# IMPLICATIONS OF CLIMATE VARIABILITY ON WESTERN WATER TRANSACTIONS

by

Jennifer Lindsey Pullen

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## STATEMENT BY AUTHOR

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This thesis has been approved on the date shown below:

________________________________________ ____________________________

Bonnie G. Colby
Professor
Agricultural and Resource Economics

Date

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# DEDICATION

To my husband, Alex, with out you this would not have been possible

To my parents Kenneth and Ponezella Kanipe, my entire life you have supported me in all my endeavors to you I owe everything

Finally to my little boys, Cosmo and Cowboy, who put up with a few less trips to the park

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# Abstract

Water markets in the western United States have emerged as declining water supplies and urban growth have created an increased pressure on existing resources. A two-stage least squares econometric model is estimated to examine the factors that influence water prices in the intermountain west. Results suggest that water prices are strongly influenced by demand factors and the characteristics of the water right. Econometric analysis indicates a significant relationship between the price of a water right and the quantity transferred, the year the transaction occurred, the percent change in population of an area, the new use of the water right, whether the transaction occurred during a drought year, and the location that the transaction occurred. The importance of climate variability in the intermountain west is suggested by the significance of the drought index. Increased water market activity will likely be a dominant strategy used to alleviate increased demand on water supplies.

# Chapter 1: Water Transactions and Research Objectives

## *1.1 Introduction*

Water markets have slowly evolved in response to pressures to change the historic distribution of water rights and usage patterns in the western United States. Water markets have flourished in regions where water resources are fully allocated and new water development is costly. Well functioning water markets encourage the transfer of water rights to satisfy demand for additional supplies.

During the past decade population growth has occurred at an astounding rate in the western United States. Increased population, combined with commonly occurring drought conditions, has contributed to an increased pressure on the already limited water supply. During the last decade, many agricultural water rights have been retired and transferred to municipal uses. Water markets across the western United States have slowly emerged in response to pressures to move water to new uses.

This purpose of this research is to develop an econometric model of water prices in the intermountain region of the western United States. Several models are explored for five states: Arizona, Colorado, New Mexico, Nevada, and Utah. This research explores the factors that affect market prices for water in Arizona, Colorado, New Mexico, Nevada, and Utah. Several factors influence the development of water markets. These factors include the legal and institutional distinctiveness of the region, the ease of market entry, the number of buyers and sellers, and the market structure. One major similarity seen throughout each of the five states examined is the occurrence of prolonged drought conditions. Each state's water markets have developed at their own rate depending on these factors.

There are several similarities among these five states. For example they all rely on Colorado River water though each state is unique in their own rights to Colorado River water. Each state's reliance upon Colorado River water differs. Some states such as Colorado have a greater surface water supply than other states such as Arizona. Each state is also entitled to a different allotment of Colorado River water, Arizona receives 2.8 million acre feet of Colorado River water a year while Nevada receives just 300,000 acre feet annually (Colorado River Water Users). Each state also has their own set of legal and sociological views on how water rights and water markets should be managed.

Water rights and contractual access to public project water are purchased for a variety of reasons throughout the western United States; for domestic use, as a production input in mining, as an input in agricultural crop production and livestock watering, for environmental purposes, and as an input in recreational activities. Several applications of water rights are common across the western United States these include: environmental restoration, urban growth, budgeting for acquisitions, and planning for drought year reliability. Both purchases and leases occur in the western United States. Leases can occur as annual or multi-year and as dry-year and split season options. This research examines the purchases of water rights, as it focuses on the effect of drought and other factors on long term investments in water rights.

Laws and policies that allow water rights to be traded facilitate regular transactions which generate a market price for water that can reflect its economic value. Well functioning water markets can provide an economic incentive for water users to allocate water based on the marginal value of its use. For example, municipal water generally has a higher marginal value than agricultural water. This has created an incentive for agricultural users to lease or sell their surplus water to municipal users. The first account of agriculture water being purchased for municipal use occurred in the Owens Valley in the early 1990's. Owens Valley water transfers encountered several transactions cost problems and is often used as an example for opposing the development of water rights. However, Libecap (2005) suggests that the farmers in Owens Valley Great Basin agricultural area were made greatly better off with the transactions than they would have been without.

Several of the states are discussed in detail in specific subsequent chapters. Due to insufficient transaction data for Utah and Nevada, only preliminary models are developed for these states and their results are reported in the appendix. An econometric model is presented that combines the purchases from each state. The legal and political aspects of surface water and groundwater are discussed for Arizona, New Mexico and Colorado as these significantly affect the development and expansion of water markets. These factors can influence the time it takes for water rights to change hands, the ease with which individuals may purchase water rights, and the ability for water rights to be transferred to other uses. All these factors contribute to each state's progression of water market activity.

Drought has been a persistent issue across the western United States throughout history. Prolonged drought conditions cause many problems to arise, given that much of the western United States is subject to an already over-allocated water supply. During periods of drought, surface water resources are often depleted causing dry stream beds, along with falling reservoir and lake levels. Some rivers are seriously depleted during summer periods to irrigate low value field crops even though economic analyses often show that keeping the water instream for hydropower, fisheries, recreation and higher value agriculture downstream is more economically efficient (Watts *et al.* 2001). Water markets may help to alleviate the stress placed on water supplies by these prolonged drought conditions.

Little research has provided econometric analysis of water markets in the western United States and very few research projects have provided insight into how drought influences the market price of water. Brookshire *et al.* (2004) is the only publication to date that examines how drought may influence water market prices. This research adds to an exceedingly thin amount of prior research. Several publications related to the econometric analysis of water markets are discussed in the succeeding chapter.

The western United States has been increasing in population at a rapid rate and this has amplified the demand for urban water. There are very few options for increasing the supply of water, so other ways to meet demand must be established. Voluntary water transfers are a logical way to move water from low value to high value uses. This research explores the market forces that determine the price of water rights throughout the western United States.

# Chapter 2: Literature Review

This chapter reviews published literature related to the econometric analysis of water market transactions and prices. Throughout the world, water markets exist in arid regions and several publications examine transactions and prices in these markets. An abundance of literature is available on the structure and functioning of water markets. However, very little empirical literature has been published on prices and transaction characteristics. This section highlights what econometric work has been previously published on prices in water markets across the western United States. The literature is reviewed in chronological order of publications, giving a summary of how this relatively specialized field has evolved over time.

Water marketing is generally referred to as an exchange of water rights or other entitlements to use water, such as water project contracts, by willing buyers and sellers. If water rights are considered private property, as they are in the western United States, then potential market activity exists to exchange these rights for money or other property. Often water rights are considered property separate of the land they were originally used on. Nearly all water rights originated for agricultural purposes.

It has long been argued that water markets provide a possible avenue in which water resources may be more efficiently allocated and used. Theory suggests that markets provide an economic incentive to allocate water according to it value of use. For example this incentive may alleviate wasteful application of irrigation water as farmers may be made better off by conserving and selling unused water rights.

Certain institutional factors must be in place in order for water markets to function. Kemper and Simpson (1999) discuss some of the key institutional arrangements in the water market of the Northern Colorado Conservancy District these institutional factors are outlined below. The Northern Colorado Conservancy District is a well functioning institution that provides insight into the necessary institutional arrangements needed to support a water market. The most important factor is the need for clearly defined property rights that are detached from the land and easily sold or leased. All individuals involved in the buying and selling process must have easy access to information. It is also important to have administrative framework in place to facilitate the market transactions and to provide security, enforcement and access to low-cost information. Several other elements contribute to the functionality of water markets that are difficult to measure such as customs and informal norms in particular regions, and the rate at which the water market is developing. Kemper and Simpson indicate that these institutional factors must be in place before water markets can function effectively.

## *2.1 Previous Research Modeling Market Prices for Water*

Crouter (1987) provides a quantitative basis for assessing the efficiency of regional water markets. Crouter examines the questions of separability and competitiveness by empirically estimating a hedonic price function for farm real estate. This function relates a parcel’s selling price to its attributes; quantities of land and water, value of improvements, and location.

Crouter examined the extent that the water market located in the portion of Weld County, Colorado that is served by the Northern Colorado Water Conservancy District (NCWCD) is efficient (separate and competitive). If water rights associated with a certain parcel of farm real estate could be sold separately from the land in a perfectly competitive market, the allocation of water would be efficient. The hedonic price model was applied to data collected from the Weld County Recorder's and Assessor's offices for 1970. The model examines the price of a parcel of farm real estate as a function of the distance from the nearest town greater than 1,000, the actual value of improvements, water, land, and an index soil quality.

Results indicated that the hedonic price function for the data of the NCWCD area of Weld County is not both additively separable in land and water and linear in water. The author suggests that the water rights market of the sample area in 1970 was not efficient in the sense of being separate from the land market and competitive. The nonseparability of the function suggests the water market functioning in the NCWCD area had not developed to the point where it was distinct from the land market.

Colby *et al.* (1993) analyze market data for the Gila-San Francisco Basin in New Mexico to demonstrate how water prices are determined. Their research applies a hedonic approach to analyze the contribution of water right attributes to market prices. The Gila-San Francisco Basin is representative of many areas throughout the western United States. This basin has been closed to additional groundwater appropriations since the mid-1960s and water rights in this basin were adjudicated in the 1960s in *Arizona v.*

*California.* The court decision and the closing of the groundwater basin create fixed water supplies in the basin.

Their econometric analysis is based on data from 95 water market transactions which occurred during the period of 1971 – 1987. Several independent variables were included in their model. These include: priority date, the geographic location (Gila or San Francisco Basin), if the water transaction was high-profile meaning was it well-publicized and politically sensitive, the quantity transferred, and the year the transaction occurred. In their model they hypothesize the unit price of a water right to be positively related to priority date, geographic location, time, and the participation of a high-profile buyer. The unit price is expected to be negatively related to the size of the transaction.

Their results indicate reasonable explanatory power with all independent variables statistically significant. The significance of the priority date variable indicates that in the Gila-San Francisco Basin, senior water rights are valued higher than junior water rights. The Gila Sub-basin displays significantly higher prices than the San Francisco Sub-basin. The authors suggest this can be attributed to increased growth pressure in the Gila Sub-basin where Silver City and mining companies are actively acquiring water rights. The significant coefficient on the quantity variable suggests economies of scale in the Gila-San Francisco Basin. The authors' final results suggest that prices of water rights have risen over time in the Gila-San Francisco Basin.

The authors conclude that market prices are strongly influenced by specific water right and transaction characteristics. Their results indicated a significant relationship between market prices and water right priority dates, size of the transaction, buyer characteristics, and geographic area. They believe this methodology can be applied elsewhere for valuing public water supplies that are being reallocated among irrigators, cities, and wetlands, between tribes and non-Indian water right holders. They suggest that water right attributes and transaction characteristics need to be systematically accounted for when estimating the market value of water supplies and evaluating the impact of water reallocation.

Faux and Perry (1999) demonstrate application of hedonic price analysis to sales of irrigated land in Treasure Valley, Oregon. They estimate the value of water in irrigation, as well as the value of other attributes connected to the land. In the Treasure Valley area, water use is primarily for irrigation but pressures have been mounting to allocate more of the water supply to aid salmon migration and survival. The hedonic analysis of irrigated farm property sales can reveal the implicit price of irrigation water. The sale price of irrigated farm property can be disaggregated using hedonic analysis to reveal the implicit price paid for the water component of the transaction.

Their study included all sales of agricultural property in Treasure Valley during the years 1991 through 1995. The hedonic model estimated price per acre as a function of the land class (I – VII), the Land Class is identified on its capability to support crop growth, the distance to town (Ontario), the month of the sale, the number of residences permitted divided by total acres, and the assessed value of buildings divided by total acres. Due to previous findings of nonseparability between land and water, the contributions to asset price from the land resource and from the water resource were represented as interaction terms. This means that Class I acreage represents the interaction of Class I soil and the irrigation water applied to that soil. In this study area irrigation supply comes from different sources so the authors disaggregated the variables for Land Classes to reflect the five different sources of water. So, instead of a single variable for Class III there are five variables, one corresponding to each source of water supply. This means that distinct variables tie the water source with the Land Class. For example, Land Class III is associated with five different water sources: Old Owyhee, Owyhee Hiline, Vale, Warm Springs, and other sources. There means that there are five variables linked to Land Class III: IIIoldowyhee, IIIowyhee, IIIhiline, IIIvale, IIIwarmsprings, and IIIothersources.

The authors found that the source of irrigation water did not prove to be a significant cause of difference in land values, so the land variables were aggregated across water source. Their model explained 92% of the variation in price per acre. The results indicate that the value of a non-conforming use permit for a residence on agriculturally-zoned land in Treasure Valley was estimated to be $6,200. The coefficient on the assessed value of buildings indicated that the market value was 17% greater than the assessed value. The time appreciation variable was estimated at $3.77 per acre per month. This is equivalent to an annual rate of 3.2% at the median farm price. The linear and reciprocal variables for distance to town center were significant. This result indicates that land values drop off rapidly in a nonlinear fashion as distance to town center grows, until at five miles distance the rate of decline in land value evens out to an approximate linear rate of about $6 per acre less for each additional mile to town center. The final result shows that the price of land is strongly influenced by the capability of the soil to grow crops.

The results also provide the value of irrigation water by subtracting the value of dryland acreage from the five irrigated land classes. The value of irrigation water ranged from $514 per acre of Class V land to $2551 per acre of Class I land. The marginal value of irrigation water in Treasure Valley was found to be $9 per acre-foot. The authors conclude that the value of irrigation supply in Treasure Valley was shown to be consistent, irrespective of the differing water rights and water storage facilities of the district providing water. Observed differences in sales prices between the districts were instead attributed to differences in quality of soils found in the districts.

Michelsen *et al*. (2000) investigate the determinants of variation and trends in the pricing of water rights, and role that expectations have. They use information developed from an analysis of 2698 water right transactions over a 30-year period from an established water market in Colorado. They construct a two-equation model of current water right prices and expectations in prices. The included variables for agricultural production value and returns, municipal demand and regional economic activity, investment costs, water market shares and changes in water supply in their model.

The authors hypothesize that water rights are valued as real property. Therefore, the demand for water rights may change due to factors affecting the cost of obtaining them, or the value they carry over time. Anticipated change in demand, supply and other factors may influence the price of a water right. Expectations about future population growth, economic growth, inflation and interest rates, regional water supply or changes in institutions may affect willingness to pay for water. The authors believe that these expectational forces may cause shifts in both the market demand and supply of water rights.

The authors used a rational expecations (RE) model to incorporate market participants' anticipations as well as traditional demand and supply variables. A two-equation RE model was developed to explain price variation in the Colorado Big Thompson (CBT) water market over 33 years. This model incorporates historical information in the form of a linear distributed lag structure with future-value expectations to account for speculative pressures. The price-expectation equation is intended to capture the effects of long-term market and financial conditions. The Colorado Big Thompson market is particularly attractive for testing the hypothesis that expectations are an important determinant of water prices because this market has experienced rapid regional population growth and has few limitations on use within the area.

