An Econometric Test of Water Market Structure in the Western United States

by
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Abstract. Water markets form differently across the western United States, depending on the relative importance of water supply uncertainty and impediments to water transfers. In many locations, trades take the form of short-term leases of water, where the underlying property rights remain unaffected. In other regions, water right transfers predominate. A theoretical model developed here shows the conditions that favor leasing water or purchasing rights. Econometric analysis of 3,499 transactions reported in the *Water Strategist* over 1990-2008 supports the conclusion that institutions have influenced not only whether water trades occur, but also the style of the trades. (JEL D23, L22, Q25)

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Introduction

Over the past several decades, western U.S. states have implemented institutions and regulations to facilitate water transfers from low-value rights holders to higher-value purchasers. Since Hartman and Seastone (1970) demonstrated the theoretical gains possible from water markets, much work has been done to quantify the efficiency gains realized in practice (e.g., Vaux and Howitt 1984; and Hearne and Easter 1997). However, the emphasis on aggregate efficiency gains leaves uninvestigated how the transfers have been achieved. Using a recently available data source, it is now possible to use information on existing transfers to examine the influence of economic and hydrological variables on the style of trading.

Water transfers fall into two broad categories. First, the transfer of a water right grants the purchaser the flow of water every year in perpetuity. Second, a water transfer may be in the form of a lease, granting the purchaser a pre-specified volume of water for the term of the lease. Leases may be short-term (here defined to be one year or shorter) or long-term (longer than one year). Leases may be similar to spot market transactions, with negotiation occurring close in time to the physical transfer of water, or they may be negotiated in advance of need as forward contracts. Leases of twenty years or longer with provisions for renewal bear more resemblance to water rights transfers than short-term leases. Leases may also be dry-year options, so that water is only transferred in dry years when economic value is particularly high. What factors does a water agency consider when it decides whether to purchase or lease a water right? Do different conditions in different states affect the probability of observing one type of transaction over the other? How is the probability of observing a sale or a lease affected by various institutional, economic, and hydrological factors?

The situation studied here has similarities with the literature on firms' choice of short-term loans or long-term bonds as a source of funds (Aigner and Sprenkle 1973; Emery 2001). The problem also shares key features with the make-or-buy literature of transaction-cost economics, such as when a medical equipment firm makes a key valve itself rather than using an independent machine-tool shop (Shelanski and Klein 1995; Klein 1998). Quantitative analysis of the make-or-buy decision is rare; comparisons across firms and industries are difficult when other parties' actions are uncertain, investment is transaction-specific, and transaction frequency varies. Water markets alleviate some of the difficulties for quantitative analysis by providing buyers and sellers with a discrete choice between leases and sales, which makes observation of their choice cleaner, and generalization possible.

This article investigates the style of transfers within western water markets with reference to 3,499 transactions compiled from a monthly trade journal called the *Water Strategist* from 1990 to 2008. The *Water Strategist* reports rights transfers and leases (including price, quantity, buyer and seller identification, buyer and seller use, and some additional contract terms) in sixteen western states on a monthly basis. With the details of transactions, this article is able to explore reasons why leases prevail in some states and sales prevail in others. The patterns evident among the transactions reported in the *Water Strategist* provide insight into the issue of how market institutions develop.

Western Water Markets

Two primary sources of heterogeneity among water users in the western United States contribute to the value differentials that induce trading. First, precipitation in the western United States is characterized by great spatial and temporal variation. Second, many water rightsholders utilize their water in relatively low-value agriculture, whereas many urban agencies and environmental interests do not have enough water and are willing to pay high prices to acquire it. Conversely, water has a number of characteristics that have hindered trading. First, conveyance costs are a large portion of delivered water price, as water can be cumbersome and expensive to transport. Second, the high degree of interaction among users of water often results in physical and environmental externalities. Third, sellers of agricultural water often leave fields fallow, leading to controversial third-party effects in the basin-of-origin. Fourth, regulatory requirements are often imposed expressly to limit and prevent environmental externalities and to protect third parties from economic impacts (Hanak 2005). Other state-imposed barriers to transferring water exist simply through inertia, carryovers from a time when water was plentiful enough that its allocation rarely involved a trade-off between existing low value and potential higher-value uses (Saleth and Dinar 2004).

In spite of these hindrances, water's increasing relative scarcity has intensified efforts to move water from low- to higher-value uses through some type of trade. The second through fourth hindrances are more of a problem for rights transfers than for leases, so leases often occur simply because of the difficulty of transferring rights. In many western states, leases are common. Leases face less stringent legal restrictions due to environmental and third-party impacts, because water transferred temporarily causes less disruption in the exporting basin and community than water transferred permanently

(Howitt 1998). The prevalence of short-term leases in many states may be a response to artificial impediments to rights transfers. Alternatively, leases may be the preferred type of transaction for purchasers responding to changing economic and hydrological conditions in the short-term.

Water law in most western United States follows the doctrine of prior appropriation, so that water claimed earlier in time has greater seniority on a waterway than water claimed later; in the event of a drought, rights with seniority receive water before more junior rights, making them more valuable. For example, in 2001 the Metropolitan Water District of Southern California acquired 100,000 af/year under long-term lease from the Palo Verde Irrigation District, which has very senior rights to Colorado River water. The seniority of the water rights was an important aspect of the transaction to (Selig 2008). Seniority is less important for short-term leases because short-term leases generally occur when the water is already physically present and available, regardless of the seniority of the underlying right.

Several other studies have used the *Water Strategist* data.[1] A recent example is Brewer et al. (2008), who use the data from 1987 to 2005 to survey how western water markets have responded to the large disparity in value between urban and agricultural water uses. They note in particular that the number of agricultural-to-urban transfers is increasing over time and that water is increasingly transferred under longer-term leases and sales rather than one-year leases. Brown (2006) uses *Water Strategist* data from 1990 to 2003 to estimate the effect of time, precipitation, population, buyer use, groundwater, and transaction size on sale and lease price. Consistent with our

[1] In addition to the three studies mentioned here, other studies include Czetwertynski (2002), Loomis et al. (2003), Adams, Crews, and Cummings (2004), and Howitt and Hansen (2005). The *Water Strategist* appears to be the best available data source for a comprehensive review of western U.S. water markets.

observations from the *Water Strategist*, he finds that sale prices are increasing over time but remain unaffected by drought periods. Lease prices are higher during drought periods than during wet periods and for transfers to municipal and environmental uses than to agriculture. Brookshire et al. (2004) also use the *Water Strategist* data (1990-2001), to estimate a demand function for water rights for three of the most active markets in the western United States, in Arizona, New Mexico, and Colorado. They note that much of the variation in price and quantity across markets is due to institutional differences.

Although the effects of some economic and hydrological variables on prices and quantities have been examined using the *Water Strategist* data, no study has attempted to quantify the effects of these variables on the interaction between the rights and lease markets. This paper is consequently the first to quantify the relative effects of economic, hydrological, and state regulatory variables on the trading styles observed in the western United States.

