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Economic Organization and the Structure of Water Transactions

Kyle Emerick and Dean Lueck

This paper analyzes the structure of water transactions using data on contract duration from California. Water rights in the western United States are transferred through short-term and long-term leases as well as permanent ownership contracts. We test predictions about the type of water contracts derived from the literature on economic organization by using ordered probit models to investigate the correlates of contract duration. 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 purchase from sellers with more certain rights, suggesting that urban municipalities use long-term contracts to reduce risk. We do not find robust evidence supporting the hypothesis that short-term agreements are more likely when the costs of transfer to third parties are potentially high.

Key words: economic organization, transaction costs, water transaction

"The City Owns Its Water"

It is not the economic theory of municipal ownership and administration of public utilities which concerns us; we are confronted with a condition and not a theory. The city owns its water, and our experience should convince us of . . . the farsighted wisdom of our Spanish and Mexican predecessors in holding on to the rights of the waters of Los Angeles with a grip of iron.

—Los Angeles Board of Water Commissioners (1902)[1]

Introduction

The emergence and expansion of markets for environmental and natural resources in the last several decades has been an important development influencing the use and conservation of these resources (Anderson and Libecap, 2014). In particular, water in the western United States has seen a dramatic increase in market use (Brewer et al., 2008; Hanak et al., 2012), and many argue that the potential for markets is vast (Anderson and Hill, 1997; Anderson and Libecap, 2014; Hanak and Stryjewski, 2012). Despite their importance for reallocating assets from lower-valued to higher-valued uses, our understanding of the economic structure of these market transactions is still limited.

This paper examines the structure of water-market transactions using lease and ownership data from California. In California and the western United States water rights are transferred through short-term and long-term leases as well as permanent ownership contracts. We employ the insights

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[1] See http://wsoweb.ladwp.com/Aqueduct/historyoflaa/cityownswater.htm.

from transaction-costs economics and the economics of organizations to develop and test predictions about the determinants of the length of water-transfer agreements. We combine data on water transactions in California with economic, demographic, hydrologic-climatic, and political data to estimate models of contract/transaction choice, focusing on the choice among short-term leases, long-term leases, and permanent transfers (i.e., sales). Detailed data on water contracts is notoriously difficult to obtain, so our findings not only inform the economic forces at work but also illuminate the basic structure of water-market transactions.

Water is most commonly transferred between users through three types of contracts (Hanak, 2003; Brewer et al., 2008). First, short-term leasing is a common method of temporarily reallocating water. A short-term lease is an agreement between an owner of the water right and a willing lessee in which a negotiated quantity is transferred at a single point in time, typically for a season or a year. Second, longer-term leasing is a contractual relationship in which water is transferred annually until the expiration of the contract. Both short-term and long-term leases do not involve permanent transfer of the specific water right. Third, ownership (or sales) contracts are permanent agreements in which a buyer purchases the legal right to divert a certain quantity into the future. Unlike leases, ownership contracts transfer the actual water right.

A classic question in economics organization is whether or not assets or activities should be undertaken or controlled by the firm or by another contracting party (Coase, 1937; Williamson, 1979). As the epigraph notes, the City of Los Angeles owns its water, its aqueducts, and the related land from the Owens Valley to the Los Angeles Basin. This outcome was the result of many transactions over three decades (Libecap, 2007). The integrated ownership of water, land at the headwaters over 200 miles from the city, the aqueduct, and the urban delivery system alleviates potential holdup problems that could arise if separate asset owners were contractually connected. This integration is rather rare but illustrates how complete integration can emerge in the organization of water.

This study stresses the transaction-cost approach to economic organization in the examination of water transfers.[2] A primary prediction is that the presence of specific assets will lead to longer-terms deals or outright sales (Klein, Crawford, and Alchian, 1978; Williamson, 1979). We also expect that transfer decisions are influenced by asymmetric information, asset complexity, moral hazard, monitoring costs, and other economic and even political forces. In the case of water we also expect uncertainty and the presence of third-party effects to influence these contracts.

Several characteristics of water make the lease-own decision between buyers and sellers distinct compared to frequently studied assets such as coal mines, trucks, or airplane parts. Most importantly, water is not a fixed asset but rather a large-scale environmental asset the size and quality of which are subject to substantial uncertainty depending on weather and hydrologic conditions. In addition to uncertainty, transportation costs are relatively high and political factors are relatively important compared to many natural resource markets (Libecap, 2007; Hanak et al., 2012).

Our empirical evidence generally supports the prediction from the economic organization literature that long-term relationships and vertical integration are more likely to result when asset specificity is present, and this adds to a rather large literature mostly outside of natural resources.[3] In particular, we find that long-term deals are more likely when the distance between buyers and sellers increases (indicating more specific investment for water delivery and use). We also find that uncertainty in the quantity of the asset is an important correlate of contract duration, suggesting that longer-term deals are used to reduce overall water variability. For instance, we find that long-term deals are more likely when water is being delivered from streams that have relatively low

[2] For reviews of the literature see Shelanski and Klein (1995) and Lafontaine and Slade (2007).