The model examined included the expected price, as a linearly lagged function of past prices, as a function of current regional economic activity, housing starts, the farm debt-asset ratio, and the inflation rate and nominal interest rate. The actual price equation estimates price as a function of the CBT price expectation, the lagged price history, and proxies for the use value of a unit of CBT water.

The results for the price expectation model indicate that regional economic activity is a significant determinant for water right prices. The number of local housing starts is suggested to have a positive influence on CBT price variation. The authors found that a low real cost of money in the late 1970s may have contributed to an increased pressure on the demand for perpetual water rights. The results suggest that new water-supply projects may cause a substantial decrease in the value of existing water rights. The results for the current-price equation indicate that an expected CBT price increase in the following year is likely to increase the current price. The authors believe that this stresses the importance of expectations in price determination.

The authors conclude that the econometric model developed for the CBT market successfully explains the variation in historical prices and trends with an r-squared of approximately 94%. The results were consistent with previous findings values in use (production) fail to explain the level and variation in prices. The authors believe that the study findings support the hypothesis that water rights are being used as investment assets. The results indicate that factors influencing speculative expectations (such as local economic growth and population, interest rates and expectations of future prices) are all statistically significant in explaining CBT water right prices.

Weinberg (2002) examines the economic impacts of policy alternatives for addressing allocation inefficiency among agriculture, urban and environmental uses of federal water. The Central Valley Project Improvement Act (CVPIA) forms the context for this analysis. The CVPIA provisions include economic incentives and an environmental water allocation, a “command and control” policy. Weinberg examines conceptually and empirically economic changes arising from the complex package of policy reforms in the CVPIA. An optimization model composed of benefit functions for water use in agricultural and urban sectors is developed for the empirical analysis. Estimated multi-output agricultural revenue functions and urban water demand functions are incorporated into a nonlinear programming model to predict changes in water use, returns to agriculture, and urban consumer surplus.

The author concludes that water markets, tiered water prices, and environmental surcharges are all policies that can motivate water conservation and improve allocation efficiency of scarce water resources but that these policies will only be effective when prices rise above shadow values for this quantity constrained resource. Empirical results suggest that the net annual cost of the CVPIA will be relatively small: the farmers' net revenues are predicted to decline by approximately 6% of average net revenues, urban consumer surplus increases by nearly $20 million, and the environment presumably will benefit from additional water supplies and expenditures from a fish and wildlife restoration fund of $44 million. Finally, results indicate that analysis that does not explicitly model policy instruments implemented at sub-optimal levels and, as part of a package of reforms, could over or under estimate the costs, benefits, and effectiveness of each policy instrument.

Loomis *et al.* (2003) examine the market evidence for environmental values of water in the western United States. This paper explores water transactions acquired for instream flows and how they influence water market prices. The authors use a quasi-hedonic non-linear logarithmic equation to estimate their model. Their main source of data on environmental transactions was the *Water Strategist.* They analyze transactions that occurred between 1995 and 1999.

Their model explains price per acre-foot of water as a function of several different independent variables. The independent variables in their model include the new purpose for the water transaction (such as recreation, endangered species and wetland restoration), the average precipitation at the location of the transaction, the type of purchaser and seller, and whether the transaction was a lease or purchase.

Their model has good explanatory power with an R-Square of 0.61. Almost all of their independent variables were statistically significant and have signs that fit hypotheses related to variation in price per acre foot of a water right. The variable “purchaser” was significant and indicates that when the government is the purchaser of a water right the price is less per acre-foot than when a private entity purchases it. The second variable included in their model, “seller”, was also statistically significant. This result indicates that when a government agency is the seller the value of a water right per acre-foot decreases. The results also indicate that when the precipitation of the area increases, the value of the water per acre-foot decreases. Their results suggests that if water is being purchased for recreational purposes, threatened and endangered species, or to benefit a wetland the value per acre-foot is greater than if the water was being purchased for other uses. They included a variable to estimate the difference in price between a purchase and lease it was significant which implies that the value per acre-foot will increase when the transaction is a purchase instead of a lease. Their models also examine whether the price per acre-foot increases or decreases as the amount of water transferred in a transaction increases. This estimate was found to be insignificant, which offsets a general hypothesis regarding economies of scale.

The authors conclude that water transactions for environmental purposes are occurring more frequently and involve large monetary values. They suggest that water markets for environmental purposes will help facilitate the reallocation of water from older, lower valued uses to new, higher valued uses of water. The authors believe that as water markets evolve and the values are revealed through market transactions, those values will further demonstrate that environmental uses of water are valuable to society and should be recognized as beneficial uses, on an equal basis with traditional uses of water.

Brookshire *et al.* (2004) examine water market prices in three major markets located in the semiarid states of Arizona, Colorado, and New Mexico. These three markets include the Central Arizona Project (CAP) which is located in the Lower Colorado Basin in Arizona, the Colorado Big Thompson (CBT) market located in the Upper Colorado Basin, and the Middle Rio Grande Conservancy District (MRGCD) market located in the Rio Grande basin of New Mexico. They chose these three particular markets due to the sufficient data available and a relative long history of market transactions compared to other western regional markets. The three water markets studied emerged from U.S. Bureau of Reclamation (BOR) projects. This ensures the existence of physical infrastructure that is necessary for water markets to progress.

Their study explains water right price variation by examining many characteristics of the markets, including both demand and supply factors. They relied upon water transaction data published in the *Water Strategist* from 1990 to 2001. They also collected yearly population and income data from the U.S. Bureau of Economic Analysis, and monthly mean temperature and Palmer Drought Severity Index values from the National Oceanic and Atmospheric Administration (NOAA). The data they collected provided

490 observations in the CBT market, 55 water transfers in Arizona’s CAP market, and 94 observations for New Mexico’s MRGCD market. They pooled all available observations and created a dummy variable for each market. Several explanatory variables were included in their model. They include the type of buyer, annual change in basin population each year, yearly per capita income, the Palmer Index (a measure of drought conditions), and the value of agricultural output and value of agricultural land.

A (double-log) reduced form simple market model was used to estimate their model. The equations defined the quantity supplied and quantity demanded, as a function of price, and other factors. A system of structural supply and demand equations were estimated but only the demand equation is identified. They used a two-stage least squares method to estimate the quantity demand equation while instrumenting for the endogenous price.

Their estimated price equation had good explanatory power and most of their independent variables are statistically significant. Colorado and New Mexico’s markets both have higher prices when compared to Arizona’s CAP market. This reflects the different stages of market maturity and Colorado’s higher prices signify a more efficient market. The buyer-type estimates indicate that agricultural and municipal buyers pay the same price for water but government buyers pay a lower price. They suggest that this may reflect the monopsony power of the government sector. The significance of the Palmer Index revels that water prices are lower in wetter periods. Their results also indicate that population growth is not significant in determining water demand but per capita income had a positive and significant coefficient, this suggests that demand for water comes from a wealthier population.

Their second stage equation explains the quantity traded. The negative coefficient on price is statistically significant and the size of the estimate indicates that demand for water rights is relatively elastic. Their results indicate that higher-valued agricultural production is associated with lower quantities of water being traded, and that higher land prices reflect the opportunity cost of holding and maintaining agricultural land through the value of the water rights associated with the land.

This research indicates substantial variation in the water rights market activity and price levels across basins and over time. They suggest this may be explained by the differences in institutional arrangements in each market. Their results suggest that water rights markets are active, and through prices, provide both suppliers and buyers the marginal value of water in its higher-valued uses. They conclude that it is reasonable to predict that as the value of water in nonagricultural uses increases, water will move toward domestic uses.

Water markets first emerged in Australia during the mid 1980s but during this time little market activity occurred. It was not until the last half of the 1990s that water market activity increased and water transfers became a normal occurrence in the agriculture sector. Bjornlund and Rossini (2005a) explore the prices paid for water rights in order to establish evidence of rational behavior in water markets. The authors suggest that in an efficient and competitive market the price of allocations and entitlements should reflect the general level of interest in the economy given a similar level of risk.

The prices in the two markets should therefore follow each other, with prices of allocations driving the price of entitlements so they explore prices paid in the Goulburn Murray Irrigation District in Northern Victoria over the ten-year period 1993 to 2002 to look more closely at this relationship.

This relationship is considered in three different ways: 1. calculation and comparison of the earnings to investment ratio at the time of buying water; 2. comparing and analyzing the cycle factors for the price of allocations and entitlements produced by the ratio to moving average method; and 3. by estimating the internal rate of return which could have been obtained by investing in water, selling the allocations yielded by the entitlement over a holding period, and the selling of the entitlement again at the end of the holding period.

The earning to investment ratio was computed by dividing the mean monthly prices paid for allocations, less the cost of water supply, by the mean monthly prices paid for entitlements. The authors suggest that this ratio should indicate the kind of return that investors in entitlements could expect to receive if they reacted to short-term price signals. The authors observe that the earnings to investment ratio for water fluctuates widely due to the variation in the price of seasonal water and that towards the end of the irrigation season the price of allocations trend very low. Bjornlund and Rossini using the classical decomposition technique computed cycle factors for both the price of allocations and entitlements. These cycle factors should show the price variation that is not explained by trend or seasonality. The authors conclude that the two cycles move together which suggests a close relationship between the movement in allocation and entitlement prices and that irrigators make financially sound decisions in the two markets.

Finally Bjornlund and Rossini treated water as an investment opportunity. Their findings suggest that returns on investments in water entitlements during the first ten years of market operations have been in excess of the return that could have been obtained by investing in other assets.

Bjornlund and Rossini conclude that when comparing the relationship between prices paid for allocations and entitlements, the price of entitlements clearly reflects the price of allocations as rational market behavior would suggest. The results indicate that the price of allocations fluctuates at about twice the rate of the price of entitlements. This suggests that the price of allocations react to short-term changes such as allocation level, evaporation and rainfall while the price of entitlements reacts to long-term trends.

Bjorlund and Rossini (2005b) analyze prices paid and volumes traded in water allocation in order to identify factors driving market activities. To quantify the determinants of prices and volumes of water traded, they collected data for two dependent variables. For prices, mean water prices were collected on a monthly basis from the Goulburn Murray Irrigation District in Victoria, Australia, from July 1993 to June 2003. For volumes traded, Goulburn Murray Water provided volumes traded on a monthly basis beginning in July of 1996.

Monthly data was collected for several explanatory variables they included: 1) water allocation, 2) precipitation, 3) evaporation, 4) commodity prices for: lamb, mutton, wool, cattle, wheat, feeding, barley, butter, milk powder, cheese, Cabernet sauvignon and

Chardonnay grapes, 5) interest rates, 6) exchange rates (US$), 7) trade weighted index, 8) inflation indexes, 9) index of rural commodity prices and 10) Gross Domestic Product (GDP) for the farm and non-farm sectors. Three different techniques were applied to the data: 1) correlation analyses; 2) regression analyses; and 3) classical decomposition. Correlation and regression analyses use prices adjusted for inflation while time series analyses use real prices.

Correlation analysis measures the strength of the association between two variables such as the price paid and the level of seasonal allocation without considering the implications of any other variables. The authors also applied regression analyses to water prices in order to determine which of the price determinants had a significant impact on price in the presence of other variables. Both correlation and regression analysis were applied to price and quantity as the dependent variables in separate models.

In the correlation analysis, prices were found to be significantly correlated with the activity in the market in terms of the number of transfers and the volume traded. The authors found that in response to higher prices irrigator buy less water more frequently to accommodate their cash flow and in the anticipation of rain or an increase in allocation. The authors also found a significant relationship between prices paid in the markets for temporary and permanent water. The regression analysis explained 52% of the variation in water prices.

In the correlation and regression analysis the authors found that the allocation level is an important determinant of price. With higher allocation levels irrigators do no need to buy water. The importance of climatic conditions is reflected in both analyses.

The results indicate that the higher the level of rainfall, the lower the price, and the higher the level of evaporation, the higher the price. Analyses also indicated a number of significant relationships between the price of water and commodity prices. Higher commodity prices for lamb, mutton and wool resulted in higher water prices. Coefficients for wheat and cattle were negative suggesting that water prices increase as these commodity prices decrease. All dairy products were statistically significant with negative signs. The authors conclude that this result suggests that the willingness of dairy farmers to pay increases as their commodity prices decrease.

Several macro-economic indicators were examined for water prices. The authors found that price has a significant negative correlation with interest rates and the exchange rate between Australia and the Untied States. As the interest rates increase, farmers' willingness to pay for water decreases. Results also indicate that the correlation with the CPI inflation index in significantly positive. This indicates that the increase in water prices has been well above inflation since the prices used for the analysis had already been adjusted for inflation.

The authors also applied basic time series analyses to nominal real-time prices to investigate the results found in the correlation and regression analysis further and to examine the trend, seasonality and cycle of water prices. The authors use a regression model in an exponential form using a time index and seasonal dummy variables to estimate seasonal indices and a compounding growth rate (trend). They also apply a ratio to moving average approach to estimate seasonal indices through the ratio of observed values to a 12-period centred moving average. This 12-period centred moving average is then used to estimate the trend via a simple time index regression in exponential form.

Both time series analyses indicate that seasonal indices from May, June, and July are significant. The seasonal fluctuations are related to the seasonal effects of rain and evaporation. Only from May through July when rainfall is reasonably high and trading is limited is there a statistically significant seasonal effect. The authors suggest that this supports the results from the hedonic model that prices are a function of actual rainfall and not ‘expected’ rainfall. The authors also found that there has been an underlying trend in growth of temporary water prices. This growth has been experience over the entire period of data but a significant proportion of the growth occurred when scarcity was most severe. The authors expect that growth will closely follow the growth of the overall economy.

Bjorlund and Rossini also analyzed volume traded in the temporary water market. Correlation analysis show a significant negative relationship with rainfall: the more it rains the less water is traded. Evaporation had a positive correlation with volumes traded indicating that evaporation has an effect on demand for water. The price of water had an impact on volume trade but did not have a negative estimate as anticipated. The results indicate a strong correlation between the three seasonal variables and volume traded. The regression analysis had an adjusted r-squared of 0.6404. The results from the regression analysis confirm the findings in the correlation analysis. The model suggests that the volume traded is directly impacted by evaporation, rainfall, and price.

Similar time series techniques were applied to quantity as discussed for prices. Given the strong relationship between seasonal variables and volume traded identified in the regression and correlation analyses the authors expect that volume traded should show a stronger seasonal variation than prices did.  The results indicate that 79% of the variation in volume traded can be explained by seasonal variation.  All monthly coefficients except April are significant.  The results suggest that volume traded over the spring and autumn months are larger than during the summer months the authors conclude that this reflects the high level of variability in rainfall during spring and autumn.

