are various third parties that are affected by a water transfer. For transfers of water originating from agriculture, rural agricultural communities are opposed to transfers on the grounds that reduced agricultural water use leads to less demand for agricultural inputs (including labor). While these externalities are pecuniary, their significance in rural communities is not negligible. Further, transfers which include a change in the point of diversion will lead to reduced return flows for users downstream of the seller. For these reasons transfers are generally viewed negatively by rural agricultural communities. Environmental interests may also be impacted by transfers. Transfers where the new point of diversion is further upstream from the original one result in reduced instream flows between the two points (Anderson and Johnson, 1986). This has the effect of reducing water available for both recreation and fish and wildlife habitat.

The obvious remaining question is why do participants in a transaction care about the effects of the transfer on third parties? In terms of agricultural transfers, the actions of irrigation and water supply districts are quite visible in rural communities. Board members are elected by district members and expected to act in the best interest of all irrigators. Transfers of water outside a district's boundaries are viewed negatively in areas where agriculture contributes significantly to the local economy. In addition to pecuniary externalities, agricultural water supply districts have to consider the different effects of the transfer on all types of irrigators within the district. The point of diversion for a transfer is an example of a contract term that has differential impacts on irrigators.

Depending on the location of diversion, different irrigators may be affected differently by the reduction in return flows. Rosen and Sexton (1993) use a combination of club theory and game theory models to demonstrate the conflicts that can arise within an agricultural water supply district from a transfer. Their results indicate that disagreements between irrigators within districts can cause transfer outcomes to diverge from predicted optimal outcomes. Irrigation districts and other agricultural water supply agencies are thus faced with the additional burden of being constrained by political forces and the divergent opinions of heterogeneous irrigators. We expect irrigation districts to consider these political constraints when negotiating the terms of a transfer.

The state is the true legal owner of all surface water under California water law. The State Water Resources Control Board oversees all transfers due to their impacts on third parties. Participants of a transfer are required to submit a petition to the board in order to obtain a permit for the transfer. The petition requires the parties to state the proposed points of diversions, places of use, and estimated impacts on instream flows, fish habitats, and water quality. There are additional oversights for permanent transfers of rights. The legal oversights by the state clearly make it impossible for participants in a water transfer to overlook the impacts on third parties. The question we ask is whether participants consider these impacts when negotiating the length of the contract.

## 3.4 Predictions

The discussion up to this point has led to some testable predictions which are the focus of our empirical analysis. Before moving to the empirical model, we summarize our predictions as follows:

**PREDICTION 1:** As specific assets for conveyance become more important long term agreements are more likely.

**PREDICTION 2:** When buyers face uncertain water supplies long term agreements

are more likely.

**PREDICTION 3:** When the transfer has fewer third party impacts long term agreements are more likely.

# 4 Data and Empirical Model

In this section we give and overview of the water transaction data and outline the econometric model we use to test the predictions about the length of transfer agreements. Empirical studies in transaction cost economics have relied on various proxies to measure impacts of characteristics such as asset specificity. Limited micro-level data on actual contracts often makes measurement a tedious task. Nonetheless, our data allow for sufficient empirical testing of the predictions of the previous section. Namely, we focus on the effects of asset specificity, uncertainty, and externalities on the duration of contracts.

The water transaction data are taken from a publicly available database on water transfers maintained at the University of California, Santa Barbara.[7] The data consist of transactions from 1987-2008. Answering our empirical questions requires micro-level data on the participants in the transactions. We therefore focus our analysis on a single state, California. Doing so allows us to identify the buyers and sellers for the transactions and supplement the transaction data with explanatory variables of interest.[8] We use publicly available data from the California Department of Water Resources, California Irrigation Management Information System, California State Parks Department, California Department of Finance, U.S. Geological Service, U.S. Fish and Wildlife Service, and U.S. Bureau of Economic Analysis to build a set of independent variables that includes both controls and variables meant to test our hypotheses. For those interested

[7]The database is the first comprehensive database on western water transactions. The data are collected from the trade journal *The Water Strategist* (published by Stratecon Inc.) Brewer et al. (2007) use these data to give a broad overview of western water transfers.

[8]Some transactions in the database do not have identifiable buyers or sellers. For example, it is common for transactions to be listed as between "irrigators" and "municipal interests". We do not include such transactions in our analysis as we are unable to identify buyers and sellers.

in the details of our supplementary data sources, we have included a data appendix for further reference.