[3] Many studies in a large literature across many industries generally find evidence in support of the economic-organization hypothesis. The studies most closely related examine ownership (i.e., vertical integration) of public utilities (Troesken, 1997; Troesken and Geddes, 2003; Masten, 2009). The latter two studies find that municipal ownership of water systems is explained by contracting costs.

annual variability. Finally, we find limited evidence that measureable third-party effects determine the length of transfer agreements.

Institutions and Markets for California Water

Water allocation and transfer are generally not simple; in California—where markets are relatively primitive and governed by a complex mix of legal, administrative, and political institutions (Libecap, 2007; Hanak et al., 2012)—they are particularly complicated. Water use varies: the technology can range from primitive to sophisticated and capital intensive, and a mix of consumers includes agricultural, urban, and industrial users. California is the largest of the western states in terms of both agricultural and municipal water use and has the largest agricultural economy of all states. The fertile soils in the central part of the state are generally unproductive without sufficient irrigation. On average, Californians use over 40 million acre-feet of water per year (Hanak et al., 2012), 75–85% of which is used for agricultural purposes (Hanak and Stryjewski, 2012).

Water Ownership and Governance

California's water institutions evolved from the combined forces of Spanish-Mexican law and the law of the mining camps early in California's American history (Getches, 1997; Kanazawa, 1998). Under the western water law doctrine of prior appropriation, water rights are defined to allow holders of the right to divert a given quantity during a given time period, most often one period. Under this doctrine, water rights are defined in terms of the volume of diverted water per period (usually a year) but not in terms of the amount actually used or consumed.[4] 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 (Hanak et al., 2012). 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 earlier are referred to as "senior" appropriators, while "junior" appropriators are those with more recently established rights. 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.[5]

Water users are also diverse, ranging from farmers and urban residents to fishermen. It has been widely noted that the marginal values of water vary widely among 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 ten times the value of agricultural water (Brewer et al., 2008; Edwards and Libecap, 2015; Hanak and Stryjewski, 2012). Contracting is required for transfer participants to realize these gains from trade. Yet the determinants of contractual forms have yet to be investigated by the literature.

Local agencies such as irrigation districts and water supply districts are the most common source of water for California farmers. These public entities are responsible for holding water rights and allocating water to individual farmers within their districts. For instance, the Imperial Irrigation District (IID) in Southern California owns rights to divert water from the Colorado River. The IID sells and leases this water to the individual farmers who make up the district. Irrigation districts are also responsible for developing and maintaining the facilities necessary to convey water to irrigators.

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[4] 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)

[5] Transfers of appropriative rights are governed by highly variable state laws. For a more detailed description of state regulations, see Getches (1997, pp. 155–176) and in particular Hanak et al. (2012) on California regulations.

These include ditches, canals, and storage facilities. Landowners elect board members to manage district activities.[6]

These agencies often rely on water from California's Central Valley Project (CVP), which was created in the late 1930s by the United States Bureau of Reclamation 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. In addition to the CVP, the California State Water Project (SWP) also supplies irrigation water to farmers. The SWP is a system of lakes and reservoirs, canals, pumping plants, and storage facilities that transports water from north to south for both agricultural and municipal purposes.

Another major user group is municipal customers (Hanak and Stryjewski, 2012), most of which are served by public municipal water providers. Cities and towns have water departments that are responsible for distributing water to those living within city limits. In addition to distribution, municipal water utilities are also responsible for acquiring 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 its customers.

Finally, environmental water use is increasingly important in California. Environmental users are most interested in maintaining water in streams for recreation and fish/wildlife habitat. The U.S. Fish and Wildlife Service, California Department of Water Resources, and 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 short-term demands.

Water Transfer Agreements

Water transfers in California have become increasingly important in the last two decades. Hanak et al. (2012) report that in the early 1980s annual transfers were around 100,000 acre-feet. By the 2000s, annual transfers were between 1–2 million acre-feet, as much as 5% of annual state-wide use (Hanak et al., 2012). Contracts for these transfers take a wide variety of forms, ranging from simple two-page agreements to complex agreements with numerous contract terms (Brewer et al., 2008).[7] A simple contract specifies duration, price and quantity schedules, conveyance procedures, and timing and location of diversion.[8] More complicated contracts specify land-fallowing commitments; conservation measures by sellers; how environmental impact reports will be prepared; environmental mitigation cost sharing; water-quality requirements; and transfer quantities contingent upon availability, arbitrage clauses, and termination clauses.