The authors conclude by suggesting that the results have significant policy implications.  Their findings show that irrigators have an increasing need to use water markets to manage highly variable and diminishing water supplies.  The authors suggest that periods of scarcity are going to be more frequent as markets activate previously unused water entitlements and as the climate changes, becoming hotter and dryer.  The authors believe that the findings serve as a strong indicator that governments need to address the issues of unused entitlements and instream flows before introduction water markets.  The authors suggest that more sophisticated market processes and instruments need to be developed to ensure that redistribution of entitlements and seasonal allocations can take place quickly and at low transaction costs.  Water users also need to know how to resolve and deal with scarcity during periods of normal supply so they may make rational decisions in times of shortage.

## 2.2 Conclusion

Water markets exist at some level throughout the world. To date little empirical analysis has been conducted on prices and transactions of these markets. The limited research that has been performed was discussed in the preceding paragraphs. Only Brookshire *et al.* and Bjornlund and Rossni to this point have explored the relationship between drought and water market prices. This thesis expands on previous work from Brookshire *et al.* on how drought and population growth have influenced water market price. Extended drought coupled with rapid population growth in the west will continue to exert pressure on our water supplies. As a result, water rights may need to be reallocated to support domestic needs. An analysis of how water markets behave during drought will be explored in the following sections.

# Chapter 3: Analytical Methods

## *3.1 Motivation*

The derived demand models presented are motivated by Palmquist (1989). The models analyze water price data from 1987 to 2004 to better understand the factors that determine water prices in the intermountain region of the western United States. Water rights are comprised of a number of characteristics that vary among each right. These characteristics include traits that cannot be changed by the owner of the water right and traits that can be changed in response to market information. The price for which each water right sells for depends on the characteristics associated with that particular water right, along with regional factors related to the derived demand for water.

In an active market, an individual who purchases a water right is unable to influence the equilibrium price. The price the buyer pays depends on the characteristics of the water right they select, as well as on regional water demand factors. Similarly, a single seller cannot influence the equilibrium price. The equilibrium price for a specific bundle of characteristics is determined by the interaction of all buyers and sellers of water rights in a particular market.

On the demand side, are the individuals who wish to obtain water rights for use as an input for agricultural crop production, mining, environmental enrichment, recreation, or domestic uses. Individuals using water rights as an input in production seek to maximize profits and their offer price for a particular water right will depend on its characteristics, prices of outputs and other inputs, the desired profit level, and the producers' skill level (as in the case of farmers and miners).

The market equilibrium price will adjust to eliminate excess demand or supply for water rights. In select regions throughout the intermountain study area, the amount of water that can be consumptively used in a given year is fixed by court decree. For example the amount of water that can be consumptively used in the Gila-San Francisco water market, located in southwestern New Mexico, is fixed by the 1964 court decree in *Arizona v. California*. Since price and quantity are likely to be determined simultaneously in markets, a two stage least squares derived demand model is estimated using instrumental variables for quantity in the price equation.

Water market regions are very specialized in the western United States due to hydrological, legal, and financial restrictions on water transfers. The models presented here estimate the relative importance of various factors on the market price of water rights in these regions. This research particularly focuses on the effect that drought has had on the market price of water.

## 3.2 Legal and Institutional Factors

All five intermountain states discussed follow the doctrine of prior appropriation. This means that an individual acquires a right to the water by taking the water from a natural stream and putting it to "beneficial use" in a non-wasteful manner with due diligence (Sax *et al.* 2002). The individual who acquires the water right receives a priority date of when the water was first put to "beneficial use". If there is not enough water to meet the demand on the river, then the most junior appropriator will lose their privilege to the water.

Prior appropriation is the general rule for the western United Sates for surface water but some states have embraced a similar legal doctrine for groundwater. Glennon (2002) suggests that with groundwater the doctrines of capture and reasonable use encourage the exploitation of this common-pool resource and that these rules encourage overinvestment in pumping by rational economic individuals, by assuring them that the "biggest pump wins". Glennon argues that to control the impact of groundwater pumping, a command-and-control model of pumping permits combined with market forces of transferable rights should be used. He suggests the 1980 Arizona Groundwater Management Act as a model.

## 3.3 Data

The Water Strategist and Water Market Update are the primary sources of information used in the collection of data for this research. The Water Strategist is a private journal that one must subscribe to it reports on the analysis of water marketing, finance, legislation and litigation. Each issue contains a section called Transactions which reports on purchases, leases, and exchanges of water in the western United States. Each transaction that is reported states the amount of water transferred, the price the water sold or leased for, the acquirer and supplier of the water, and the purpose of the transaction. The Water Strategist was used to gather data on transactions from 1990 on.

The journal was issued monthly from 1990 to 1995 and then quarterly from 1995 to December 1998. The journal then returned to monthly issues starting in January of 1999.

The Water Market Update is also a subscription-only journal that provided information on water transactions occurring in the western United States published from 1987-1989. The journal also provided information on federal, state, and local actions regarding water issues, and community impacts and their responses to water issues. Other sources of data collection used in this analysis are interviews with transactors and administrative officials. All water transaction data collected was adjusted to 2004 dollars using the Consumer Price Index. Water transaction data analyzed in this research involves both water rights defined under state law and contractual access to water supplied under public projects such as Arizona’s CAP water. The water transaction data used in this research is the most comprehensive available for these regions.

On occasion, a transaction had to be deleted from the dataset. This occurred when there was the question of whether the transaction was a true market transaction. For instance transactions that were donated or sold at an extremely low value, such as $0.25, were deleted. Transactions that did not provide price or quantity data were also deleted. In some cases, land and water rights were sold together; these transactions were also deleted, as there is no way of extracting the portion of the price that was paid for the water.

### 3.4 Drought

The major climate variable used in determining drought is precipitation (rain and snowfall). There are several drought indices that measure how precipitation over time has deviated from normal. The Standard Precipitation Index calculation is based on the precipitation record for a specific location and time period (National Drought Mitigation Center). These time scales reflect the impact of drought on the availability of the different water resources. For example, soil moisture conditions respond to a relatively short-term scale while groundwater, streamflow, and reservoir storage reflect longer-term precipitation patterns (Hayes). To compute the SPI, a long-term time series of precipitation accumulations over the desired time scale are used to estimate an appropriate probability density function, which is then transformed into a normal distribution so that the mean SPI for the location and desired period is zero (Edwards and McKee, 1997). The SPI can be interpreted as a probability using the standard normal distribution users can expect the SPI be within one standard deviation about 68% of the time and two standard deviations about 95% of the time. The SPI is measured from -4.0 to +4.0 with +4.0 indicating a period of heavy precipitation and -4.0 severe drought conditions.

Several Standard Precipitation Index time scales can be calculated to look at drought conditions in a region on a short to long-term basis. Initially six time scales were examined to explore the difference that short and long term precipitation patterns had on the market price of water. They include the SPI 3, 6, 12, 24, 36, and 48 month time scales. The SPI 3 and 6 month time scales react quickly to changing precipitation patterns, but do not reflect longer term trends such as depleted groundwater and surface water conditions and the SPI 36 and 48 month time scales react slowly to changing precipitation patterns and may not reflect current water availability. Therefore, this research focuses on two different time scales of the Standard Precipitation Index (SPI), the 12 and 24 month calculations. Both the SPI 12 and 24 represent long-term precipitation patterns that reflect streamflows, reservoir levels, and groundwater levels. The 12 and 24 month SPI are closely linked to surface water runoff and reservoir infill. The SPI is not influenced by complex operating rules and management objectives (such as treaty and environmental obligations) as which influence data on reservoir levels and water stocks stored behind dams.

In analyzing water transaction data that is reported on a monthly or quarterly basis, it is important to consider that transactions are not typically reported in the month that they occur. One must consider that negotiations of water transactions may start several months prior to the completion of the transaction. Ideally, one would include in a model the drought indicators that transactors were able to observe at the time they were negotiating a transaction. However, data indicating the time period of negotiations does not exist. Consequently, we compare the performance of two long-term drought indices (12 and 24 month SPI) to explore the role of drought information on negotiated prices.

Nearly all western states require a change of ownership application to be filed with a state agency for water right transfers. The application period can vary considerably by state. The time period from when the application is submitted to the time when the water right actually changes hands may vary between a few months to over a year (Colby, 1995). To account for the time delay involved in the water transfer application process, a six month and one year lag of the drought index is explored. When averaging the time to process water transfer applications across states, the six month lag is the most appropriate. The six month lag is compared to the model with a non-lagged drought index and the results are reported for each state. The results from the one year lag are reported in the appendix for each state.

## *3.5 Econometric Analysis*

This section discusses the techniques used to estimate the models within each state and the multi-state models. Analysis for each model is based on the purchases of water rights that occurred from 1987 to 2004. State-specific econometric results are discussed in subsequent chapters. All models are estimated using a derived demand hedonic price method as either an ordinary least square or two stage least square equation. In every model, except Arizona's, a two stage least squares instrumental variable approach is used to account for the endogeneity between price and quantity.

Endogeneity is tested for using the Hausman-Wu test. The Hausman-Wu test compares the ordinary least square estimates with the two-stage least square estimates to determine whether the differences are statistically significant (Wooldridge, 2003). Price and quantity are found to be endogenous in nearly all the models explored, this means that the explanatory variable quantity is determined simultaneously with the dependent variable price. This causes a correlation between the quantity and the error terms of the model. Arizona is unique in that price and quantity are exogenous in all three models examined. The reasons behind this exogeneity are explored in the Arizona Chapter. The instrumental variables included in the quantity equation attempt to explain as much variation as possible. A few independent variables that are included in the price equation are also included in the instrumental variable equation, such as the drought index. The instrumental variable equation also examines supply side variables such as agricultural output prices, average per capita income, and the type of supplier to explain variation in quantity. The instrumental variable equation results are presented in each chapter appendix. Each variable included in the regression analysis are discussed in detail below.

The functional form of the models examined is based on the results indicated by performing a Box-Cox transformation. The Box-Cox transformation is a device used to generalize a linear model. The transformation

$$X^{(\lambda)} = (X^{(\lambda)} - 1)/\lambda \tag{1.1}$$

is defined for all values of $\lambda$, X must be strictly positive (Box and Cox). Several functional forms were examined. These included: linear, log-linear, linear-log, and double-log specifications. The results of the Box-Cox transformation indicated a double-log model for all water markets. This result is consistent with the econometric results found when comparing each of the functional forms examined and with what has been evaluated in previous research.

The double-log model is used to estimate all water market models. The double-log model is a commonly used functional form, so the interpretation of the results is straightforward. For the independent variables that were not transformed with the natural log operator, the regression coefficients have the same interpretation as they would in a semi-log specification. That is, the coefficients are partial or semi-elasticities. That is:

(1.2) $\beta_1 = (\partial \ln y) (\partial X_1)$

For the independent variables that have been transformed with the natural log operator, the coefficients can be interpreted as elasticities. Elasticity measures the percentage change in the dependent variable for a 1% change in one of the variables. That is:

(1.3) $(\partial Y/\partial X_k) (X_k/Y) = \partial \ln Y / \partial X_k = \beta_k$ (Greene)

The independent variables that were not transformed by the natural log operator are the dummy variables and the variables that are not strictly positive. The marginal effect calculation for the non-dummy variables is:

(1.4) $E_k = \beta_k X_k$ (Franklin and Waddell)

where $X_k$ = the average value of the independent variable. The marginal effect calculation for the dummy variable is:

(1.5) E=(100*(EXP(parameter estimate)-1))/100

All models are tested for heteroskedasticity using the White’s General Test and the Breusch-Pagan Lagrange Multiplier Test. Several of the models examined exhibited heteroskedasticity of an unknown nature. To correct for the heteroskedasticity, the White estimator (corrected covariance-variance matrix) can be used to estimate the asymptotic variance of the least square estimator. The corrected variance follows a chi-square distribution because it is asymptotic rather than exact. The Chi-Square Distribution is the sum of squared independent standard normal random variables. These corrected standard errors are reported in the results section of each Chapter.

## 3.6 Independent Variable Descriptions

Several independent variables are included in each of the models analyzed. These include the quantity of water transferred, the year the transaction occurred, the drought index, population percent change and the new use of the water right. Each region may also have their own specific characteristics that require distinct explanatory variables. These types of unique variables include the location of the transaction within a specific state, calf pricing, and mining output prices in the Gila-San Francisco model. An instrumental variable equation approach is applied in nearly all the econometric models explored due to price and quantity being endogenous. Supply side variables are included as the instrumental variables. These instrumental variables include: the type of seller, agricultural output prices, average per capita income, and the drought index. A detailed description of all variables is included below.

In the models developed here, the drought indices are hypothesized to be negatively related to the price of water. This implies that as drought intensifies the price of water increases. It is expected that individuals purchase water rights as a long-term investment that involves their expectation and perception of future conditions. The price of water is also expected to be negatively correlated with the size of the water transaction indicating economies of scale. It would be expected that some regions would not experience economies of scale due to high transaction costs associated with the purchase of water rights. Population growth is expected to have a positive influence on price per acre foot. In most regions, water purchased for agriculture is expected to cost less than water purchased for domestic purposes. The expected sign of the explanatory variable included in the models are illustrated in Table 3.1. Each of the independent variables that represent the characteristics of water markets throughout the western United States are discussed next.

Table 3.1 Expected Sign of Explanatory Variables

| Variable Name | Description | Expected Sign |
|---|---|---|
| Lnaf/qhat | Quantity of water transferred in each transaction | Varies |
| SPI | Standard Precipitation Index climate data linked to each transaction | – |
| Population%Change | Population percent change for the county where the transaction occurred | + |
| Trend | Year the transaction occurred | Varies |
| Location | Location where the transaction occurred could be region or state location | Varies |
| New Use | New use that the water will be used for | Varies |

### 3.6.1 Variables included in all models

*Size of the Transaction*

Water rights are defined in acre feet per year throughout the western United States. In the econometric analysis, the independent variable *lnaf* (natural log of acre feet) measures the quantity of water transferred to the buyer on a logarithmic scale. This variable is included in the model to test the hypothesis that larger quantities of water rights sell for lower prices per acre foot, thus reflecting economies of scale in water acquisitions.

*Drought Index*

Two drought indices are examined in separate models. All other independent variables are treated identically across these models, in order to focus on differences attributed to different drought indices. The different time scales of the *SPI* measure how drought has influenced the price of water transactions per acre foot. The hypothesized value for the different time scales of the *SPI* is a negative impact on price. The 12 and 24 month *SPI* represent long-term drought conditions. As explained previously, both of these time scales are also examined with a six month and one year lag to account for the application procedure involving the change of ownership of water rights.

*Change in Population*

The intermountain region of the western United States has experienced as a whole rapid growth in annual population over the study period. The variable *population%change* examines how the percent change in population has influenced the price of a water right per acre foot over time. The change in population is explored for the region where the transaction occurred and is analyzed on a yearly basis.