We use these data to estimate an ordered probit model explaining variation in the length of transfer contracts. Classic empirical studies in the transaction cost economics literature have taken one of two forms. In cases where contract duration is continuous and finite, standard econometric procedures for continuous variables are used to test predictions (Joskow, 1987). In other cases the outcome of interest is qualitative (i.e make/buy or buy/lease) and binary probit or logit models are sufficient (Monteverde and Teece, 1982; Masten, 1984). Our water transaction dataset is similar to the literature on qualitative decisions, yet we are able to observe the length of lease agreements. The standard ordered probit model with three categories lends itself to these data. The model is expressed as,

$$y_i^* = \mathbf{x}_i^{'}\boldsymbol{\beta} + u_i \tag{1}$$

and

$$y_i = \begin{cases} 0 & \text{if } y_i^* < \mu_1 \text{ (short-term lease)} \\ 1 & \text{if } \mu_1 < y_i^* < \mu_2 \text{ (long-term lease)} \\ 2 & \text{if } y_i^* > \mu_2 \text{ (sale)} \end{cases}$$

where $y_i^*$ is the unobserved latent variable describing the propensity for a longer term agreement in transaction $i$, $y_i$ is the observed categorical variable for the three types of contracts, $\mathbf{x}_i$ is a column vector consisting of the explanatory variables, $\boldsymbol{\beta}$ is a column vector of parameters to be estimated, and $u_i$ is a random error term which is distributed as a standard normal. The predicted probabilities of short-term leases, long-term leases, and sales are given respectively by, $\Phi(\mu_1 - \mathbf{x}_i^{'}\boldsymbol{\beta})$, $\Phi(\mu_2 - \mathbf{x}_i^{'}\boldsymbol{\beta}) - \Phi(\mu_1 - \mathbf{x}_i^{'}\boldsymbol{\beta})$, and $1 - \Phi(\mu_2 - \mathbf{x}_i^{'}\boldsymbol{\beta})$, where $\Phi$ is the standard normal CDF. The estimates of $\boldsymbol{\beta}$, $\mu_1$ and $\mu_2$ are obtained by maximum likelihood. The magnitude of the estimates $\boldsymbol{\beta}$ have little interpretable meaning. We thus focus our interpretation on the marginal effects of the explanatory variables.

Table 1 provides descriptions and summary statistics of the variables used in the model. The dependent variable is a discrete ordered variable that is set to 0 for short-term (one year) leases, 1 for long-term leases, and 2 for permanent transfers. We do not report summary statistics for the dependent variable in the table, as the mean value is largely irrelevant. Of the 416 transactions where at least the buyer or seller is identified, 286 or short-term leases, 65 are long-term leases, and 65 are permanent transfers. Short-term leasing is obviously the dominant contracting type. Short-term leasing is frequently used as a reallocation mechanism during dry years. Long-term arrangements are more complex and involve much more than temporary supply fluctuations. The dominance of short-term leasing is consistent with water markets in all western states.

The explanatory variables in Table 1 are organized according to the factors for which they are proxies. Precipitation in the area of the buyer is is a measure of the short-term supply availability of the buyer. Leases of water are common sources of supplemental supply when precipitation is below average. We expect an inverse relationship between contract duration and buyer precipitation. The buyer long-term streamflow represents average streamflow on sources where buyers hold water rights as a percentage of the long-term average (10 years preceding transaction).[9] It also measures supply availability and is expected to be inversely related with contract duration. The dummy variable for urban buyers controls for variation in contract types preferred by different buyer types. 49% of the transactions have buyers that are municipal water districts. We expect a positive association between the urban buyer indicator and contract duration.

We use the distance between the buyer and seller as a measure of asset specificity. Transporting of the water is simple when the parties are close in distance. In many cases the water is simply left in a stream by the seller for the buyer to then divert. Physical

[9]Some buyers do not hold appropriative water rights licensed with the California State Water Board. We used two alternatives to measure the variable for these observations. If the buyer was a CVP contractor, we used the streamflow data from the nearest CVP canal or Sacramento River station. In the event that the buyer is not a CVP contractor, we used streamflow from major streams within a 40 mile radius of the buyer's office.