An example of a complicated transaction is the aforementioned agreement between the Imperial Irrigation District (IID) and the San Diego County Water Authority (SDCWA). This contract includes contingencies in both prices and quantities, price adjustments over time, resale terms, and predetermined delivery schedules. The agreement involves transferring the water conserved from the IID irrigation canals in the Lower Colorado River basin to San Diego. While reducing consumptive use in agriculture made water available to transfer, reduced return flows were judged to be potentially

[6] Some agricultural producers also hold rights directly without the involvement of irrigation districts. We do not 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.

[7] Under California water law, the state is the true legal owner of all surface water (California Water Code Section 102). The State Water Resources Control Board oversees all transfers. Participants in 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. Details can be found at http://www.swrcb.ca.gov/laws_regulations/.

[8] Agreements for water transfers are typically more complicated than contracts for other assets, such as agricultural land or trucking equipment (Allen and Lueck, 2003).

harmful to the Salton Sea, which is a downstream body of water dependent upon return flows from irrigation by IID. The no-harm-to-third-parties clause forced the contract between IID and SDCWA to also include mitigation efforts. The IID-SDCWA transfer shows that varying environmental and economic conditions can cause transfer contracts to vary substantially in complexity.

Opposition to transfers by rural communities is not unique to the IID-SDCWA agreement. Hanak and Stryjewski (2012) discuss how the transfer approval process has raised the costs of transfer. In particular, rural interest groups are often wary of water transfers out of agriculture. Much of the wariness seems to stem from the historic case of the land purchases by the city of Los Angeles in the Owens Valley (Libecap, 2007). 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, which it built and continues to own and operate. The decrease in the viability of the valley as an agricultural region created abundant opposition by valley residents (and politicians) to the transfer. The Owens Valley-Los Angeles transfer is the most commonly cited case by opponents of water transfers (Libecap, 2007).[9]

Economics of Water Transfer Contracts

The literature on transaction costs and water economics suggest several straightforward predictions regarding the structure of water transfers. We focus on asset specificity and related contracting costs, uncertainty, and externalities in confronting the following predictions:

1. Long-term agreements are more likely as specific assets for conveyance become more important.
2. Long-term agreements are more likely when buyers face uncertain water supplies and less likely when sellers have uncertain supplies.
3. Long-term agreements are more likely when the transfer has fewer third-party impacts.

We explain these predictions in the context of water transfers in California.

Water Transfers and Asset Specificity

An asset is "specific" if it has little value outside of an existing relation between buyers and sellers. As noted, the general result from the literature is that vertical integration or long-term contracting is likely to dominate temporary contracting when asset specificity is present.[10] If either side of a transaction makes investments specific to that relationship, then there is scope for opportunistic behavior in short-term contract renegotiation.

Asset specificity (especially physical asset specificity) can be important for water markets. Water must be delivered from seller to buyer, and the costs of transportation are relatively high (compared to value). Existing conveyance facilities may be inadequate to transport water between geographically separated buyers and sellers. Investments in assets specific to the particular transaction are then needed for appropriate conveyance. When specific investments are required to convey water between transacting parties, longer agreements are expected to arise. Energy costs are the most significant determinant of the costs of conveying water between parties. Water-transfer contracts often include provisions that allow transfer prices to vary with the cost of conveyance. While our empirical analysis focuses on contract duration, it is important to keep in mind that other contract terms are affected by specific assets and opportunism.

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[9] However, Libecap (2007) provides evidence that the Owens Valley transfer generated substantial gains for both Los Angeles and Owens Valley residents.

[10] MacLeod and Malcomson (1993) also show that price escalator clauses are expected to arise under such long-term agreements as mechanisms to prevent renegotiation.

Water Transfers and Uncertainty

Uncertainty is important for water allocation because—unlike land or a building—water is not an asset fixed in size. Because water stocks vary over time and across space, transactions of water rights are expected to be influenced by uncertainty. The combination of the water rights system and hydrologic conditions therefore creates uncertainty that would be expected to impact the choice of contract duration for transfers. Uncertainty leads directly to transaction costs by increasing the costs of measurement and enforcement (Allen, 1991; Barzel, 1982). Uncertainty also creates differential incentives for those with different risk preferences. 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.[11]

Because of this inherent variability in water stocks—both those currently held by the potential buyer and by potential seller—parties negotiating a transfer will structure the agreement in ways that limit the adverse impacts of this uncertainty. In years when streamflow is limited, junior rights holders may not have access to their entire endowment. In short, longer-term contracts are more likely when the water being transferred comes from streams with lower coefficients of variation of annual streamflow. This prediction has two components.

First, for a given transfer, we expect that a long-term agreement is more likely as variability in the buyer's water stock increases. A longer-term agreement will give such a buyer a more reliable source of water over time. A longer agreement means longer-term contracts are more likely when the assets held by the buyer holds rights in streams with more variation in annual streamflow.

Second, for a given transfer, we expect that a long-term agreement is less likely as variability in the seller's water stock increases. A longer-term agreement is less important when sellers have uncertain supplies (e.g., junior rights) because they are more likely to have short-term surpluses. Sellers with more senior rights may expect to have excess water (i.e., supply will depend on current weather and on rights' seniority).