*Time Trend*

This explanatory variable looks at the year the transaction occurred. It is a time trend that numbers each year 0 through 17. The price of each water right is adjusted to 2004 dollars using the Consumer Price Index. The time trend variable explains the price variation in water rights for each given year after accounting for inflation. The time trend variable is hypothesized to be positively related to price. In other words the price of water is expected it increase over time.

### 3.6.2 Variables Unique to Particular Regions

*Location of the Transaction*

This independent variable looks at the location where the water right transaction took place. In the state models, this is typically a city or specific region of the state. For example, in the Arizona Model the location variables are Phoenix, Tucson, and other. The dummy variable takes on a value of a 1 if the transaction involves a water transaction occurring in Phoenix and a value of 0 if the transaction occurred outside Phoenix. In the multi-state model, the location variable is the state that the transaction occurred in.

*Price of Copper*

The explanatory variable, price of copper, is only applicable to the Gila-San Francisco Model. Copper mining has been a prominent economic activity in the Gila-San Francisco Basin. The mining industry purchased several water rights during the study period examined. The variable *lncopper* is examined to explore the impact that the natural log of average annual price of copper has on a water right per acre foot. The average annual price of copper is analyzed from the New York Commodity price index. The average annual price of copper is measured as cents/pound and is converted to 2004 dollars using the Consumer Price Index (CPI).

*Calf Prices*

The independent variable, calf prices, is only examined in the Gila- San Francisco Model. Along with irrigated hay and pasture, ranching has been a widespread economic activity. The variable *lncalf* examines the average annual price that calves sold for in the state of New Mexico on a logarithmic scale. Calf prices are measured in dollars/cwt and are converted to 2004 dollars using the CPI. Livestock production makes up a large portion of the agricultural sector in the Gila-San Francisco Basin.

### 3.6.3 Instrumental Variables

*Alfalfa Output Prices*

To examine the influence that price fluctuations in the agricultural sector have on the quantity of a water right, the variable *lnalfalfa* is analyzed. The variable *lnalfalfa* examines the three month average price as dollars/ton for dry alfalfa for each state on a logarithmic scale. The price for dry alfalfa is converted to 2004 dollars using the CPI.

*Average per Capita Income*

This instrumental variable explores the influence that average per capita income has on the quantity of water rights being purchased. The average per capita income is examined for the county where the new use of the water transaction occurred. The average per capita income is converted to 2004 dollars and is calculated for each county.

*Type of Seller*

The type of seller is an important determining factor in the size of the overall water transaction. Agricultural water rights tend to be sold in much larger quantities than municipal rights. This instrumental variable is a dummy variable that takes on the value of 1 if the type of seller is agriculture and a 0 if the type of seller is not agriculture.

*Drought Index*

The Standard Precipitation Index is included in both the price and instrumental variable equation. In the instrumental variable equation the drought index variable measures how drought influences the quantity of water rights purchased. As in the price equation two different drought indices are measured, the 12 and 24 month SPI. Each model is treated identically while changing only the drought index. A six month and one year lag of each is also analyzed.

### 3.6.4 Variables Considered But Not Included

Several variables examined were ultimately not included in the final regression models. These variables include: an interaction term between the new use of the water right and the drought index, a drought index that looked at the location of the precipitation supply rather than the location the transaction occurred, and an interaction term between the Active Management Areas in Arizona and the drought index. The interaction terms that looked at drought and the new use of the water right were not statistically different from one another. This was also the case with the interaction term between drought and the Active Management Areas.

Many regions across the western United States rely upon precipitation patterns that occur in other areas of the state or country for their water supply. This is the case in Albuquerque, New Mexico. Albuquerque relies on precipitation from the southern mountains of Colorado, where the headwaters of the Rio Grande are located. Two separate climate regions were explored for the drought indices: one that links the climate region to the location of the transaction and the other that ties the climate data to the region where the water supply is located. There was no statistical difference between the two different climate regions. This indicates that there is no difference between the price of a water right and the precipitation patterns of the either the location the transaction occurred or the region where the majority of the water was supplied from. As a result only the models that estimated the drought index where the transaction occurred are reported.

A general overview of each variable included in the econometric models has now been provided. Each explanatory variable is described in detail as to its significance in a particular region in the respective state chapter. Next the econometric models of Arizona are discussed followed by their results, then the econometric models of Colorado and New Mexico are examined respectively. These separate state chapters are followed by the intermountain and urban Chapter. A concluding Chapter will reflect on water market activity in the intermountain region of the western United States as a whole. All Nevada and Utah results are presented in the appendix, as well as various models estimated for Arizona, Colorado, and New Mexico that are not presented in their particular chapter.

# Chapter 4: Modeling Water Transaction Prices in Arizona

## *4.1 Introduction*

Arizona is characterized by rapid population growth, a large irrigated agricultural sector, declining groundwater supplies and dependence of imported Colorado River water that is susceptible to curtailment during drought. This combination of increasing demand and variable supplies has motivated numerous water sales and leases. The State of Arizona's current population is 5.7 million, with over half living in Maricopa County and the remaining majority in Pima County. The U.S. Census Bureau expects a 109% increase by the year 2030 adding another 5.5 million individuals to the State. This will increase the population of Arizona to just over 10 million by 2030. Currently, Arizona uses 7.24 million acre feet per year of water under normal conditions (Arizona Department of Water Resources). This water is supplied by four main sources: Colorado River water, surface water that is not Colorado River water, groundwater, and effluent/reclaimed water.

Groundwater was the primary source of withdraws prior to introduction of the Central Arizona Project in the 1980s. The Central Arizona Project delivers Colorado River water to many regions of Arizona where it was previously unavailable. The introduction of the Arizona Canal increased the surface water use in the State by approximately 58 percent. Agriculture is the dominate use in the State and accounted for roughly 80 percent of total water use in 2000. In 2000, the average State-wide agriculture application rate per acre was 6.21 acre feet of water. To put in perspective how much water the agriculture sector uses, it only takes one acre foot of water to supply a family of five for one year. During the period 1950 to 2000 the population of Arizona increased by 600 percent and withdrawals for domestic water supplies increased more than 1,100 percent (Konieczki *et al*.).

Arizona treats groundwater and surface water as separate legal entities. Surface water is based on the prior appropriation doctrine otherwise known as “first in time, first in right”. The individual who acquires the water right receives a priority date of when the water was first put to “beneficial use”. If there is not enough surface water to meet demand then the most junior appropriator will lose their privilege to the water. The prior appropriation doctrine is commonly applied throughout the western United States. Groundwater on the other hand is governed by the common law rule suggesting that the overlaying land owner holds all groundwater rights. This law has contributed to the depletion of groundwater resources throughout the State.

The State of Arizona has incredibly diverse hydrological conditions ranging from extreme desert to high alpine mountains. Most locations within Arizona receive very limited rainfall. The state is extremely dependent on the high elevations, such as the White Mountains, that receive precipitation in both the form of rain and snowfall. Arizona has been experiencing drought conditions state-wide since the mid 90s.

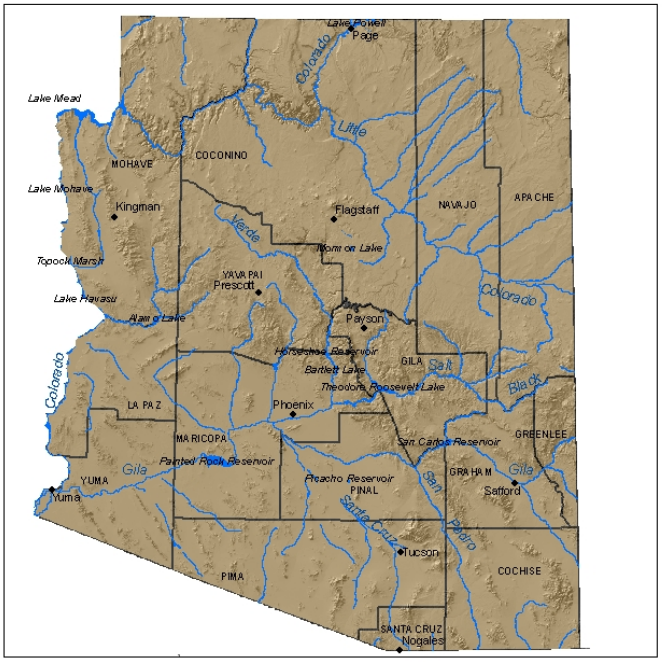
## *4.2 Types of Water Sources in Arizona*

Arizona has four primary sources of water: Colorado River water, surface water sources other than Colorado River water, groundwater, and effluent. Groundwater use is wide spread with most rural areas depending heavily, if not entirely, on this source. The main source of surface water in the state is the Colorado River which supplies Arizona with 2.8 million acre feet per year. Several smaller rivers provide surface water as well: Gila, Salt and Verde Rivers. Reclaimed water is a relatively small portion of the current water use in Arizona but will become increasingly important in the future. Only 2% of Arizona's water use comes from effluent/reclaimed water, while 40% comes from groundwater, 39% from Colorado River water and 19% from other surface water sources (Arizona Department of Water Resources).

### 4.2.1 Surface Water

The majority of all surface water available in the State of Arizona has been developed and is currently used for irrigation or municipal purposes. Surface water includes water from lakes, streams and rivers and is the only renewable source of water in Arizona. Surface water availability depends heavily on precipitation patterns and can therefore vary tremendously by location and year. Several storage facilities have been constructed in order to mitigate the variation in surface water availability and insure that water is available in times of drought and increased demand. Figure 4.1 illustrates the available surface water sources throughout the State of Arizona.

Figure 4.1 Arizona Surface Water



* Arizona Department of Water Resources Map accessed at
http://www.azwater.gov/dwr/Content/Find_by_Category/ABCs_of_Water/default.htm

## 4.2.2 Colorado River Water

Colorado River water is utilized in seven states in the western United States. The Colorado River Compact of 1922 divided the Colorado River into two separate basins at Lee's Ferry, the Upper Basin and the Lower Basin. Arizona is located in the Lower Basin as are California and Nevada. The Upper Basin States include: Colorado, Utah, New Mexico, and Wyoming. Each basin is allocated 7.5 million acre feet per year and the States located in each of these two basins are allocated their supply from this amount. The allocation to each State in the Upper Basin was agreed upon by the Upper Colorado River Basin Compact in 1948, the Lower Basin was unable to reach an allocation agreement. In 1952 Arizona filled suit with the U.S. Supreme Court to determine how the Lower Basin allotment should be allocated. The U.S. Supreme Court ruled that Arizona is allowed 2.8 million acre feet per year (U.S. Department of Interior).

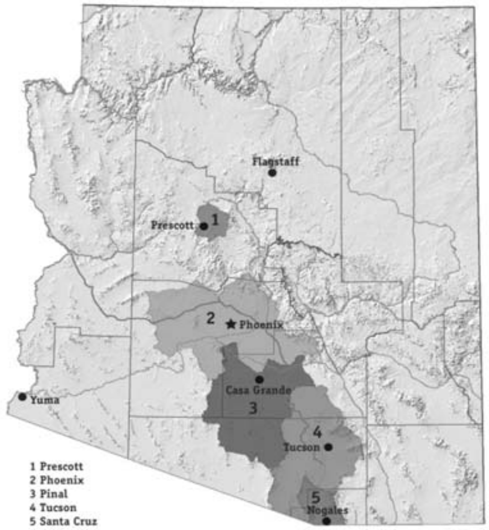
Colorado River water is the main surface water source in the State of Arizona and accounts for nearly 40% of our total water use. Colorado River water is delivered by the Central Arizona Project via the Arizona Canal. Arizona’s allotment of 2.8 million acre feet allows for 1.5 million acre feet to be transported via the Central Arizona Canal to Maricopa, Pima, and Pinal counties. The other 1.3 million acre feet are used as the primary water supply for Mohave, La Paz, and Yuma Counties.

### 4.2.3 Groundwater

Groundwater is the other main source of water in the State of Arizona. It accounts for 40% of total water use. Groundwater is located below ground in aquifers. Most groundwater supplied in these aquifers has been there for millions of years. Groundwater supplies are replenished by precipitation and when groundwater supplies are withdrawn at a rate that exceeds replenishment overdraft occurs and there is a danger of depleting a resource that may be needed in the future.

The State introduced the 1980 GroundWater Management Act to mitigate the effects of overdraft in the portions of Arizona that are designated Active Management Areas. Active Management Areas were designated to provide long-term management and conservation of limited groundwater supplies in urban areas, which account for 80 percent of Arizona’s population. There are currently five Active Management Areas located throughout the state: Prescott, Phoenix, Pinal, Tucson, and Santa Cruz. Figure 4.2 shows the location of Arizona’s Active Management Areas. The Arizona Department of Water Resources (ADWR) was created to oversee the primary goals of the 1980 Groundwater Management Act. The Code’s primary goals are to control the severe overdraft occurring in many parts of the State, to provide a means to allocate the State’s limited groundwater resources to effectively meet the needs of the changing State, and to offset Arizona’s use of groundwater through renewable water supply development (Arizona Department of Water Resources, Annual Report).

Figure 4.2 Arizona’s Active Management Areas



### 4.2.4 Reclaimed Water

Reclaimed water is also referred to as effluent. Reclaimed water is a small portion of the total water used in Arizona, only 2%. Reclaimed water is wastewater that is treated to a level where it can be used for landscape irrigation such as in golf courses and parks, industrial purposes, and even agricultural purposes. As the population of Arizona increases more reclaimed water will be available for use through increased waste water.

## 4.3 Types of Water Entitlement in Arizona

Arizona has several distinct water markets located throughout the State. Arizona's water markets are segmented both by types of water traded and by geographic area. Markets exist for groundwater, Central Arizona Project (CAP) water, surface water and effluent. This chapter will explore the impact that drought conditions, along with increased demand for water supplies, has played on the market price of water rights. There are many different types of water rights that exist in Arizona such as: CAP water, Type II, Type I, Reclaimed, groundwater, and surface water. Table 4.1 illustrates the total number of purchases that occurred in Arizona for each type of water during the study period 1987 to 2004. Each type of water right is defined and their potential for marketability discussed in the following sections.

