ENVIRONMENTAL WATER MARKETS

by

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DEDICATION

To Dean and my mom.

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ABSTRACT

In this thesis, water sale and lease prices for environmental and non-environmental purposes are estimated and compared for the states of Arizona, California, Nevada, New Mexico, Utah, and Wyoming. Factors hypothesized to affect water demand and prices in these states include per capita income, population, development pressure, climate conditions, the new use of the water, and the state in which the transaction occurred. The trend in price dispersion over time is also examined.

CHAPTER 1

Introduction

1.1 Environmental Water Use in the West

Environmental water uses have now become more valuable than some agricultural water uses. The evidence is in the water market; farmers willingly sell or lease water to environmental buyers (Loomis et al., 2003). Now that an environmental water market is a reality, we move from a phase of advocating its use to investigating its effectiveness. Are environmental water markets working well, what are their characteristics, and how do they compare to other water markets? This thesis compares environmental water transfers to non-environmental water transfers and examines price dispersion in the western states of Arizona, California, Nevada, New Mexico, Utah, and Wyoming in an effort to answer these questions.

Environmental water markets emerged as people began to recognize the benefits provided by leaving water flowing in a stream instead of consuming it. The benefits from non-consumptive uses of water: water quality improvement, fishing, birding, and nonuser values, for example (Colby, 1990a), are significant but difficult to quantify. The benefits of taking water from a stream for consumptive use by agriculture and municipalities are obvious and supported by years of historical use. Non-consumptive or environmental uses have also provided benefits for years, but only when increasing diversions or prolonged drought decreased the availability of water for non-consumptive uses were these benefits appreciated and missed. The divide between long recognized consumptive uses and newly recognized non-consumptive uses creates tension that markets can help alleviate.

The water market is a good tool for obtaining environmental water because it meets with less opposition than regulatory approaches (Loomis et al., 2003). However, the term market may be misleading. Many regions have few buyers or suppliers of water; water transfers that occur take place in a more negotiated, not perfectly-competitive or classical, marketplace. This thesis explores transactions in environmental water markets and non-environmental markets over 21 years. Findings include the emergence of an environmental water market similar to the non-environmental market, the significance of regional income levels in most models, and mixed results using climate variables. This analysis has limitations in the variety of variables available for instrumental variable estimation, the number of water transaction observations available, and the imprecise nature of some of the water transaction data available for the analysis.

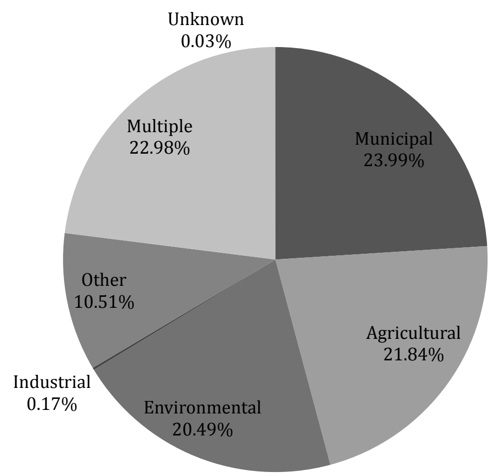
1.2 Water Transfers in the West

Water transfers have been occurring in the West for many years now. In this thesis, water transfers refer solely to the voluntary negotiated transactions that facilitate transfer of access to water by groups like government, agriculture, or non-profit organizations. The tap water purchased by residential water users from their water company is not included. If that company buys more water to service its customers though, that type of transaction is included. Large amounts of water are often spoken of in acre feet. One acre foot is equal to about 325,800 gallons of water and is generally considered enough to supply two families with water for one year. Agricultural use varies, but water applied to crops can range from less than one to over four acre feet per acre (National Agricultural Statistics Service, 2004).

Water transactions are used to move water between and among different uses, on both a temporary and permanent basis. Figure 1.1 [1] summarizes some of the major new uses of water permanently transferred over the past two decades. Water transfers in the West are supported and constrained by the prior appropriation doctrine governing water use. Under this doctrine, a right to water allows the holder to consumptively use the water as long as they put it to beneficial use (Burness and Quirk, 1979). The right may or may not be tied to a particular type of use or

[1] Source: Author's compiled data from Western Network (1987) - (1989), Stratecon, Inc. (1990) - (1997), and Stratecon, Inc. (1998) - (2007)

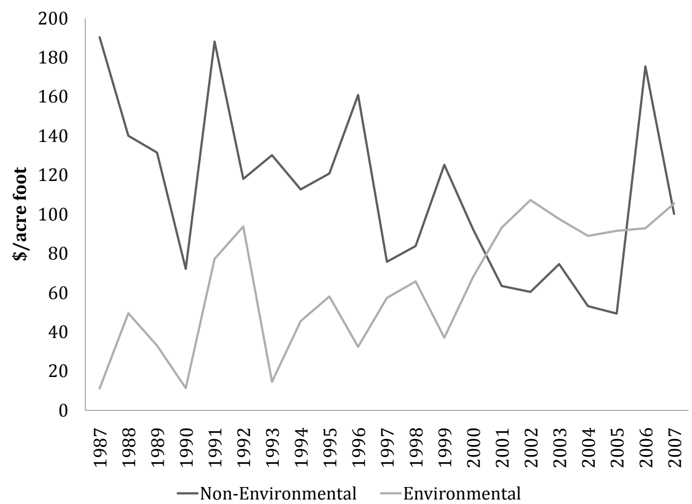
Figure 1.1: New Uses of Water Sold, 1987-2007



piece of land and can be lost if the water is not used. Water markets have been supported because they can facilitate the voluntary movement of water from lower to higher valued uses and improve economic efficiency. For example, Burness and Quirk (1979) assert that under the prior appropriation doctrine, the absence of a competitive market will lead to inefficient water use. Regulation or litigation can and is used to reallocate water as well but both can be risky in terms of time and cost. Markets are not risk free but have the advantage that the players can still influence the outcome.

Water markets may have an increasingly important role in the West if climate change causes an increasingly arid climate as Seager et al. (2007) concluded after examining several Intergovernmental Panel on Climate Change models. Even if climate change does not reduce precipitation as the majority of models predict, research on historic flow levels in the Colorado River Basin using tree-ring reconstructions reveal prolonged droughts in the past more extreme than any that have been observed (Meko et al., 2007). As water managers try to imagine what a mega-drought would mean for water supplies, voluntary transactions in a water market may be their best

Figure 1.2: Mean Lease Price ($2007)



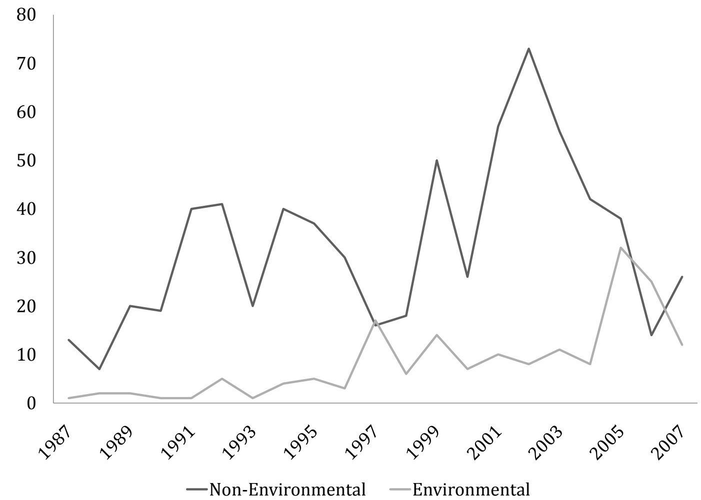
option. The increasing costs of building dams and water conveyance systems (both in terms of capital and environmental costs) make these traditional options less and less attractive (Michelsen and Young, 1993).

1.2.1 Environmental Water Markets

Environmental water markets do not have as many transactions, as much volume traded, or as wide a range of prices as non-environmental water markets. Environmental water prices have generally been lower than non-environmental prices but they appear to be converging over time, see Figure 1.2 [2] for a summary of lease prices over time. Leases temporarily transfer a water right while sales permanently transfer a water right. Sale prices in the two markets have tended to diverge less, although environmental prices are still lower. Environmental water prices may tend to be lower because of free-riders. The number of leases, particularly environmental, appears to be increasing over time, see Figure 1.3. [3] No trend is obvious in number

[2]Ibid.
[3]Ibid.

Figure 1.3: Number of Leases per Year



of sales transactions.

1.2.2 Price Convergence

I make a preliminary investigation into the maturity of the water market. Immature markets may produce inefficient outcomes and impacts on exporting and importing communities (Bjornlund, 2002). Market maturity is investigated by looking at price differentials across transactions over time. If markets are not found to be maturing over time, additional research into the causes may be warranted. Some price dispersion is expected or even useful if it accounts for externalities that might otherwise be ignored (Colby, 1990b). However, if water prices differ systematically this implies the market is not able to signal an equilibrium price. Under these circumstances, efficiency improvements that many cite as a reason for using water markets to transfer water for environmental or other uses (see (Jaeger, 2004) for example) may be much less pronounced.

CHAPTER 2

Literature Review

I review selected literature that provides quantitative analysis of water transfers with a focus on research about the western or southwestern U.S. After a review of research on general water transfers and prices, I review papers specifically dealing with environmental water transfers or uses. Most papers examine multiple states and the similarities and differences among them. Generally, results suggest that water transfers are occurring more and more frequently in the West. Prices continue to fluctuate and can be explained by drought, income, and characteristics of buyers and sellers or the new use of the water. Study location and dates, types of transfer, and selected results from the reviewed literature are summarized in Table 2.1.

Table 2.1: Summary of Literature

Authors	Location & Dates	Transfer Type	Results
Brewer et al. (2007)	12 Western states, 1987-2005	Urban to urban, ag to ag, & ag to urban leases & sales	Introduced committed measure for sales and multi-year leases that discounts and sums the flows each year. Found that most water transferred from agriculture to urban uses; prices are higher for ag to urban transfers than for ag to ag transfers; and the number of short-term leases is not increasing but sales and multi-year leases are.
Butsic and Netusil (2007)	OR, 2000-2001	Land sales	Hedonic estimation of the value of an acre foot of water in land sales. Irrigation rights increase sale price per acre by approximately 26-30% holding other effects constant. Water contributes less to sales price the more acres are sold.
Emerick (2007)	9 Western states, 1990-2004	Ag to urban & ag to ag sales & leases	Empirically tested bargaining model for water transfers. Drought does not affect the amount of water transferred but does lead to higher prices. Market power in regions with a limited number of sellers may make transfers unattractive to potential buyers.

Continued on next page

Table 2.1 – Continued from previous page

Authors	Location & Dates	Transfer Type	Results
Brown (2006)	14 Western states, 1990-2003	Leases & sales	Regressed price on 7 variables using ordinary least squares. For leases, higher prices associated with drier climates, larger populations, municipal and environmental use compared to ag. For sales, higher prices associated with recent sales, smaller quantities sold, smaller populations, and surface water compared to groundwater. Municipal use was most expensive followed by ag, then environmental.
Pittenger (2006) & Pullen (2006)	Western U.S., 1987-2005	Leases & sales	Ordinary least squares and two-stage least squares estimation. For leases, virtually all models indicate that price increases with drier weather. For sales, demand and water right characteristics are significant determinants of price; drier weather as measured by the Standard Precipitation Index has mixed results on price. Selected results from both theses were published in Colby et al. (2006).
Pullen and Colby (2006)	CBT & CAP, 1987-2004	Sales	Ordinary least squares and two-stage least squares estimation. Drought was associated with higher prices in both markets. Quantity, trend, and percent population change were significant in both models but had opposite signs. New use was significant in CAP but not CBT. Temperature was significant in CBT but not CAP.
Bjornlund and Rossini (2005)	Victoria, Australia, 1993-2003	Leases	Price and volume studied using correlation, regression, and time-series analyses. Most important determinants of price and volume were water allocation, rain, and evaporation.
Howitt and Hanak (2005)	CA, 1985-2004	Leases & sales	Environmental uses gained same protection against harm as other surface uses in CA in 1980. State and federal water reforms in 1990's made transfers easier. Groundwater substitution, fallowing, water banks, and dry-year options have all been used to transfer water with varying success. Environmental demands have contributed to market growth.
Howitt and Hansen (2005)	14 Western states, 1999-2002	Leases & sales	Externalities slow or prevent transfers by making them prohibitively costly. Implicit capitalization rate averages 6.6%. Leases more prevalent in 12 of 14 states because of fewer environmental and legal restrictions.
Brookshire et al. (2004)	AZ, CO, & NM, 1990-2001	Sales	Reduced form two-stage least squares estimation of quantity demanded with price instrumented. In the 1st stage, NM & CO prices are higher than AZ, government buyers pay less than ag buyers, higher prices are associated with drier periods and higher income. In the 2nd stage, demand is price elastic, lower quantities are associated with higher ag value and lower ag land value.

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Table 2.1 – Continued from previous page

Authors	Location & Dates	Transfer Type	Results
Loomis et al. (2003)	11 Western states, 1995-1999	Environmental leases & sales	Lease values are similar to non-market values estimated for instream flows from other studies. Instream flows are the most common environmental use for both leases and sales. Environmental water values exceed agricultural values in some instances.
Bjornlund (2002)	Australia, 1987-1996	Sales	Market maturity is important because inefficient outcomes will result from immature markets. Standard deviation as a percent of mean prices is used to measure market maturity. Prices that vary more and have a fluctuating minimum price suggest an inefficient market in the Goulburn-Murray Irrigation District.
Adams and Cho (1998)	OR, 1995	Environmental	Farm profits fall as the minimum required level in Klamath Lake rises to protect endangered species. Meeting the Endangered Species Act restrictions would cost agriculture an estimated $2 million/year, and up to $15 million/year during the worst drought.
Isé and Sunding (1998)	NV, 1990-1997	Environmental sales	Financial crisis most important predictor of a sale. Some farmers did not sell water for environmental purpose because they feared it would be transferred to development purpose by the government. Results show that farmers sold water more for personal reasons and may not have received a price equal to the long-term value of the water in agriculture.
Howitt (1994)	CA, 1991	Water bank	Demand and supply were more price elastic than anticipated. Value of water increased without raising prices for farmers because price in water bank was administratively set. The water bank created a net economic gain in CA but there were losses in some agricultural sectors.
Colby, Crandall, and Bush (1993)	NM, 1971-1987	Sales	Hedonic estimation of the characteristics of water rights and transactions, finding that senior rights are more expensive, the location of the right affects price, high-profile buyers pay more, larger quantities sell for less, and real prices are increasing over time.
Colby (1990b)	Western U.S., 1987-1989	Environmental	Use and non-use values of environmental water when taken in combination are higher than some agricultural values. Environmental uses could be compatible with consumptive uses if only the timing or location of diversion needs to be changed.

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Authors	Location & Dates	Transfer Type	Results
Crouter (1987)	CO, 1970	Land sales	Hedonic estimation to test if separate water market present. Used Box-Cox transformation to test for separable and linear functions but finds neither. Since the legal and institutional setting would allow for separate and competitive water markets, its absence may be due to data problems, empirical errors, or high transaction costs.