Water Transfers and 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 impact and the parties have relatively limited collective action problems themselves. For water, however, 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 affected by a transfer. Two kinds of third-party effects can potentially impact the structure of water transfers.

The first set of third-party effects are externalities that can arise because transfers are typically measured in terms of the amount of water diverted and not the amount of water actually consumed (Johnson, Gisser, and Werner, 1981), because water quality might be altered by changes in water use after a transfer, and because transfers might alter the points of diversion and streamflow across space.[12] Where these effects are present we expect that transfers are more likely to be short-term agreements in order to mitigate these impacts.

The second set of third-party effects are pecuniary externalities that arise when parties' incomes or wealth are affected by potential transfers. This scenario is most likely for transfers of water originating from agriculture and transferred to urban or environmental uses. Politicians

[11] 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.

[12] It is also possible that transfers might benefit third parties. For example, if water is transferred to an upstream user, more water will be available to those users just downstream from the new users.

and agricultural interest groups oppose transfers on the grounds that reduced agricultural water use leads to less demand for agricultural inputs (including labor). Rural communities, in particular, are dependent on agricultural labor, input purchases, and other factors. Previous work on third-party impacts of water markets highlights some of the factors that create opposition to transfers among local community residents and downstream appropriators (Vaux and Howitt, 1984; Young, 1986; Hanak, 2003).

In some cases, transfers might have both real and pecuniary effects. For example, transfers that include a change in the point of diversion will lead to reduced return flows for users downstream of the seller. Transfers out of agriculture therefore affect both rural agricultural communities and downstream irrigators who benefit from agricultural water use. Depending on the location of diversion, different irrigators may be affected differently by the reduction in return flows.[13] 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.

Empirical Analysis

Data and Empirical Strategy

Water market data are notoriously scarce and incomplete. No government agencies or NGOs routinely collect data on water transactions. The available data tend not to come from systematic surveys of water transfer, so information varies considerably across observations. These limitations have plagued many who have studied water markets.

Given these limitations, our water transaction data are taken from a publicly available database on water transfers.[14] The data consist of transactions from 1987–2008. To avoid unobservable differences in water institutions across states, and to collect a data set with micro-level information on the participants in the transactions, we focus our analysis on transfers in California.[15] These data allow us to identify the buyers and sellers for some of the transactions and supplement the transaction data with data from other sources.[16] These additional data come from publicly available sources at 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.

Our water transaction data are cross-sectional in nature.[17] Given that our identification comes from cross-sectional variation in attributes of transacting parties, caution must be taken with regards to causal interpretation of our estimates. We use these data to estimate an ordered probit model

[13] 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 as a result of a transfer. Their results indicate that disagreements between irrigators within districts can cause transfer outcomes to diverge from predicted optimal outcomes.

[14] The database is available at the University of California, Santa Barbara, and is the first comprehensive database on western water transactions. The data were collected from the trade journal *The Water Strategist*, published by Stratecon, Inc. (Brewer et al., 2008). Data from this source are no longer publically available. Hanak et al. (2012) provide summary statistics from a large and proprietary database on California water transfers.

[15] Hansen, Howitt, and Williams (2014) use these data in their study of western water markets, which examines data from ten western states.

[16] 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.

[17] In an ideal data environment we would be able to guarantee that the explanatory variables used to test our predictions would be strictly orthogonal to all unobserved factors affecting contract duration. Random assignment of asset specificity, supply uncertainty, and third-party impacts to transacting parties is obviously not possible. Though not available, panel data on water-transfer agreements would also assist in identifying causal effect because the researcher can control for unobserved time-invariant characteristics of buyers and sellers that affect contract duration and are potentially correlated with variables of interest.

(Greene and Zhang, 2003) explaining variation in the length of transfer contracts.[18] Our basic model is

$$y_i^* = x_i^* \beta + \varepsilon_i \quad (1)$$

and

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

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, x_i is a column vector consisting of the explanatory variables, β is a column vector of parameters to be estimated, and ε_i is a random error term that is distributed as a standard normal. We estimate equations (1) and (2) using maximum likelihood. An alternative empirical approach is to estimate the choice between leasing and ownership. The Data Appendix reports the parameter estimates from probit estimates of the lease-own decision (table A2). These estimates are similar to those discussed below.

The California dataset contains 416 water transactions, including 286 short-term leases (one year or less), 65 long-term leases (more than one year), and 65 permanent transfers. The dominance of short-term leasing is consistent with water markets in all western states. Of these, only 207 transactions have information on both buyers and sellers, and from this we obtain our baseline estimates: a set of 168 observations with a complete set of information on the transfer as well as our explanatory variables.