Table 4.1 Arizona Water Transaction Totals

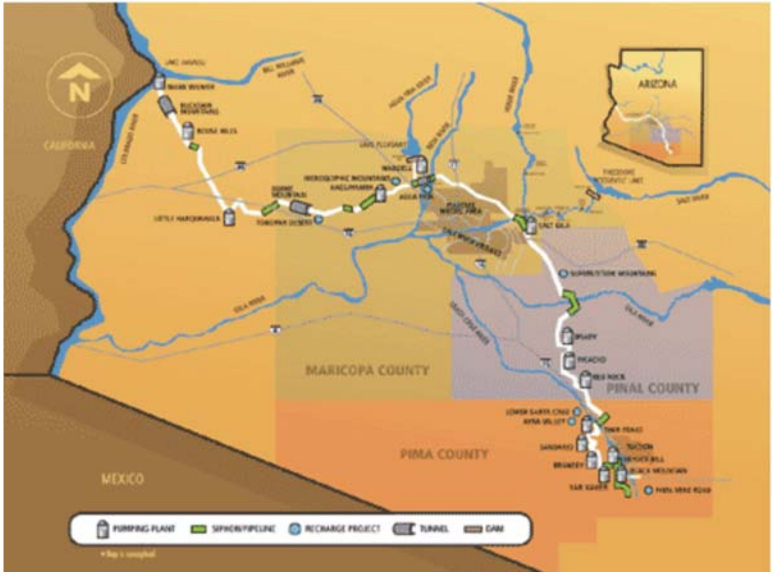
| **Type of Water** | **# of Transactions** | **Average # of Acre Feet Transferred** | **Average Price ($2004 dollars)** |
|---|---|---|---|
| CAP | 24 Purchases | 7,497.66 | 660.37 |
| Type II Groundwater | 43 Purchases | 425.62 | 1,580.67 |
| Groundwater Outside AMAs | 5 Purchases | 3,711.24 | 1,534.36 |
| Reclaimed | 14 Purchases | 5,931.75 | 667.72 |
| Surface Water | 6 Purchases | 8,916.67 | 998.50 |
| Total | 92 Purchases | 5,296.59 | 1088.32 |

### 4.3.1 CAP Water

Central Arizona Project (CAP) water is taken from the Colorado River and is available for use to municipal water service organizations, water companies, and irrigation districts through service contracts with the Central Arizona Water Conservancy

District. CAP water is transported across the State of Arizona via the Arizona Canal to the cities of Phoenix and Tucson. Figure 4.3 illustrates the Arizona Canal's route. Transactions involving CAP water do not occur in a "free" market. The price of CAP water has been set for various classes of users by the Central Arizona Water Conservancy District. This price may or may not change each year. While the price at which CAP water is permanently transferred is constrained by administrative policies, there has been significant market activity for CAP water throughout the state of Arizona. An econometric model for CAP purchases is explored.

Figure 4.3 Arizona Canal



## 4.3.2 Reclaimed Water

Reclaimed water currently only accounts for 2% of the total water use in the State of Arizona. There has been an increase in market activity for reclaimed water over the past decade. Reclaimed water is currently being purchased for landscape irrigation in both the Tucson and Phoenix metropolitan areas. With increasing pressures on Arizona's water supply one can expect to see a continuation of market activity. The study period examined did not provide enough market activity for meaningful econometric analysis.

### 4.3.3 Type II Water

Type II water is non-irrigation groundwater that can be transferred within an Active Management Area only. Type II water rights must stay within their own AMA. There are currently five Active Management Areas in Arizona: Prescott, Phoenix, Casa Grande, Tucson and Santa Cruz. Type II water rights are sold at a specific quantity that may not be divided. Both the Tucson AMA and Phoenix AMA have shown significant market activity for Type II water rights. Several Type II purchases have occurred in the State’s Active Management Area. Therefore an econometric model is examined for all Type II purchases.

### 4.3.4 Groundwater Outside AMAs

Groundwater is located throughout the State of Arizona. Rural Arizona relies almost entirely on its availability. Arizona is currently withdrawing more groundwater than is being replenished, causing overdraft in the state’s aquifers. There has been progress within Arizona to rely on sources other than groundwater. While there are occasional groundwater transactions occurring outside of AMAs, there is not enough data for accurate statistical analysis.

### 4.3.5 Surface Water – Other than Colorado River Water

Surface water is defined, by Arizona Revised Statutes 45-101, as waters of all sources, flowing in streams, canyons, ravines or other natural channels, or in definite underground channels, whether perennial or intermittent, floodwater, wastewaters, or surplus water, and of lakes, ponds, and springs on the surface. Many surface water rights exist in Arizona other than rights to Colorado River water. Arizona currently uses water supplied from the Gila, Verde, Salt, and Aqua Fria Rivers. There has not been sufficient market activity from surface water sources other than the Colorado to estimate an econometric model. As pressure increase on water supplies within the state, we may see an increase in transactions involving surface water rights.

## *4.4 Arizona Water Transaction Models*

Several econometric models are discussed in this section. A model that combines all the purchases for all the different types of water in the State of Arizona is examined and a model of CAP purchases is analyzed. The last model explored is the Type II purchases that have occurred in Arizona. Each market is represented by two models, one with a drought index that has a six month lag and one that includes the same drought index without a lag. Other water market activity does exist in the State, but due to limited data, a meaningful econometric model of this activity is not possible.

Several explanatory variables are examined for each model. A derived demand hedonic method is used to explain price variation in water rights. Variables that explain the characteristic of the water right are included such as: number of acre feet transferred in the transaction, the new type of use of the water right, the type of buyer or seller and the location of the water right. Numerous demand variables are included in the models such as the drought conditions of the regions, the year the transactions occurred, and the percent change in population of the region where the transaction occurred. Not all variables are included in each model, as not all variables are relevant to each type of water being modeled.

The Hausman-Wu test indicates that price and quantity are exogenous variables in all the Arizona water models. Price and quantity are typically endogenous variables, but in this case there are reasons why they are not. In the CAP water market, price is fixed administratively and therefore price and quantity can not be simultaneously determined. In the Type II water market, quantity is fixed since these rights cannot be sub-divided and transferred in smaller units. Since the Arizona Full Model is primarily made up of CAP and Type II transactions price and quantity are also exogenous in this water market model. Since price and quantity are exogenous, two-stage least squares is not necessary and an ordinary least squares equation is estimated.

Numerous drought indices exist to measure different lengths of dry conditions. In the models explored here, the Standard Precipitation Index (SPI) is used to explain the effect that drought has on the price of a water right. The 12 month SPI represents longer-term drought conditions. Longer length drought conditions will likely be characterized by lowered surface water levels. Finally, a very longer-term drought index such as the 24 month SPI represents extended dry conditions or hydrological drought. These conditions can be seen in severe surface water depletion and decreasing groundwater levels. Figures

4.4 and 4.5 illustrate the variation in drought conditions for the 3 and 24 month SPI graphed for the Phoenix metropolitan area (Climate Division 6). The 3 month SPI fluctuates greatly depending on current precipitation patterns, while the 24 month SPI is much slower to react to dry or wetter periods due to the long-term cumulative nature of this index.

Figure 4.4 3 Month Standard Precipitation Index Climate Division 6 Arizona

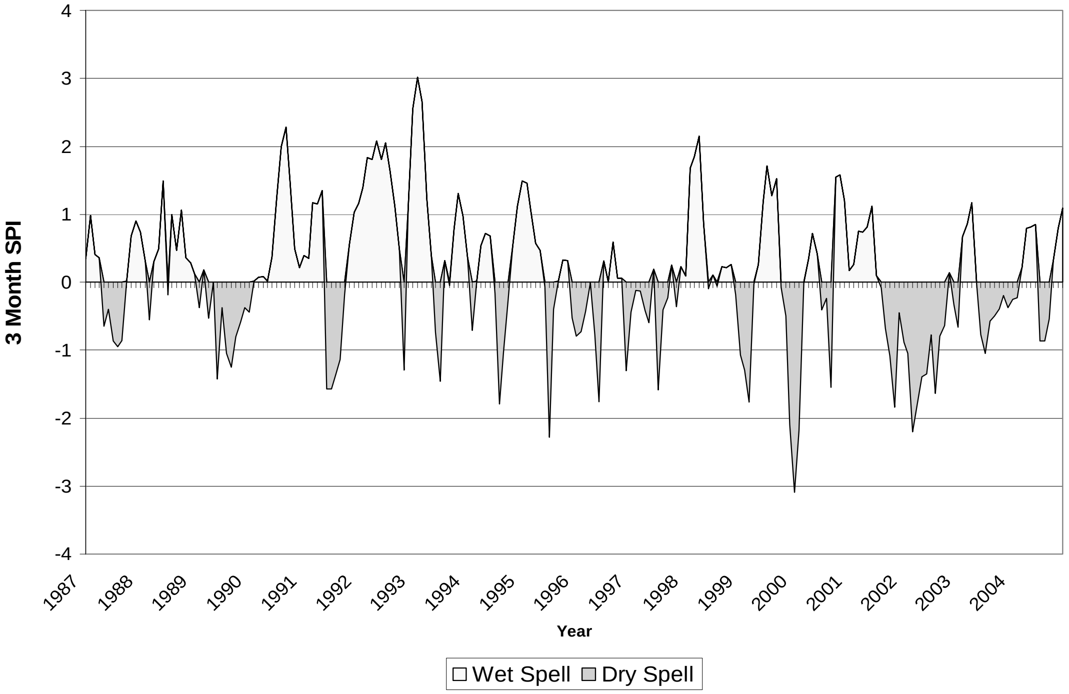
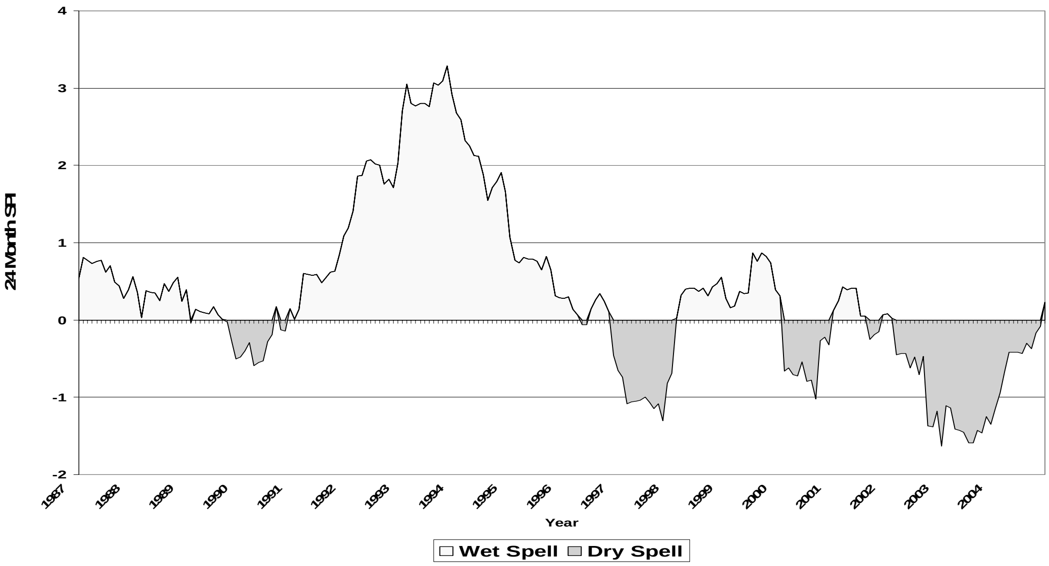


Figure 4.5 24 Month Standard Precipitation Index Climate Division 6 Arizona



## 4.4.1 Arizona Full Model

A total of 92 water transactions are documented in adequate detail for inclusion in the Arizona Models during the study period 1987 to 2004. The average price paid for the purchase of a water right is $1,089 (2004 dollars) while the average quantity purchased is just over 5,000 acre feet. This econometric model explores all the different types of water purchases that occurred in Arizona.

A double-log model is used for the analysis of the Arizona Full Model:

$$\text{lnAdjustedPrice} = \beta 0 + \beta 1 * \text{lnAF} + \beta 2 * \text{SPI} + \beta 2 * \text{Population\%Change} + \beta 3 * \text{trend} + \beta 4 \text{statelanddept} + \beta 5 * \text{cap} + \beta 6 * \text{typeii} + \beta 7 * \text{phx} + \beta 8 * \text{munuse} + \beta 9 * \text{envuse}$$

Table 4.2 Description of variables included in the Arizona Full Model

| **Variable:** | **Description:** |
|---|---|
| *lnAdjustedPrice* | The natural log of the price per acre-foot in the transaction adjusted to year 2004 dollars |
| *lnAF* | The natural log of the volume of water per acre-foot purchased |
| *SPI* | The Standard Precipitation Index |
| *Population%Change* | Percent change in population for the region the transaction occurred each year |
| *Trend* | The year the transaction occurred minus 1987 |
| *Statelanddept* | Binary variable equal to one if the purchaser of acquirer of a water right is the state land department |
| *Cap* | Binary variable equal to one if the water being purchased is Central Arizona Project water |
| *TypeII* | Binary variable equal to one if the water being purchased is TypeII water |
| *Phx* | Binary variable equal to one if the location of the transaction occurred in the Phoenix area compared to all other areas. |
| *Munuse* | Binary variable equal to one if the water purchased is to be used for municipal purposes |
| *Envuse* | Binary variable equal to one if the water purchased is to be used for environmental purposes |

### 4.4.2 Central Arizona Project Model

Central Arizona Project water purchases occurred during the study period for a variety of reasons, the most common transpiring for municipal and agricultural purposes. During the study period from 1987 to 2004 there are 24 purchases of CAP water. The average purchase price for Central Arizona Project water during this period is $660 and the average quantity transferred per transaction is approximately 7,500 acre feet. Although the price of CAP water is not freely negotiated, several individuals and cities have sold their CAP allocations. This model attempts to explain the price variation in the purchases of CAP water.

A double-log model is used for the analysis of the Arizona CAP Model:

$$lnAdjustedPrice = \beta 0 + \beta 1 * lnAF + \beta 2 * SPI + \beta 3 * trend + \beta 4 * Population\%Change + \beta 5 * munuse + \beta 6 * envuse + \beta 7 * phx$$

Table 4.3 Description of variables included in CAP Model

| **Variable:** | **Description:** |
|---|---|
| *lnAdjustedPrice* | The natural log of the price per acre-foot in the transaction adjusted to year 2004 dollars |
| *lnAF* | The natural log of the volume of water per acre-foot purchased |
| *SPI* | The Standard Precipitation Index |
| *Trend* | The year the transaction occurred minus 2004 |
| *Population%Change* | Percent change in population for the region the transaction occurred each year |
| *Munuse* | Binary variable equal to one if the water purchased is to be used for municipal purposes |
| *Envuse* | Binary variable equal to one if the water purchased is to be used for environmental purposes |
| *Phx* | Binary variable equal to one if the location of the water transaction occurred in Phoenix compared to other areas |

### 4.4.3 Type II Model

Type II water purchases occurred for primarily landscape irrigation and municipal purposes. Landscape irrigation uses include water to irrigate golf courses, parks, and schools. Type II water is used for other purposes such as municipal, industrial and environmental uses. The average price paid for a Type II water right during the study period 1987 to 2004 is approximately $1,600 and the average quantity purchased is 425 acre feet. 42 purchases of Type II water rights occurred during the study period.