2.1 Water Markets

Brewer et al. (2007) compare lease and sale prices, and water volumes traded by sector in the West. They use Water Strategist data from 1987-2005 for 12 western states (a slightly longer time period than (Brown, 2006)). They focus on trades from agriculture-to-agriculture uses, from agriculture-to-urban uses, and from urban-to-urban uses. In contrast to other published water market studies they break leases into single or multi-year and analyze them separately. They also calculate a different measure of committed water compared to the standard amount of annual flow. The committed measure discounts and sums all the possible flows that a multi-year lease or sale represents over time. This measure makes sales and multi-year leases more comparable to one-year leases in terms of actual amount of water being acquired but presents a small problem. If sales are discounted into perpetuity they may be given too much weight in the analysis. A sale of 50 acre feet discounted to perpetuity, using their 5% discount rate, results in a total committed flow of 1,000 acre feet. However, if the same water right was sold after 10 years its total consumed flow would be only 500 acre feet. If that same right was sold again, its flow would again be valued at 1000 acre feet. In a market where rights are frequently resold this could eventually amount in total water sales greater than the amount of water available in a given basin. I do not use a committed measure in this thesis because of this difficulty. Additionally, Brown (2006) found that implicit capitalization rates calculated from lease and sale prices are on average much lower than commercial rates. His finding lends support to the conclusion that lease and sale markets are distinct and care should be taken when comparing them. For these reasons, lease and sale volumes in this thesis are not comparable.

Brewer et al. (2007)'s findings include that most transactions involved agriculture to urban sales and that prices are higher for water going from agriculture to urban than from agriculture to agriculture, showing that markets are responding to differences in marginal use values. They also find the number of sales and multi-year leases is increasing while the number of leases is not. Their committed measure shows that in terms of total volume, more water is being purchased by urban users than the annual flow measure would suggest. They found differences among states with faster growing states seeing more water market activity.

Brown's 2006 analysis of western water markets uses 14 years (1990-2003) of water sale and lease data published by Stratecon, Inc. A significant increase in median sale price over time is observed but not in median lease price. Brown regressed seven variables on price using ordinary least squares to determine what factors influence price. The variables used were: transaction year, a drought measure, ML transferred, buyer's county population in 2000, a groundwater dummy variable with surface as the alternative, and dummy variables for municipal or environmental use with irrigation use as the alternative. The last six months of the Palmer Drought Severity Index, a monthly index, were used as a drought measure. The results of both regressions are significant but with relatively low adjusted R^2 values. For leases, higher prices were linked to drier climates and larger populations, and to municipal and environmental use compared to irrigation. For sales, higher prices were associated with surface water, later sales, and smaller quantities and populations. Sale price was higher for municipal use than irrigation use, which was higher priced than environmental use. Sale price was not found to increase with drier climates. Lease price was not affected by transaction size, suggesting that transaction costs do not influence leases as much as sales (Brown, 2006). Lease price grew with population but sale price didn't. Surface water versus groundwater was insignificant for lease prices.

Brown does not address possible endogeneity between prices and quantity in his models. He also aggregates Colorado Big Thompson transactions when prices are similar and only disaggregates other transactions if separate price information is given resulting in fewer observations (n=1380) than this research, for all states over the 14-year period.

In their working paper, Pullen and Colby (2006) compare prices for permanent water acquisitions in two federal water projects: the Colorado Big Thompson and the Central Arizona Project. They estimate how drought influences water prices using *Water Strategist* transactions from 1987 to 2004. Colorado Big Thompson water prices are estimated using two-stage least squares regression with quantity instrumented in the first stage. Central Arizona Project water prices are estimated using, presumably, ordinary least squares. Heteroskedasticity is corrected for in both models using Huber-White estimators.

Results for the Central Arizona Project model include a significant, negative trend in prices and significantly higher prices for water transferred to municipal use compared to agricultural use but not for environmental use compared to agricultural use. A dummy variable for location indicates that prices are lower in Phoenix compared to other parts of the state. The quantity transferred has a significant but positive association with price. Percent change in population is positively associated with price. Temperature was not significant. The drought measure, Standard Precipitation Index, is significant and negative; prices decrease as precipitation increases.

The Colorado Big Thompson model, in contrast to the Central Arizona Project model, has a significant positive trend in prices and different uses are not predicted to have significantly different prices. The predicted value of quantity transferred is significant and negative. Percent change in population is negatively associated with price. Temperature is significant and has the expected positive association with prices. Standard Precipitation Index is again significant and negative.

Pullen and Colby (2006) conclude that drought plays a role in water prices in both models despite their differences. There are many transactions and transparent prices in the Colorado Big Thompson market. The Central Arizona Project market, on the other hand, has fewer transactions and prices are constrained by political and administrative forces.

Howitt and Hansen (2005) examine western water markets and find that although water markets would help reallocate water to its best use they have been slow to develop. They say the main reasons market formation is hindered are: the public good aspects of water, the fluctuations in water supply that create “thin” markets, and the high transaction costs from institutional and physical constraints. To the extent that these forces are present in different states, different markets have emerged. Water transfers have been facilitated in places where the Bureau of Reclamation or states have developed water projects; the storage and canals allow more flexibility to stockpile and exchange water. However, lack of strictly definable, enforceable, and transferable property rights is still a problem in most places.

Although willing buyers and sellers exist in many places, externalities slow or prevent sales by making them prohibitively costly. Common externalities are altered streamflow, aquifer drawdown, and financial impacts on exporting regions. Howitt and Hansen (2005) expect increased pressure from groups suffering externalities to lead to an increase in leases as water trading increases. Leases are already heavily relied on; 90% of the reported volume traded in the Water Strategist from 1999-2002 was leased. Permanent transfers only need to occur once though; leases must be periodically renewed for the same amount of water to be available over a long period of time.

The authors report that sales should be more expensive than capitalized leases because they reduce the risk of having to return repeatedly to the lease market and because sellers require a premium to compensate for unsure future water rights prices. On the other hand, sale prices should not be too much higher because leases will be most popular in dry years while sales values include wet and dry years. The implicit capitalization rate averages to 6.6%, lower than the standard commercial rate of 10%.

Howitt and Hansen (2005) explain the prevalence of leases in most states (12 out of 14) in two ways. Leases have fewer environmental and legal restrictions so they are easier to obtain. Many buyers only need water in dry years so avoid purchasing water rights that would not be needed in most years. Option agreements — prearranged lease contracts that have a two-part payment — are being used in California. Options are attractive because they only take water from agriculture during dry years; the water is used by agriculture in wet and normal years so third-party impacts are lower than with a permanent sale.

Previous Agricultural and Resource Economics Department Master's students have also used *Water Strategist* transactions in their theses. Emerick (2007) estimated water transfer characteristics using a game theory model. He argues that water transfers are negotiated and do not occur in a traditional market. He estimates price, quantity, and the decision to buy or lease water. He first estimates the bargaining model separately using two-stage least squares, ordinary least squares and probit estimation. He then estimates the three equations simultaneously. His results show that drought does not affect the amount of water transferred but does lead to higher prices. He also finds that market power in regions with a limited number of sellers may make transfers unattractive to potential buyers. Pullen (2006) and Pittenger (2006) both examined the determinants of price with a focus on the effects of climate change. Pullen (2006) looked at sales and Pittenger (2006) looked at leases in multiple separate and combined Western markets using both ordinary least squares and two-stage least squares. Neither looked at separate markets for specific uses, like environmental. Colby et al. (2006) featured combined results from both theses on the effect of climate on prices. Results from the Colorado Front Range sales, Southwest urban sales, Colorado lease, and Southwest lease models are reported. Results indicated that price usually increases with drier conditions and that price usually decreases as quantity transferred increases. In the sales models prices are predicted to increase over time, to decrease as population increases and to differ for municipal and environmental uses compared to agricultural uses. In the lease models there was no significant price trend. The type of transfer was significant and positive in the Southwest lease model only for ag-to-municipal and ag-to-environmental transfers compared to ag-to-ag transfers.

Brookshire et al. (2004) look at price history in three western water markets. Their research could provide a historical look at prices as well as a means to predict water right prices that could be used by stakeholders all over the West. They compare the prices, administration and infrastructure, and legal peculiarities of water markets in Arizona, Colorado, and New Mexico. They focus specifically on the Central Arizona Project, the Colorado Big Thompson Project, and the Middle Rio Grande Conservancy. To examine prices, they pool the data from the three markets being studied and include a dummy variable for the markets. They also investigate the role of climate (using monthly mean temperature and the Palmer Drought Severity Index), population change, per capita income, and buyer on the price of water rights. They estimate a reduced form model. The structural equations for quantity demanded and supplied could not be estimated because only demand was identified in the system.

The two-stage least squares approach is used to estimate the demand equation, with price instrumented in the first stage. They do not include all variables from the second stage in the first stage equation. Thus the requirement that the instruments should be partially correlated with the endogenous variables once the effects of all the other exogenous variables have been controlled for (Wooldridge, 2002) is not met. However, adding the exogenous variables from the second stage may not alter the significance of the first stage parameters. From their first stage equation they conclude that prices are higher in New Mexico and Colorado compared to Arizona reflecting differences in market maturity. Government buyers pay less than agricultural buyers but municipal buyers do not pay more or less than agricultural buyers. The drought measure shows that prices are lower during wetter periods. Population has no significant effect on price but per capita income does. Higher per capita income is associated with higher water prices. The second stage equation estimated was quantity as a function of price, value of agriculture, and land prices (all logged). The significant price parameter of -1.1 shows that demand is price elastic. The value of agricultural output parameter is also negative showing quantity transacted goes down as the value of agriculture rises. Land value is positive; higher quantities are related to higher agricultural land value.

Bjornlund and Rossini (2005) aim to empirically explain the factors affecting price and quantity of water allocations traded using mean monthly water prices in the Goulburn Murray Irrigation District and monthly volumes traded from Goulburn Murray Water. Price and volume were studied using correlation analysis, regression analysis (both inflation adjusted), and time-series analysis. Lagged variables were tested in correlation and regression analysis because irrigators may have delayed responses to market changes. Price was regressed on allocation level, evaporation, interest rate, and cattle, wool and wheat prices. Serial correlation (corrected using first differences) and multicollinearity (corrected by using proxy variables) were a problem. Seasonal dummy variables were not used because of strong multicollinearity with evaporation. The final model had an adjusted R^2 of .522. Volume was regressed on evaporation, rain, accumulated deficit, lease prices, and summer using first differences. Results showed that evaporation affected current trading and that trading increased as the deficit between rainfall and evaporation increased.

In this study, commodity prices were less important than expected and had inconsistent effects on prices. The most important determinants of water price and volume were allocation, rain, and evaporation. High-value farmers pushed prices up during drought by buying water to protect their investments. The authors conclude that the results show that irrigators need water markets to manage variable water supply. High-value users will increasingly need to buy or lease water and low-value users will either sell their rights or lease them in dry years and use them only in normal or wet years. Urban water authorities should also plan ahead (using dry-year options) for periods of dryness instead of relying on lease markets to avoid drought-induced price instability.

Howitt's 1994 empirical analysis of the 1991 California water market aims to answer two questions: what are the costs and benefits of the water bank at the state and local level and how could the impacts of the water bank be changed by changing how the water bank is administered? He says that because of increasing water development costs, water resource control now focuses on creating incentives for efficiency and reallocation. The operation of the bank showed that both demand and supply were more price elastic than anticipated; water users altered their demand after the price was set because the cost of water in some areas was close to the cost of conservation. Also, since the price was administratively set, the value of water increased without the cost to farmers increasing.

Overall, the water bank created a net gain in California although there were losses in some agricultural sectors. Third-party impacts are also important because while the farmers hold the water right, some of the value of that right comes from past or present public investment, so the impacts of moving the water on the community should not be ignored. In California, the dominant view is that regional well-being should constrain private property rights to water. Howitt uses a regional constant elasticity of substitution model to model the effects of different water bank administration choices. Third-party impacts were then calculated based on changes in production using input/output multipliers. He finds that impacts are lower, in terms of jobs and county income, when the amount of water sold by region is restricted. Impacts are highest when there is no restriction in place. The actual water bank impacts are simulated to be between these two extremes. He says that impacts are highly correlated with the net return to water so farmers will automatically fallow crops with the lowest impacts because they are also the lowest profit.

The value of water has also been estimated using the hedonic method (Butsic and Netusil, 2007; Colby, Crandall, and Bush, 1993; Crouter, 1987). Butsic and Netusil (2007) used the hedonic method to value water rights in Douglas County, OR in a recent study. They estimate the minimum payment a seller would accept to sell or lease water by estimating water's contribution to agricultural land sale prices. Holding other property characteristics constant, they find that the presence of irrigation rights is estimated to increase sale price per acre by approximately 26-30% (depending on the model used). They also include an interaction term for water and the number of acres sold. The interaction variable is negative, meaning water contributes less to sale price as more acres are sold. Their water variable is a dummy though so all acres sold are not necessarily irrigated. The willingness-to-accept price for water is estimated at $261/acre foot and is close to other price estimates in the state.

Colby, Crandall, and Bush (1993) use a hedonic approach to investigate the water right and transaction characteristics that affect water prices in the Gila-San Francisco Basin of western New Mexico. Water right characteristics included in the model are seniority and location of the right. They find that more senior rights are more expensive and that location of the right affects price. Transaction characteristics included in the model are a dummy for high-profile buyers, quantity transferred, and the year the transaction occurred. Their results indicate high-profile buyers pay more, larger quantities sell for lower prices, and real prices are increasing over time. Their results are significant overall and have an R^2 of 0.54. They note, however, that considerable price variation is not explained. This is expected because even if all water right and transaction characteristics were included, prices will vary widely in markets with high information costs and a small number of participants. The authors also compare transactions in the Gila-San Francisco Basin to those in Northern Colorado Water Conservancy District, the Lower Sevier River Basin in Utah, and Truckee Meadows in Nevada. Their qualitative comparison shows that prices vary more where transaction costs are high and water rights have different characteristics. They conclude that water right and transaction characteristics are important factors in the market value of water and the costs of water reallocation.

Crouter (1987) used hedonic estimation of agricultural land to see if separate and efficient water markets had developed. She proposed that if a separate water market was present, the combined hedonic price function for land and water could be separated into two functions: the price function for land plus the price function for water. She also proposed that if an efficient water market had developed, competitive pricing would lead to a constant unit price for water; a linear water function indicates an efficient market. She notes though that separate and linear water hedonic price functions may not be present if transactions costs hinder water market development. She estimates a hedonic price function for agricultural land in Weld County, CO to test her hypotheses. Using a Box-Cox transformation that allows for separable and linear functions she tests for their presence but finds neither. She thinks the results may be attributed to empirical errors, problems with the data, or the presence of high transactions costs. Since the legal and institutional setting would have allowed for a separate and competitive water market its absence is surprising. The transaction cost hypothesis can be tested by comparing the rental rates for water to the sale price. If there are no transactions costs then the rental rate should be equal to the sale price times the interest rate. If transactions costs are high for permanent purchases, then higher rental prices would be expected because they would be preferred.