Table 1 provides descriptions and summary statistics of the variables used to estimate our empirical model. The dependent variable—which matches the empirical model defined by equations (1) and (2)—is a discrete ordered variable set to 0 for a short-term (one year) lease, 1 for a long-term (more than one year) lease, and 2 for a permanent transfer. We do not report summary statistics for the dependent variable in the table 1 because the mean value is largely irrelevant.

We use two variables to measure asset specificity. First, *Distance* is the geographic distance between the buyer and seller. Table 1 shows that the mean distance is 102 miles and that the range of transfers is from 0 to 528 miles. Transporting 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 conveyance of the water is likely to be much more complicated when buyers and sellers are farther 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 more likely as buyers and sellers become more distant. As is seen in table 1, our data include transactions from buyers and sellers within the same ZIP code (where the distance is 0) and transactions from buyers and sellers located at extreme ends of the state.[19] A second measure of asset specificity is *Urban*, a dummy variable for urban buyers. Table 1 shows that municipal water districts are buyers in 49% of transactions. A water transfer to an urban buyer can plausibly be viewed as a measure of specific assets because urban water use will require addition treatment and delivery systems particular to a transaction.[20] Prediction 1 implies that the estimated coefficients for both of these specific asset variables will be positive.

[18] Classic empirical studies in the transaction cost economics literature have taken one of two forms. In cases in which contract duration is continuous and finite, standard econometric procedures for continuous variables are used to test predictions (Joskow, 1985; Allen and Lueck, 1992). 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). Our water-transaction dataset is similar to the literature on qualitative decisions, yet we are able to observe the length of lease agreements.

[19] We also include a squared distance term to investigate the potential nonlinear relationship between the ordered probit index function and the distance between buyers and sellers.

[20] Even if the interpretation of *Urban* as a measure of specific assets is not perfect, it is important to control for buyer types.

Table 1. Variable Descriptions and Summary Statistics

Variable	Description	N	Mean	SD	Min	Max
Asset Specificity						
Distance	Distance between buyer and seller (in miles)	207	102	127	0	528
Urban	1 if buyer is urban municipality, 0 otherwise	277	0.49	0.50	0	1
Uncertainty						
Buyer Uncertainty	Ten-year coefficient of variation for buyer water supplies	275	0.79	0.42	0.03	1.96
Seller Uncertainty	Ten-year coefficient of variation for seller water supplies	341	0.73	0.53	0.04	2.55
Third-Party Effects						
Ag Income	Agricultural income / total personal income in seller county	346	0.03	0.03	0	0.22
State Water	Park water feet / total land area in seller county	346	65.17	136.38	0	611.12
Endangered Species	Number of endangered and threatened species listed in seller county, ten years prior to transaction	346	0.82	1.09	0	4
Controls						
Buyer Precip	Precipitation in buyer county during transaction year	231	12.44	7.37	1.80	41.09
Buyer Streams	Streamflow percentage for buyer during transaction year	275	101.92	109.40	2.25	648.42

Notes: See Data Appendix for sources.

Uncertainty is measured using two variables, both of which use the ten-year coefficient of variation in streamflow as a measure of uncertainty in water supplies. *Buyer Uncertainty* is the stream variation at the buyer's location while *Seller Uncertainty* is the stream variation at the seller's location. Both of these variables have a mean coefficient of variation around 0.75. We expect buyers to be averse to this supply variability. Purchasing a long-term water right with little uncertainty is one way for buyers to create less uncertainty in water supplies. Longer-term agreements are expected when buyers have uncertain water supplies and sellers hold more certain rights. Prediction 2 implies that the estimated coefficients will be positive for *Buyer Uncertainty* and negative for *Seller Uncertainty*.

Third-party effects are measured using three variables that vary by the origin of the water being transferred. Rural communities with productive agricultural economies are likely to oppose transfers, especially long-term transfers, originating from agriculture. *Ag Income* is the ratio of total agricultural income to total personal income in the seller's county; this variable measures the economic importance of agriculture in the seller's area. Table 1 shows that mean share of income from agriculture in a county is just 3% but that it can be as high as 22%.

Two additional third-party variables are used. As a measure of instream flow values, we use *State Water*, which is the ratio of acre-feet of water owned by the state parks department to county land area in the seller's county. We assume that in-stream flow values are higher in areas with more lakes and streams in state parks. Table 1 shows the mean of *State Water* values to be 65 linear feet per acre, with a high variation across counties. We also examine the effect of endangered species listings on the length of transfer agreements. The variable *Endangered Species* is the number of endangered or threatened fish species (in the seller's county) that were added to the list by the U.S. Fish and Wildlife

Table 2. Mean Values of Independent Variables, by Contract Type

Variable	Short-Term Leases	Long-Term Leases	Permanent Sales
Asset Specificity			
Distance	0.85	1.02	1.77
Urban	0.29	0.72	0.65
Uncertainty			
Buyer Uncertainty	0.71	1.02	0.84
Seller Uncertainty	0.73	0.76	0.72
Third-Party Effects			
Ag Income	0.03	0.03	0.02
State Water	75.17	56.27	22.93
Endangered Species	0.71	1.00	1.22
Controls			
Buyer Precip	10.80	15.77	14.03
Buyer Streams	93.11	114.70	119.68
N	133	43	31

Service in the last ten years.[21] Table 1 shows that some transactions have no species listings, while others have a maximum of four new listings. Prediction 3 implies that the estimated coefficients on the third-party variables will be negative because shorter-term transfer will mitigate third-party impacts.