Table 1: Variable Descriptions and Summary Statistics

| Variable | Description | N | Mean | SD | Min | Max |
|---|---|---|---|---|---|---|
| *Controls* | | | | | | |
| Buyer Precipitation | Precipitation in buyer county during transaction year | 231 | 12.44 | 7.37 | 1.80 | 41.09 |
| Buyer Long-Term Streamflow Percentage | Streamflow percentage for buyer during transaction year | 275 | 101.92 | 109.40 | 2.25 | 648.42 |
| Urban Buyer | 1 if buyer is urban municipality, 0 otherwise | 277 | 0.49 | 0.50 | 0 | 1 |
| *Asset Specificity* | | | | | | |
| Distance Buyer and Seller | Distance between buyer and seller (100 miles) | 207 | 1.02 | 1.27 | 0 | 5.28 |
| *Uncertainty* | | | | | | |
| Buyer Water Uncertainty | 10 year coefficient of variation for buyer water supplies | 275 | 0.79 | 0.42 | 0.03 | 1.96 |
| Seller Water Uncertainty | 10 year coefficient of variation for seller water supplies | 341 | 0.73 | 0.53 | 0.04 | 2.55 |
| *Third Party Effects* | | | | | | |
| Agricultural Income Ratio | Agricultural income / total personal income in seller county | 346 | 0.03 | 0.03 | 0 | 0.22 |
| State Park Water Area | State park water feet / total land area in seller county | 346 | 65.17 | 136.38 | 0 | 611.12 |
| Endangered and Threatened Species Listings | No. of endangered and threatened species listed in seller county, 10 years prior to transaction | 346 | 0.82 | 1.09 | 0 | 4 |

conveyance of the water is likely to be much more complicated when buyers and sellers are further apart. Investments in conveyance facilities are needed to move water between geographically separated parties. While transfers do not generally require construction of entirely new canals, investments in pumping and storage facilities and extensions to existing conveyance facilities are likely when buyers and sellers are far apart. As is seen in Table 1, our data include transactions from buyers and sellers within the same zip code (0 distance) to transactions where buyers and sellers are located at extreme ends of the state. Thus, there is sufficient variation to test the hypothesis from prediction 1 that long-term contracts are more likely when buyers and sellers are further apart. We also include a squared distance term to investigate potential nonlinear relationship between the ordered probit index function and the distance between buyers and sellers.

The 10 year coefficient of variation (10 years preceding transaction) in streamflow is used as a measure of uncertainty in water supplies. A larger coefficient of variation indicates a greater degree of variability in the water availability. The mean coefficient of variation is around 0.75 for both buyers and sellers. We expect buyers to be averse to this supply risk. A long-term purchase of a water right with little uncertainty is one way of creating less uncertainty in water supplies for buyers. Longer term agreements are expected when buyers have uncertain water supplies and sellers hold more certain rights. Consistent with prediction 2, we expect a positive relationship between buyer supply uncertainty and contract duration. The opposite relation is expected between seller supply uncertainty and length of agreements.

Our last testable prediction relates to the impact of third party effects on contract duration. The relevant third party impacts vary by the origin of the water being transferred. For transfers originating from agriculture, rural communities with productive agricultural economies are likely to oppose transfers, especially long-term transfers. To test whether these concerns impact contract types chosen by irrigation districts, we constructed a variable that is the ratio of total agricultural income in the county of the

seller to the total personal income in the county. The variable proxies for the significance of agriculture in the area of the seller. If sellers are constrained by these third party impacts, then we expect short-term leasing to be more common in counties where the agricultural income ratio is higher. Other third party impacts are tested using two variables. As a proxy for instream flow values, we include the ratio of state park water feet to county land area in the county of the seller. The assumption in using this proxy is that instream flow values are higher in areas with more lakes and streams in state parks. We expect greater opposition from environmental interests and short-term leasing to dominate in these areas. We also look at the effect of endangered species listings on the length of transfer agreements. We construct a variable that is the number of endangered or threatened fish species that were newly listed by the U.S. Fish and Wildlife Service within the last ten years in the county of the seller.[10] From Table 1 we see that there are some transactions with no species listings, while at a maximum there are transactions where there were four new listings in the county of the seller in the ten years preceding the transaction. We expect a negative relationship between contract length and the number of endangered and threatened species listed in the seller's county.

Before presenting the ordered probit results, we first look at the mean values of the explanatory variables by contract type. Table 2 presents mean values for short-term leases, long-term leases, and permanent transfers. While these mean values clearly do not make up a formal test of our predictions, it is useful to highlight some trends in the data. Our measure of asset specificity, the distance between buyers and sellers, is increasing in mean for longer contract types. The result provides some initial evidence that longer term contracts may be associated with buyers and sellers that are further apart in distance. The state park water area variable also has a clear trend in mean value between contract types, potentially indicating a negative relationship between duration and instream water use in the area of the seller. For the other variables the direction of

[10]We relied upon the NatureServe online conservation database for identifying habitat areas of species.