2.1.1 Water Markets and the Environment

Howitt and Hanak (2005) examine California's water market development with an emphasis on how problems have been overcome through time. They focus on local economic impacts of transfers, exchange agreements, options markets, and an emerging environmental water market. The laws and policies that have allowed California's water market to evolve started in the late 1970's. Fish and wildlife gained the same protection against harm from transfers as other surface water users in 1980. State and federal water project reforms contributed to the ease of trading within and between the projects in the 1990's and the number of temporary transfers increased after these reforms. State and federal programs to purchase water for environmental protection and restoration began appearing in the late 1990's and accounted for a quarter or more of all purchases from 1995 to 2001. Environmental policy also affected agricultural demand when the Central Valley Project Improvement Act cut water to junior users in order to leave water in stream. Those junior users went to the market to buy water to supplement their supplies.

A major argument against the use of water markets is the local impacts that exporting regions must bear. Fallowing and groundwater substitution, the two major ways to free water up for transfer, have direct effects on local communities by reducing input purchases and return flows. Groundwater substitution has been limited by county ordinances, reducing the amount of water exported from many counties. Fallowing cannot be restricted at the county level although some water districts have adopted anti-fallowing policies. Buyers and sellers have taken the task of mitigating third-party impacts on themselves in order to make some water transfers possible. Some counties are also investigating better systems to allow groundwater export in light of the potential sales revenue.

Exchange agreements allow buyers to bank water during wet years and retrieve some portion of that water during dry years. Metropolitan Water District has made arrangements to bank water with Kern Water Bank, Arvin Edison, and Semitropic Water Storage District. These agreements require more water to be banked than can be retrieved but are reasonably priced and allow the district to take advantage of lower cost local water supplies during wet years while not abandoning more expensive supplies completely.

Option markets may be used to spread risk and add flexibility to water supplies. Metropolitan Water District is again a major force in the option market and has set up option contracts with many agricultural water agencies. The options are contingent on flows in major northern rivers. Option contracts were slow to gain acceptance at first but resistance to their use has been declining.

Howitt and Hanak also find that environmental demands have led to water market growth. The Environmental Water Account has been successful by facilitating voluntary water reductions to be used for environmental purposes instead of mandated cutbacks that could be required by state and federal law. Environmental water programs are expensive and have been primarily funded by taxes. Depending on the goals of the program, different types of funding may be more appropriate, such as a fee for water use affecting the Delta.

Loomis et al. (2003) document water market transactions for environmental purposes in the west. They argue that water continues to be used off river to irrigate some low-value crops when that water would be more valuable for instream purposes, particularly during dry periods. Environmental uses of water are sometimes ignored because the uses are hard to place a dollar value on. They summarize water prices and volumes to provide evidence of the value of water or what organizations are willing to pay. Both leases and sales have been used for environmental purposes and each has some benefit. Leases allow buyers and sellers to test the market out. Sellers that may be hesitant to engage in water marketing can gain experience. Buyers can see how the water aids in achieving an environmental goal. Third-party impacts can also be gauged without causing permanent harm. Sales, on the other hand, provide long-term protection and are good for rivers with chronic shortages. The water transaction data used in the analysis may not represent competitive markets, particularly in small watersheds. Small watersheds may have only one buyer or seller with money or water sufficient to protect the river. Using data on water transactions mainly from the Water Strategist for 1995 to 1999 the authors calculate the average quantity and price for environmental water leases and sales. The lease values are similar to non-market values that have been estimated for instream flows in other studies. The most common use for both leases and sales was instream flows. Other common uses were recreation, threatened or endangered species, waterfowl, and fisheries. They conclude that environmental values now exceed agricultural values of water in some instances because government agencies and non-profit organizations have been able to purchase water from farmers.

Isé and Sunding (1998) examine the characteristics of sellers and non-sellers of agricultural water for environmental purposes in the Lahontan Valley of Nevada. They aim to see which characteristics explain whether or not a grower will sell water, what participation means for program success, and to a lesser extent what effects selling water has on the agricultural economy.

They survey growers who did and did not sell water to the U.S. Fish and Wildlife Service to support the wetlands of Lahontan Valley. The survey asked questions about land, and personal and financial grower characteristics. These characteristics were used in a regression to predict whether or not a grower would sell their water right. Financial distress (including bankruptcy, foreclosure or divorce) was the most important predictor of a sale. Soil quality, distance from the town of Fallon, and off-farm employment were also significant. The model had an 86% success rate for predicting which growers sold their water.

The survey also revealed growers feelings towards the program and the way it was managed. Some farmers would have sold water to benefit wetlands but did not because they thought the government would resell the water to support nearby urban growth. Growers also felt that restrictions against selling water outside the area were depressing local prices and that prices offered by the U.S. Fish and Wildlife Service were too low. On the contrary, all growers who did sell reported that they were paid a fair price. Finally, growers expressed interest in a leasing program to complement the current sales only approach.

Isé and Sunding conclude with a caution against the presumption that a water market will allocate water efficiently. Their results show that many sellers sold for personal reasons and may not have received a price equal to the long-term value of the water in agriculture. They say that a program designed to target land less suitable for farming could help solve the problem.

Adams and Cho (1998) aim to measure opportunity cost to farmers in the Klamath Basin at different constrained lake levels and identify potential farming techniques (input/output substitutions) to reduce these costs using hydrological, crop yield, and economic farm models. The hydrological model estimates water supplies for a range of lake levels. The crop yield model estimates changes in crop yield with varying irrigation techniques and water application rates using a linear water-yield function that plateaus after max attainable yield; regression analysis was used to estimate yield and water supply relationships for each crop. The economic impacts of water supply and crop yield changes were estimated using farm level models. Each farm model includes variable and fixed constraints, farm activity and resource requirements, and net returns over variable costs. A General Algebraic Modeling System was solved for the profit-maximizing use of water given its availability and other constraints. The solution combines crop acres, irrigation type, and irrigation options to maximize net profit. The average profit of all farm models falls as water supply falls (because of rise in lake levels). Meeting the Endangered Species Act restrictions would cost an estimated $2 million/year to agriculture. The cost during the worse drought is estimated at $15 million/year. At higher beginning lake levels the cost of raising the level increases at an increasing rate because agricultural water saving methods are exhausted. The marginal value of water also increases as water supply decreases. More research is needed to measure the benefits of higher lake levels for fish since the costs of reduced water supply to agriculture can be high.

In 1990, Colby advocated the use of water markets for environmental uses based on the value of their economic benefits. She argues that when these values are taken together they can be higher than some agricultural uses. Some benefits attributed to environmental water uses are: water quality improvements that reduce municipal wastewater treatment costs and benefit agricultural water users; recreation values and the associated income local communities receive; and existence or option values of natural riparian areas.

Environmental water values such as these can compare to consumptive use values

(Colby, 1990a). Additionally, some environmental uses would only change the timing or location of diversion and would still be compatible with consumptive uses (with some adjustments). Despite the role that water markets could play in reallocating water from lower to higher valued uses, as of 1990, few environmental transactions had occurred. Colby attributes the lack of transactions to legal obstacles, such as environmental uses not being recognized at the time, and local water right owner opposition.

2.1.2 Maturing Water Markets

A final and emerging topic in water markets is the level of development of markets. Bjornlund (2002) examines prices in two Australian water markets to determine if the markets are showing signs of maturity. Market maturity is important because inefficient outcomes will result from immature markets (Bjornlund, 2002). In the paper, hedonic functions are used to value the characteristics of permanent water transfers in two time periods. Details about the sale were obtained as well as the names and contact information for buyers and sellers. Questionnaires were then sent to the buyers and sellers asking for personal and enterprise characteristics.

Bjornlund compares minimum and maximum prices and standard deviation as a percent of mean prices for the two markets. In the Murray River South Australia market, the market is growing and prices are becoming less dispersed over time. In the Goulburn-Murray Irrigation District prices have a wider spread and a fluctuating minimum price; Bjornlund suggests these are signs of an inefficient market. Both markets had increased volumes traded in the second period.

Other signs of maturing markets cited by Bjornlund (2002) are reduced trade barriers over time and space that allow freer trade of water, and an increased use of water brokers. He also notes that as information access increased, inefficient irrigators were not able to purchase water at the low prices they previously had.

2.1.3 Contribution

This research empirically examines environmental water transfers and how they are both similar and different from non-environmental water transfers. Additionally, different statistical techniques are used with the aim of refining or improving upon work by Brown (2006), Pittenger (2006), Pullen (2006), and Brookshire et al. (2004). The results of this research may be useful for those seeking to buy or sell water for environmental purposes. Having more information about past sales and leases can inform negotiations and potentially lead to a more efficient market over time. This research may also support policy development that encourages voluntary water transfers for environmental use. By doing more research on environmental water markets and making them more familiar, their use may become increasingly acceptable to policy makers and the public as a possible low-cost solution to the problems of decreasing flow and lake levels. Policy makers may also be interested in whether the market is becoming more efficient over time. If state policy is keeping the market from developing in a more efficient way, policy reform can be explored where those inefficiencies are unnecessary.

CHAPTER 3

Econometric Model and Data

3.1 Data Description

The transaction data used in the analysis comes from the *Water Strategist* (formally known as the *Water Market Update*) for the years 1987 - 2007. The *Water Strategist* is a monthly publication detailing water sales and leases in the western U.S. as well as trends in water policies, laws, and legal actions. In the *Water Strategist* transaction entries there are varying degrees of detail on the buyer, seller, price, quantity, and other characteristics of water transactions. Examples of two transactions are in Appendix A. Transactions are reported by month and year although the date they are reported does not represent the date the transaction occurred in most cases. Some entries are for transactions that took many months to complete while others are summaries of a number of transactions that occurred within the past month or even year. I tried lagging various independent variables to account for the time ambiguity present in the data. I used longer lags for sale transactions than for lease transactions because sales often face more obstacles to completion. The *Water Strategist* usually provides price and quantity, and whether the transaction was a sale or lease. Characteristics of the acquirer and supplier of the water including type of entity and water purpose are also usually provided. Transactions are reported by state; however, not every state has transactions reported in every month. Some states do not have transactions reported every year.

The *Water Strategist* describes transactions in narrative form that must be translated into a form suited to econometric analysis. I define a transaction as one negotiation or purchase of water by an entity from another entity. If a city negotiated a 10-year lease from an irrigation district, the lease would be reported as one transaction. Each entry was examined to determine if it represented more than one transaction, if the price was disclosed, and if there was any other missing or ambiguous information. If more than one transaction was reported in one entry, it was separated into the number of transactions reported with as much detail as was provided. Generally, quantities and prices were available for the largest transactions and the remaining transactions had average quantities and prices. Multiple transactions were sometimes reported without sufficient information to split them into multiple observations. Because of the varying amount of detail reported by the *Water Strategist* observations in the regression models may represent individual transactions or a summary of multiple transactions. A summary of the transactions by state and type is in Table 3.1. Table 3.2 illustrates the number of transactions over time as well as total quantity, mean price, and the standard deviation of price in three-year intervals.

Table 3.1: Summary Statistics, 1987-2007

	AZ	CA	NV	NM	UT	WY	Total
Environmental Sales							
n	5	4	31	1	2	1	44
min quantity	70	803	0.56	9	86	56	0.56
mean quantity	828	3,482	1,566	9	316	56	1,530
max quantity	1,660	10,000	19,600	9	546	56	19,600
min price	810	13	342	2,644	1,256	3,091	13
mean price	3,525	1,070	9,051	2,644	1,508	3,091	7,073
max price	6,307	1,724	46,445	2,644	1,759	3,091	46,445
Non-Environmental Sales							
n	113	102	257	84	54	3	613
min quantity	1	2	0.15	0.13	6	275	0
mean quantity	2,417	8,771	379	476	4,489	14,357	2,595
max quantity	33,250	300,000	17,375	8,835	60,000	32,795	300,000
min price	54	17	426	103	86	24	17
mean price	1,459	9,070	10,778	2,904	1,337	974	6,817
max price	12,745	257,998	46,440	7,500	7,874	2,674	257,998
Environmental Leases							
n	13	112	-	54	3	-	182
min quantity	75	120	-	16	1,900	-	16
mean quantity	10,691	30,959	-	6,967	4,433	-	21,956
max quantity	89,583	200,000	-	70,000	9,500	-	200,000
min price	44	8	-	8	30	-	8
mean price	52	96	-	54	51	-	80
max price	77	384	-	147	89	-	384
Non-Environmental Leases							
n	57	576	-	25	18	-	676
min quantity	8	2	-	49	74	-	2
mean quantity	133,315	12,760	-	7,055	6,773	-	22,554
max quantity	1,200,000	500,000	-	44,760	15,924	-	1,200,000
min price	8	6	-	25	7	-	6
mean price	97	105	-	72	29	-	101
max price	787	1,290	-	114	188	-	1,290

Quantity in acre feet; Price in 2007 dollars/acre foot

Table 3.2: Transactions Over Time

Years	N	Total Volume	Mean Price	Std. Dev. Price
		Environmental Sales		
1987-1989	6	3,206	988	964
1990-1992	5	11,859	1,190	1,188
1993-1995	-	-	-	-
1996-1998	2	7,726	2,479	1,858
1999-2001	12	34,813	2,195	1,783
2002-2004	4	2,724	3,124	1,628
2005-2007	15	6,978	17,037	12,911
		Non-Environmental Sales		
1987-1989	96	237,837	2,212	1,392
1990-1992	48	538,555	2,154	1,506
1993-1995	67	153,836	1,774	1,917
1996-1998	33	80,778	2,052	1,523
1999-2001	110	271,454	3,638	3,082
2002-2004	118	105,298	4,554	3,964
2005-2007	141	202,935	19,425	37,224
		Environmental Leases		
1987-1989	7	111,666	46	32
1990-1992	7	176,092	80	64
1993-1995	13	286,612	42	26
1996-1998	27	634,287	69	73
1999-2001	32	811,682	65	64
2002-2004	27	1,059,616	98	50
2005-2007	69	916,015	94	50
		Non-Environmental Leases		
1987-1989	38	434,854	156	104
1990-1992	100	5,143,189	137	112
1993-1995	94	3,072,645	123	105
1996-1998	63	1,351,914	114	98
1999-2001	132	2,199,459	92	120
2002-2004	171	1,203,063	63	88
2005-2007	78	710,207	89	154

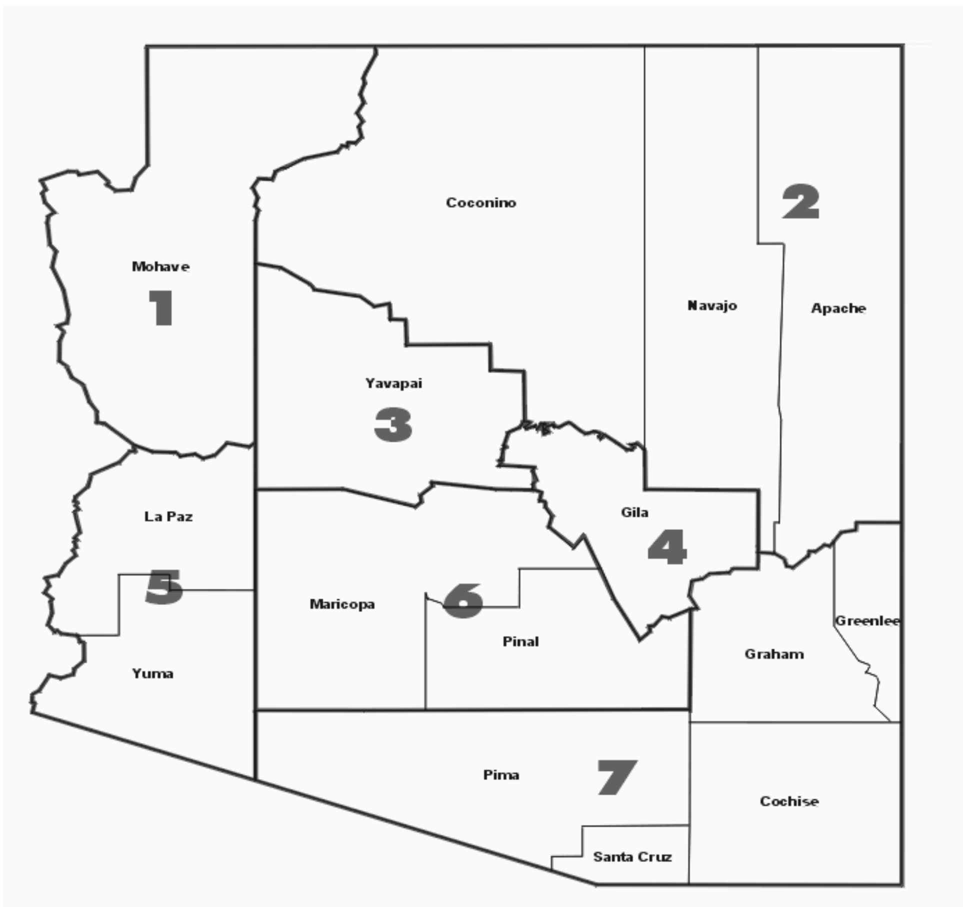
Quantity in acre feet; Price in 2007 dollars/acre foot

I paired climate and demographic information with the transactions in the analysis. The additional variables are either at the state or climate division level. Climate divisions divide a state into regions with similar climate and hydrologic conditions (CLIMAS, 2003). Figure 3.1 shows the seven climate divisions in Arizona (CPC, 2008). In addition to climate variables, population was included at the climate division level since it can vary greatly across the state. Population was available at the county level and summed over climate divisions. Not every state has climate divisions that line up as perfectly with counties as Arizona. In the case where one county spanned more than one climate division it was assigned to the climate division where most of its area lay upon visual inspection.