The *Water Strategist* often records multiple transactions within a single entry. We have separated these entries into distinct observations when possible, so that our own database for the years 1990 to 2008 consists of 5,158 observations. However, not all of these observations are directly relevant to the decision whether to buy or lease a water right. We exclude exchange and storage contracts, retail transactions, options that are not known to have been exercised, transactions in which water price or volume transferred is not indicated, and transactions involving land and water where water is not priced separately. We also exclude states with minimal trading volume (Kansas, Nebraska, North Dakota, Oklahoma). Statistics on the remaining 3,499 observations we present below.

Table 1 contrasts the quantities of water transferred by sale and by lease. The four states that transfer the most water in absolute terms are California, Arizona, Idaho, and Texas (column 2). These states also report the highest volume transferred through leases (column 4). Most leases are short-term; only 15% of leases (representing 7% of transaction-year volume) were for durations of longer than one year. When water is transferred under a long-term lease or sale, only the quantity transferred in the first year of the contract is reported in table 1. As these numbers include only transaction-year volume, they under-report the significance of sales and long-term leases relative to short-term leases.

Long-term leases are in some respects more similar to rights transfers than to short-term leases, because they allow water agencies to avoid repeated negotiation costs associated with multiple transactions and exposure to future price uncertainty, often without the more burdensome regulatory restrictions imposed on rights transfers. The buyer and seller in a number of transactions reported in the *Water Strategist* explicitly identified their short-term leases as a means of acquiring information before executing longer-term contractual arrangements.

Table 1 also indicates the number of transctions within each state by contract type (columns 1, 3, and 5). Markets are thin. In approximately half of the 228 state-year cells within this dataset, there are no transactions reported in the *Water Strategist*. Although markets are growing, the volume traded remains small compared to overall consumption (column 7). In most states, less than 1% of water consumed each year is transferred through sales or leases. When volume is calculated cumulatively (so that the volume transferred under a long-term lease in 2001 is counted in 2001 and each subsequent year), transferred water is still less than 3% of consumptive use in most states.

The most striking feature within table 1 is the variation by state in lease-to-sale ratios (column 8). For example, far more water was transferred under lease relative to sales in California than in Colorado. This particularly difference is undoubtedly due to the institutional conditions that prevail in the Central Valley Project (CVP) in California and the Colorado-Big Thompson Project (CBT) in Colorado. The CBT operates as a single water district, encompassing both agricultural and urban areas, which lowers trading costs significantly compared to the more jurisdictionally fragmented CVP. Second, proportional water rights in the CBT make rights transfers easy compared to the CVP, where the priority rationing system requires that water be quantified and potentially adjudicated before it is traded away (Carey and Sunding 2001).

Table 2 compares average volume-weighted lease and sale prices for transactions over the study period. "Lease price" is the cost in dollars per acre-foot of acquiring a pre-specified volume of water in each year of the contract. "Sale price" is the total cost of obtaining a right to one acre-foot of water each year, in perpetuity. Sale and lease price distributions are both skewed, with small, high-value transactions (for mining in remote regions, for example) driving average results. To compensate for this skewness, the prices presented are volume-weighted.

Across states and years, there is large variation in lease and sale prices. The final column of table 2 reports the implicit capitalization rate, which is the ratio of annual lease price to total sale price. States' individual implicit capitalization rates vary greatly. The ratios for Oregon and Washington are relatively high, in part because it was common over the study period for irrigators to lease out water at very low prices in wet years to avoid losing rights due to non-use. A variety of state and non-profit institutions have developed in Oregon and Washington to facilitate such transfers. The average implicit capitalization rate for the entire dataset is 5.95% (6.78% excluding CBT sale transactions),[2] below even the lowest market cost of borrowing money that tax-exempt organizations observed over the same years. The low implicit capitalization rate is likely due to the fact that many transfers occur at administratively set prices that do not reflect water value. Most notably, irrigators often pay subsidized rates for leased water. Further, municipal users are willing to pay a premium to acquire water rights.

In the absence of transaction costs and uncertainty, those wanting water would be indifferent between purchasing a right, which yields a flow of water each year in perpetuity, and acquiring water each year from the market in the form of a short-term lease, each year for all time. Several characteristics might prevent parity between the two alternatives. First, buyers may be willing to pay more than the annualized sale cost for an annual lease, because the decision to postpone an investment, such as the purchase of a water right that is very expensive to reverse due to high transaction costs, has value (Dixit and Pindyck 1994). Alternatively, sellers may require a premium to sell their water rights,

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[2] Brown (2006) compensates for the skewness of the data by presenting median rather than volume-weighted prices. Using median prices, he calculates an implicit capitalization rate of 1.94%. Using his time period (1990-2003) and his methods for categorizing data, we generate similar implicit capitalization rates by new use. Brewer, et al. (2008) also make the same calculations for purposes of comparison.

Comparison of implicit capitalization rates by new use (1990-2003)

Purpose	Brown	Brewer et al.	This study
MI	2.64	2.73	1.80
A	0.65	0.87	0.57
E	5.37	6.78	5.70
All	1.94	2.00	1.38

which in theory should equal the uncertainty cost to the buyer of repeated exposure to spot prices in the lease market. Buyers may be willing to pay such a premium to purchase a right for the same reason (Howitt 1998).

In western water markets, the second phenomenon appears to prevail; the low ICR indicates high annualized sales price relative to lease price. This finding is consistent with the utmost importance of reliability. Among western water managers, even a long-term lease is not perceived as being as reliable as a rights transfer (Pineda 2007).

Trends in the new uses of water are striking. Tables 3 provides descriptive statistics of sale and lease transactions by buyer use. Overall lease activity was divided relatively evenly between agricultural, environmental, municipal, and other purposes.[3] Municipal purchasers dominated sale and share transactions.

Over the study period, sales and leases to environmental use increased in absolute and relative terms. Environmental transfers have been facilitated by institutions such as the Environmental Water Account in California, under which fishery managers purchase water in real-time to augment in-stream flows at critical periods (Hanak 2001). Environmental buyers tended to acquire water under short-term lease. Of the 482 sales and leases to environmental buyers, 377 were leases. Of these, only 46 were longer than one year.

Water for agricultural use also tended to be purchased under short-term lease rather than long-term lease or rights transfer. Of the 557 transfers to agricultural buyers, 340 were leases. Of these leases, only 36 were longer than one year. Sales to agricultural

[3] New uses for transactions reported in the Other column are either not reported or are split between multiple uses for a single transaction.

buyers decreased over the study period, though lease activity remained relatively constant.