Table 2: Mean Values of Independent Variables, By Contract Type

| Variable | Short-Term Leases | Long-Term Leases | Permanent Sales |
|---|---|---|---|
| *Controls* | | | |
| Buyer Precipitation | 10.80 | 15.77 | 14.03 |
| Buyer Long-Term Streamflow Percentage | 93.11 | 114.70 | 119.68 |
| Urban Buyer | 0.29 | 0.72 | 0.65 |
| *Asset Specificity* | | | |
| Distance Buyer and Seller | 0.85 | 1.02 | 1.77 |
| *Uncertainty* | | | |
| Buyer Water Uncertainty | 0.71 | 1.02 | 0.84 |
| Seller Water Uncertainty | 0.73 | 0.76 | 0.72 |
| *Third Party Effects* | | | |
| Agricultural Income Ratio | 0.03 | 0.03 | 0.02 |
| State Park Water Area | 75.17 | 56.27 | 22.93 |
| Endangered and Threatened Species Listings | 0.71 | 1.00 | 1.22 |

the relationship is not clear from the mean values. We rely on our econometric results from the next section to more formally test our predictions.

# 5 Econometric Results

Table 3 presents the results from estimating three versions of of (1) using different subsets of our data. Specification 1 uses the entire data set and allows us to test our predictions on asset specificity and uncertainty (Predictions 1 and 2). Specification 2 limits the sample to transactions where the seller is an agricultural entity. This allows us to test the hypothesis that leasing is more likely in areas with highly productive agricultural economies (Prediction 3). The third specification excludes transfers to environmental users and allows us to test the effects of instream use and endangered species on con-

tractual form (Prediction 3). The estimated marginal effects on the probabilities of the three contract types are given in Table 4.[11]

Precipitation in the area of the buyer has the expected sign and is statistically significant in two of the three specifications. Shorter term agreements tend to dominate when buyers are experiencing relatively dry years. The impact of buyer streamflow conditions is however not consistent with our expectations. The results indicate that longer term agreements are more likely when buyers are in low streamflow years. While the direction of the estimate is counterintuitive, the absolute magnitude of the coefficient is small. The marginal effects (Table 4) are noticeably small across all specifications. The results for the other control variables indicate that longer term agreements are more likely for urban buyers and that contracts have tended to increase in duration over time.

The estimate on the distance variable is consistent with our expectations (Prediction 1). The estimated relationship between distance and the ordered probit index function is concave. Using the results from column 2 of Table 3, the index function is increasing with distance initially and then decreasing after a distance of 234 miles. Considering that only 20% of the observations lie outside this range, the marginal effects of distance on the probabilities of long-term leases and permanent contracts are generally positive, but decreasing in distance. The marginal effects at mean values from Table 4 suggest that at mean values the probability of short-term leases is decreasing in distance while the probabilities of long-term leases and permanent transfers are increasing in distance. These results are consistent with our hypothesis on asset specificity. Longer term agreements are more likely when buyers and sellers are further apart in distance. Investments in assets that are specific to the physical conveyance of the water make water districts choose permanent transfers rather than repeated leasing. Permanent transfers protect the participants from opportunistic behavior during contract renegotiations.

The results for the uncertainty variables confirm the hypothesis that long-term con-

[11]For continuous variables the marginal effects are derivatives of probabilities. Differences in probabilities are given for binary variables.

Table 3: Ordered Probit Results for Contract Duration

| | Specification | | |
|---|---|---|---|
| Explanatory Variable | (1) | (2) | (3) |
| *Controls* | | | |
| Buyer Precipitation | 0.0608*** | 0.0154 | 0.0722*** |
| | (0.0169) | (0.0254) | (0.0179) |
| Buyer Long-Term Streamflow Percentage | -0.0025** | -0.0012 | -0.0035*** |
| | (0.0012) | (0.0019) | (0.0013) |
| Urban Buyer | 0.6962*** | 1.3908*** | 0.6372*** |
| | (0.2293) | (0.3643) | (0.2457) |
| Time Trend | 0.0481** | 0.0072 | 0.0381* |
| | (0.0200) | (0.0294) | (0.0209) |
| *Asset Specificity* | | | |
| Distance Buyer and Seller | 0.7508** | 0.8802** | 0.6709* |
| | (0.3393) | (0.4411) | (0.3524) |
| Distance Squared | -0.1603** | -0.2256** | -0.1690** |
| | (0.0793) | (0.1074) | (0.0839) |
| *Uncertainty* | | | |
| Buyer Water Uncertainty | 1.1680*** | 1.0836* | 1.1170*** |
| | (0.3585) | (0.5644) | (0.3674) |
| Seller Water Uncertainty | -0.7164** | -1.6377*** | -0.7323** |
| | (0.3069) | (0.5919) | (0.3195) |
| *Third Party Effects* | | | |
| Agricultural Income Ratio | | -9.3604* | |
| | | (5.0191) | |
| State Park Water Area | | | -0.0012 |
| | | | (0.0013) |
| Endangered and Threatened Species Listings | | | 0.1925* |
| | | | (0.1060) |
| $\mu_1$ | 2.5464*** | 1.3218** | 2.4588*** |
| | (0.4265) | (0.6603) | (0.4343) |
| $\mu_2$ | 3.5259*** | 2.2618*** | 3.4692*** |
| | (0.4566) | (0.6788) | (0.4650) |
| Number of Observations | 168 | 107 | 164 |
| Pseudo $R^2$ | 0.225 | 0.344 | 0.242 |
| Log-Likelihood | -121.7946 | -57.3619 | -115.9001 |