3.1.1 Splitting Entries

Three models, using California leases as an example, were estimated to see what effect splitting *Water Strategist* entries into multiple observations had on model variance and R^2. Entries representing multiple transactions were disaggregated two ways and tested. In previous studies the observation level, either *Water Strategist* entry or transaction, is not always evident (Brown, 2006; Brookshire et al., 2004). Initially, I disaggregated California entries when the number of transactions was given so that an observation would represent one transaction instead of one *Water Strategist* entry. I would split entries even if only average quantities and prices were available. Using averages resulted in multiple observations with the same values for price and quantity. Since price and quantity are major factors in the water market, using averages was worrisome because no new information was being revealed. Was I inadvertently decreasing the error variance by including multiple observations with averages?

Figure 3.1: Climate Division Map of Arizona



To investigate, I ran three regressions using California lease transactions from 1995-2007. The original data set was not disaggregated at all (observations may represent many transactions even where more detailed information on price and quantity is available) resulting in 211 observations. The second was disaggregated as much as possible, resulting in 1022 observations. The third was a compromise: when actual prices and quantities for separate transactions were available they were split, resulting in 512 observations. The number of observations used in the preliminary models does not match the number of observations used in the final models because the preliminary models were for a shorter time period and combined environmental and non-environmental leases. A new binary variable was added indicating if a transaction was split and a new count variable was added to record the number of transactions represented in an observation if it was not split. As expected, compared to the original, the error variance was lower for the completely disaggregated regression (close to 1/3 lower) and the adjusted R^2 was higher (6 times). The compromise regression's error variance and R^2 were similar to the aggregate. Wary of artificially altering the regression statistics but simultaneously wanting to use the most information available, I decided to disaggregate transactions only where additional information is available for price and quantity rather than just the average. Observations in the final data set are single transactions when possible and multiple transactions when not.

3.1.2 Data Cleaning

There were some instances where transactions were removed from the data set, summarized in Table 3.3. Transactions were removed if the price was undisclosed (for example, water sold together with land), if the information provided was too

Table 3.3: Transactions Used

	All Transactions	Useable Transactions	Percent Removed
n	1,853	1,563	15.49
sales	778	657	15.44
leases	1,075	909	15.55
mean price ($/af)	$2,488	$2,649	
mean quantity in af	13,112	13,548	

Prices in nominal dollars. Averages calculated from available data for removed transactions.

ambiguous to extract price or quantity, or if the price was less than $5.00/acre foot. Transactions under $5.00/acre foot were removed because they are unlikely to represent true market transactions; they often involved sales between family members or administratively set prices. Transactions were also removed if they were for reclaimed water or storage. Reclaimed water is inherently different from other surface or groundwater: it has restricted uses due to political, technological, and environmental constraints. Transactions for storage were removed only if they involved no actual water and were solely for storage space. Some *Water Strategist* entries provided more detail on a single transaction. If one transaction included multiple quantities and prices, the total quantity was used with a weighted average price (e.g. a buyer and seller negotiated multiple price and quantity combinations). Leases were reclassified as sales if they exceeded 50 years in length. A final caution should be made that the transactions are not necessarily representative of the water market as a whole. The *Water Strategist* does not report all types of water transactions, but any selection bias is expected to be consistent across states (Howitt and Hansen, 2005).

3.2 Model and Variable Description

I estimate a demand model for price of environmental water. Non-environmental water price is also modeled as a basis for comparison. Similar methods have been used for water transactions in the literature (Brookshire et al., 2004). The traditional demand equation is solved for price. Price is the dependent variable because there is a predetermined quantity of water available in a region at the time when water transfers are negotiated. As more people move to the West and as more environmental uses become recognized, roughly the same amount of water will need to be reallocated to different uses. Since the overall quantity of water available is not expected to change dramatically, the price of water must change to balance demand with supply. If drought reduces the naturally available water, the demand for water transfers will increase and price will adjust accordingly.

Additionally, I estimate a price-dependent form because the determinants of price are more relevant for policy makers and non-governmental institutions seeking to purchase water for environmental purposes; and because strong instruments are available for the first stage regression of quantity. Strong instruments are important because quantity is instrumented when it is endogenous. If the instruments are weak, parameters may be "badly biased" and test statistics may not have the correct asymptotic properties even if the sample size is large (Staiger and Stock, 1997). The instruments include all the demand equation variables (excluding quantity) plus additional exogenous variables. All the exogenous demand variables are included to make sure the instruments chosen are at least partially correlated with quantity after controlling for the effect of the other variables (Wooldridge, 2002).

Sales and leases are modeled separately for both the environmental and non-environmental water markets using a semi-log functional form. I chose a semi-log

Table 3.4: Regression Models

	Lease	Sale
Environmental	Semi-log 2SLS	Semi-log OLS
Non-environmental	Semi-log 2SLS	Semi-log OLS

Table 3.5: Hausman Test Results

H_0: Q is exogenous

	Sales		Leases	
	Env	Non-Env	Env	Non-Env
P-value	0.177	0.906	0.274	0.006
Result	Fail to reject H_0	Fail to reject H_0	Fail to reject H_0	Reject H_0

form for a number of reasons. First, outliers in price led to a poorly fitting model and non-normally distributed errors. Taking the natural log improved the model's fit and returned errors that more closely approximate a normal distribution. Second, I suspected there was a non-linear relationship between price and explanatory variables like temperature, drought, and income. Third, past studies have used this form and found it to model the market well. A double-log model was also investigated but lead to heteroskedasticity in the non-environmental leases model. The double-log model had similar results to the semi-log for the sales model so the semi-log model was chosen to allow comparisons across models.

Two-stage least squares regression was used to estimate lease prices. Ordinary least squares was used to estimate sale prices. Table 3.4 summarizes the regression models. Endogeneity may be a problem when using quantity as a regressor for price if these values are simultaneously determined. The regression form of the Hausman test (Wooldridge, 2002) was performed to check for endogeneity with the result that the null hypothesis of exogenous quantity was rejected in the non-environmental lease model as summarized in Table 3.5. Sale quantity is not expected to be endogenous because sale transactions are generally carried out under public scrutiny and prevailing prices are widely known. Lease price and quantity are suspected to be endogenous because no prevailing price exists.

The regression endogeneity test consists of an initial regression using ordinary least squares. Quantity is regressed on the proposed instruments and the residuals are saved. Price is then regressed on quantity, the exogenous variables, and the residuals, also using ordinary least squares. A significant parameter for the predicted errors suggests the errors from quantity are related to the errors in the price equation, i.e. quantity is endogenous. When heteroskedasticity was present the test was carried out using robust standard errors. The inferences did not change when robust standard errors were used. Although the test failed to reject exogeneity of quantity in the environmental lease model, two-stage least squares was still used for two reasons: the instruments were weak in the environmental model so the test results may not be reliable and to maintain comparability with the non-environmental lease model. The two-stage least squares estimator is less efficient than the ordinary least squares estimator but if endogeneity is present, the ordinary least squares estimator will be inconsistent (Greene, 2003). As suggested by Thurman (1986) the exogeneity of price was also tested in quantity-dependent models for comparison. In the sales models, the exogeneity of price was not rejected. In the environmental lease model, the exogeneity of price was rejected, supporting the idea that price and quantity are endogenous. In the non-environmental lease model, the results differed depending on whether robust standard errors were used to perform the test.

Heteroskedasticity may be a problem, particularly because all models include multiple western states. Examination of the errors revealed no apparent patterns. The Bruesch-Pagan/Godfrey test (Johnston and Dinardo, 1996) was used for the sales models and homoskedasticity was rejected for the non-environmental model. Heteroskedasticity is controlled for using robust standard errors in this case. Normal heteroskedasticity tests cannot be carried out in the presence of endogeneity because the tests explicitly assume that the error has zero mean given the explanatory variables. To avoid this problem for the lease models, I performed the tests using the predicted errors from the second stage of the two-stage least squares regression and excluding the endogenous variable, quantity. Homoskedasticity was also rejected for these models. Robust standard errors were calculated for the leases as well.

A few final specification tests were performed. The environmental water market is suspected to differ from the general water market. A Chow test was also used to confirm this difference. The null hypothesis for the test is that the parameters are the same for the two regression models (Greene, 2003): environmental and non-environmental water transactions. The null hypothesis was rejected for both sales and leases as summarized in Table 3.6. Results for the combined environmental and non-environmental models are in Appendix B. Collinearity was also investigated using variance inflation factors and condition indexes of all parameters and instruments. Some degree of collinearity was detected in all models. The collinearity stems from the inclusion of state dummies and variables measuring income or land value. State dummies and income are important components of the model so I chose to leave them in the model. State dummies help account for fixed effects of differences between states, such as legal or administrative differences. Income is expected to be an important component in both demand and prices for environmental and non-environmental water. Collinearity was reduced by using a ratio of agricultural real estate value to agricultural income instead of those variables alone or separately. Per capita income remains in the model untransformed and still leads

Table 3.6: Chow Test Results

H_0: $\beta_{Env} = \beta_{Non\text{-}Env}$		
	Sales	Leases
Test Statistic	4.2	7.1
F(14, 622)	2.1	
F(13, 825)		2.2
Result*	Reject the H_0	Reject the H_0

*at the 99% significance level

to some collinearity. Significance of variables, their magnitudes, and signs are not largely affected by the remaining collinearity, as dropping per capita income does not cause any large changes.

3.2.1 Variables

The variables used in the ordinary least squares and two-stage least squares regressions for the environmental and non-environmental water markets are summarized briefly in Table 3.7 and described in more detail afterwards.

Table 3.7: Summary of Variables

Name	Description	Expected Sign
lnP07	Natural log of real price (2007 dollars)	
Q or $\hat{Q}$	Quantity in acre feet (sales models) or predicated quantity (leases models)	−
Temp#	Temperature lagged # of months by climate division	+
L#SP#	SPI 6 or 12 lagged # of months by climate division	−
Income	Quarterly real per capita income by state lagged one quarter	+
LandInc	Ratio of agricultural real estate value/acre to net income/acre by state	+
DivPop	Yearly population by climate division in 10,000's	+
NumTrans	All reported transactions per climate division per year	+
Yrs	Length of lease	+
	Dummy Variables (=1 for:)	
Pub	State or Bureau of Reclamation project water	−
Mand	New use for threatened & endangered species or water quality (excluded dummy)	
Env	New use is general environmental or recreation	−
Multi	New use for environmental and non-environmental purposes	+
Ag	New use is agricultural (excluded dummy)	
Muni	New use is municipal, domestic, or municipal industrial	+
Dev	New use for development	+
Ind	New use is power plant or mining	+
Noncu	New use is storage, interstate compact, or tribal settlement	−
Other	New use is unknown or multiple non-environmental uses	+/−
Transaction Location Dummies: AZ, CA, NV, NM, UT, WY (CA is excluded dummy)		
	Instrumental Variables	
Split	= 1 if *Water Strategist* entry was split into multiple observations	−
L3SP24	SPI 24 lagged 3 months by climate division	−
L2Income	Real per capita income by state lagged two quarters	+

Description of Variables and Expected Signs

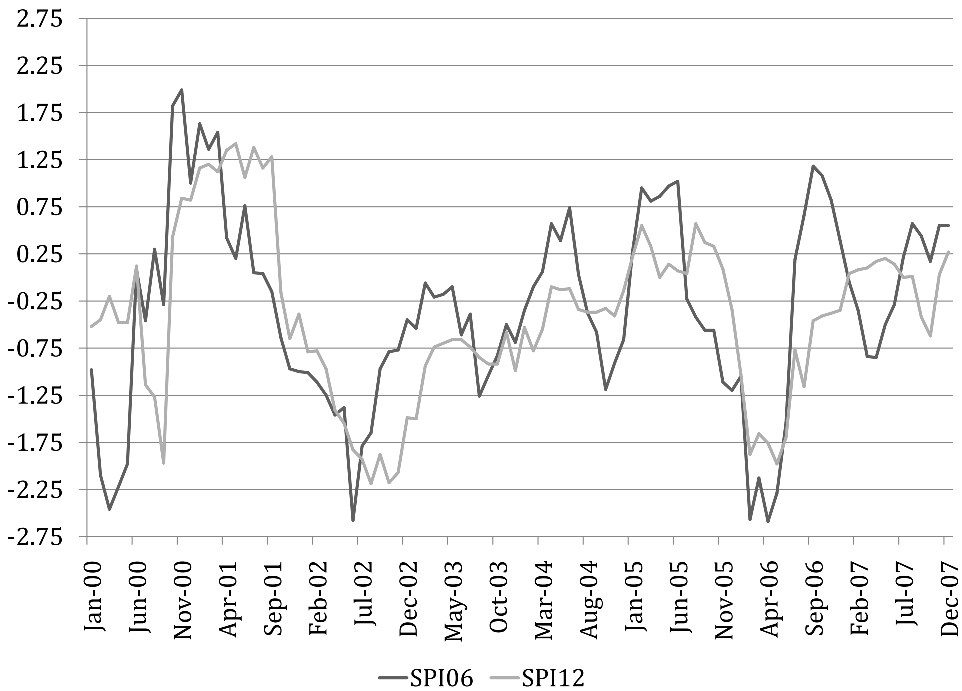
lnP07: The natural log of the price per acre foot in 2007 dollars for each transaction. Price was deflated using the Consumer Price Index for 2007 from the Bureau of Labor Statistics website (BLS, 2007). Price is the dependent variable.