Municipal agencies acquire water rights with far greater frequency and volume than either agricultural or environmental entities, reflecting their primary concern with reliability. Table 3 also indicates that municipal buyers consistently paid higher prices for rights than environmental and agricultural users. Within the CBT, it is not uncommon for municipal water agencies to purchase a water right and lease the water back to the agricultural seller until the water is needed for municipal use (Pineda 2007). Table 3 indicates that significant quantities of water are acquired under lease for municipal purposes, though less in absolute terms than is acquired for either agricultural or environmental use. Municipal leases are more likely to be long-term than are leases for agricultural or environmental use; of the 457 municipal leases reported in table 3, 122 are longer than one year. These trends in buyer use affect the aggregate trading patterns that occur within different markets.

Theoretical Model

Before proceeding with an empirical investigation of the transactions reported in the *Water Strategist*, we derive the qualitative properties of the explanatory variables in the regression analysis. The model focuses on a water agency who has already decided to meet its excess water demand through the market. Based on locational characteristics, will this agency decide to lease or to buy a water right? The theoretical model is not intended to capture all the variables that affect a water agency's decision regarding contract type. For example, the model does not incorporate demand-side conservation and individual storage capacity, both of which would decrease an agency's responsiveness to changes in water supply conditions. Because our focus in the regression analysis that follows is marketwide variables, the model emphasizes economic and hydrological variables common to all agencies within a region rather than agency-specific variables.

The agency's current decision takes into account the value of current purchases and leases and the expected value of future purchases and leases. The agency buys and leases water rights in a given period so as to minimize the present expected value of the stream of costs of acquiring water, according to the objective function:

$$\min_{B_t L_t} \sum_{t=0}^{\infty} \left(\frac{1}{1+r}\right)^t E\{e_t(B_t p_{Bt} + L_t p_{Lt} + R_t p_{Rt})\}, \quad (1)$$

where the cost function, $e_t(B_t p_{Bt}+L_t p_{Lt}+R_t p_{Rt})$, is total expenditures each period.

The variable B_t is the number of water rights purchased in the current period t, and R_t is the number of water rights acquired in previous periods, including any initial endowment the agency may have had. Once purchased, each water right of B_t and R_t yields the buyer one unit of water each period in perpetuity. Annual yield from a water right is a function of the quantity of water available annually, whether from surface reservoirs or groundwater. Natural and constructed storage increases the positive correlation of water availability across years and the prevalence of multi-year droughts and wet periods within the hydrological history.

The variable L_t is the number of lease units the agency purchases at time t. Each lease unit purchased yields one unit of water at time t. Unlike yield from a water right, the lease unit size in the model is identical for all t and normalized to 1, so that $\bar{y}_{Rt} = y_{Lt} = 1$.

The variable p_{Bt} is the annualized price for one perpetual water right. The variable p_{Lt} is the unit price for an annual lease. The variable p_{Rt} is the annual debt repayment made on water rights purchased in previous years. The cost function $e_t(\ldots)$ is convex in B_t, R_t, and L_t, reflecting the systemic nature of water supply risk. When the water agency seeks to acquire a larger amount of water from the market because its own supplies are unusually low, neighboring water agencies that also lack rights, or sufficiently senior rights, must do likewise; prices for purchases and leases are relatively higher in dry periods than they are low in wet periods.[4] Because water prices map into the distribution of water availability differently from region to region, prices are location-specific, though location indices on the cost function and prices have been suppressed for ease of exposition.

Each period, the water agency supplements its portfolio of water resources by transfering and leasing water rights so as to meet its excess demand requirements, D_t:

$$\widetilde{y_{Rt}}(B_t + R_t) + y_{Lt}L_t = D_t. \quad (2)$$

This type of quantity constraint is not unrealistic for urban water agencies. In the short term, urban water agencies are unable to influence retail customer demand. In the longer term, they have integrated resource plans upon which they base current acquisition decisions. The hard quantity constraint is less realistic for agricultural water purchasers, as they are more likely to behave as profit-maximizing firms responsive to price. However, agricultural water purchasers are generally locked into specific cropping patterns. They acquire water under short-term leases during dry years, when their

[4] In the data, we observe that lease price in any given year is inversely correlated with quantity available. One might expect the purchase price of a stochastic resource with mean-preserving yield to be constant over time. However, there may be increased pressure on purchasing water agencies to acquire water during dry years; consequently, more funds may be available during such times.

supplies from other sources are insufficient. They are willing to pay prices larger than water's value of marginal product in order to protect their long-term investment in high-value perennial crops. Thus even agricultural water purchasers' demand is quite inelastic over the range of prices they face in the market.

Holdings of water rights in the next period is the sum of legacy rights held over from previous periods and new rights purchased in the current period, according to the equation of motion:

$$R_{t+1} = R_t + B_t. \tag{3}$$

At the start of each period, the water agency inherits water rights that it has purchased in previous periods. The agency learns whether the water year is wet, normal, or dry. Although it would be unrealistic to state unequivocally that a water agency knows at the start of the year how much water it has available to it for the entire year, water agencies do have relatively reliable forecasts of spring runoff by March, which indicate how much water will be available throughout the summer season. The water agency subsequently makes the dynamic decision of how many water rights to purchase in the current period and simultaneously fills the remainder of its current-period demand with short-term leases. Each period, the agency decides how many water rights to buy (B_t) and how many to lease (L_t), based upon acquisitions made in the past (R_t), and the relative prices of water for sale and water for lease. The variables (B_t) and (L_t) can be negative, as nothing prevents a water agency from selling existing rights.

When it makes its decision whether to buy or lease in the current period, the agency knows the current yield from a water right as well as current purchase and lease prices. The agency does not know future realizations of water right yield, purchase price, or lease price. Because purchase and lease prices within a given period map directly from contemporaneous water yield, the sole independent source of risk a water agency faces when it makes its decision whether to buy or lease are the realizations of the water right yield ($\tilde{y}_{Rt}$) in all future periods.[5]

The decision facing a water agency of how many water rights to purchase in the current period versus how many to purchase in future periods can be expressed using the backwards induction of dynamic programming introduced by Bellman (1957). The Bellman equation balances the immediate reward of consumption in the current period against expected future rewards, which are collapsed into a single future period through recursive substitution:

$$V_t(R_t) = \min_{B_t}\left(e_t\left(B_t p_{Bt} + \frac{D_t - \widetilde{y_{Rt}}(B_t+R_t)}{y_{Lt}} p_{Lt} + R_t p_{Rt}\right) + \frac{1}{1+r} E V_{t+1}(R_{t+1})\right), \quad (4)$$

with equation of motion $R_{t+1}=R_t+B_t$. Because we assume that excess demand not met through water rights purchases in the current period (B_t) or legacy purchases from previous periods (R_t) is met with leases, the quantity constraint of Equation (2) can be substituted into the cost function for quantity of leases (L_t).