We also use two control variables in our estimates. The first variable is *Buyer Precip*, which is the precipitation in the buyer's area and is a measure of short-term water availability. Given that leases can be used to supplement current supplies, we expect an inverse relationship between contract duration and buyer precipitation. Second, *Buyer Streams* is the buyer long-term streamflow, which represents average streamflow on sources where buyers hold water rights as a percentage of the long-term average (in the ten years preceding the transaction).[22] We expect leasing to be more likely if current streamflow is less than average. Table 1 shows that both variables have considerable variation across our sample. In our estimates we also use the variable *Time Trend*, which identifies the year of the contract.

Table 2 presents mean values for short-term leases, long-term leases, and permanent transfers. While these mean values do not test our predictions, they are useful to highlight some trends in the data. Our primary measure of asset specificity, *Distance*, is increasing in mean for longer contract types, providing some initial evidence that longer-term contracts may be associated with buyers and sellers that are farther apart in distance. *State Water* also has a clear trend in mean value between contract types, potentially indicating a negative relationship between duration and instream water use in the seller's area. The direction of the relationship between contract duration and other variables is not clear from the mean values.

[21] We relied upon the Nature Serve online conservation database (www.natureserve.org) for identifying habitat areas of species. "Endangered" and "threatened" are two categories of species governed by the Endangered Species Act of 1973 (for details see http://www.fws.gov/endangered/).

[22] 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 was not a CVP contractor, we used streamflow from major streams within a forty-mile radius of the buyer's office.

Econometric Estimates

Table 3 presents the maximum likelihood estimates from three specifications of equations (1) and (2) using different subsets of our data. Specification 1 uses the entire dataset (168 observations with information on both parties in the transaction) 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 (104 observations), allowing 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 (164 observations) and allows us to test the effects of in-stream use and endangered species on contractual form (prediction 3).

The estimated coefficients for the asset-specificity variables are consistent with Prediction 1. The estimates for *Distance* are positive and statistically significant in all specifications. All estimates for *Urban* are also positive and statistically significant. The negative estimates for *Distance Squared* indicate that 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 initially increasing with distance 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.[23]

The estimated coefficients for the uncertainty variables are consistent with the hypothesis that long-term contracting is a way for buyers to protect themselves from variability in water supplies. The probabilities of longer-term agreements are increasing with *Buyer Uncertainty* and decreasing with *Seller 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.

The estimated coefficients for the third-party variables showed limited evidence that third-party impacts are important determinants of contract duration. Of the three third-party variables, only estimated coefficients for *Ag Income* have the expected sign and are statistically significant. This could be considered as moderate evidence that agricultural sellers consider pecuniary effects on rural communities when negotiating the length of water-transfer agreements. The estimates for *State Water* do not provide convincing evidence in support of prediction 3, nor do the estimates for *Endangered Species*. Indeed, the negative coefficient estimates for *Endangered Species* indicate that long-term agreements are actually more likely when sellers are located in areas with more endangered and threatened species listings. An alternative interpretation, however, is that dealing with endangered species increases the fixed costs of transacting, so that the presence of such species leads to longer-term transfer. Still, taken together the estimates of third-party effects provide at most limited support for the hypothesis that effects on third parties are most important for determining contract duration.[24]

The estimated coefficients for the control variables are generally statistically significant. The *Time Trend* estimates are generally positive, indicating that more recent contracts tend to be longer term, a finding consistent with data presented by Hanak et al. (2012). The estimates for *Buyer Precip* have the expected sign and are statistically significant in two of the three specifications. Shorter-term agreements tend to dominate when buyers are experiencing relatively dry conditions. The estimates for *Buyer Streams*, measuring the impact of buyer streamflow conditions, are negative and not consistent with our expectations. The results indicate that longer-term agreements are more likely when buyers are in low streamflow areas. While the sign of the estimate is counterintuitive, the absolute magnitude of the coefficient is small.

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[23] A plausible reason for the non-monotonicity of distance is that more distant markets are thin and uncertainty becomes relatively more important with distance.

[24] Since we only observe transactions that took place—and failed negotiations or transactions that did not meet regulatory approval—we are unable to rule out that third-party effects are important for actually allowing transactions to take place. Our estimates must therefore be interpreted as conditional on a transaction occurring.