Q or $\hat{Q}$: The quantity purchased or predicted quantity purchased in acre feet. The quantity parameter is expected to be negative, indicating a downward sloping demand curve.

Temp#: The mean monthly temperature in the climate division where the water was acquired. It is lagged three months for leases and six months for sales from the date the transaction was reported, to account for delays in reporting and the time needed to complete a transaction. Temperature data were obtained from the National Climatic Data Center website (NCDC, 2007). The temperature parameter is expected to be positive. If temperature increases, water demand by the environment, cities, and agriculture will also increase and price will increase.

L#SP#: The Standard Precipitation Index (SPI) measures drought in terms of standard deviations from the mean. These deviations are calculated using accumulated precipitation over the past months (for example, last six or twelve for SPI06 and SPI12) compared to the long-term precipitation mean in the same climate division. The index will be negative if precipitation has been below normal and positive if it has been above normal. More extreme values indicate more extreme conditions. The shorter index measures recent conditions while the longer index gives an indication of more chronic conditions (WRRC, 2008). Figure 3.2 illustrates the six- and twelve-month indices for

Figure 3.2: Standard Precipitation Index - 6 & 12 Month



the climate division including Tucson and southeastern Arizona from 2000 to 2007. The variable is lagged three months for leases and six months for sales allowing for time to complete a transaction and possible delay in reporting by the *Water Strategist*. SPI data were obtained from the National Climatic Data Center website (NCDC, 2007). The SPI parameter is expected to be negative. As conditions become wetter, the value of the SPI becomes larger. Demand is expected to decrease with wetter conditions so price will decrease.

Income: Income is the quarterly per capita income at the state level lagged one quarter. The lag value was used because the last quarter's income was not available at the time of this research. Additional lags to match temperature and SPI were also tried but because income changes only slightly from quarter to quarter, the results were basically the same. Income data comes from the Bureau of Economic Analysis website (BEA, 2007). The income parameter is expected to be positive. Environmental, municipal, and agricultural water are all expected to be normal goods. Increasing income is expected to increase demand and price for these goods.

LandInc: The average real estate value of agricultural land per acre divided by the average agricultural net income per acre. Both are at the state level and in 2007 dollars. Real estate value and net farm income come from the Economic Research Service website (ERS, 2008). This variable measures the value of land compared to the value it produces. States with more development pressure are expected to have a higher land value to income ratio and higher demand to reallocate water from agricultural to municipal uses. Prices are expected to be higher because previous studies show municipal users are willing to pay more.

DivPop: The yearly population by climate division lagged two years in 10,000's. The climate division population was calculated by first obtaining the county population and then summing the population over counties located within a climate division. If a county spanned more than one climate division, a climate division and county map provided by the Climate Prediction Center was consulted (CPC, 2008) and the county was assigned to the division where the majority of its area lay. County populations come from the Census Bureau Website (Census, 2008) and were lagged because the most recent two years were not available at the county level. This parameter is expected to be positive. Demand is expected to increase as an area becomes more developed causing prices to increase.

NumTrans: The total number of transactions reported per climate division per year, including both sales and leases for environmental and non-environmental purposes. It is expected to have a positive effect on price. As people in an area become more familiar with water transactions, more people may compete for available water and they may bid up the price for sales and leases.

Yrs: This variable measures the length of a lease in years. The value ranges from less than one to 50. Leases over 50 years in length are treated as sales. The parameter for Yrs is expected to be positive. A longer lease benefits demanders because they will not have to go back to the lease market as frequently. Since they will be able to meet the same demand but with less time investment, they are expected to be willing to pay more.

Pub: A dummy variable which equals one if the water is controlled by a state or government agency instead of a private water user. Examples are the State Water Project in California and Central Arizona Project. The parameter is expected to be negative because public water project water may be less desirable to demanders. It often does not represent as secure a supply as privately held water rights. Public project water may also have administratively set prices.

Mand: A dummy variable which equals one if the water was purchased to be used for threatened or endangered species, or water quality improvement. These uses are deemed mandatory because law requires the protection of listed species and certain water quality levels. This is the excluded variable in the environmental water models.

Env: A dummy variable which equals one if the water was purchased to be used for general environmental purposes. Water for instream flows, recreation, and open space are examples. The parameter is expected to be negative as general environmental uses are expected to represent demand that is more elastic than mandatory environmental uses. Several environmental uses were combined for this variable because there were too few observations on each environmental use per state to disaggregate further.

Multi: A dummy variable which equals one if the water was purchased for uses that include both environmental and non-environmental purposes. Examples include cities purchasing water for both municipal and open-space use. The parameter is expected to be positive because agricultural and municipal users are willing to pay more for water.

Ag: A dummy variable which equals one if the water was purchased for agricultural use. This is the excluded variable in the non-environmental models.

Muni: A dummy variable which equals one if the water was purchased for municipal use. Municipal uses include general domestic, light industrial, and golf course or other landscaping. The parameter is expected to be positive; municipal buyers are expected to be willing to pay more than agricultural buyers.

Dev: A dummy variable which equals one if the water was purchased for new development. Muni and Dev are mutually exclusive categories. The parameter is expected to be positive; developers are expected to be willing to pay more than agricultural buyers.

Ind: A dummy variable which equals one if the water was purchased for heavy industrial uses (power plants or mining). The parameter is expected to be positive; heavy industrial users are expected to be willing to pay more than agricultural users.

Noncu: A dummy variable which equals one if the water was purchased for a non-consumptive but non-environmental use. These uses are: storage that is not obviously purchased for municipal or another use, tribal settlements, and interstate compacts. This parameter is expected to be negative; non-consumptive users are expected to be willing to pay less than agricultural users.

Other: A dummy variable which equals one if the water was purchased for either unknown or multiple non-environmental uses. I have no expectation about the sign of this parameter because it includes both unknown and multiple uses which may both contain agricultural uses; the direction of the relationship with price is ambiguous.

Location Dummies: Dummy variables for each of the states: AZ, CA, NV, NM, UT, and WY. CA is taken as the baseline. All states are expected to have lower prices than California except possibly Nevada. California users are expected to pay more because of development pressure and the already full use of available water in the state.

Description of Instrumental Variables and Expected Signs

Instrumental variables are used in addition to the above variables to estimate quantity in the first stage of the lease models. The instruments were chosen based on their correlation with the quantity transacted but not with the error in the price equation.

Split: Split is a dummy variable that equals one if the original entry reported by the *Water Strategist* provided information about more than one transaction with enough detail that it could be split into multiple observations. The parameter is expected to be negative; entries that are split will have smaller quantities than entries that represent multiple transactions. Split is exogenous because it has nothing to do with the actual transaction as it occurred, only with the way it was reported by the *Water Strategist*. If an entry was split into multiple observations, then the per observation quantity would be lower but the per observation price would be unchanged.

L3SP24: An extra 24 month SPI term is used for quantity to capture the effects of long-term conditions on the amount of water demanded. The parameter is expected to be negative; wetter conditions (more positive SPI) will lead to less demand in the water market. L3SP24 is predetermined because it represents the prior two years of precipitation conditions plus a three month lag.

L2Income: An extra lagged income term. Quantity is expected to increase as income increases although possibly not immediately. The expected sign is positive. L2Income is predetermined because it is the income reported two quarters before the transaction was reported.

CHAPTER 4

Results

4.1 Environmental and Non-Environmental Water Price

Within the sale and lease markets, environmental and non-environmental models were estimated using the same techniques and variables so results would be as comparable as possible. Sale and lease estimations were also chosen with comparability in mind but comparisons are not as straightforward since two-stage least squares regression was only used for leases. All models are in a semi-log functional form; non-dummy variable parameters represent the percent change in price for a unit increase in the variable. For dummy variable parameters, the percent change in price is given by $e^{\hat{\beta}} - 1$ (Kennedy, 2003).

4.1.1 Sales

Sales for environmental uses are preferred to leases when a permanent solution is needed or when there is long-term environmental demand for water (Loomis et al., 2003). Table 4.1 contains summary statistics for the variables in the environmental sales estimation. Arizona, California, Nevada, New Mexico, Utah, and Wyoming all had at least one environmental sale from 1987 to 2007. Most sales occurred in Nevada; much of the water was purchased to protect either the Lahontan Valley wetlands or Pyramid Lake and was purchased by both environmental organizations and the U.S. Fish and Wildlife Service. The state with the next largest amount of transactions was Arizona. Water was purchased to protect the San Pedro River and to maintain recreational lake levels in the Phoenix area.

Table 4.1: Summary Statistics: Environmental Sales

Variable	Mean	Std Dev	Min	Max
Q	1,530	3,567	0.56	19,600
lnp07	7.86	1.58	2.60	10.75
Temp6	59.49	15.74	29.10	79.30
L6SP12	0.44	1.16	-1.42	2.44
Income	35,157	4,584	23,578	40,144
LandInc	42.74	39.73	14.51	279.47
DivPop	88	112	3	654
NumTrans	18.11	12.48	1	36
Pub	0.14	0.35	0	1
Mand	0.27	0.45	0	1
Env	0.64	0.49	0	1
Multi	0.09	0.29	0	1
AZ	0.11	0.32	0	1
CA	0.09	0.29	0	1
NV	0.70	0.46	0	1
NM	0.02	0.15	0	1
UT	0.05	0.21	0	1
WY	0.02	0.15	0	1

n = 44

Table 4.2: Summary Statistics: Non-Environmental Sales

Variable	Mean	Std Dev	Min	Max
Q	2,595	14,025	0.13	300,000
lnp07	7.77	1.52	2.81	12.46
Temp6	56.27	16.71	16.40	93.00
L6SP12	-0.05	1.20	-3.09	2.54
Income	32,295	5,382	22,368	40,868
LandInc	41.56	43.00	10.14	279.47
DivPop	167	282	2	1,705
NumTrans	12.78	10.22	1	42
Pub	0.12	0.32	0	1
Ag	0.08	0.27	0	1
Muni	0.40	0.49	0	1
Dev	0.39	0.49	0	1
Ind	0.01	0.08	0	1
Noncu	0.03	0.16	0	1
Other	0.09	0.29	0	1
AZ	0.18	0.39	0	1
CA	0.17	0.37	0	1
NV	0.42	0.49	0	1
NM	0.14	0.34	0	1
UT	0.09	0.28	0	1
WY	0.005	0.07	0	1

n = 613

Non-environmental sales are summarized in Table 4.2. The non-environmental sales market is much more active than the environmental sales market and a wider range of quantities and prices is observed. Other variables appear to fall in roughly the same range as the environmental market. The same states are included in the non-environmental market but sales are more evenly spread between the states; Arizona, California, Nevada, and New Mexico all have numerous sales in the data set.

Estimation results for both sales models are presented in Table 4.3. The new uses are not the same in each model because the transactions used in each model are mutually exclusive. Both models have an adjusted R^2 of around .65. Quantity is significant and negative in the non-environmental market reflecting the expected negative sloping demand curve but not significant in the environmental market. Too few observations may be available to establish a relationship between price and quantity in the environmental market. The marginal effect of quantity in the non-environmental model is a .001% decrease in price for an additional acre foot purchased.

Temperature (Temp6) is negative and significant in the non-environmental model. The marginal effect of temperature is a .75% decrease in price for a one degree increase in mean monthly temperature. This counterintuitive result would imply that water tends to sell at lower prices in hotter time periods or places holding everything else constant. I expected that demand would increase as temperatures increased, leading to an increase in price. The temperature variable may not measure the general weather conditions at the time of sale well. It is only a mean temperature for a month, six months before the transaction was reported. Since it is a mean temperature and not a standardized index, it may be picking up effects of water prices in hotter versus cooler areas instead of how water prices change with temperature in one area. Water users in areas that are accustomed to hot weather may have less increase in demand during hot periods than areas that are typically cooler. A temperature index that measures deviations from the temperature mean over longer periods of time, like the Standard Precipitation Index, might work better but is not currently available.

Table 4.3: Sales Estimation Results

Variable	Non-Environmental Model	Variable	Environmental Model
Intercept	0.1216	Intercept	-1.3053
	(0.5521)		(3.1590)
Q	-0.0000079***	Q	-0.000044
	(0.000002)		(0.00005)
Temp6	-0.0075***	Temp6	-0.0143
	(0.0022)		(0.0110)
L6SP12	0.0526*	L6SP12	-0.1332
	(0.0313)		(0.1577)
Income	0.00017***	Income	0.00015
	(0.00002)		(0.0001)
LandInc	0.0015*	LandInc	0.0062
	(0.0008)		(0.0041)
DivPop	0.0009***	DivPop	0.0043
	(0.0002)		(0.0030)
NumTrans	0.0078	NumTrans	0.0966***
	(0.0061)		(0.0239)
Pub	-0.9445***	Pub	0.0542
	(0.1878)		(0.4989)
Muni	0.7439***	Env	-0.1587
	(0.1995)		(0.4090)
Dev	1.2664***	Multi	0.6746
	(0.2691)		(0.6617)
Ind	1.6637***		
	(0.4183)		
Noncu	-0.0413		
	(0.3927)		
Other	0.4715**		
	(0.2213)		
AZ	1.5927***	AZ	4.6243***
	(0.2509)		(1.0923)
NV	1.5226***	NV	1.8156
	(0.3289)		(1.1750)
NM	3.0069***	NM	6.2224***
	(0.3207)		(1.5911)
UT	1.8420***	UT	3.7630***
	(0.3117)		(1.2644)
WY	0.5706	WY	5.8034***
	(1.0760)		(1.5361)
	n=613		n=44
	Adj. R^2=.646		Adj. R^2=.661

(Robust Standard Errors Non-Environmental Model Only)
Significance Levels: *.10 **.05 ***.01
CA is base state, Ag and Mand are base uses.

Table 4.4: Marginal Effects, Sales Results

Variable	Non-Environmental Sales	Environmental Sales
Q	**-0.001%**	-0.004%
Temp6	**-0.75%**	-1.43%
L6SP12	*5.3%*	-13.3%
Income	**0.02%**	0.02%
LandInc	*0.15%*	0.62%
DivPop	**0.09%**	0.43%
NumTrans	0.78%	**9.7%**
Pub	**-61.1%**	5.6%
Muni	**110%**	
Dev	**255%**	
Ind	**428%**	
Noncu	-4.0%	
Other	*60.2%*	
Env		-14.7%
Multi		96.3%
AZ	**392%**	**10,093%**
NV	**358%**	514%
NM	**1,923%**	**50,291%**
UT	**531%**	**4,208%**
WY	76.9%	**33,041%**

Significant at 10%, **Significant at 1%**

The Standard Precipitation Index (L6SP12) was significant only in the non-environmental model. It has an unexpected positive sign. The marginal effect of a one unit increase in L6SP12 (an additional standard deviation from the precipitation mean toward wetter conditions) is a 5.3% increase in price. I tried different lags and SPI lengths in the estimation but results were similar. Demand for permanent water rights for environmental purposes may be unrelated to drought because permanent needs are not as dependent on current climatic conditions.