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 4: Marginal Effects on Contract Choice

| | (1) | (2) | (3) |
|---|---|---|---|
| *Controls* | | | |
| Buyer Precipitation | -0.0224 | 0.0130 | 0.0095 |
| Buyer Long-Term Streamflow Percentage | 0.0009 | -0.0005 | -0.0004 |
| Urban Buyer | -0.2532 | 0.1424 | 0.1107 |
| Time Trend | -0.0178 | 0.0103 | 0.0075 |
| *Asset Specificity* | | | |
| Distance Buyer and Seller | -0.1596 | 0.0924 | 0.0672 |
| *Uncertainty* | | | |
| Buyer Water Uncertainty | -0.4313 | 0.2497 | 0.1816 |
| Seller Water Uncertainty | 0.2645 | -0.1531 | -0.1114 |
| *Third Party Effects* | | | |
| Agricultural Income Ratio | 2.6240 | -1.8582 | -0.7659 |
| State Park Water Area | 0.0004 | -0.0003 | -0.0002 |
| Endangered and Threatened Species Listings | -0.0705 | 0.0426 | 0.0279 |

Marginal effects calculated at mean values of independent variables

Specification 1 is used for all variables other than those measuring third party impacts.

tracting is a way for buyers to protect themselves from uncertainty in water supplies. The probabilities of longer term agreements are increasing with buyer water uncertainty and decreasing with seller water uncertainty. The combined results suggest that holding all else constant, long-term leases and permanent transfers are more likely when buyers have uncertain existing supplies and sellers are able to offer more certain supplies. Using the marginal effects from specification 1, the probability of long-term leases increases by 0.025 with an increases in buyer uncertainty of 0.1. The same increase in buyer uncertainty results in an increase in the probability of permanent transfers by 0.018. A *decrease* in seller uncertainty by 0.1 would lead to an increase in the probability of long-term leases by 0.015 and an increase in the probability of permanent contracts by 0.011. We help to quantify the effects of the uncertainty variables by calculating predicted probabilities. Table 5 presents predicted probabilities of the different contract types for various values of buyer and seller water supply uncertainty (all other variables held constant at mean values). As an example, the probability of a permanent sale

is 0.25 when buyer water uncertainty is 1.25 and seller uncertainty is 0.5. Obviously, the probabilities of long-term leases and permanent sales are highest when buyer water supplies are uncertain and seller supplies are more certain. When seller water supplies are relatively certain, the effect of buyer water supplies becoming more uncertain is to shift probability mass towards permanent sales.

Buyer water uncertainty is a feature of the particular agent in the transaction. Seller water uncertainty is meant to measure an attribute of the particular asset being traded. Long-term contracting is the efficient contractual form when the agreement has the potential to create less uncertainty in water supply for buyers that have experienced larger fluctuations in water availability. As is predicted by classic theory, contractual form is a way to mitigate hazards as well as effectively manage risks. The effects of uncertainty on contract duration are fairly unique to water. Most other assets being traded are certain in their quantity. Further, buyers generally know their resource endowments. Both of these elements being uncertain for water creates an opportunity for contract duration to be used as a mechanism to reduce future uncertainty in the availability of the asset being traded.

Specifications 2 and 3 in Table 3 are for testing our hypotheses on third party effects. In specification 2 we limit the sample to sellers that are agricultural entities. The parameter of interest is the coefficient for the agricultural income ratio. The sign of the estimate is consistent with prediction 3, yet the estimate is only marginally statistically significant (p-value = 0.06). Longer term agreements face greater opposition in areas reliant on agriculture. We consider the result as moderate evidence that agricultural sellers consider pecuniary externalities on rural communities when negotiating the length of water transfer agreements. In specification 3 we subset the data to transactions that end in non-environmental uses.[12] The estimate on the state park water area variable does

[12]There are only 4 environmental transactions for which we have identified both the buyer and seller. A majority of leases and purchases for environmental purposes are made by state and federal agencies. We can not identify a specific geographic location for the potential use of the water in these circumstances, so the buyers are considered as unidentified.