A double-log model is used for the analysis of the Arizona Type II Model:

$lnAdjustedPrice = \beta0 + \beta1 * lnAF + \beta2*SPI + \beta3*trend + \beta4*population\%change + \beta5*tucama + \beta6*otherama + \beta7*golfuse$

Table 4.4 Description of variables included in Type II Model

| **Variable:** | **Description:** |
|---|---|
| *lnAdjustedPrice* | The natural log of the price per acre-foot in the transaction adjusted to year 2004 dollars |
| *lnAF* | The natural log of the volume of water per acre-foot purchased |
| *SPI* | The Standard Precipitation Index |
| *Trend* | The year the transaction occurred minus 2004 |
| *Population%change* | Percent change in population for the region the transaction occurred each year |
| *Tucama* | Binary variable equal to one if the location of the transaction occurred in Tucson |
| *Otherama* | Binary variable equal to one if the location of the transaction occurred in any other AMA than Tucson |
| *Golfuse* | Binary variable equal to one if the water purchased is to be used for golf course watering |

## *4.5 Arizona Econometric Results*

A double-log model is used to estimate all Arizona water market models. Several different functional forms are examined. These include: linear, log-linear, linear-log, and double-log specifications. The results of the Box-Cox transformation indicated a double-log model for all of the Arizona models. The double-log model is a commonly used functional form and the interpretation of the results is straightforward.

All Arizona models are tested for heteroskedasticity using White’s General Test and the Breusch-Pagan Lagrange Multiplier Test. The Arizona Full Model and the Type II Model exhibited heteroskedasticity of an unknown nature. The Arizona CAP Model did not display heteroskedasticity of any form. All Arizona models that display heteroskedasticity have been corrected and their robust standard errors are reported in the results.

### 4.5.1 Arizona Full Model Results

The Arizona Model examines all the purchases that occurred during the study period 1987 to 2004. All types of water right transactions are included in this analysis as binary variables with one variable being left out as the base comparison. The SPI with a six month lag is statistically significant but the non-lagged SPI is not. This likely is because of the time delay associated with change of ownership of particular types of water rights. The SPI 24 is examined since the model includes several different types of water: groundwater, surface water, and reclaimed water. The SPI 24 reflects long-term drought conditions that effect groundwater supplies. The SPI 12 is also examined and the results are provided in Appendix. The Arizona Model did display heteroskedasticity, so the robust standard errors are displayed in the results. No changes in the significance of the explanatory variables when correcting for heteroskedasticity.

Table 4.5 Arizona Full Model with SPI 24
Dependent Variable: Natural Log of Adjusted Price per acre-foot

| **Variable Name** | Parameter Estimate | Robust Standard Error | Chi-Square | Pr > Chi-Square |
|---|---|---|---|---|
| *Intercept* | 5.97112 | 0.44716 | 178.32 | <.0001 |
| *lnAF*** | -0.01695 | 0.05135 | 0.11 | 0.7413 |
| *SPI 24*** | -0.12364 | 0.13231 | 0.87 | 0.3501 |
| *Population%change* | 0.29672 | 0.15064 | 3.88 | 0.0489 |
| *Trend*** | -0.01854 | 0.01610 | 1.33 | 0.2494 |
| *Stlanddept*** | -0.43420 | 0.39460 | 1.21 | 0.2712 |
| *CAP*** | -0.30564 | 0.39941 | 0.59 | 0.4441 |
| *TypeII* | 0.75166 | 0.29874 | 6.33 | 0.0119 |
| *Phoenix** | -0.33581 | 0.20349 | 2.72 | 0.0989 |
| *Munuse*** | 0.24388 | 0.17470 | 1.95 | 0.1627 |
| *Envuse* | -1.84587 | 0.38310 | 23.21 | <.0001 |
| Observations | 92 | | | |
| R-Squared | 0.6451 | | | |

*Insignificant at the 5% level
**Insignificant at the 10% level

Table 4.6 Arizona Full Model with SPI 24 six month lag
Dependent Variable: Natural Log of Adjusted Price per acre-foot

| **Variable Name** | Parameter Estimate | Robust Standard Error | Chi-Square | Pr > Chi-Square |
|---|---|---|---|---|
| *Intercept* | 5.94919 | 0.42796 | 193.24 | <.0001 |
| *lnAF*** | -0.01853 | 0.05139 | 0.13 | 0.7185 |
| *SPI 24 six month lag** | -0.15468 | 0.09090 | 2.90 | 0.0888 |
| *Population%change* | 0.33325 | 0.12816 | 6.76 | 0.0093 |
| *Trend*** | -0.02491 | 0.01678 | 2.21 | 0.1376 |
| *Stlanddept*** | -0.46756 | 0.38729 | 1.46 | 0.2273 |
| *CAP*** | -0.32862 | 0.40617 | 0.65 | 0.4185 |
| *TypeII* | 0.73911 | 0.30442 | 5.89 | 0.0152 |
| *Phoenix*** | -0.31674 | 0.20692 | 2.34 | 0.1258 |
| *Munuse*** | 0.24659 | 0.17264 | 2.04 | 0.1532 |
| *Envuse* | -1.84764 | 0.36565 | 25.53 | <.0001 |
| Observations | 92 | | | |
| R-Squared | 0.6529 | | | |

*Insignificant at the 5% level
**Insignificant at the 10% level

The Arizona full models have good explanatory power with an r-square of approximately 0.65. This means that 65% of the variation in the price of a water right is explained by the variables included in the model. The SPI 24 without a six month lag is significant while the SPI 24 with a six month lag is significant at only the 10% level. The negative parameter estimate of the SPI 24 with a six month lag indicates that as Arizona becomes wetter the price of water rights decrease.

The variable *lnAF* is not a significant variable in this model, indicating no systematic relationship between price and the quantity purchased. This is not a surprising result due to the large variation in the number of acre feet of water transferred between the different types of water. Water transactions that involve Type II rights tend to transfer in quantities under 100 acre feet while CAP transactions involve thousands of acre feet.

The population of Arizona has been increasing at a high rate. One would expect that this would have an impact on the price paid for water rights. The variable *population%change* evaluates the percent change each year for the metropolitan area closest to the location of the transaction. This variable is significant at the 5% level in the model with the SPI 12 without a lag and is significant at the 1% level in the model with a six month lagged SPI 12. The parameter estimate is approximately 0.30 for both models. This result can be interpreted as the following: a one unit increase in the percent change of the population of an area will increase the price of a water right by nearly 30%. This result at first appears to be extremely large, but when considering the effect of rapid growth it makes sense. The variable *population%change* is exploring the percent change in population of an area, not the absolute population number.

The variable *trend* examines the year the transaction occurred. This result is insignificant. This result indicates that time has not played a role in the price of water rights. This is not the result that one would expect. Time is hypothesized to be positively correlated to price meaning that prices increase each year after adjusting for inflation.

The variable *stlanddept* is a binary variable that examines if a State Land Department is the purchaser or seller of a water right. This variable takes on the value of 1 when the State Land Department purchased or sold water rights and it takes the value of 0 for all other purchasers or sellers. This variable is insignificant in both models examined. Several other binary variables are included in the model that looked at the different types of water supplies purchased. The variables *CAP* and *TypeII* are compared to all other types of water. The variable *CAP* is found to be an insignificant variable. This means that when compared to other types of water such as: groundwater, surface water and reclaimed, there is not a significant difference in price. The binary variable *TypeII* is significant at the 1% level and the parameter estimate for both models is approximately 0.75. This result indicates that Type II water rights sell for just over 70% more than other types of water rights available in the State of Arizona.

Several binary variables explored other potential reasons for variation in the price of a water right. The binary variable *phx* looked at water transactions that occurred in the Phoenix metropolitan area compared to transactions occurring in other parts of the State. The variable *phx* is significant at the 10% level in the model that examined the SPI without a lag. The results indicate that water rights purchased in Phoenix cost less. This seems counter intuitive to what most individuals would expect considering that Phoenix holds most of the State of Arizona's population. However, Phoenix has a much broader portfolio of water supplies than other areas of Arizona as it can draw upon several surface water sources as well as groundwater and effluent. Binary variables are also created to explore what the water right was being purchased for. For example the variable *envuse* is statistically significant when compared to other types of uses such as agriculture. The results indicate that water purchased for environmental transactions cost less than water transactions occurring for agriculture. The binary variable *munuse* is statistically insignificant indicating that water purchased for municipal purchases costs the same as water purchased for agriculture.

### 4.5.2 Arizona CAP Model Results

Central Arizona Project water rights being purchased are not as freely negotiated as one would expect in a free market. The CAWCD sets water prices each year but some individuals and cities sell their appropriation to others. Some Arizona cities have CAP water allocations but are unable to fully utilize these rights. This model attempts to explain the price variation in purchases of CAP water rights.

The 12 month Standard Precipitation Index was the drought index chosen for the CAP Model. Central Arizona Project water is surface water and long-term drought index is an appropriate measure for valuing its significance on price. One would expect that individuals purchasing water rights look at longer dry periods that cause decreased surface water and reservoir levels. The 12 month SPI is a reliable measure of surface level drought conditions. The Arizona CAP Model did not display heteroskedasticity so no standard error corrections are necessary. The econometric results illustrate the characteristics of Arizona's CAP water market.

Table 4.7 CAP Model with SPI 12
Dependent Variable: Natural Log of Adjusted Price per acre-foot

| **Variable Name** | Parameter Estimate | Standard Error | T-Value | Pr > T-Stat |
|---|---|---|---|---|
| *Intercept* | 3.02741 | 2.43363 | 1.24 | 0.2314 |
| *lnAF* | 0.44929 | 0.13725 | 3.27 | 0.0048 |
| *SPI_12* | -1.48323 | 0.50832 | -2.92 | 0.0101 |
| *Trend* | -0.30225 | 0.09016 | -3.35 | 0.0040 |
| *Population%change* | 1.11297 | 0.39632 | 2.81 | 0.0126 |
| *Munuse** | 1.23145 | 0.58717 | 2.10 | 0.0522 |
| *Envuse*** | 0.31899 | 0.72842 | 0.44 | 0.6673 |
| *Phx* | -2.35623 | 1.02888 | -2.29 | 0.0359 |
| Observations | 24 | | | |
| R-Squared | 0.7955 | | | |

*Insignificant at the 5% level
**Insignificant at 10% level

Table 4.8 CAP Model with SPI 12 six month lag
Dependent Variable: Natural Log of Adjusted Price per acre-foot

| **Variable Name** | Parameter Estimate | Standard Error | T-Value | Pr > T-Stat |
|---|---|---|---|---|
| *Intercept* | 2.78324 | 2.91468 | 0.95 | 0.3538 |
| *lnAF*** | 0.18280 | 0.13270 | 1.38 | 0.1873 |
| *SPI_12 six month lag*** | 0.40784 | 0.37170 | 1.10 | 0.2888 |
| *Trend *** | -0.14605 | 0.09985 | -1.46 | 0.1629 |
| *Population%change*** | 0.50329 | 0.49135 | 1.02 | 0.3209 |
| *Munuse* | 1.90395 | 0.67073 | 2.84 | 0.0119 |
| *Envuse*** | -0.21862 | 0.91815 | -0.24 | 0.8148 |
| *Phx*** | 0.28477 | 0.76476 | 0.37 | 0.7145 |
| Observations | 24 | | | |
| R-Squared | 0.7085 | | | |

The model that examines the SPI without a lag has excellent explanatory power with an r-squared of 0.79. The model that examines the SPI with a six month lag has a lower r-square and only one significant variable. Given the manner with which CAP water is administered, there is little bureaucratic delay in the transfer of water. The positive parameter estimate on the variable *lnAF* is not the result that one would expect. This result illustrates that for a 1% increase in the quantity of water purchased the price of water will increase by over 0.40%. This result indicates diseconomies of scale. As the quantity per acre-foot increases the price increases. One possible explanation is the large average size, over 7,000 acre feet, of the quantity of water transferred per transaction in combination with the low overall price of CAP water, and the fact that prices for CAP water are largely administratively determined.

The variable *SPI_12* is statistically significant and has the hypothesized negative parameter estimate. The variable *SPI_12* represents the Standard Precipitation Index calculated for the prior 12 months. This drought index captures long-term cumulative drought conditions. The negative parameter estimate suggests that as the region becomes wetter the price of a permanent water right becomes less expensive.

Two other significant variables in this model are the percent change in population and the year the transaction occurred. The results for the variable *population%change* indicate that when the percent change in population increases the price of a water right will increase. The variable *trend* is significant at the 1% level and the negative parameter estimate of this variable indicates that when there is a one unit increase in the year the transaction occurred the price paid for a water right decreases. This result does not hold with the expectation that the price of water becomes more expensive over time. This is explained by the fact that the price of CAP water is not freely negotiated and that administratively set CAP prices fluctuated both upward and downward over time.

The binary variables included in the model examined the new use for the water transfer. Binary variables are created if the new use is for environmental or municipal purposes and compared to CAP water purchased for agriculture. The binary variable *munuse* is statistically significant at only the 10% level when compared to water being purchased for agriculture. The positive parameter estimate indicates that water purchased for municipal purposes cost more. The binary variable *envuse* is insignificant in both models indicating that there is no statistical difference in water purchased for environmental and agricultural purposes.

The final binary variable estimated *phx* examines if the water transactions occurred in Phoenix or outside of the city. The variable is statistically significant at the 5% level and has a negative parameter estimate. The parameter estimate of -2.36 indicates that CAP water purchased in the Phoenix metropolitan area cost more than 200% more than CAP water supplied to areas outside of Phoenix.

### 4.5.3 Arizona Type II Model Results

Several purchases of Type II water have occurred during the study period. Type II water is groundwater that may be used for non-irrigation purposes. Since drought conditions take longer to affect groundwater levels a longer-term drought index is explored. The 24 month Standard Precipitation Index with and without a six month lag is used because this length drought index reflects longer term drought conditions such as, depleted groundwater sources. The Type II Model is also explored using a 12 month SPI with and without a six month lag these results are reported in Appendix.

The Type II Model displayed heteroskedasticity of an unknown nature. Several explanatory variables significance levels changed after adjusting for heteroskedasticity. The variable *trend* is significant at the 5% level before adjusting for heteroskedasticity and is now significant at the 1% level. The variable *other_ama* is no longer a significant variable when heteroskedasticity is corrected for. The corrected standard errors are reported in the results.