Income is significant and positive in the non-environmental model. The marginal effect of income is a 20% increase in price associated with a $100 increase in state average per capita income. The positive result upholds the expectation that as income increases, water price increases. The ratio of agricultural real estate value to net income per acre (LandInc) is also positive and significant in the non-environmental model. If agricultural real estate values are much higher than the income earned per acre in the state, development pressure is expected to be high. With higher development pressure comes higher demand for water in municipal use. The marginal effect on non-environmental prices is a .15% increase for every unit increase in the land value to income ratio. If the ratio was 40, hypothetically representing a land value of $4000/acre to a net income of $100/acre, a one unit increase could represent either a $1000/acre increase in land value or a roughly $3/acre decrease in net income. Population at the climate division level (DivPop) is significant in the non-environmental model. It has the expected sign: larger populations are associated with higher water prices.

The number of transactions per division per year (NumTrans) is significant in the environmental model. The parameter estimate indicates that as the number of transactions per year increases by one, price increases by 9.7%. This is expected to be true because as buyers become more accustomed to using the water market to meet their needs, they will be willing to pay more. NumTrans may be insignificant in the non-environmental market because it has many more transactions regardless of the total quantity demanded each year. The dummy variable indicating a public water transaction was significant for the non-environmental model. The parameter is not the percent change in price in this case; it must be calculated as $e^{\hat{\beta}} - 1$. Public project water is estimated to be 61.1% cheaper than non-public project water.

The new use categories of municipal, development, industrial, and other are significantly different than the excluded category, agriculture, in the non-environmental model. Non-agricultural uses are estimated to have 110%, 255%, 428%, and 60.2%

higher prices than agricultural use, respectively. No new use category is significant in the environmental model. Arizona, Nevada, New Mexico, and Utah have significantly different prices than California in the non-environmental model. Prices are estimated to be 392%, 358%, 1,923%, and 531% more expensive than California. In the environmental model, prices is Arizona, New Mexico, Utah, and Wyoming are estimated to be 10,093%, 50,291%, 4,208%, and 33,041% higher than California. Collinearity may cause unrealistically large coefficients for the state dummy variables because income and population are correlated with state. A majority of transactions occur in Nevada in the environmental model, leading to high correlation with the intercept term.

4.1.2 Leases

Leases may be preferred for environmental purposes when buyers and sellers are unfamiliar with the market or the effects of moving water on the environment or the community (Loomis et al., 2003). Not all states included in the sales models had environmental leases. The majority of environmental lease activity occurred in California but New Mexico also has a large number of transactions. In both states, the Bureau of Reclamation and state agencies are frequent purchasers of environmental water. Environmental leases in California are used for a variety of purposes including salmon migration, waterfowl habitat, riparian areas, and Delta restoration. Most New Mexico purchases related to the Rio Grande and the endangered silvery minnow. Environmental leases are summarized in Table 4.5.

The majority of non-environmental leases also take place in California. Leases are frequently used in California because of the environmental and third-party impacts associated with sales (Howitt and Hanak, 2005). The very large leased quantities are

Table 4.5: Summary Statistics: Environmental Leases

Variable	Mean	Std Dev	Min	Max
lnp07	4.12	0.79	2.08	5.95
Q	21,956	32,076	16	200,000
Temp3	64.82	12.96	36.10	91.50
L3SP06	0.38	1.07	-2.44	2.23
Income	33,420	4,823	23,077	40,868
LandInc	18.90	10.94	8.75	112.23
DivPop	256	197	10	1,605
NumTrans	11.69	7.22	1	28
Yrs	1.80	3.71	1	25
Pub	0.47	0.50	0	1
Mand	0.27	0.45	0	1
Env	0.71	0.46	0	1
Multi	0.02	0.13	0	1
AZ	0.07	0.26	0	1
CA	0.62	0.49	0	1
NM	0.30	0.46	0	1
UT	0.02	0.13	0	1
Split	0.70	0.46	0	1
L3SP24	0.39	0.90	-1.71	1.90
L2Income	33,158	4,840	22,561	40,366

n = 182

transactions for Central Arizona Project water that were sometimes reported as one transaction for all leases. Non-environmental leases are summarized in Table 4.6.

Estimation results for the lease models are presented in Table 4.7. Marginal effects are summarized in Table 4.8. Lease models are estimated using two-stage least squares. The results from the first stage are in Appendix C. The F-statistic value for the first stage of the non-environmental model is 10.31, indicating that the instruments are not weak (Stock and Watson, 2002). The F-statistic value for the

Table 4.6: Summary Statistics: Non-Environmental Leases

Variable	Mean	Std Dev	Min	Max
lnp07	3.97	1.25	1.70	7.16
Q	22,554	91,841	2	1,200,000
Temp3	62.19	11.95	22.30	91.50
L3SP06	-0.34	1.09	-3.09	2.39
Income	34,406	3,851	22,398	40,868
LandInc	16.73	8.23	8.75	58.83
DivPop	585	516	14	1,705
NumTrans	15.24	10.87	1	42
Yrs	1.98	4.49	0	50
Pub	0.43	0.50	0	1
Ag	0.28	0.45	0	1
Muni	0.45	0.50	0	1
Dev	0.01	0.09	0	1
Ind	0.01	0.12	0	1
Noncu	0.04	0.21	0	1
Other	0.21	0.40	0	1
AZ	0.08	0.28	0	1
CA	0.85	0.36	0	1
NM	0.04	0.19	0	1
UT	0.03	0.16	0	1
Split	0.79	0.41	0	1
L3SP24	-0.18	1.11	-2.21	2.79
L2Income	34,441	3,884	22,920	40,366

n = 676

first stage of the environmental model is 5.68, which does not fulfill that criterion. However, the instruments not included in the price estimation are significant, which satisfies the instrument conditions outlined by Wooldridge (2002). The R^2 for the lease models are lower than the sales model. The environmental model has an adjusted R^2 of .319; the non-environmental model has an adjusted R^2 of .453.

Table 4.7: Leases Estimation Results

Variable	Non-Environmental Model	Variable	Environmental Model
Intercept	6.3258***	Intercept	-0.1310
	(0.7149)		(0.9829)
$\hat{Q}$	0.000009*	$\hat{Q}$	0.000004
	(0.000005)		(0.00001)
Temp3	0.0036	Temp3	-0.0079*
	(0.0042)		(0.0047)
L3SP06	-0.1212***	L3SP06	-0.0118
	(0.0439)		(0.0491)
Income	-0.0001***	Income	0.0001***
	(0.00002)		(0.00002)
LandInc	0.0247*	LandInc	0.0155
	(0.0135)		(0.0125)
DivPop	0.0003***	DivPop	0.0003
	(0.0001)		(0.0005)
NumTrans	-0.0116***	NumTrans	0.013
	(0.0043)		(0.0086)
Yrs	0.0021	Yrs	-0.0087
	(0.0119)		(0.0234)
Pub	-1.5761***	Pub	-0.3418***
	(0.0956)		(0.1343)
Muni	0.2366*	Env	0.3859*
	(0.1292)		(0.2077)
Dev	1.0475**	Multi	1.1377**
	(0.4634)		(0.4792)
Ind	-0.8001		
	(0.6541)		
Noncu	0.1516		
	(0.1814)		
Other	-0.4751***		
	(0.1654)		
AZ	-0.7703	AZ	0.6218*
	(0.6631)		(0.3573)
NM	0.0455	NM	0.8236***
	(0.3908)		(0.3192)
UT	-1.3637***	UT	0.2265
	(0.4662)		(0.8328)
	n=676		n=182
	Adj. R^2=.453		Adj. R^2=.319

(Robust Standard Errors)

Significance Levels: *.10 **.05 ***.001

CA is base state, Ag and Mand are base uses.

Table 4.8: Marginal Effects, Leases Results

Variable	Non-Environmental Leases	Environmental Leases
$\hat{Q}$	*0.0009%*	0.0004%
Temp3	0.36%	*-0.79%*
L3SP06	**-12.1%**	-1.2%
Income	**-0.007%**	**0.011%**
LandInc	*2.5%*	1.5%
DivPop	**0.03%**	0.03%
NumTrans	**-1.2%**	1.3%
Yrs	0.21%	-0.87%
Pub	**-79.3%**	**-29.0%**
Muni	*26.7%*	
Dev	*185.1%*	
Ind	-55.1%	
Noncu	16.4%	
Other	**-37.8%**	
Env		*47.1%*
Multi		*211.9%*
AZ	-53.7%	*86.2%*
NM	4.7%	**127.9%**
UT	**-74.4%**	25.4%

Significant at 10%, **Significant at 1%**

The instrumented value for quantity is significant and positive in the non-environmental leases model. The positive relationship between price and quantity is unexpected and opposite of the sales model. As quantity leased increases one acre foot, price increases .0009%. A possible explanation for this relationship is the presence of higher transaction costs for larger transactions. Large transactions may require the buyer to pay more in order to account for possible third-party impacts, increasing the per acre foot cost of water. For example, San Diego County Water Authority paid over $5 million for 20,000 acre feet of water in 2004 to Imperial Irrigation District but the district paid less than $2 million to the landowners who provided the water (Sunding, Mitchell, and Kubota, 2004). Buyers may be willing to pay more on a per acre foot basis for large quantities of water in order to avoid having to negotiate several smaller transactions and incur additional transaction costs. The state approval process, the possibility of opposition to the transfer, and the time required to get transfers negotiated and approved all add to transaction costs. Larger transactions have been shown to have lower per acre foot transaction costs (Colby, 1990b).

Temp3, the mean temperature three months before the transaction was reported, is only significant in the environmental lease model but has an unexpected sign. I would expect increased temperatures to increase the demand for and price of water transacted. The mean temperature from three months before the transaction was reported may be a poor choice for detecting a relationship between temperature and prices. If the actual transaction date was known, a better measure might be constructed. Buyers may also purchase water based on the forecast temperature for the coming months, not the actual temperature at the time they purchase the water.

The Standard Precipitation Index variable, L3SP06, is significant and negative in the non-environmental leases model. As the index increases (indicating wetter conditions) by one standard deviation, price decreases by 12.1%. The precipitation index may not be significant in the environmental model because environmental leases were uncommon until around 1996. Demand for environmental water during this time period may be more closely related to efforts to rehabilitate rivers and habitats in general, not only during drought.

Income is significant in both lease models but negative in the non-environmental model and positive in the environmental model. For the environmental model, the marginal effect of income is .011%; as state per capita income increases $100, environmental water lease prices are predicted to increase 11%. Water for environmental purposes may be viewed as a luxury good, leading to the large positive effect. The marginal effect of income is smaller for the non-environmental market, at -.007%. A negative result may indicate that as the state becomes wealthier, leases are not the preferred means for supplying water. Leases might be viewed as inferior to sales because of their temporary nature.

The ratio of agricultural real estate value to net income per acre is positive and significant in the non-environmental model. A unit increase in the ratio is associated with a 2.5% increase in prices. Development pressure may be the cause of a higher agricultural land to income ratio and may also lead to increased water demand and prices. Climate division population is also positively associated with price in the non-environmental market, with a marginal effect of a .03% price increase per 10,000 person increase in population. The number of transactions per year in each division is negatively associated with price in the non-environmental market. Its marginal effect is a 1.2% decrease in price for every additional transaction. The sign is unexpected and may be picking up a supply effect. As more sellers enter the market, competition may decrease prices. The number of transactions does not have a significant effect on prices in the environmental market.

No effect on price is detected depending on the number of years of a lease. Although longer leases may represent a more sure supply of water, they do not appear to attract higher prices holding other effects constant. The dummy for public water leases is significant in both models. Public water is expected to be less expensive than privately held water, and the marginal effects support this expectation. Prices are predicted to be 79.3% and 29% cheaper for public water than for private water for non-environmental and environmental leases.

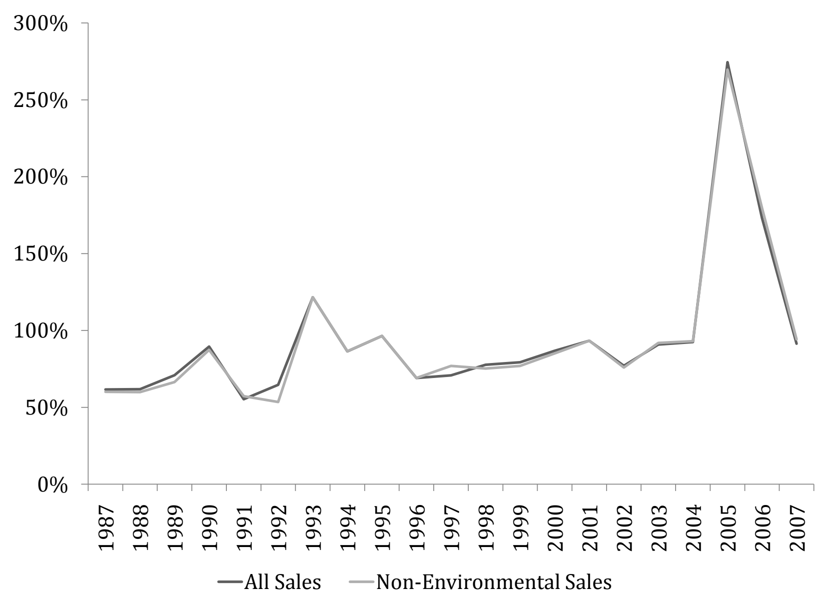
For the non-environmental model, the new uses of municipal, development, and other are significant compared to agriculture. Municipal and development uses are predicted to be 26.7% and 185.1% more expensive. The other use (containing multiple and unknown uses) is predicted to be cheaper by 37.8%. In the environmental model, environmental uses and multiple uses are both predicted to be more expensive than the mandated uses for endangered species or water quality by 47.1% and 211.9%. The multiple uses may be much more expensive because municipal or agricultural uses could be included. General environmental uses were expected to be cheaper than mandated environmental uses. The higher price for general environmental uses may represent an effort by communities or states to protect a resource or species before it becomes listed to avoid legal fees or penalties.

Utah is the only state estimated to have a significantly different price than California in the non-environmental model with a marginal effect of -74.4%. Arizona and New Mexico are estimated to have significantly higher environmental lease prices than California. Their marginal effects are 86.2% and 127.9%. I would expect prices to be higher in California based on observation of average state prices but once the income effect is controlled for, California may not have as high of prices as would be expected given its high income compared to the other states in the model.