Table 5: Predicted Probabilities for Various Values of Uncertainty Variables

| Short-Term Leases | | | | | | |
|---|---|---|---|---|---|---|
| | | | *Seller* | | | |
| *Buyer* | 0.25 | 0.5 | 0.75 | 1 | 1.25 | 1.5 |
| 0.25 | 0.75 | 0.80 | 0.85 | 0.89 | 0.92 | 0.94 |
| 0.5 | 0.65 | 0.71 | 0.77 | 0.82 | 0.86 | 0.90 |
| 0.75 | 0.54 | 0.61 | 0.67 | 0.73 | 0.79 | 0.84 |
| 1 | 0.42 | 0.49 | 0.56 | 0.63 | 0.70 | 0.76 |
| 1.25 | 0.31 | 0.38 | 0.45 | 0.52 | 0.59 | 0.66 |
| 1.5 | 0.22 | 0.27 | 0.33 | 0.40 | 0.47 | 0.54 |
| Long-Term Leases | | | | | | |
| | | | *Seller* | | | |
| *Buyer* | 0.25 | 0.5 | 0.75 | 1 | 1.25 | 1.5 |
| 0.25 | 0.20 | 0.16 | 0.13 | 0.10 | 0.07 | 0.05 |
| 0.5 | 0.26 | 0.23 | 0.19 | 0.15 | 0.12 | 0.09 |
| 0.75 | 0.32 | 0.29 | 0.25 | 0.21 | 0.17 | 0.14 |
| 1 | 0.36 | 0.34 | 0.31 | 0.27 | 0.24 | 0.20 |
| 1.25 | 0.38 | 0.37 | 0.35 | 0.33 | 0.30 | 0.26 |
| 1.5 | 0.36 | 0.37 | 0.38 | 0.37 | 0.35 | 0.32 |
| Permanent Sales | | | | | | |
| | | | *Seller* | | | |
| *Buyer* | 0.25 | 0.5 | 0.75 | 1 | 1.25 | 1.5 |
| 0.25 | 0.05 | 0.03 | 0.02 | 0.01 | 0.01 | 0.01 |
| 0.5 | 0.09 | 0.06 | 0.04 | 0.03 | 0.02 | 0.01 |
| 0.75 | 0.14 | 0.11 | 0.08 | 0.05 | 0.04 | 0.02 |
| 1 | 0.22 | 0.17 | 0.13 | 0.09 | 0.07 | 0.05 |
| 1.25 | 0.31 | 0.25 | 0.20 | 0.15 | 0.11 | 0.08 |
| 1.5 | 0.42 | 0.35 | 0.29 | 0.23 | 0.18 | 0.14 |

A typical entry is the predicted probability for the given contract type when buyer water uncertainty is set at the value corresponding to column 1 and seller water uncertainty is set at the corresponding row value. All other variables are held constant at mean values. For example, when buyer water uncertainty is 1.25 and seller water uncertainty is 0.5, the probability of a long-term lease is 0.37.

not provide convincing evidence in support of prediction 3. The estimate on the endangered species variable is actually counterintuitive and marginally statistically significant (p-value = 0.07). The result indicates that long-term agreements are actually more likely when sellers are located in areas with more endangered and threatened species listings. The result clearly fails to provide evidence that instream flows for endangered species prohibit sellers from permanently transferring their water rights.

# 6 Summary and Conclusions

Our study is the first to use micro-level data to look at contractual form for water transfers. We first outlined the economics of water transfers as a way of generating testable predictions on the determinants of contract duration. In order to test these predictions, our model uses the classic technique of regressing an endogenous contracting outcome on features of the participants in the agreement. Empirical studies on contracting from the transaction cost economics literature use this framework to identify the key incentives affecting contracting outcomes. Asset specificity is no doubt the most commonly cited determinant of contract duration, buy/lease, or vertical integration decisions. Consistent with the literature, our results indicate that asset specificity is a key determinant of the length of water transfer agreements. The type of asset specificity that we have observed is unique to an asset that requires specific investments to physically transfer the asset between buyer and sellers. Buy/lease decisions for traditional goods are not affected by these investments. Goods that require transport between buyers and sellers can most frequently be transferred without any additional investments in infrastructure. Water is a different type of asset. Large-scale transfers require some investments in conveyance facilities when buyers and sellers are further apart. Our empirical results suggest that longer-term contracting is used to prevent the holdup problems during renegotiation of short-term agreements.

We have also looked at some unique determinants of contract length for water transfers. Water rights are uncertain. There are always elements of uncertainty in transfer agreements. We found that long-term contracting is less likely when sellers hold rights to streams with highly variable streamflows (more uncertainty). The reverse is true for uncertainty of a buyer's water supply. Buyers holding rights to more uncertain streams are more likely to choose long-term leases or permanent sales. The results suggest that long-term contracting is a a way for water agencies to manage uncertainty in water supplies. The effect of uncertainty in the quantity of the asset being traded is not a common determinant of contractual outcomes. Water transfers are governed by uncertainty due to the variability in supply and the seniority allocation mechanism used in most western states.