The agency problem at any point in time balances purchases of stocks and flows of water under changing expectations and scarcity. The first-order conditions of this objective function consequently produce the Euler equation, which holds for a dynamic problem at all points in time. The derivative of the value function with respect to the control variable (B_t) is:

$$\frac{\delta V_t(R_t)}{\delta B_t} = e_t'\left(B_t p_{Bt} + \frac{D_t - \widetilde{y_{Rt}}(B_t+R_t)}{y_{Lt}} p_{Lt} + R_t p_{Rt}\right)(p_{Bt} - p_{Lt}\widetilde{y_{Rt}}) + \frac{1}{1+r} E V_{t+1}(R_{t+1}) = 0. \quad (5)$$

[5] Water right yield is here assumed to be mean-preserving. An interesting extension of the analysis would incorporate declining yields associated with current climate change predictions. In this circumstance, there would be uncertainty regarding future average yield as well as future annual realizations of yield.

Because this first-order condition holds for all *t*, the terms from equation (5) can be arranged the following two ways:

$$\frac{1}{1+r}EV_{t+1}(R_{t+1}) = e_t'\left(B_t p_{Bt} + \frac{D_t - \widetilde{y_{Rt}}(B_t + R_t)}{y_{Lt}}p_{Lt} + R_t p_{Rt}\right)(p_{Lt}\widetilde{y_{Rt}} - p_{Bt}), \quad (6)$$

$\frac{1}{1+r}EV_t(R_t) =$

et−1′Bt−1pBt−1+Dt−1−yRt−1Bt−1+Rt−1yLt−1pLt−1+Rt−1pRt−1pLt−1yRt−1−pBt−1. (7)

Differentiating the value function with respect to the state variable (R_t) gives the dynamic envelope condition, also known as the Benveniste-Scheinkman condition (Benveniste and Scheinkman, 1979), which indicates the relationship between investment in water rights across adjacent time periods:

$$\frac{\delta V_t(R_t)}{\delta R_t} = e_t'\left(B_t p_{Bt} + \frac{D_t - \widetilde{y_{Rt}}(B_t + R_t)}{y_{Lt}}p_{Lt} + R_t p_{Rt}\right)(p_{Rt} - p_{Lt}\widetilde{y_{Rt}}) + \frac{1}{1+r}EV_{t+1}(R_{t+1}). \quad (8)$$

Substitution of equations (6) and (7) into (8) yields, with some re-arrangement of terms, the Euler condition. The Euler condition defines the dynamic first-order condition at any time and thus provides the theoretical basis for signs on the empirical estimates:

$$e_t'\left(B_t p_{Bt} + \frac{D_t - \widetilde{y_{Rt}}(B_t + R_t)}{y_{Lt}}p_{Lt} + R_t p_{Rt}\right)\cdot(p_{Bt} - p_{Lt}\widetilde{y_{Rt}})$$

$$-\frac{1}{1+r}Ee_{t+1}'\left(B_{t+1}p_{Bt+1} + \frac{D_{t+1} - \widetilde{y_{Rt+1}}(B_{t+1} + R_{t+1})}{y_{Lt+1}}p_{Lt+1} + R_{t+1}p_{Rt+1}\right)$$

$$\cdot(p_{Lt+1}\widetilde{y_{Rt+1}} - p_{Rt+1}) \quad (9)$$

$$-\frac{1}{1+r}Ee_{t+1}'\left(B_{t+1}p_{Bt+1} + \frac{D_{t+1} - \widetilde{y_{Rt+1}}(B_{t+1} + R_{t+1})}{y_{Lt+1}}p_{Lt+1} + R_{t+1}p_{Rt+1}\right)\cdot(p_{Bt+1} -$$

pLt+1yRt+1=0.

The first term in Equation (9) is the current cost of buying a water right at time *t*. This term is the annualized purchase cost of a water right (p_{Bt}) less the cost of leasing a comparable amount of water ($p_{Lt}\tilde{y}_{Rt}$), which is what the agency would have done to fulfill its demand for water (D_t) if it had not bought a right. (Note that the purchase and lease price differential in the Euler condition is weighted by yield.) The second term is the benefit in the next period of having bought a right in the current period. Because the water agency bought a right in the current period, it will incur the capitalization cost of holding a legacy right (p_{Rt+1}) in the next period rather than leasing a comparable amount of water ($p_{Lt+1}\tilde{y}_{Rt+1}$) in the next period. These two terms together represent the net cost of buying a water right at time t.

The third term in Equation (9) is the net cost of waiting until $t+1$ to buy the water right. The water agency buys a right (p_{Bt+1}) rather than leasing a comparable amount of water ($p_{Lt+1}\tilde{y}_{Rt+1}$). Along the optimal path of water rights purchases, the net cost of purchasing a water right in the current period just equals the net cost of waiting until the next period.

Comparative dynamics from the Euler condition indicate how agencies change their behavior in a given period in response to changes in expected future prices for purchases and leases of water rights. Increases in expected future purchase and lease prices lead to increases in the number of water rights purchased in the current period:

$$\frac{\delta B_t}{\delta p_{Lt}(\theta,\alpha)} > 0, \qquad (10)$$

$$\frac{\delta B_t}{\delta p_{Bt+1}(\sigma,\upsilon,\gamma,I)} > 0. \qquad (11)$$

These conditions hold when next period's annualized expected purchase price is greater than next period's debt repayment on held rights, a reasonable assumption given rising price expectations. As current lease quantity is the difference between current demand and rights held and acquired in the current period, increases in expected future purchase and lease prices cause lease quantity to decline in the current period.

In equations (10) and (11), expected future purchase and lease prices are expressed as functions of the economic, hydrological, and regulatory variables discussed in the previous section. The price of leasing water at time t, $p_{Lt}(\theta,\alpha)$, depends first on realized precipitation, θ, because lower levels of precipitation increase reliance on temporary water markets, $\partial p_{Lt}(\theta,\alpha)/\partial\theta<0$. The lease price is also a function of the value of agricultural production, α, because an increase in this variable increases the short-term value of marginal product of water in the agricultural sector, increasing the likelihood that water will be retained for on-farm use rather than offered for sale in the temporary lease market, $\partial p_{Lt}(\theta,\alpha)/\partial\alpha >0$.

The annualized purchase price of water p_{Bt} $(\sigma,\upsilon,\gamma,I)$ is a function of the size of the variance of inter-annual precipitation, σ, as higher levels of chronic uncertainty may lead to greater reliance on sales, $\partial p_{Bt}(\sigma,\upsilon,\gamma,I)/\partial\sigma>0$, all else being equal. Water's purchase price also depends on the value of agricultural land, υ; higher values indicate an increase in the long-term opportunity cost of selling water, thereby lowering the amount of water offered for sale by agriculture, $\partial p_{Bt}(\sigma,\upsilon,\gamma,I)/\partial\upsilon<0$. An increase in anticipated future growth, γ, is expected to increase the purchase price of water, as municipal agencies would prefer to rely on permanent rights rather than leases to meet projected increased demand, $\partial p_{Bt}(\sigma,\upsilon,\gamma,I)/\partial\gamma>0$. Finally, purchase price increases in regulatory jurisdictions where the high transaction costs associated with prevailing market institutions (high transaction costs or onerous transfer proceedings) make rights purchases relatively difficult, as such regulations for both are more often targeted at rights transfers than leases, $\partial p_{Bt}(\sigma,\upsilon,\gamma,I)/\partial I >0$. Although such regulations do tend to dampen lease activity, their effect on sales activity is generally larger. The third price is debt on water rights purchased in previous periods, $p_{Rt}(p_{Rt-1}, \ldots, p_{R1})$. It is the opportunity cost of holding water rights and is a function of prices paid for water rights in previous periods.