4.1.3 Price Dispersion

The water transaction data examined in this thesis spans 21 years and six western states. Prices during that time period appear to be becoming more dispersed. Figures 4.1 and 4.2 illustrate the coefficient of variation (standard deviation of price as a percent of the mean) for sales and leases. In 2005 and 2006, the maximum sale price per acre foot increased dramatically with the sale of water rights for a

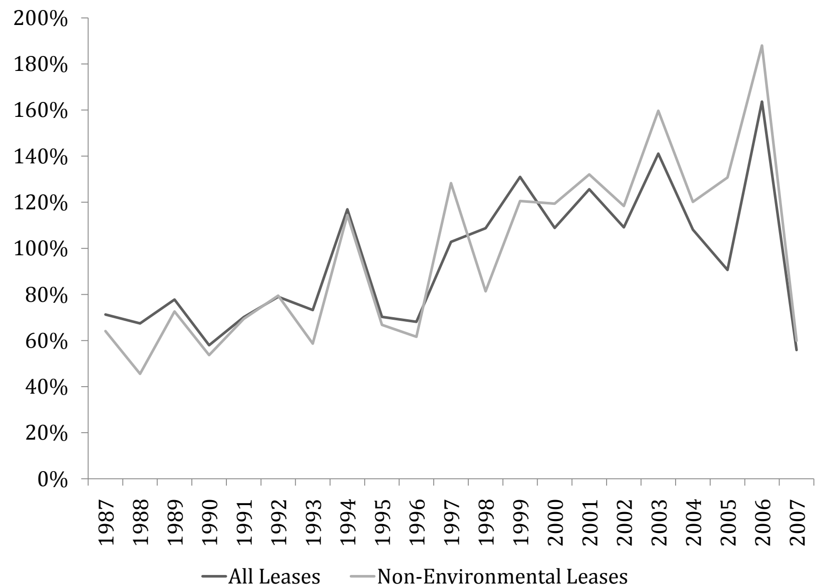
Figure 4.1: Coefficient of Variation: Sales



development in Pebble Beach, CA (Stratecon, Inc., 2005, 2006) leading to a large coefficient of variation. Without these sales, the coefficient of variation for non-environmental sales would have been 124% and 84% in 2005 and 2006 instead of 270% and 180%. The non-environmental transactions are compared to all transactions (including environmental transactions) because there were fewer than two environmental transactions in many years and standard deviations could not be calculated.

Bjornlund (2002) cites a decreasing coefficient of variation as evidence of a maturing market in Australia. The opposite case appears to be true in the six states I examine in the American West. Combined state results presented in Figures 4.1 and 4.2 show a upward trend in coefficient of variation over time. Coefficient of variation results for individual states on three time intervals appear in Appendix D. Most

Figure 4.2: Coefficient of Variation: Leases



states have several missing values because less than two transactions were reported in the one, three, or seven year intervals used. On an annual basis, sale coefficients of variation fluctuate from state to state with few noticable patterns. Some patterns are apparent in annual lease coefficients of variation. In California from 1987 to 1996, the value for all leases hovers mostly between 50 and 80% but from 1997 to 2005 it is generally over 100% and frequently between 110 and 130%. Environmental leases however, have lower coefficients of variation. New Mexico leases tend to have the lowest coefficient of variation most years.

Examining the coefficient of variation on three and seven year intervals reveals some additional patterns. New Mexico sales and leases have a more consistent and lower coefficient of variation in most categories. California often has high coefficients of variation and large changes in the value between time intervals. Arizona and

Utah show no obvious trends, with coefficients of variation alternately increasing and decreasing. From the perspective of price dispersion as measured by coefficient of variation, water markets in Arizona, California, Nevada, New Mexico, Utah, and Wyoming do not appear to be maturing. The New Mexico market is perhaps the most mature by this measure, with its comparatively stable and low coefficients of variation.

CHAPTER 5

Conclusion

5.1 Interpretation of Results

Comparisons of environmental and non-environmental water transactions reveal roughly consistent, if not always statistically significant, results. Environmental and non-environmental sales parameters tend to have similar signs and magnitudes for important variables like quantity, income, and population. The lease model parameters also have similar sings and magnitudes for quantity and population but differ on income. Income has the expected positive effect on water prices except in the non-environmental leases market. Income in the non-environmental leases model shows a negative and smaller effect compared to the sales models.

Most new use results were expected: other, municipal, and development uses are estimated to be more expensive than agricultural use. Multiple uses are estimated to be more expensive than water purchased solely for environmental purposes in the lease model. State results were unexpected for the sales models and the environmental lease model as California prices are predicted to be lower than most other states.

Across the sale and lease models, population is statistically significant only for the non-environmental transactions. Environmental prices may not be affected by population in the division where the transaction takes place but by population up or downstream. For example, if a city upstream of wetlands is growing and increasing its water use, the state may purchase water rights from agriculture nearer to the wetlands to protect it.

The ratio of agricultural land value to net income per acre (LandInc) variable is statistically significant and positive in the non-environmental models as well. Prices in the state are expected to increase as pressure to develop agricultural land increases. The upward trend in sales prices noted by Brown (2006) and Brewer et al. (2007) may be attributable to development pressure in western states.

The climate variables have mixed results. Temperature is either not significant or significant and negative. Higher temperatures were expected to be associated with increased water prices but the effect of temperature on prices may be hard to gauge because extreme values of temperature are not as cumulative or apparent as extreme values in precipitation. Drought, measured by the Standard Precipitation Index, is estimated to have the largest statistically significant effect on prices for non-environmental lease transfers. The lease market is expected to be more sensitive to drought because during a drought growers of perennial crops and certain municipal users with inelastic demands enter the lease market to fill deficiencies in their water supply.

Taken as a whole, the results suggest that if population, income, and agricultural-to-municipal development pressure continue to increase in the western states examined, water prices in lease and sale markets will rise. If climate change reduces or changes precipitation, or if a prolonged drought (like the one observed in the medieval period using tree-ring data (Meko et al., 2007)) occurred, lease prices would likely rise. Additionally, environmental lease prices may surpass those of non-environmental leases in places where income is growing faster than population. A $1,000 increase in per capita income is predicted to increase environmental lease prices by 11% while at the same time reducing non-environmental lease prices by

7%.

The preliminary look into market price dispersion suggests that water markets are becoming less predictable over time. The influence of speculation in prices suggested by Michelsen, Booker, and Person (2000) may be increasing over time as continued drought and the threat of an increasingly dry Southwest hangs over the region (Seager et al., 2007) and suggestions to use water as an investment become more common (Markman, 2005).

5.2 Policy Implications

States in need of more water supply should make arrangements to get the water they need sooner rather than later as prices will likely continue to rise. Regions with more than one growing population center may find prices being bid up by competition among nearby cities. If price fluctuation also continues, waiting to purchase water will become a riskier choice.

Environmental water uses may be in the most danger if climate change or a prolonged drought were to become a reality in the region. As cities and farmers work to increase water use efficiency, less water may be available for the environment. Policy makers and groups interested in protecting the environment may need to predict where increasing water use efficiency will have the greatest impact on environmental resources and try to make arrangements to protect those resources before they become degraded. States with environmental and recreation amenities available during drought could reap significant benefits from tourism.

Dire predictions about climate change and drought continue to be published in major news sources (Barringer, 2008). Although water policies are designed to deter speculation (Michelsen, Booker, and Person, 2000), for example, with requirements that water must be put to beneficial use, states may need to consider what effect speculation has on water prices and how speculation can be handled.

Users may prefer a permanent acquisition of water to a lease but as sale prices continue to rise, leases will probably remain a popular solution to meet short-term water needs. Leases, particularly during wet periods, may provide a low-cost source of water that can be banked for dryer periods. Many western states have already explored banking water (see Clifford, Landry, and Larsen-Hayden (2004) for example). Environmental users may also benefit from banking leased water underground and in reservoirs during wet periods to be called on during drought.

5.3 Future Work

Additional work could be done to investigate what is causing the apparent increasing dispersion in prices over time. The effects of increasing price dispersion could also be examined. Depending on the causes of fluctuating prices, states may be able to explore policies to encourage water pricing that better reflects the value of water. The data used in this thesis may not be well suited to an analysis involving time as an important factor though, because of the ambiguity of transaction dates reported by the *Water Strategist*. Future work could involve improving upon or expanding the water transaction data by incorporating other data sources. Although the transactions reported by the *Water Strategist* are sometimes incomplete, they offer the most comprehensive information available. Unfortunately, changes or additions to the data are difficult. The transactions are not publically available or easily accessible; a subscription is required to access them and they must be transcribed into a usable format.

In the existing models, future work could involve finding additional variables to reduce collinearity. The creation of a temperature index might also be useful for determining if temperature has any statistically significant or important effect on environmental transaction prices and if it actually has the predicted negative effect on non-environmental sales prices. Income and the LandInc ratio were both at the state level; additional information may be gained by using a finer scale for these variables. In models containing many states, a variable the measures the difference in state water policies may be more useful than state dummy variables. Variables that account for the political leanings in the state may also help explain environmental water prices.

APPENDIX A

Water Strategist Entry Examples

The entry below appeared in the January, 1994 issue of the *Water Intelligence Monthly* published by Stratecon, Inc.

NM: Albuquerque Leases 27,101 af of its San Juan-Chama Project Water

Acquirers: a) Middle Rio Grande Conservancy District; b) New Mexico State Interstate Stream Commission; c) Las Campanas residential development; d) 21 domestic and industrial users; and e) 2 wine growers

Supplier: City of Albuquerque

Water: a) 20,000 af; b) up to 5,500 af; c) 800 af; d) 646 af; and e) 155 af of the City's San Juan-Chama Project water entitlement;

Purpose: a) Maintaining minimum stream flow of 250 cfs in Rio Grande during irrigation season; b) preservation of sediment pool in Jemez Canyon Dam; c) residential development and landscape irrigation; d) domestic and industrial use; and e) vine irrigation

Terms: a) na; b) $45,000/year; c), d), and e) $45.49/af (an increase of $2.15/af over 1992) through leases extending until 2010

Status: Complete

During 1993, the City of Albuquerque leased 27,101 af of its annual allotment of 48,200 af from the San Juan-Chama Project. The largest lease was 20,000 af to the Middle Rio Grande Conservancy District to maintain a minimum stream flow of 250 cfs in the Rio Grande during the irrigation season. The second largest lease was for up to 5,500 af to the New Mexico Interstate Stream Commission (an increase of 1,000 af over 1992), under a ten-year lease at $45,000/year that began in 1991, for the preservation of a sediment pool in the Jemez Canyon Dam. Other customers included Las Campanas, a residential development near Santa Fe, 21 different domestic and industrial users who leased 646 af, and two wine growers who leased 155 af. All the latter customers paid $45.49/af (an increase of $2.15/af over 1992 prices).

The San Juan-Chama Project diverts flows into the Rio Grande watershed from tributaries of the San Juan River, which flows into the Colorado River watershed. The water is stored in the Heron Reservoir, which is operated by the Bureau of Reclamation. Lessors pay the per acre foot amount the City is assessed under its Bureau contract plus a five percent charge to pay the city's administrative costs. Users pump the water from wells and the BuRec releases water into the Rio Grande to offset the adverse effects of pumping on river flow. Albuquerque anticipates that it will need its full allotments in the future to offset the effects of pumping, but leases water not currently used. The wine growers will divert water directly from the Elephant Butte Reservoir. (Stratecon, Inc., 1994)

The transaction above was deconstructed into five observations, four of which were used in the final data set. The first transaction described is not included in the final data set because no price is listed. An excerpt of the four observations appearing in the final data set is in Table A.1.

Table A.1: New Mexico Leases Example

Month	01	01	01	01
Year	1994	1994	1994	1994
State	NM	NM	NM	NM
Acq	5	10	1	16
Sup	3	3	3	3
Old Use	16	16	16	16
New Use	5	4	3	16
Q	5,500.00	800.00	646.00	155.00
P	8.18	45.49	45.49	45.49
Tran	1	1	1	1
Split	1	1	1	1
Sale	0	0	0	0
Pub	1	1	1	1

The codes used for acquirer, supplier, old use, and new use are used in every observation to track information provided in the entries. The acquirer (acq) codes of 5, 10, 1, and 16 represent state, development, private parties, and unusual agricultural buyers. The supplier (sup) code, 3, represents a city supplier. The old use, 16, represents unused allotment. The new uses of 5, 4, 3, and 16 represent general environmental, development, domestic, and agricultural. The price is in nominal dollars but is adjusted before being used in estimation. Tran indicates the number of transactions in the observation. Split indicates whether the entry was split into multiple observations. Sale equals one is the transaction was a permanent sale. Pub equals one if the transaction involved public project water.

The entry above included more information than some. An example of a more ambiguous entry from the January, 2004 issue of the *Water Strategist* follows.

Nevada

> **Acquirer:** Truckee Meadows Water Authority
>
> **Suppliers:** Various landowners
>
> **Water:** Purchase of 55 AF of Truckee River water rights
>
> **Purpose:** M&I
>
> **Terms:** $3,252/AF
>
> **Status:** Complete
>
> During the second half of 2003, Truckee Meadows Water Authority purchased 55 AF of Truckee River water rights from various landowners who are no longer using their irrigation rights because the land has been developed. TMWA paid an average of $3,252/AF and will pay any fees associated with converting the water to municipal use. (Stratecon, Inc., 2004)

The transaction above appeared as one observation in the final data set. The acq was a water district and the suppliers were private parties. The old use was agriculture and the new use was municipal. Tran equals two because the entry indicates there was more than one seller but does not indicate how many sellers there were. Split equals zero because the entry lacked enough information to split it into multiple observations.

Table A.2: Nevada Sales Example

Month	01
Year	2004
State	NV
Acq	7
Sup	1
Old Use	2
New Use	3
Q	55.00
P	3,252.00
Tran	2
Split	0
Sale	1
Pub	0

APPENDIX B

Combined Model Results

Table B.1: Combined Sales Model

Variable	Estimate	Standard Error	t Value	Pr > t
Intercept	0.1115	0.5691	0.2	0.8447
Q	-0.00001	0.000003	-2.59	0.0098
Temp6	-0.0070	0.0025	-2.84	0.0047
L6SP12	0.0614	0.0324	1.9	0.0583
Income	0.0002	0.00002	9.74	0.0001
LandInc	0.0014	0.0010	1.39	0.1639
DivPop	0.0010	0.0002	4.96	0.0001
NumTrans	0.0160	0.0053	3.03	0.0026
Pub	-0.8419	0.1329	-6.33	0.0001
Muni	0.7292	0.1613	4.52	0.0001
Dev	1.2789	0.1932	6.62	0.0001
Ind	1.6070	0.4884	3.29	0.0011
Noncu	-0.0750	0.2941	-0.25	0.7989
Other	-0.3077	0.3472	-0.89	0.3759
Env	0.2161	0.2432	0.89	0.3746
Mand	0.9933	0.3303	3.01	0.0027
Multi	0.8593	0.3601	2.39	0.0173
AZ	1.7137	0.1927	8.89	0.0001
NV	1.5711	0.2061	7.62	0.0001
NM	3.1271	0.2616	11.95	0.0001
UT	2.0069	0.2547	7.88	0.0001
WY	1.3684	0.5052	2.71	0.0069
n=657				
Adj. R^2=.622				

Table B.2: Combined Leases Model

Variable	Estimate	Standard Error	t Value	Pr > t
Intercept	5.3094	0.6442	8.24	0.0001
$\hat{Q}$	0.00001	0.000004	2.51	0.0122
Temp3	0.0017	0.0034	0.51	0.6129
L3SP06	-0.0947	0.0362	-2.62	0.0091
Income	-0.00004	0.00002	-2.41	0.0161
LandInc	0.0240	0.0087	2.77	0.0058
DivPop	0.0004	0.0001	3.48	0.0005
NumTrans	-0.0095	0.0044	-2.17	0.0304
Yrs	-1.3438	0.0814	-16.51	0.0001
Pub	-0.0016	0.0097	-0.16	0.8708
Muni	0.2563	0.1163	2.2	0.0278
Dev	1.1558	0.5366	2.15	0.0315
Ind	-0.6765	0.4953	-1.37	0.1724
Noncu	0.3228	0.2095	1.54	0.1238
Other	-0.2118	0.2836	-0.75	0.4555
Env	0.2751	0.2048	1.34	0.1797
Mand	0.3074	0.1282	2.4	0.0167
Multi	-0.2793	0.3071	-0.91	0.3635
AZ	-0.5357	0.4889	-1.1	0.2735
NM	-0.1967	0.2570	-0.77	0.4443
UT	-1.2618	0.3824	-3.3	0.0010
n=858				
Adj. R^2=.385				