Water is also a unique asset in that transfers can create externalities and distributional effects. A transfer between two parties has the potential to have external effects on numerous third parties. Downstream users are often impacted by lost return flows. Rural communities suffer from pecuniary effects from reduced agricultural production. These effects make transfers controversial in areas where agricultural contributes significantly to the local economy. Also, long-term transfers to other water basins result in permanent reductions in instream-flows in the water basin of the seller. Our results on third party effects are mixed. There is moderate evidence that long-term agreements are less likely in areas where agriculture contributes significantly to the local economy. However, we do not find evidence that the impact on instream flows is considered by sellers of water rights. Overall, asset specificity and uncertainty appear to be the key variables governing the length of water transfer agreements.

A limitation of our study is that we only look at a single contracting outcome. Empirical studies in transaction cost economics are mostly focused on how various incentives affect the structure of economic agreements. The length of agreements is almost always the endogenous variable being analyzed. It is plausible to consider the effects of asset

specificity, uncertainty, and third party effects on other contract outcomes, such as price or quantity. There are no theoretical developments on the impacts of asset specificity on other endogenous contracting variables. This is therefore an empirical question that we leave for future research. Our empirical model does not consider the possibility of endogenous matching of buyers and sellers. It has been shown that econometric estimates can be biased when participants in a transaction contract with each other based on incentives that are considered as explanatory variables in the estimating equation (Ackerberg and Botticini, 2002). If certain types of districts choose to transfer to other types of districts based on distance or uncertainty, then a two-staged estimation procedure would be required to estimate the coefficients in (1). Our estimation does not test for the existence of endogenous matching of transfer participants.

Water transfers are recognized by policymakers as a way of efficiently reallocating water between users with different marginal values of water use. Yet, there is variability in the type of transfer contracts that are used. An understanding of the incentives of water districts is needed to identify the key determinants of the choice of contractual form. We have identified transaction-specific investments and uncertainty in water supply as two key factors leading to longer term (or permanent) transfers. In addition to the basic gains from trade, these micro-level incentives should be expected to affect contract outcomes.

# Data Appendix

The data were obtained from the online water transfer database from the University of California, Santa Barbara. The database includes transactions from 12 western states from 1987-2009. We chose to limit our analysis to California in order to maintain the ability to collect micro-level data on the specific participants in each transfer.

Identification of buyers and sellers was necessary before matching in explanatory variables on buyer and seller characteristics. When possible, we identified the buyer and seller using a combination of matching logic and manual matching between the water transfer data and a list of water utilities provided by the California Department of Water Resources (DWR). Many of the transactions in the data are between unidentified individuals or municipal entities. Also, some transactions involve state or federal agencies. These transactions are not included in the analysis as we were not able to identify the physical location of the buyer or seller. The resulting dataset consists of 207 observations where both the buyer and seller are identified. The DWR list of water providers was used to obtain the postal code and hence county of each transfer participant. The approximate longitudes and latitudes were obtained based on matching by postal code.

The explanatory variables were collected from a variety of sources. Table 6 provides the source of each variable. The buyer precipitation variable was collected from the California Irrigation Management Information System. The value corresponds to the average annual precipitation across CIMIS weather stations in the county of the buyer during the year of the transaction. The streamflow variables (buyer streamflow percentage, buyer water uncertainty, and seller water uncertainty) were collected using streamflow data from the U.S. Geological Service. The California Electronic Water Rights Information System (eWRIMS) was used to identify the appropriate streams where districts hold water rights with the California State Water Board. We also used streamflow values at the nearest CVP canal or Sacramento River station when the district was identified as a CVP contractor. The streamflow values at all major streams within a 40 mile radius

of the district's office were used for districts that did not have water rights at streams for which we had streamflow data and were not CVP contractors. The distance between the buyer and seller was calculated by the Haversine formula using the approximate longitude and latitude values. The agricultural income ratio is calculated as the ratio of agricultural income to total personal income in the county of the seller during the year of the transaction. The income data were obtained from the Bureau of Economic Analysis online database. State park water area was collected from the California State Park System Statistical Report. The 2008 values were used for all transactions in the dataset, as state park water area does not vary much over time. The endangered and threatened species listings were obtained from the U.S. Fish and Wildlife Service website. We identified the counties for which each fish species was known to exist using the NatureServe free online database.