Economic, hydrological, and regulatory variables thus influence purchase (B_t) and lease (L_t) activity through their effect on prices. When decisions are made in the current period, all three prices are known. Relative prices determine quantities of water rights and leases held. Table 4 summarizes the causal relationships discussed thus far.

If a large differential between the annualized purchase and lease prices persists, the obviously less expensive contractual form will prevail. However, over a relatively narrow band of prices, price will influence whether a transaction takes place as a sale or lease. Arbitrage generally serves to keep observed prices, when not administratively set or otherwise institutionally constrained, within this band. Consequently it is when prices are within this band that our model provides insight into the relationship between contractual forms.

These comparative dynamics define a framework that explains why trading styles vary by location. In the empirical analysis that follows, the Euler condition in equation (9) is really multiple location-specific Euler conditions, each representing a local market equilibrium. For example, if Nevada projects higher urban growth and consequently higher expected future purchase price than other states in the sample, we would expect to observe more purchases now relative to leases in Nevada compared to other states in the sample.

The market equilibrium represented by the Euler condition exists because heterogeneity among agencies within a single market causes differential responses to market conditions. The descriptive statistics presented in the previous section suggest that the market can be characterized by three types of buyers and one type of seller.

The first buyer type is a municipal water agency who primarily uses water markets to secure long-term supply to meet projected future growth, or to "firm up" existing water supplies. It follows that urban water demand is price inelastic.[6]

The second buyer type is a high-value agricultural producer with a more elastic demand than an urban agency.[7] To the extent that they are able to substitute away from water-intensive crops on short notice, this buyer type is likely to be in the market only during dry periods when their own supplies are low. Due to the intermittent nature of their excess demand for water and because the environmental and third-party costs associated with water rights purchases increase the annualized cost of a water rights purchase above the cost of a one-period lease, this type of buyer is more likely to lease than to buy.

The third buyer type is a state or federal environmental manager. This buyer shares characteristics with each of the other two buyer types. Like an urban buyer, an environmental manager has relatively inelastic demand and a relatively high penalty for being short water. Like a high-value agricultural producer, its excess demand is relatively responsive to short-term fluctuations in precipitation.

The sellers are low-value agricultural producers who can either transfer water rights or lease water out in dry periods, preserving their ability to use the water as an agricultural input in wet and normal periods. Agricultural producers prefer to lease out

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[6] In a meta-analysis of residential water demand, Dalhuisen et al. (2003) find an average price elasticity of -0.41, though estimates of residential elasticity of water demand vary greatly depending on season and location, time horizon, and retail pricing structure.

[7] For example, Schoengold, Sunding, and Moreno (2006) estimate an agricultural demand elasticity of -0.79.

water because they wish to avoid future exposure to the spot market (Howitt, 1998). However, the environmental and third-party costs of water transfers are greater for sales than for leases, since the latter is only a temporary disruption to the local environment and economy. Both of these factors contribute to a price premium on rights transfers relative to leases. This hurdle price reflects the future uncertainty of water availability.

Even when the annualized purchase price is higher than the lease price, the urban agency buys rights, because reliability is of utmost importance to it. Urban agencies prefer to avoid exposure to the uncertainty from acquiring sequential short-term leases. This result is the key insight offered by the model: Because of the nonlinear nature of their cost curves, some agencies will prefer to deal in the purchase market even if they are risk-neutral.[8]

These exercises in comparative dynamics characterize a discrete period during which both information about water conditions is revealed and the resulting trades take place. Such discreteness fits most naturally an annual setting with brief but intense winter rains and a leisurely spring for negotiation of trades, and with summer growing season conditions known in advance. Such discreteness does not accurately fit a location with a continuous probability of rain and trades. If the period considered were shorter than a year, the model could be adjusted so that randomness in the weather is not independent from period to period. Alternatively, a single period in the model could be construed as covering many years, in which case, the uncertainty could refer to, for example, regulatory changes in the treatment of third parties.

[8] The same effect could be achieved by modeling a risk-averse firm affected by uncertainty, as in Sandmo (1974) and Howitt (1998). Williams (1987) and Goldberg (1990) explore the relative merits of these approaches.

This analysis is from the perspective of a single agency, taking the current and future purchase and lease prices as given. At the market level such prices are endogenous. If, for example, lease prices are sufficiently low relative to purchase prices, potential providers of water will offer water rights for sale while potential users will want leases. Consequently, at the market equilibrium at one location, buyers may have both rights transfers and leases in their portfolios purchased at prices not simple multiples of each other.

Empirical Framework and Additional Data

The comparative dynamics derived in the previous section give location-specific Euler conditions explaining the decision to buy or lease a water right. To test the expectations of these causal relationships, we must assemble indicators for local hydrological, economic, and regulatory conditions. Hydrological conditions argue for a basin-level analysis, yet variables capturing economic and regulatory conditions primarily exist at the state and county levels. We consequently construct a maximum likelihood logit model first at the state and then at the county levels, with an eye for consistency between the two analyses. We employ two specifications at each geographical resolution. In the first, the dependent variable is equal to 1 when the transaction is a rights transfer and 0 otherwise. In the second, the dependent variable is contract length rather than contract type, with dependent variable equal to 1 for longer-term transactions and equal to 0 for short-term transactions lasting one year or less. In the first of these, explanatory variables are state-level measures of physical and financial scarcity and demographic variables:

Contract Type=f(*Taf, TafStock, stAgProdn, stAgLand, stBld, stBldStock, stPDI, stPDIcvar, stTaf, stTafStock, stPopn, stInc, Time*). (1)

The variable *stTaf* is the transaction-specific quantity of water transferred, measured in thousand acre-feet. The variable *stTafStock* is a running total of volume acquired by each buyer in the dataset since 1990. It provides an indication of the long-term involvement and degree of participation of each buyer in the market.

The variables *stAgProdn* and *stAgLand* (United States Department of Agriculture 2006) capture the statewide opportunity cost to agricultural producers of participating in the market. The variable *stAgProdn* is the statewide annual value of production per acre, measured in thousands of dollars. We lag the agricultural production variable one year, as farmers are unaware of the value of the current year's crop when they make cropping decisions at the start of the season.[9] The agricultural production variable is further expressed in terms of percentage of each state-specific average to avoid correlation with the variable *stAgProdn*. The variable *stAgLand* is the state-level, average per-acre value of farm real estate over the study period.

The variable *stBld* (United States Census Bureau 2006) is the number of building permits issued for each state in the sample, weighted by state population. Generally speaking, only urban areas require developers to acquire permits.[10] The variable *stBldStock* indicates long-term urban development pressure.