Table 4.9 Type II Model with SPI 24
Dependent Variable: Natural Log of Adjusted Price per acre-foot

| **Variable Name** | Parameter Estimate | Robust St. Error | Chi-Square | Pr > Chi-Square |
|---|---|---|---|---|
| *Intercept* | 7.71814 | 0.19289 | 1601.01 | <.0001 |
| *lnAF* | -0.05062 | 0.02179 | 5.40 | 0.0202 |
| *SPI24*** | -0.03018 | 0.03443 | 0.77 | 0.3807 |
| *Trend* | -0.01473 | 0.00713 | 4.26 | 0.0390 |
| *Population%Change*** | -0.06809 | 0.05395 | 1.59 | 0.2069 |
| *Tusama* | 0.38171 | 0.06549 | 33.97 | <.0001 |
| *Otherama*** | 0.30598 | 0.19776 | 2.39 | 0.1218 |
| *Golfuse*** | -0.07682 | 0.08460 | 0.82 | 0.3639 |
| Observations | 43 | | | |
| R-Squared | 0.7204 | | | |

**Insignificant at the 10% level using robust standard errors

Table 4.10 Type II Model with SPI 24 six month lag
Dependent Variable: Natural Log of Adjusted Price per acre-foot

| **Variable Name** | Parameter Estimate | Robust St. Error | Chi-Square | Pr > Chi-Square |
|---|---|---|---|---|
| *Intercept* | 7.53210 | 0.19053 | 1562.81 | <.0001 |
| *lnAF** | -0.03908 | 0.02015 | 3.76 | 0.0524 |
| *SPI24 six month lag* | -0.06970 | 0.02420 | 8.29 | 0.0040 |
| *Trend* | -0.01947 | 0.00643 | 9.16 | 0.0025 |
| *Population%Change*** | -0.01397 | 0.05349 | 0.07 | 0.7940 |
| *Tusama* | 0.42400 | 0.06607 | 41.18 | <.0001 |
| *Otherama*** | 0.31260 | 0.19695 | 2.52 | 0.1125 |
| *Golfuse*** | -0.07121 | 0.08021 | 0.79 | 0.3747 |
| Observations<br>R-Squared | 43<br>0.7397 | | | |

*Insignificant at the 5% level using robust standard errors
**Insignificant at the 10% level using robust standard errors

Both Arizona Type II Models have good explanatory power with an r-square over 0.72. This means that the independent variables included in the models explain 72% of the variation in the price per acre foot of a water right. Most results in this model are as one would expect. The significant coefficient of *lnAF* indicates that larger quantities of water rights sell for a lower price per acre foot than do smaller quantities of water rights. The elasticity of *lnAF* is approximately -0.04 in both models. This can be interpreted as the following: holding other independent variables fixed, a 1% increase in the quantity of water rights being transferred will result in a decrease in the price of the water right by .04%. This result indicates economies of scale in the Arizona Type II water market.

The independent variable *SPI24lag6* which represents the SPI 24 with six month lag is statistically significant at the 1% level and has a negative parameter estimate. This means that for a one unit increase in the SPI24 the price of water will decrease by 6%. This shows that as the region becomes wetter the price of water decreases. The variable *trend* is significant at the 5% level and has a negative parameter estimate. The result does not hold with ones' expectation that water prices increase over time.

The binary variables *tusama, phxama,* and *otherama* are created to examine how the location that the transaction occurred influenced the price of the water right. The *otherama* variable includes transactions that occurred in the Pinal and Prescott Active Management Areas. The results indicate that the binary variable *tusama* is statistically significant at the 1% level and when compared to the Phoenix AMA, the price of water is more expensive in the Tucson AMA. This illustrates that when someone sells a Type II water right in the Tucson the water right sells for more than if the transaction had occurred in the Phoenix AMA. The Phoenix AMA has a much greater water supply than the Tucson AMA, so one would expect the price of water to be greater in the Tucson AMA.

## 4.6 Conclusion

Results presented for Arizona's water market models indicate that regional water markets are strongly influenced by the characteristics of water transactions and demand factors. Econometric analysis has shown a statistically significant relationship between the price of a water right and the quantity of water transferred, the year the transaction occurred, the percent change in population, where the transaction occurred, the new use of the water right, and whether the transaction occurred during a drought year.

The statistical summary provided in Table 4.1 shows that Arizona's water markets, in particular the CAP and Type II markets, do not include a large number of transactions.  A well developed market exhibits the characteristics of: numerous transactions, easy market entry and exit, and price transparency.  The emerging markets in Arizona do not yet exhibit these characteristics.  They lack the large number of transactions that occur in other water markets established throughout the United States. The sporadic prices in the Type II Model suggest that this market has yet to settle on an equilibrium price.  Arizona's CAP transactions are not freely negotiated as in a "free market".  The infrastructure and institutional factors needed to support a market are in place in Arizona.  With time, the emerging water markets examined may develop into well established markets like those seen in other regions.

The results indicate that drought conditions play a role in the market price of water.  All Arizona markets tend to suggest that the new use of the water right is an important determinant in the price of the water right.  This may vary, though, depending on the regional characteristics of other markets such as the Type II.  Arizona has experienced tremendous growth over the 17 year study period.  This has cause an increase in the demand for municipal water and a possible explanation for the higher price of municipal water rights in some markets.  The implication of Arizona's growth is evident by the significance of the population variable included in most of the Arizona water models.

The significance of the drought indices in the Arizona Full Model, CAP Model and Type II Model illustrate the importance that climate variability has on the market price of water.  The six month lagged drought index is significant in both the Arizona Full and Type II Models while the non-lagged drought index is significant in the CAP

Model.  The difference in these results is easily explained by the nature of the CAP market.  CAP water is readily available and delivery dates are known in advance the change of ownership process is not the same as with other types of water rights in the State.  Drought has been a persistent issue throughout Arizona during many different time periods.  As drought conditions occur or intensify in Arizona, one can expect that the price of water will increase.  Arizona’s emerging water markets can look to the well established markets in other regions for potential strategies to implement in order to handle the pressures of prolonged drought and increased demand.

# Chapter 5: Modeling Water Transaction Prices in Colorado

## *5.1 Introduction*

Colorado, like Arizona, is characterized by rapidly increasing population, a significant agricultural sector, growing dependence on groundwater, and a significant reliance on Colorado River water and other surface water sources. Surface water is highly vulnerable to climate conditions making it a potentially unreliable water source. Significant water market activity has occurred for surface water supplies in the form of leases and purchases throughout the State of Colorado. Most of the State’s water market activity has occurred along the Front Range region. The Front Range is located just to the east of the Rocky Mountain foothills and runs north and south on the western edge of the Great Plains. The Front Range stretches from Colorado Springs in the south to Fort Collins in the north. This region contains approximately 80% of the population located in the State of Colorado (Active Along Colorado’s Front Range). The U.S. Census Bureau is expecting an increase in population of 35% by the year 2030; this will add another 1.5 million individuals to the states’ 2005 population of just over 4.6 million.

The headwaters of many major rivers that provide water supplies to the southwestern United States are located in the State of Colorado. The North and South Platte, the Arkansas, the Rio Grande, and the Colorado River all begin in the mountainous regions of Colorado. The Colorado River begins in the Rocky Mountain National Park in northern Colorado and travels southwesterly until it meets the Gunnison

River near Grand Junction Colorado. From Grand Junction the Colorado River continues into the State of Utah. The Colorado River is separated into two basins: the Upper and Lower, Colorado is located in the Upper Basin. The State of Colorado is allocated 3.855 million acre feet of Colorado River water each year. This amount was specified in the 1948 Upper Colorado River Basin Compact. Several major Colorado River tributaries also begin in the State of Colorado.

Nearly 80 percent of Colorado's annual water supply comes from the form of snow and agriculture is the dominate use for water supplies in the State of Colorado accounting for approximately 88 percent of total water use (Colorado River Water Users Association). Colorado River water is used to irrigate nearly two thirds of the State's irrigated land.

Annual average precipitation in Colorado is 16.5 inches but this varies widely from just a few inches to over 60 inches depending on the region. Much of Colorado's precipitation falls in the western slope where the Colorado River drainage is located but most of Colorado's population lives on the eastern slope along the Front Range. The eastern slope receives significantly less precipitation than the western slope. Therefore several transmountain diversions have been created to transport Colorado River water for agriculture and to the major cities on the eastern slope: Denver, Boulder, Colorado Springs and Pueblo. These transmountain diversions convey nearly half a million acre feet transported each year of Colorado River water. Colorado River water serves fewer than 500,000 people in its own natural basin, but due to transmountain diversions 1.85

million individuals use Colorado River water on the eastern slope. Colorado River water serves nearly 60% of Colorado's population (Colorado River Water Users Association).

The State of Colorado follows the prior appropriation doctrine for surface water. The prior appropriation doctrine is otherwise known as "first in time, first in right". This means that the date the water was first put to beneficial use is the priority date of the water right. Colorado is the only state in the United States that maintains a water court. Water rights in Colorado are established through this water court system. There are seven water courts, one for each of the major river basins. In order to obtain water rights, surface or groundwater, an application must be filed with one of the seven water courts. Water rights in Colorado can be absolute or conditional. Absolute rights have been diverted and put to beneficial use, while a conditional right is a water right that will be put to beneficial use in the future.

Groundwater rights follow a modified form of the prior appropriation doctrine. Colorado groundwater use is governed by the Ground Water Management Act of 1965 (Western States Water Law). This act was adopted to allow the development of groundwater resources, without causing harm to prior appropriators. Colorado is differs significant from Arizona in considering all water in the state to be tributary to a stream, unless established otherwise. If groundwater cannot be shown to be non-tributary, it falls under the prior appropriation doctrine and groundwater use must be integrated with existing water rights.

Water rights in Colorado can be held by any legal entity. Colorado considers water rights property so they can be bought, sold, or leased. Any change in the water right requires filing a change of water right application with the water court. Colorado's establishment of water rights as property has contributed to the development of water market activity within the state. Colorado has relatively well-defined water rights and as a result well-functioning water markets exist throughout the State.

## *5.2 Types of Water Sources in Colorado*

Colorado gets new water supplies from only one source: precipitation. Precipitation in the form of rain, snow or hail contributes to Colorado's water supply. Precipitation is the only source in the State of Colorado because no major rivers flow into the state. The headwaters of several major rivers that supply water to the southwestern United States begin in Colorado. Precipitation in Colorado is stored in one of the five ways: as snowpack, groundwater, surface water, in reservoirs, and as soil moisture (McKee *et al*.). Most of Colorado's surface water supplies exist on the west slope while the majority of groundwater is located along the eastern slope. Figure 5.1 illustrates the major rivers and basins located in the State of Colorado.

Figure 5.1 River Basins of Colorado

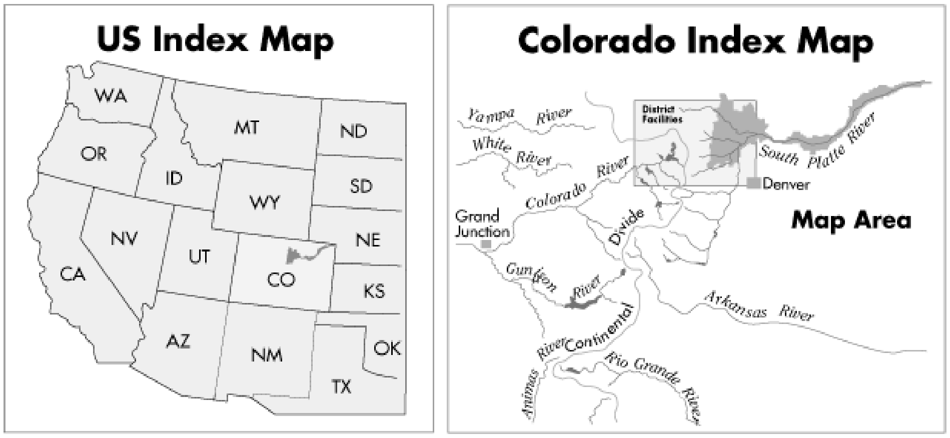
*Colorado Water, University of Colorado, Water Knowledge Webpage accessed at http://waterknowledge.colostate.edu/rivers.htm

Water serves several purposes within the State of Colorado. The largest consumer of water supplies in the State by far is agriculture. Other users within the State are municipalities, industries, recreation: such as snow making, hydropower, and for environmental purposes. Over 50% of the municipal water use in Colorado is used for landscape irrigation.

### 5.2.1 Colorado Big Thompson

The Colorado Big Thompson Project is one of the largest transmountain water diversion systems undertaken by the Bureau of Reclamation. The Colorado Big Thompson region is located in north-east Colorado (Fig. 5.2). The project diverts approximately 260,000 acre-feet of water annually from the Colorado River headwaters on the western slope to the Big Thompson River, a South Platte River tributary on the eastern slope (BuRec webpage). Colorado Big Thompson water is used for a variety of purposes such as agricultural, municipal, industrial, and environmental. The majority of the transactions presented in this paper are used for municipal or agricultural purposes. The market is well defined with numerous buyers and sellers, and is currently one of the few U.S. water markets where water rights are traded widely and competitively (Water Strategist, November, 2004). The Colorado Big Thompson project first started diverting surface water in 1947.

Figure 5.2 Colorado Big Thompson Study Area



*****Northern Colorado Water Conservancy District Webpage Accessed at http://www.ncwcd.org/project_features/cbt_maps.asp

## *5.3 Types of Water Entitlement in Colorado*

Most water transactions have occurred along the Front Range where the majority of Colorado's population resides. Most of the market activity has occurred primarily for surface water rights. Colorado's water markets are segmented by geographic area and type of water. A unique water market exists in the northeastern corner of Colorado referred to as the Colorado Big Thompson (CBT). Several other water markets exist throughout the state, but none of them come close to comparing to the volume of water transactions that occur in the CBT market. This chapter explores the impact that drought has had on the market price of water rights purchased within the State of Colorado. Table 5.1 illustrates the number of purchases of water rights that have occurred in the State of Colorado during the 17 year study period. Each water market is discussed in the following sections.

Table 5.1 Colorado Water Transaction Totals

| **Type of Water** | **# of Transactions** | **Average # of Acre Feet Transferred** | **Average Price ($2004 Dollars)** |
|---|---|---|---|
| Colorado Purchases | 1150 | 129.42 | 7152.27 |
| Colorado Purchases w/out CBT Transactions | 204 | 534.89 | 3287.65 |
| CBT Purchases | 946 | 41.87 | 7972.93 |
| All Front Range Purchases | 1132 | 281.94 | 6984.06 |
| Front Range Purchases w/out CBT Transactions | 186 | 1311.72 | 2742.17 |

## *5.4 Colorado Water Transaction Models*

Several econometric models are explored in this section. A model that combines all the purchases that have occurred throughout the State of Colorado is examined. A separate model for purchases occurring in the Colorado Big Thompson market is explored. A model examining the purchases along the Front Range concludes the analysis of Colorado's water markets.

Several explanatory variables are examined in each Colorado model. A two-stage lease squares derived demand equation is used to explain price variation in water rights. Variables that explain the characteristic of the water right are included such as: number of acre feet transferred in the transaction, the new type of use of the water right, and the location of the water right. Several transactions have occurred as a result of two interstate compact requirements on the Arkansas River with Kansas and the Rio Grande River with New Mexico, a dummy variable is included in the necessary models. Numerous demand variables are included in the models such as the drought conditions of the region, the year the transactions occurred, and the percent change in population of the region where the transaction occurred. Not all variables are included in each model, as not all variables are relevant to each model.