Table 6: Variable Sources

| Variable | Source |
|---|---|
| Buyer Precipitation | California Irrigation Management Information System |
| Buyer Long-Term Streamflow Percentage | U.S. Geological Service |
| Urban Buyer | Original transaction data |
| Distance Buyer and Seller | Calculated from longitude and latitude using Haversine formula |
| Buyer Water Uncertainty | U.S. Geological Service |
| Seller Water Uncertainty | U.S. Geological Service |
| Agricultural Income Ratio | Bureau of Economic Analysis |
| State Park Water Area | California Department of State Parks |
| Endangered and Threatened Species Listings | U.S. Fish and Wildlife Service |

## PRELIMINARY BINARY PROBIT RESULTS

Table 7: Preliminary Probit Results for Lease-Own Decision

| | Specification | | |
|---|---|---|---|
| Explanatory Variable | (1) | (2) | (3) |
| Constant | -2.5423*** | -0.7289 | -2.3950*** |
| | (0.5644) | (0.9788) | (0.5688) |
| *Controls* | | | |
| Buyer Precipitation | 0.0330* | -0.0145 | 0.0435** |
| | (0.0200) | (0.0376) | (0.0211) |
| Buyer Long-Term Streamflow Percentage | -0.0007 | 0.0017 | -0.0015 |
| | (0.0014) | (0.0025) | (0.0015) |
| Urban Buyer | 0.4651 | 1.5470** | 0.4245 |
| | (0.2956) | (0.6519) | (0.3120) |
| Time Trend | 0.0428* | -0.0363 | 0.0339 |
| | (0.0256) | (0.0418) | (0.0269) |
| *Asset Specificity* | | | |
| Distance Buyer and Seller | 0.8005* | 1.7070** | 0.6542 |
| | (0.4146) | (0.7355) | (0.4274) |
| Distance Squared | -0.1492 | -0.4234* | -0.1303 |
| | (0.0963) | (0.2258) | (0.1011) |
| *Uncertainty* | | | |
| Buyer Water Uncertainty | 0.3812 | -0.6730 | 0.2965 |
| | (0.4412) | (0.9002) | (0.4561) |
| Seller Water Uncertainty | -0.6317 | -2.6222** | -0.7049* |
| | (0.3941) | (1.0697) | (0.4187) |
| *Third Party Effects* | | | |
| Agricultural Income Ratio | | -7.9917 | |
| | | (6.5486) | |
| State Park Water Area | | | -0.0006 |
| | | | (0.0016) |
| Endangered and Threatened Species Listings | | | 0.1505 |
| | | | (0.1264) |
| Number of Observations | 168 | 107 | 164 |
| Pseudo $R^2$ | 0.203 | 0.406 | 0.214 |
| Log-Likelihood | -59.0134 | -25.7474 | -56.3507 |

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 8: Preliminary Probit Results for Lease-Own Decision (Marginal Effects)

| | Specification | | |
|---|---|---|---|
| Explanatory Variable | (1) | (2) | (3) |
| *Controls* | | | |
| Buyer Precipitation | 0.0064* | -0.0010 | 0.0081** |
| | (0.0039) | (0.0025) | (0.0040) |
| Buyer Long-Term Streamflow Percentage | -0.0001 | 0.0001 | -0.0003 |
| | (0.0003) | (0.0002) | (0.0003) |
| Urban Buyer | 0.0902 | 0.1761* | 0.0794 |
| | (0.0572) | (0.1015) | (0.0577) |
| Time Trend | 0.0082* | -0.0024 | 0.0063 |
| | (0.0048) | (0.0029) | (0.0049) |
| *Asset Specificity* | | | |
| Distance Buyer and Seller | 0.1542* | 0.1150* | 0.1222 |
| | (0.0806) | (0.0692) | (0.0809) |
| Distance Squared | -0.0287 | -0.0285 | -0.0244 |
| | (0.0186) | (0.0183) | (0.0190) |
| *Uncertainty* | | | |
| Buyer Water Uncertainty | 0.0734 | -0.0453 | 0.0554 |
| | (0.0848) | (0.0580) | (0.0850) |
| Seller Water Uncertainty | -0.1217 | -0.1767* | -0.1317* |
| | (0.0756) | (0.1002) | (0.0772) |
| *Third Party Effects* | | | |
| Agricultural Income Ratio | | -0.5384 | |
| | | (0.4900) | |
| State Park Water Area | | | -0.0001 |
| | | | (0.0003) |
| Endangered and Threatened Species Listings | | | 0.0281 |
| | | | (0.0235) |
| Number of Observations | 168 | 107 | 164 |
| Pseudo $R^2$ | 0.203 | 0.406 | 0.214 |
| Log-Likelihood | -59.0134 | -25.7474 | -56.3507 |

Marginal effects; Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

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