APPENDIX C

1st Stage Results

Table C.1: 1st Stage Non-Environmental Leases Results

Variable	Estimate	Standard Error	t Value	Pr > t
Intercept	84612.06	49096.95	1.72	0.085
Split	-31166.92	7639.562	-4.08	0.000
L3SP24	-2393.187	3433.489	-0.7	0.486
L2Income	2.173065	4.435292	0.49	0.624
Temp3	-362.83	301.0833	-1.21	0.229
L3SP06	-130.2819	3306.766	-0.04	0.969
Income	-2.469846	4.600668	-0.54	0.592
LandInc	-2440.296	604.2189	-4.04	0.000
DivPop	21.52661	7.161349	3.01	0.003
NumTrans	40.33461	329.9494	0.12	0.903
Pub	12238.61	6786.728	1.8	0.072
Yrs	782.9301	670.0782	1.17	0.243
Muni	-13442.34	7798.499	-1.72	0.085
Dev	-90258.7	33776.25	-2.67	0.008
Ind	-103133.2	26711.36	-3.86	0.000
Noncu	3012.981	15105.28	0.2	0.842
Other	29892.58	9533.24	3.14	0.002
AZ	164937.6	23103.07	7.14	0.000
NM	21676.13	25845.21	0.84	0.402
UT	42610.03	30873.37	1.38	0.168
n=676				
Adj. R^2=.208				
F = 10.31				

Table C.2: 1st Stage Environmental Leases Results

Variable	Estimate	Standard Error	t Value	Pr > t
Intercept	18415.81	37625.22	0.49	0.625
Split	-9078.388	5051.813	-1.8	0.074
L3SP24	-5983.026	3249.808	-1.84	0.067
L2Income	12.82348	4.418539	2.9	0.004
Temp3	-65.13894	192.5585	-0.34	0.736
l3sp06	2185.84	2687.885	0.81	0.417
Income	-12.53956	4.326878	-2.9	0.004
LandInc	119.8289	341.5922	0.35	0.726
DivPop	53.85457	14.33092	3.76	0.000
NumTrans	-408.1386	337.7249	-1.21	0.229
Pub	-9290.958	4847.464	-1.92	0.057
Yrs	1388.59	591.5773	2.35	0.020
Env	2132.311	6406.007	0.33	0.740
Multi	-25282.18	17321.4	-1.46	0.146
AZ	-12225.21	14649.56	-0.83	0.405
NM	1008.936	12512.48	0.08	0.936
UT	-22831.57	27675.59	-0.82	0.411
n=182				
Adj. R^2=.293				
F = 5.68				

APPENDIX D

Coefficient of Variation Tables

Table D.1: Annual Coefficient of Variation of Sales by State

	Arizona						California						Nevada					
	All		Non-Env		Env		All		Non-Env		Env		All		Non-Env		Env	
	CV	N	CV	N	CV	N	CV	N	CV	N	CV	N	CV	N	CV	N	CV	N
1987	57%	8	57%	8		0	16%	2	16%	2		0	63%	16	57%	15		1
1988	33%	6	37%	5		1		0		0		0	50%	10	39%	9		1
1989		0		0		0		0		0		0	55%	17	42%	15	20%	2
1990	0%	2	0%	2		0	14%	7	14%	7		0	35%	8	9%	7		1
1991		1		1		0		1		1		0	37%	2	37%	2		0
1992		1		0		1	139%	2		0	139%	2		1		1		0
1993	3%	2	3%	2		0	94%	14	94%	14		0	0%	6	0%	6		0
1994	52%	7	52%	7		0		0		0		0		1		1		0
1995	106%	11	106%	11		0	49%	2	49%	2		0	0%	4	0%	4		0
1996	1%	5	1%	5		0		1		1		0		1		1		0
1997	132%	2		1		1	8%	2	8%	2		0	0%	3	0%	3		0
1998	49%	2	49%	2		0		1		1		0	38%	5	5%	4		1
1999	94%	5	80%	3	16%	2	72%	10	72%	10		0	64%	22	48%	17	20%	5
2000	104%	9	104%	9		0	52%	5	52%	5		0	61%	19	57%	18		1
2001	79%	7	79%	7		0	45%	11	48%	10		1	58%	20	57%	19		1
2002	24%	4	24%	4		0	85%	6	97%	5		1	54%	20	54%	20		0
2003	38%	8	38%	8		0	22%	10	22%	10		0	65%	23	63%	21	64%	2
2004	33%	11	33%	11		0	92%	5	92%	5		0	57%	22	56%	21		1
2005	42%	8	42%	8		0	270%	8	270%	8		0	90%	23	84%	21	85%	2
2006	119%	6	119%	6		0	213%	12	213%	12		0	43%	36	32%	26	69%	10
2007	48%	13	48%	13		0	41%	7	41%	7		0	36%	29	33%	26	39%	3

Continued on next page

Table D.2: Annual Coefficient of Variation of Sales by State, continued

	New Mexico						Utah						Wyoming					
	All		Non-Env		Env		All		Non-Env		Env		All		Non-Env		Env	
	CV	N	CV	N	CV	N	CV	N	CV	N	CV	N	CV	N	CV	N	CV	N
1987	26%	13	26%	13		0	92%	8	92%	8		0		0		0		0
1988	32%	7	32%	7		0	29%	5	29%	5		0		1		1		0
1989	52%	5	61%	4		1	57%	4	57%	4		0		0		0		0
1990	34%	4	34%	4		0		1		1		0		0		0		0
1991	19%	5	19%	5		0	40%	4	40%	4		0		1		0		1
1992	56%	10	56%	10		0	65%	3	65%	3		0		0		0		0
1993	42%	6	42%	6		0		1		1		0		1		1		0
1994	66%	9	66%	9		0		1		1		0		0		0		0
1995		0		0		0	5%	2	5%	2		0		0		0		0
1996	10%	5	10%	5		0	48%	5	48%	5		0		0		0		0
1997	80%	2	80%	2		0		1		1		0		0		0		0
1998		0		0		0		0		0		0		0		0		0
1999	91%	2	91%	2		0	117%	6	149%	4	24%	2		0		0		0
2000		1		1		0	31%	2	31%	2		0		0		0		0
2001	0%	2	0%	2		0		1		1		0		0		0		0
2002	9%	2	9%	2		0		1		1		0		0		0		0
2003		1		1		0	79%	2	79%	2		0		1		1		0
2004	135%	2	135%	2		0	79%	4	79%	4		0		0		0		0
2005	0%	2	0%	2		0	15%	2	15%	2		0		0		0		0
2006	30%	4	30%	4		0	73%	2	73%	2		0		0		0		0
2007	113%	3	113%	3		0		1		1		0		0		0		0

Table D.3: Annual Coefficient of Variation of Leases by State

	Arizona						California					
	All		Non-Env		Env		All		Non-Env		Env	
	CV	N	CV	N	CV	N	CV	N	CV	N	CV	N
1987		1		1		0	71%	11	61%	10		1
1988		0		0		0	63%	5	33%	4		1
1989		1		1		0	79%	18	72%	16	41%	2
1990	24%	4	24%	4		0	61%	16	56%	15		1
1991	22%	2	22%	2		0	63%	35	62%	34		1
1992	83%	3	83%	3		0	76%	39	77%	36	80%	3
1993	0%	5	0%	5		0	57%	13	35%	11	0%	2
1994	156%	9	156%	9		0	72%	27	70%	24	43%	3
1995	48%	11	48%	10		1	60%	29	53%	24	28%	5
1996		0		0		0	65%	32	58%	29	68%	3
1997	39%	8	57%	2	2%	6	111%	23	135%	12	30%	11
1998	61%	2		1		1	111%	21	85%	16	108%	5
1999	23%	10	22%	7	22%	3	115%	43	114%	39	17%	4
2000	34%	8	38%	6	2%	2	114%	22	126%	17	55%	5
2001	110%	3	110%	3		0	134%	57	136%	53	86%	4
2002	0%	2	0%	2		0	116%	75	121%	71	45%	4
2003		0		0		0	149%	62	167%	54	47%	8
2004		1		1		0	107%	46	119%	39	58%	7
2005		0		0		0	96%	53	133%	35	45%	18
2006		0		0		0	154%	25	173%	11	38%	14
2007		0		0		0	55%	36	60%	26	46%	10

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Table D.4: Annual Coefficient of Variation of Leases by State, continued

	New Mexico						Utah					
	All		Non-Env		Env		All		Non-Env		Env	
	CV	N	CV	N	CV	N	CV	N	CV	N	CV	N
1987	0%	2	0%	2		0		0		0		0
1988	0%	3		1	0%	2		1		0		1
1989	1%	3	1%	3		0		0		0		0
1990		0		0		0		0		0		0
1991	0%	4	0%	4		0		0		0		0
1992	0%	3		1	0%	2		1		1		0
1993	88%	2		1		1		1		1		0
1994	44%	5	5%	4		1	153%	3	153%	3		0
1995		1		1		0		1		1		0
1996		0		0		0		1		1		0
1997		1		1		0		1		1		0
1998		1		0		1		0		0		0
1999	129%	8		1	0%	7	31%	3	31%	3		0
2000	17%	3	16%	2		1		0		0		0
2001	39%	7		1	4%	6		0		0		0
2002	43%	4		0	43%	4		0		0		0
2003	42%	4		1	47%	3		1		1		0
2004		0		0		0	56%	3	4%	2		1
2005	36%	15		1	32%	14	0%	2	0%	2		0
2006	47%	12		1	48%	11	0%	2	0%	2		0
2007		1		0		1		1		0		1

Table D.5: 3-Year Coefficient of Variation of Sales by State

	Arizona						California						Nevada					
	All		Non-Env		Env		All		Non-Env		Env		All		Non-Env		Env	
	CV	N	CV	N	CV	N	CV	N	CV	N	CV	N	CV	N	CV	N	CV	N
1989	47%	14	49%	13		1	16%	2	16%	2		0	56%	43	47%	39	16%	4
1992	69%	4	60%	3		1	180%	10	141%	8	139%	2	32%	11	16%	10		1
1995	76%	20	76%	20		0	239%	16	239%	16		0	23%	11	23%	11		0
1998	87%	9	69%	8		1	6%	4	6%	4		0	28%	9	12%	8		1
2001	116%	21	86%	19	16%	2	75%	26	74%	25		1	61%	61	54%	54	58%	7
2004	33%	23	33%	23		0	68%	21	70%	20		1	58%	65	57%	62	46%	3
2007	110%	27	110%	27		0	260%	27	260%	27		0	54%	88	49%	73	76%	15

	New Mexico						Utah						Wyoming					
	All		Non-Env		Env		All		Non-Env		Env		All		Non-Env		Env	
	CV	N	CV	N	CV	N	CV	N	CV	N	CV	N	CV	N	CV	N	CV	N
1989	32%	25	32%	24		1	126%	17	126%	17		0		1		1		0
1992	55%	19	55%	19		0	63%	8	63%	8		0		1		0		1
1995	72%	15	72%	15		0	71%	4	71%	4		0		1		1		0
1998	33%	7	33%	7		0	43%	6	43%	6		0		0		0		0
2001	44%	5	44%	5		0	110%	9	131%	7	24%	2		0		0		0
2004	55%	5	55%	5		0	125%	7	125%	7		0		1		1		0
2007	51%	9	51%	9		0	39%	5	39%	5		0		0		0		0

Table D.6: 3-Year Coefficient of Variation of Leases by State

	Arizona						California					
	All		Non-Env		Env		All		Non-Env		Env	
	CV	N	CV	N	CV	N	CV	N	CV	N	CV	N
1989	47%	2	47%	2		0	74%	34	64%	30	69%	4
1992	91%	9	91%	9		0	79%	90	78%	85	91%	5
1995	145%	25	145%	24		1	65%	69	57%	59	55%	10
1998	47%	10	45%	3	3%	7	90%	76	85%	57	108%	19
2001	56%	21	60%	16	18%	5	128%	122	134%	109	77%	13
2004	41%	3	41%	3		0	130%	183	143%	164	49%	19
2007		0		0		0	129%	114	172%	72	42%	42

	New Mexico						Utah					
	All		Non-Env		Env		All		Non-Env		Env	
	CV	N	CV	N	CV	N	CV	N	CV	N	CV	N
1989	3%	8	4%	6	0%	2		1		0		1
1992	1%	7	1%	5	0%	2		1		1		0
1995	54%	8	28%	6	16%	2	180%	5	180%	5		0
1998	108%	2		1		1	34%	2	34%	2		0
2001	75%	18	32%	4	76%	14	31%	3	31%	3		0
2004	39%	8		1	41%	7	130%	4	136%	3		1
2007	45%	28	2%	2	46%	26	45%	5	5%	4		1

Table D.7: 7-Year Coefficient of Variation of Sales by State

	Arizona						California						Nevada					
	All		Non-Env		Env		All		Non-Env		Env		All		Non-Env		Env	
	CV	N	CV	N	CV	N	CV	N	CV	N	CV	N	CV	N	CV	N	CV	N
1993	50%	20	51%	18	50%	2	220%	26	242%	24	139%	2	49%	60	40%	55	20%	5
2000	111%	41	82%	38	25%	3	64%	21	64%	21		0	60%	55	52%	48	26%	7
2007	90%	57	90%	57		0	375%	59	370%	57	34%	2	83%	173	83%	154	90%	19

	New Mexico						Utah						Wyoming					
	All		Non-Env		Env		All		Non-Env		Env		All		Non-Env		Env	
	CV	N	CV	N	CV	N	CV	N	CV	N	CV	N	CV	N	CV	N	CV	N
1993	42%	50	43%	49		1	99%	26	99%	26		0	78%	3	119%	2		1
2000	57%	19	57%	19		0	136%	17	157%	15	24%	2		0		0		0
2007	47%	16	47%	16		0	95%	13	95%	13		0		1		1		0

Table D.8: 7-Year Coefficient of Variation of Leases by State

	Arizona						California					
	All		Non-Env		Env		All		Non-Env		Env	
	CV	N	CV	N	CV	N	CV	N	CV	N	CV	N
1993	77%	16	77%	16		0	75%	137	70%	126	127%	11
2000	130%	48	133%	35	15%	13	95%	197	92%	161	87%	36
2007	72%	6	72%	6		0	133%	354	159%	289	49%	65

	New Mexico						Utah					
	All		Non-Env		Env		All		Non-Env		Env	
	CV	N	CV	N	CV	N	CV	N	CV	N	CV	N
1993	21%	17	6%	12	42%	5	121%	3	2%	2		1
2000	79%	19	23%	9	110%	10	205%	9	205%	9		0
2007	43%	43	5%	4	43%	39	144%	9	163%	7	7%	2

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