Table 3. Ordered Probit Results for Contract Duration

	Specification		
Variable	**(1)**	**(2)**	**(3)**
Asset Specificity			
Distance	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)
Urban	0.6962***	1.3908***	0.6372***
	(0.2293)	(0.3643)	(0.2457)
Uncertainty			
Buyer Uncertainty	1.1680***	1.0836*	1.1170***
	(0.3585)	(0.5644)	(0.3674)
Seller Uncertainty	−0.7164**	−1.6377***	−0.7323**
	(0.3069)	(0.5919)	(0.3195)
Third-Party Effects			
Ag Income		−9.3604*	
		(5.0191)	
State Water			−0.0012
			(0.0013)
Endangered Species			0.1925*
			(0.1060)
Controls			
Buyer Precip	0.0608***	0.0154	0.0722***
	(0.0169)	(0.0254)	(0.0179)
Buyer Streams	−0.0025**	−0.0012	−0.0035***
	(0.0012)	(0.0019)	(0.0013)
Time Trend	0.0481**	0.0072	0.0381*
	(0.0200)	(0.0294)	(0.0209)
μ_1	2.5464***	1.3218**	2.4588***
	(0.4265)	(0.6603)	(0.4343)
μ_2	3.5259***	2.2618***	3.4692***
	(0.4566)	(0.6788)	(0.4650)
N	168	107	164
Pseudo R^2	0.225	0.344	0.242
Log-Likelihood	−121.7946	−57.3619	−115.9001

Notes: Single, double, and triple asterisks (*, **, ***) indicate statistical significance at the 10%, 5%, and 1% level. Standard errors are in parentheses.

Because the estimated coefficients from our ordered probit model do not yield simple economic interpretations we examine the marginal effects of one-standard-deviation changes in independent variables. Table 4 present the marginal effects of these estimates, calculated at the mean of the independent variables. Each column refers to the change in the probability that a specific contract duration (short-term, long-term, or permanent sale) will be chosen.

For *Distance* the marginal effects suggest that the probability of short-term leases at mean values is decreasing in distance, while the probabilities of long-term leases and permanent transfers are increasing in distance. As an example (row 1, column 1), if the distance between buyers and sellers is increased by 100 miles—slightly less than one standard deviation—then the probability of short-

Table 4. Marginal Effects of Independent Variables on Contract Choice

Variable	Short-Term Leases	Long-Term Leases	Permanent Sales
Asset Specificity			
Distance	−0.1596	0.0924	0.0672
Urban	−0.2532	0.1424	0.1107
Uncertainty			
Buyer Uncertainty	−0.4313	0.2497	0.1816
Seller Uncertainty	0.2645	−0.1531	−0.1114
Third-Party Effects			
Ag Income	2.6240	−1.8582	−0.7659
State Water	0.0004	−0.0003	−0.0002
Endangered Species	0.0705	−0.0426	0.0279
Controls			
Buyer Precip	−0.0224	0.0130	0.0095
Buyer Streams	0.0009	−0.0005	−0.0004
Time Trend	−0.0178	0.0103	0.0075

Notes: Marginal effects calculated at mean values of independent variables. Specification 1 from table 3 is used for all variables other than those measuring third-party impacts.

term leasing decreases by 15.96 percentage points, or 23%.[25] At the same time, the probability of long-term leasing is expected to increase by 9.24 percentage points (59% off a base of 15.62%) and that of permanent transfers is expected to increase by 6.72 percentage points (43% of the base). The marginal effects for *Urban* behave similarly to those for *Distance* and have similar magnitudes.

The marginal effects of the uncertainty variables are economically significant. As table 4 shows (row 3, column 3), a one-standard-deviation increase in *Buyer Uncertainty* is associated with an 18.1 percentage-point (26%) decrease in the probability of short-term leasing. Conversely, the probability of long-term leases increases by 10.4 percentage points (67%), and the probability of permanent transfers increases by 7.6 percentage points (49%). A one-standard-deviation increase in *Seller Uncertainty* is associated with a 14 percentage-point (20.3%) increase in the probability of short-term leasing, an 8.1 percentage-point (51.9%) decrease in the probability of long-term leasing, and a 5.9 percentage-point (37.8%) decrease in the probability of a permanent transfer.

Concluding Remarks

Water allocation is not simple, and the organization of water transactions is not transparent. In this study we have used the economics of organization and transaction costs to explain the economic logic of the structure of emerging western water markets. This is the first study to use micro-level data to look at contractual form for water transfers. Our findings indicate that incentives are important in determining the structure of these markets and suggest an avenue of research for other environmental markets such as fisheries quotas and pollution emissions. Our study adds to recent work on water markets, particularly that of Brewer et al. (2008); Hanak et al. (2012); and Hansen, Howitt, and Williams (2014). These papers examine the details of water markets and their recent growth but do not focus on the structure of the transfer agreements as we do.