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[9] This modeling decision is consistent with the theory of naive expectations, where future expected value is estimated using the latest available realization of the variable in question (Chavas 2000). Should farmers' expectations be less naive, *stAgProdn* will underestimate the influence of the previous year's value of production on decisions about water.

[10] The United States Census Bureau estimates that less than 2 percent of all privately owned housing units constructed are built in areas that do not require permits. This variable thus adequately represents the increased pressure on municipal areas to meet the water needs of a growing urban population.

We utilize the Palmer Drought Severity Index (PDI) to capture the response of water markets to changing weather conditions.. The PDI is a monthly hydrological drought index measuring the severity of dry and wet spells. It takes into account precipitation, evapo-transpiration, and soil moisture conditions. PDI values below zero indicate drought conditions and those above zero indicate relatively wet conditions (United States Department of Commerce 2006). We create two drought variables from the PDI. The variable *stPDI* reflects hydrological conditions at the time of the transfer. It is the average of the PDSI values of the six months prior to a transaction.[11] This variable will register the effect of short-term fluctuations in supply on the sale-to-lease ratio. The variable *stPDIcvar* is the coefficient of variation for each state's monthly PDSI series. This variable will register the effect of expected variability in supply on market activity across different locations.

The variables *stTaf* and *stTafStock* measure volume transacted in a given year and volume transacted to date since 1990, respectively, to capture both the short-term and long-term degree of market activity in each state. The variables *stPopn* and *stInc* control for variation in population and income across states. A time trend is also included in the econometric specification.

The results for the analysis with contract type as the dependant variable (table 5 column 1) are largely consistent with theoretical expectations. All coefficients but three have the expected signs and are significant at least at the 10% level. Because the dependent variable is a discrete variable that takes the value 1 for a sale and 0 for a lease, a positive sign on a coefficient indicates an increase in the probability of observing a sale, or a decrease in the probability of observing a lease.

[11] Brown (2006) constructs his drought variable in the same fashion.

An increase in volume traded leads to a decrease in the probability of sales relative to leases. This negative coefficient is expected, since volume transferred is greatest in response to dry water years. This negative relationship also may reflect the fact that leases must be renewed each year to make up a long-term volume comparable to a sale, which is only recorded once in a database encompassing transactions rather than cumulative value transferred.

We had expected the coefficient on the financial scarcity variable *stAgProdn* (value of agricultural production) to be positive and significant, indicating that an increase in the value of agricultural production decreases the probability of observing a lease. This would be logical, as farmers would be more likely to retain water for use on-farm when the expected value of agricultural production is relatively high. However, the variable is not significantly different than zero. The coefficient on *stAgLand* (value of agricultural land) is negative and significant, as expected. The variable measures the long-term opportunity cost of water, and farmers would be expected to sell water rights in response to a decrease in the value of agricultural land.

Consistent with the theoretical model, the coefficient on *stBldStock* (building permits) is positive and significant, indicating that urban growth induces agencies to secure more water rights relative to leases. This finding is also in accordance with descriptive statistics in the previous section, not to mention anecdotal evidence gleaned from the *Water Strategist's* transaction descriptions, which indicate that municipal agencies prefer to purchase water rather than lease in response to projected growth. The variable *stBld* is insignificant. However, *stBld* is negative and significant in the second specification with contract length as the dependent variable, suggesting that municipal agencies may have to meet growth in the short-run with short-term contracts, while longer-term supplies are being acquired.

The physical scarcity variable *stPDI* (annual precipitation) behaves consistently with the theoretical model; leases are more likely to occur in drought years than during wet and normal years. The variable *stPDIcvar* (expected variation in precipitation) indicates that at the state-level at least, higher variability increases the probability of observing lease activity. The county-level analysis below indicates the opposite result, as does intuition, since one would expect more sales in areas of chronic variability. This may be an instance where a state-level definition of local is not appropriate. These drought variables are based entirely upon natural precipitation levels. A better measure of water availability would take into account existing storage and transportation infrastructure. Of course, infrastructure is endogenous; all else being equal, one might expect more investment in infrastructure in locations with greater variability in precipitation.

Table 5 and the empirical analysis to this point has been based on state-level regressors. Brown (2006) assigns each water transfer to NOAA climatic division and includes PDI at the climatic division level as a regressor. As Brown points out, sorting the transfers into climatic divisions will not capture the effects of weather when storage for a particular waterway is far enough upstream to be in a different climatic division or if the aquifer spans multiple climatic divisions. By maintaining the database at the state level rather than sorting transfers by climatic division, we risk attributing weather conditions from hydrologically distinct parts of the state to some transfers. Further, many of the variables that explain water market activity are economic in nature and tend to be measured at the state and county levels rather than by climatic region. As a complement to the preceding state-level analysis, we consequently perform a comparable analysis using county-level regressors:

Contract Type=f(*Taf, TafStock, cnAgProdn, cnAgLand, cnBld, cnBldStock, cnPDI, cnPDIcvar, cnTaf, cnTafStock, cnPopn, cnInc, Time*). (2)

Several variables become insignificant once the analysis is shifted from the state to the county level, even as the goodness of fit measures are improved at the higher resolution (table 6).[12] The county-level analysis allows us to include state-level fixed effects in the analysis (table 6 columns (2) and (4)). These fixed effects likely capture institutional differences between the states that influence the decision to buy versus lease a water right. For example, the negative and positive signs on the California and Colorado coefficients, respectively, are consistent with the differences in water market institutions described above. The negative coefficients for Oregon and Washington are likely driven in part by the tax benefits associated with transferring water rights at zero price (resulting in relatively more leases than sales included in the regression analysis). Note that the fixed effect for Idaho is negative and significant when the dependent variable is contract length but insignificant when the dependent variable is contract type. This may be explained by the fact that Idaho's many water banks are structured to facilitate short-term transfers of water primarily for irrigation and environmental purposes. Leasing activity in Idaho thus tends to be short-term, rather than a longer-term stopgap measure undertaken during negotiations for permanent transfers to municipalities, as is the case elsewhere.

[12] The county-level variables do not exhibit signs of multicollinearity.

Noticeably absent from the econometric specification is the water transfer price. We do not include prices in the empirical analysis because we observe only the price for the selected contract form and not the alternative. The variables that influence the choice of contractual form are however available to us and are consequently included in the analysis. Also missing from the analysis is a variable capturing the seniority of a water right. This information is not generally reported in the *Water Strategist*. However, the experience in one region for which data are available supports the conclusion that more senior water rights are more likely to be transferred than less senior water rights. In the Rio Grande River basin in Texas, an irrigation water right for one acre-foot can be either Class A, yielding 0.5 af for municipal use, or Class B yielding only 0.4 af for municipal use (*Water Strategist*, 1992). All transfers from this region in our database that are identified as Class A are rights transfers out of agriculture for municipal use. Half of the more junior Class B transactions are rights transfers or long-term leases from agriculture to municipal use, whereas the other half are short-term leases between agricultural users.

A more realistic characterization of a water agency's decision to acquire or sell water through a water market would be a tobit specification, reflecting the initial decision whether to acquire or sell water through a water market at all, and subsequently whether to enter the sale or lease market. However, the only data on overall consumptive use available for the western United States are estimates made by the USGS once every five years (United States Department of the Interior 2006). The data are not sufficiently precise to generate robust results with the tobit specification. We also hypothesized that the annual percentage of water consumed within a state, as an indication of the likelihood of market participation of any sort, would have an effect on the probability of observing sales versus leases, within the logit specification. The consumptive use variable generated from the USGS data did not have a significant effect; the variable was consequently removed from the analysis. The likely cause is the poor data quality rather than lack of a presumed causal relationship.

Conclusion

In this paper, we have employed a maximum likelihood logit estimation to test theoretical expectations about the influence of economic and hydrological variables on the style of water market activity, whether lease or sale. According to Williamson (2000), whose prominent research seeks to understand how agents choose among different contracting possibilities given the prevailing property rights regime, two tasks must be accomplished. First, the analyst must answer the questions of why does behavior among agents differ, and what are the characteristics of the different governance structures from among which agents may choose. Second, the analyst must generate ideas about what different types of agents will do, and corroborate these ideas with data. We have addressed these two tasks in this article.

In a study on the important role institutions have in shaping trading activity, it is worth noting that our data source the *Water Strategist* is an institution that may itself have influenced water prices, quantity and contract terms, through increasing information available to market participants. Although one should remain concerned that the data may not be comprehensive of all trades that have occurred in the western states, the analysis here supports the idea that transactions reported by the *Water Strategist* are reasonably representative, since the estimation results match theoretical expectations.

A second caveat is that the analysis would be better performed at the basin level rather than at the state or county levels. This is especially true in light of Getches (2001), who argues that federal and local laws are more important than state laws in shaping water market activity. However, even at the state level, the influence of the factors we have identified is clear. Analysis at the basin level would likely corroborate our findings of the importance of economics, hydrology and regulations on the type of trading that develops in water markets.

A measure of the seniority of rights underlying leases and sales is missing from the quantitative analysis. Although a water right with seniority would be expected to sell at a higher price than one with junior rights and also be more likely to be transferred, it is not immediately clear what effect seniority would have on the ratio of sales to leases within a state. It might be the case that rights with high seniority tend to be sold, whereas more junior rights tend to be leased in the short-term, at times when yield is sufficient to guarantee that the transfer will occur. Unfortunately, it is not possible to study the effect of seniority on style of trading, as only a handful of the transaction descriptions in the *Water Strategist* include information on seniority. If it is true that junior rights are less likely than senior rights to be transferred in the first place, then an analysis of seniority based on observed trades would not be adequate to address the issue of seniority.

Although the data set used here lacks specificity in some regards, it does have the benefit of covering a large geographical area and providing a broad picture of water markets across the western United States. We have been able to parse out the effects of time-invariant economic and hydrological conditions on lease and sale markets from those that vary from year to year through the use of short-term and long-term variables, in spite of data shortcomings. For example, agricultural production (*stAgProdn*) influences whether farmers lease out water from year to year, whereas the underlying value of agricultural land (*stAgLand*) affects whether farmers sell. These variables combined influence the agricultural producer's decision to lease or sell. Similarly, the long-term index of average variability (*stPDIcvar*) captures agents' decisions to transfer water rights, whereas the index of realizations of precipitation (*stPDI*) captures agents' decisions to utilize the lease market in response to expected (and subsequently realized) annual variability in precipitation. State-level fixed effects in the county-level analysis quantify the influence of state regulations on the development of water market institutions.

To explain why transactions take place, the institutional category "market" seemingly is too broad. To say that market transactions occur because they are permitted is far too simplistic. The form of the transaction matters as well. Statutory authorization is generally a prerequisite for market development, but the types of markets that emerge are dictated by the economic and hydrological conditions prevailing in a particular location. This analysis measures the effect of state regulations and scarcity values on the type and extent of water markets, and provides a foundation for additional measures of the development of institutions.

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Table 1. Transacted Volume for Reported Water Transactions, 1990-2008

State	Total No. of Obsvns	Total Quantity (taf)	Lease No. of Obsvns	Lease Quantity (taf)	Sale No. of Obsvns	Sale Quantity (taf)	Transactions as % of Total Use	Lease/Sale Ratio
AZ	165	7,938	59	7,614	106	323	5.55	23.54
CA	691	9,061	614	8,613	77	448	1.33	19.22
CO	1477	602	116	492	1,361	110	0.23	4.47
ID	136	4,962	117	4,837	19	125	1.31	38.59
MT	43	51	41	51	2	-	0.03	-
NM	144	605	90	569	54	36	0.96	16.01
NV	280	155	4	32	276	123	0.29	0.26
OR	104	954	86	931	18	23	0.61	-
TX	291	1,412	230	1,173	61	239	0.31	4.91
UT	65	181	21	126	44	56	0.19	2.25
WA	50	217	40	131	10	85	0.16	1.54
WY	53	316	52	316	1	-	0.25	-
Total	3499	26,454	1470	24,885	2,029	1,569	0.96	15.86

Notes: Data from the *Water Strategist*. Estimated water use by state from USGS. Sales reported in the Water Strategist for Montana and Wyoming are less than 500 af, so they are not reported here. Lease-to-sale ratios are not calculated for Oregon, Montana, and Wyoming due to low sales volume.

Table 2. Volume-Weighted Water Prices (2008$) for Reported Water Transactions, 1990-2008

State	Lease Price ($/af)	Sale Price ($/af)	Implicit Capitalization Rate (%)
AZ	68	705	9.71
CA	119	917	12.99
CO	51	3,794	1.35
ID	59	247	23.85
MT	13	2,712	0.49
NM	709	2,019	35.13
NV	15	6,801	0.22
OR	214	563	38.08
TX	66	1,527	4.30
UT	99	1,804	5.49
WA	77	262	29.25
WY	23	3,175	0.71
Total	103	1,523	6.78

Notes: Data from the *Water Strategist*. CBT sales of 47,736 af are omitted from the price calculation. If included, Colorado sale price increases to $5,842/af, total sale price increases to $1,735/af, and the overall implicit capitalization rate is 5.95%.