Using the limited data available on water transfers, we find that asset specificity and uncertainty are important determinants of contract length. Our findings on asset specificity, in particular, are

[25] This number comes from the marginal effect calculated at the mean value of distance, reported in the first row and first column of table 4. The percentage effect of 23% is based off the rate of permanent transfers in the dataset, which is 68.75%. We use this same approach to interpret the relative size of all marginal effects.

consistent with a large literature on contracting and vertical organizations. 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. Goods that require transport between buyers and sellers can often be transferred without any additional investments in infrastructure. Our findings regarding uncertainty results suggest that long-term contracting is a way for water agencies to manage uncertainty in water supplies and to decrease the risk of their overall portfolios. Our findings for third-party effects are mixed. While there is moderate evidence that long-term agreements are less likely in areas where agriculture contributes significantly to the local economy, we do not find evidence that the impact on instream flows is considered by sellers of water rights. Third-party impacts do not appear to be important determinants of contract form (conditional on the occurrence of a transaction).

While this study is the first to examine the detailed structure of water transactions, the incomplete and imperfect nature of the available data require some comments on both the limits of our findings and avenues for further research. First, as discussed above, it is not possible for us to carefully show economic causation. Second, our explanatory variables are imperfect and thus subject to alternative interpretation. Third and finally, we are only able to examine a single contracting outcome, the duration of the agreement. Empirical studies in transaction cost economics are mostly focused on how various incentives affect the structure of economic agreements, usually focused on the length of agreements. It is, however, plausible to consider the effects of asset specificity, uncertainty, and third-party effects on other contract outcomes, such as price or quantity.[26] Future economic analysis of markets for water and other environmental assets can improve our understanding by developing improved datasets and by examining a broader range of issues.

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[26] Our empirical model does not consider the possibility of endogenous matching of buyers and sellers. Econometric estimates can be biased when participants in a transaction contract with one another 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 equation (1).

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Data Appendix

The data were obtained from the online water-transfer database from the University of California, Santa Barbara. The database includes transactions from twelve 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. Buyer and seller identification was necessary before matching 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 with identifiable buyers and sellers. Table A1 provides the data source for each variable.

Table A1. Variable Sources

Variable	Source
Buyer Precip	California Irrigation Management Information System
Buyer Streams	U.S. Geological Service
Urban	Original transaction data
Distance	Calculated from longitude and latitude using Haversine formula
Buyer Uncertainty	U.S. Geological Service
Seller Uncertainty	U.S. Geological Service
Ag Income	Bureau of Economic Analysis
State Water	California Department of State Parks
Endangered Species Listings	U.S. Fish and Wildlife Service

Explanatory variables were collected from a variety of sources. 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 buyer's county 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. For districts that did not have water rights at streams for which we had streamflow data and were not CVP contractors, we used streamflow values at all major streams within a forty-mile radius of the district's office.

The distance between the buyer and seller was calculated by the Haversine calculation, which is a standard way of calculating distance between two points based on their longitude and latitude values, which were derived from postal codes. The DWR list of water providers was used to obtain the postal code and hence county of each transfer participant. The agricultural income ratio is calculated as the ratio of agricultural income to total personal income in the seller's county at the time of the transaction. Income data were obtained from the Bureau of Economic Analysis online database (http://www.bea.gov/itable). 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 (http://www.fws.gov/endangered/). We identified the counties for which each fish species was known to exist using the Nature Serve free online database (www.natureserve.org).

Table A2. 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)
Asset Specificity			
Distance	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)
Urban	0.4651	1.5470**	0.4245
	(0.2956)	(0.6519)	(0.3120)
Uncertainty			
Buyer Uncertainty	0.3812	−0.6730	0.2965
	(0.4412)	(0.9002)	(0.4561)
Seller Uncertainty	−0.6317	−2.6222**	−0.7049*
	(0.3941)	(1.0697)	(0.4187)
Third-Party Effects			
Ag Income		−7.9917	
		(6.5486)	
State Water			−0.0006
			(0.0016)
Endangered Species			0.1505
			(0.1264)
Controls			
Buyer Precip	0.0330*	−0.0145	0.0435**
	(0.0200)	(0.0376)	(0.0211)
Buyer Streams	−0.0007	0.0017	−0.0015
	(0.0014)	(0.0025)	(0.0015)
Time Trend	0.0428*	−0.0363	0.0339
	(0.0256)	(0.0418)	(0.0269)
N	168	107	164
Pseudo R^2	0.203	0.406	0.214
Log-Likelihood	−59.0134	−25.7474	−56.3507

Notes: Dependent variable $y = 0$ if lease and $y = 1$ if ownership transfer. Single, double, and triple asterisks (*, **, ***) indicate statistical significance at the 10%, 5%, and 1% level. Standard errors are in parentheses.

An alternative approach is to make the economic distinction between leasing and owning rather than the duration of the transaction. Table A2 shows these estimates.