Table 3. Lease and Sale Volume and Volume-Weighted Prices (2008$) by New Use

Lease Transactions		A	E	MI	Other
1990-1992	Annual Avge Volume (taf)	231	61	408	1,107
	% of Total Annual Average Volume	13%	3%	23%	61%
	Average Price ($/af)	55	56	151	82
2006-2008	Annual Avge Volume (taf)	180	612	116	85
	% of Total Annual Average Volume	18%	62%	12%	9%
	Average Price ($/af)	486	52	156	92
All Years	Annual Avge Volume (taf)	315	371	266	357
	% of Total Annual Average Volume	24%	28%	20%	27%
	Average Price ($/af)	89	110	148	76

Sale and Share Transactions		A	E	MI	Other
1990-1992	Annual Average Volume (taf)	1	5	59	0
	% of Total Annual Average Volume	1%	8%	91%	0%
	Average Price ($/af)	1,390	216	560	3,631
2006-2008	Annual Average Volume (taf)	2	41	21	48
	% of Total Annual Average Volume	2%	37%	19%	43%
	Average Price ($/af)	1,976	337	9,793	1,082
All Years	Annual Average Volume (taf)	5	22	43	12
	% of Total Annual Average Volume	7%	26%	52%	15%
	Average Price ($/af)	1,744	492	1,543	1,543

Notes: Prices are average annual volume-weighted prices.

Table 4. Theoretical Expectations of Relationships Between Variables

Variable Explanation	Prediction
Value of agricultural production (short-term opportunity cost)	$\partial L_t / \partial \alpha < 0$
Value of agricultural land (long-term opportunity cost)	$\partial B_t / \partial \nu < 0$
Projected urban growth	$\partial B_t / \partial \gamma > 0$
Annual precipitation (short-term drought indicator)	$\partial L_t / \partial \theta < 0$
Expected volatility in precipitation (long-term drought indicator)	$\partial B_t / \partial \sigma > 0$
State water market institutional structure	$\partial B_t / \partial I < 0$

Table 5. Determinants of Trading Patterns in Western Water Markets, State-Level Analysis (1990-2008)

Explanatory Variables		Contract Type (Sale=1) (1)		Contract Length (Long-Term=1) (2)	
Taf	Transaction volume (thousand acre-feet)	-0.0078***	(0.0024)	-0.0038***	(0.0011)
TafStock	Running total of volume acquired by this buyer since 1990	-0.0001*	(0.0001)	-0.0001***	(0.0000)
stAgProdn	Value of agricultural production (% of state average)	-0.0000	(0.0000)	0.0000	(0.0000)
stAgLand	Value of agricultural land (in $1000s)	-0.0772***	(0.0121)	-0.1216***	(0.0123)
stBld	Building permits issued annually (in 1,000,000s)	0.0410	(0.0279)	-0.0617**	(0..0297)
stBldStock	Running total of building permits issued since 1990 (in 1,000,000s)	0.0103***	(0.0031)	0.0075**	(0.0031)
stPDI	Short-term PDI drought index	0.0057*	(0.0033)	0.0108***	(0.0035)
stPDIcvar	Long-term PDI drought index	-0.0018***	(0.0003)	-0.0012***	(0.0003)
stTaf	Sum of all transactions (annual) in a state (taf)	0.0000	(0.0000)	-0.0000	(0.0000)
stTafStock	Running total of transacted volume (million-acre-feet) since 1990	0.0315***	(0.0045)	0.0272***	(0.0047)
stPopn	State population (in 1,000,000s)	-0.0012***	(0.0002)	-0.0005***	(0.0002)
stInc	State per capita income (in $1000s)	0.0402***	(0.0020)	0.0388***	(0.0019)
Time	Annual time trend	-0.0621***	(0.0032)	-0.0507***	(0.0025)
Log pseudolikelihood		-1237.707		-1331.5836	
Pseudo R2		0.4801		0.4151	
Fraction of Concordant Pairs		0.87		0.83	
Observations		3499		3499	

Notes: Estimation method is maximum likelihood logit. Marginal effects are reported at the median values of the independent variables. Marginal effects for dummy variables give change in predicted probability associated with changing the variable from 0 to 1. The fraction of concordant pairs is the fraction of observations for which the model correctly predicts probabilities and responses. Standard errors in parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

Table 6. County-Level Determinants of Trading Patterns in Western Water Markets (1990-2008)

	Contract Type (Sale = 1)				Contract Length (Long-Term = 1)			
Explanatory Variables	(1)		(2)		(3)		(4)	
Taf	-0.0071	(0.0052)	-0.0023	(0.0021)	-0.0014	(0.0019)	-0.0006	(0.0007)
TafStock	-0.0022**	(0.0010)	-0.0005***	(0.0002)	-0.0005	(0.0004)	-0.0001	(0.0001)
cnAgProdn	0.0430***	(0.0088)	0.0078***	(0.0104)	0.0351	(0.0108)	0.0339***	(0.0115)
cnAgLand	-0.0374***	(0.0043)	-0.0024	(0.0028)	-0.0339***	(0.0040)	-0.0010	(0.0019)
cnBld	5.8913	(4.9315)	2.0616	(2.9807)	3.1781	(2.1548)	1.4880	(1.5095)
cnBldStock	0.3179	(0.6199)	-0.6919	(0.3353)	-0.4564**	(0.2807)	-0.3784*	(0.1783)
cnPDI	0.0200***	(0.0038)	0.0080***	(0.0028)	0.0291***	(0.0031)	0.0090***	(0.0025)
cnPDIcvar	0.0008***	(0.0003)	0.0001	(0.0001)	0.0004*	(0.0002)	-0.0002	(0.0001)
cnTaf	-0.0015	(0.0010)	-0.0005	(0.0003)	-0.0016***	(0.0006)	-0.0000	(0.0003)
cnTafStock	-0.4873***	(0.1640)	-0.3879	(0.1735)	-0.1022**	(0.1065)	-0.0692	(0.0893)
cnPopn	-0.0712	(0.0866)	0.0166***	(0.0249)	0.0181	(0.0070)	0.0186***	(0.0059)
cnInc	0.0110***	(0.0009)	0.0030***	(0.0009)	0.0094***	(0.0011)	0.0037***	(0.0009)
Time	0.0023	(0.0020)	0.0011	(0.0013)	0.0059***	(0.0017)	0.0035**	(0.0015)
California			-0.5278***	(0.0853)			-0.6821***	(0.0512)
Colorado			0.2051**	(0.0821)			0.08545*	(0.0462)
Idaho			-0.2067	(0.1277)			-0.3155***	(0.1161)
Montana			-0.3898*	(0.2147)				
New Mexico			0.166**	(0.0824)			0.0667	(0.0483)
Nevada			0.2592***	(0.0786)			0.1156***	(0.0433)
Oregon			-0.4124***	(0.1509)			-0.4181***	(0.1093)
Texas			-0.083	(0.0965)			0.0060	(0.0458)
Utah			0.0906	(0.0931)			0.0558	(0.0563)
Washington			-0.3990***	(0.1309)			-0.3832***	(0.1060)
Wyoming			-0.5962***	(0.1239)			-0.4393***	(0.1279)
Log pseudolikelihood	-729.376		-503.675		-831.467		-504.813	
Pseudo R2	0.4463		0.6176		0.303		0.5764	
% of Concordant Pairs	0.8790		0.8502		0.9082		0.9163	
Observations	2216		2216		2216		2211	