Price and quantity are endogenous variables in Colorado water markets. Therefore an instrumental variable equation is applied. The instrumental variables included in the quantity equation are: the type of seller, the average per capita income of the state, the drought index, and agricultural output prices.

As in the Arizona Chapter, several drought indices are explored to measure different lengths of dry conditions. In the models explored here, the Standard Precipitation Index (SPI) is used to explain the effect that drought has on the price of a water right. The 3 month SPI indicates short-term drought conditions and likely is the appropriate choice when analyzing leases. The 12 month SPI represents long-term drought conditions. Long-term drought conditions will likely be characterized by lowered surface water levels. Finally, a very longer-term drought index such as the 24 month SPI represents extended dry conditions or hydrological drought. These conditions can be seen in severe surface water depletion and decreasing groundwater levels. Figures 5.3 and 5.4 illustrate the variation in drought conditions for the 3 and 24 month SPI graphed for the Colorado Big Thompson region (Climate Division 4). The 3 month SPI fluctuates greatly depending on current precipitation patterns, while the 24 month SPI is much slower to react to dry or wetter periods due to the long-term cumulative nature of this index.

Figure 5.3 3 Month Standard Precipitation Index Climate Division 4 Colorado

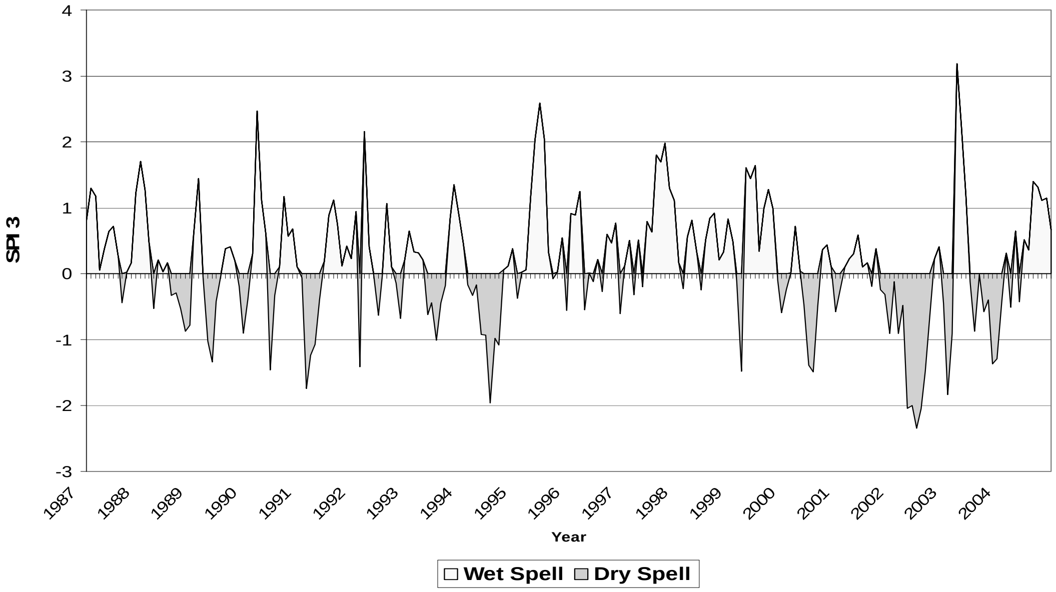
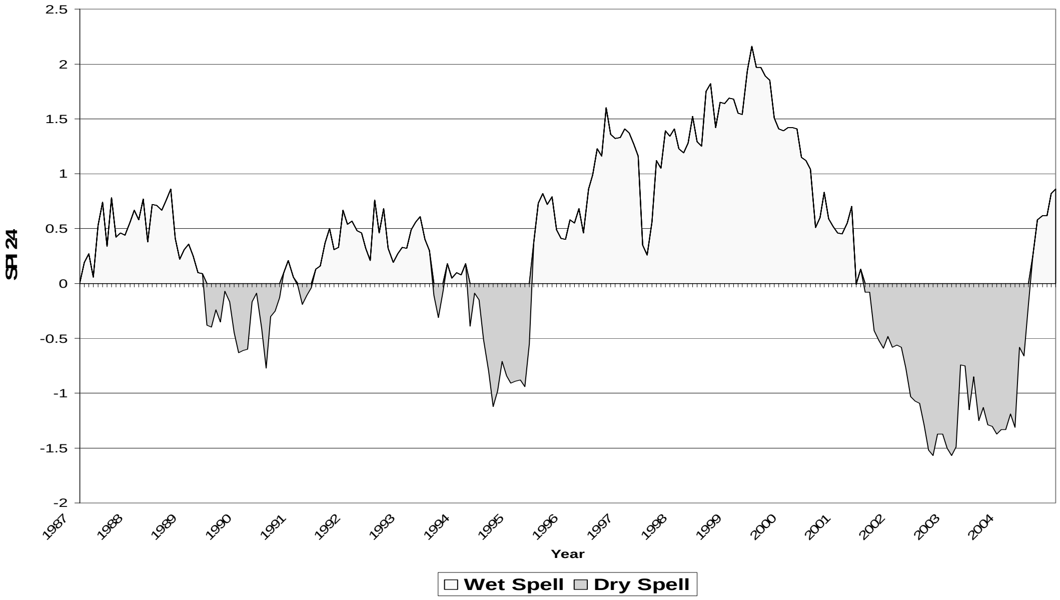


Figure 5.4 24 Month Standard Precipitation Index Climate Division 4 Colorado



## 5.4.1 Colorado Full Model

A total of 1150 purchases of water transactions occurred in Colorado during the 17 year study period. The average price paid for the purchase of a water right is $7152 dollars and the average quantity transferred is just less than 130 acre feet. This econometric model explores all the purchases of water rights within the entire State of Colorado.

A Two-Stage Least squares approach is used for the analysis of Colorado Full Model:

Price Equation:
$\text{lnAdjustedPrice} = \beta 0 + \beta 1 * \text{qhat} + \beta 2 * \text{SPI} + \beta 3 * \text{trend} + \beta 4 * \text{Population\%Change} + \beta 5 * \text{munuse} + \beta 6 * \text{envuse} + \beta 7 * \text{interstatecompuse} + \beta 8 * \text{rural} + \beta 9 * \text{lkmeredith}$

Instrumental Variable Equation:
$\text{lnaf} = \beta 0 + \beta 1 * \text{SPI} + \beta 2 * \text{lnavgpercap} + \beta 3 * \text{agseller} + \beta 4 * \text{lnalfalfa}$

Table 5.2 Description of variables included in the Colorado Full Model

| **Variable:** | **Description:** |
|---|---|
| *lnAdjustedPrice* | The natural log of the price per acre-foot in the transaction adjusted to year 2004 dollars |
| *lnAF* | The natural log of the volume of water per acre-foot purchased |
| *Qhat* | The predicted values for quantity from the instrumental variable equation |
| *SPI* | Standard Precipitation Index applied to each climate region |
| *Trend* | The year the transaction occurred minus 1987 |
| *Population%Change* | Percent change in population for the region the transaction occurred each year |
| *Munuse* | Binary variable equal to one if the water purchased is to be used for municipal purposes |
| *Envuse* | Binary variable equal to one if the water purchased is to be used for environmental purposes |
| *Rural* | Binary variable equal to one if the water transaction occurred in a rural region of Colorado |
| *Lkmeredith* | Binary variable equal to one if the water transaction is supplied from the Lake Meredith reservoir |
| *Lnavgpercap* | The natural log of the average per capita income for the county where the transaction occurred |
| *Agseller* | Binary variable equal to one if agriculture is the supplier of the water right compared to all other types of sellers |
| *Lnalfalfa* | The natural log of the three month average price as dollars/ton for dry alfalfa for the state of Colorado |

### 5.4.2 Colorado Big Thompson Model

A total of 946 purchases of water rights occurred in the Colorado Big Thompson region during the study period 1987 to 2004. The average price paid for the purchase of a water right in this region is $7972 (2004 dollars). The average quantity transferred is only 41 acre feet during the study period. The Colorado Big Thompson region is a well established water market and this econometric model attempts to explain the price per acre foot of water rights.

A Two-Stage Least squares approach is used for the analysis of Colorado Big Thompson Model:

Price Equation:
$\text{lnAdjustedPrice} = \beta0 + \beta1 * \text{qhat} + \beta2 * \text{SPI} + \beta3 * \text{trend} + \beta4 * \text{Population\%Change} + \beta5 * \text{munuse}$

Instrumental Variable Equation:
$\text{lnaf} = \beta0 + \beta1 * \text{SPI} + \beta2 * \text{lnavgpercap} + \beta3 * \text{agseller} + \beta4 * \text{lnalfalfa}$

Table 5.3 Description of variables included in the Colorado Big Thompson Model

| **Variable:** | **Description:** |
|---|---|
| *lnAdjustedPrice* | The natural log of the price per acre-foot in the transaction adjusted to year 2004 dollars |
| *lnAF* | The natural log of the volume of water per acre-foot purchased |
| *Qhat* | The predicted values for quantity from the instrumental variable equation |
| *SPI* | Standard Precipitation Index applied to each climate region |
| *Trend* | The year the transaction occurred minus 1987 |
| *Population%Change* | Percent change in population for the region the transaction occurred each year |
| *Munuse* | Binary variable equal to one if the water purchased is to be used for municipal purposes |
| *Lnavgpercap* | The natural log of the average per capita income for the county where the transaction occurred |
| *Agseller* | Binary variable equal to one if agriculture is the supplier of the water right compared to all other types of sellers |
| *Lnalfalfa* | The natural log of the three month average price as dollars/ton for dry alfalfa for the state of Colorado |

### 5.4.3 Front Range Model

This model explores all the purchases that occurred in the Front Range region of Colorado including the CBT transactions. There are a total 1132 transactions that occurred during the study period. The average price paid for the purchase of a water right in the Front Range region is $6984 and the average quantity transferred is 281 acre feet.

A Two-Stage Least squares approach is used for the analysis of the Front Range Model:

Price Equation:
$\text{lnAdjustedPrice} = \beta 0 + \beta 1 * \text{qhat} + \beta 2 * \text{SPI} + \beta 3 * \text{trend} + \beta 4 * \text{Population\%Change} + \beta 5 * \text{munuse} + \beta 6 * \text{envuse}$

Instrumental Variable Equation:
$\text{lnaf} = \beta 0 + \beta 1 * \text{SPI} + \beta 2 * \text{lnavgpercap} + \beta 3 * \text{agseller} + \beta 4 * \text{lnalfalfa}$

Table 5.4 Description of variables included in the Front Range Model

| **Variable:** | **Description:** |
|---|---|
| *lnAdjustedPrice* | The natural log of the price per acre-foot in the transaction adjusted to year 2004 dollars |
| *lnAF* | The natural log of the volume of water per acre-foot purchased |
| *Qhat* | The predicted values for quantity from the instrumental variable equation |
| *SPI* | Standard Precipitation Index applied to each climate region |
| *Trend* | The year the transaction occurred minus 1987 |
| *Population%Change* | Percent change in population for the region the transaction occurred each year |
| *Munuse* | Binary variable equal to one if the water purchased is to be used for municipal purposes |
| *Envuse* | Binary variable equal to one if the water purchased is to be used for environmental purposes |
| *Lnavgpercap* | The natural log of the average per capita income for the county where the transaction occurred |
| *Agseller* | Binary variable equal to one if agriculture is the supplier of the water right compared to all other types of sellers |
| *Lnalfalfa* | The natural log of the three month average price as dollars/ton for dry alfalfa for the state of Colorado |

## *5.5 Colorado Econometric Results*

A double-log two-stage least squares equation is used to estimate all Colorado water market models. As with the Arizona models, several different functional forms are examined. These include: linear, log-linear, linear-log, and double-log specifications. The results of the Box-Cox transformation indicated a double-log model for all of the

Colorado models. The double-log model is a commonly used functional form and the interpretation of the results is straightforward.

All Colorado models are tested for heteroskedasticity using White's General Test and the Breusch-Pagan Lagrange Multiplier Test. All of the Colorado models examined exhibit heteroskedasticity of an unknown nature. Each of the Colorado models have been corrected for heteroskedasticity and their robust standard errors are reported in the results.

Nearly all water transactions that occurred in the State of Colorado, during the 1987 to 2004 time period, are surface water transactions. Therefore, long-term drought index like the SPI12 is appropriate to accurately reflect the drought conditions linked to the price of surface water transactions. The SPI12 reflects longer term drought conditions that effect surface water and reservoir levels. The SPI12 is examined for each of the different Colorado models with and with out a six month lag. Their results are reported and contrasted in the preceding sections. All Colorado models are also estimated with the longer-term SPI 24 drought index as well. These results are presented in the Appendix.

### 5.5.1 Colorado Full Model Results

The Colorado Full Model examines all the purchases of water rights that occurred during the 17 year study period. All water right transactions are included in this model. The Colorado Full Model exhibits heteroskdasticity of an unknown nature so the corrected standard errors are reported.

When adjusting for heteroskedasticity, the binary variable *rural* is no longer significant in the Colorado Full Model. All other variables remained the same after correcting for heteroskedasticity. The endogenous variable quantity remained significant and negative after applying the instrumental variable approach to produce consistent estimators.

Table 5.5 Colorado Full Model with SPI 12
Dependent Variable: Natural Log of Adjusted Price per acre-foot

| **Variable Name** | Parameter Estimate | Robust Standard Error | Chi-Square | Pr > Chi-Square |
|---|---|---|---|---|
| *Intercept* | 8.83591 | 0.42623 | 429.75 | <.0001 |
| *Qhat* | -0.41976 | 0.10674 | 15.46 | <.0001 |
| *SPI 12* | -0.06523 | 0.02004 | 10.59 | 0.0011 |
| *Trend* | 0.09353 | 0.01049 | 79.47 | <.0001 |
| *Population%Change* | -0.19477 | 0.02547 | 58.47 | <.0001 |
| *Munuse* | 0.52521 | 0.07439 | 49.85 | <.0001 |
| *Envuse* | -0.69175 | 0.22442 | 9.50 | 0.0021 |
| *Interstatecompuse*** | 0.00738 | 0.57849 | 0.00 | 0.9898 |
| *Rural*** | 0.62041 | 0.40483 | 2.35 | 0.1254 |
| *Lkmeredith* | -3.77727 | 0.54195 | 48.58 | <.0001 |
| Observations<br>R-Squared | 1150<br>0.6140 | | | |

**Insignificant at the 10% level

Table 5.6 Colorado Full Model with SPI 12 six month lag
Dependent Variable: Natural Log of Adjusted Price per acre-foot

| **Variable Name** | Parameter Estimate | Robust Standard Error | Chi-Square | Pr > Chi-Square |
|---|---|---|---|---|
| *Intercept* | 8.96379 | 0.42346 | 448.09 | <.0001 |
| *Qhat* | -0.45125 | 0.10588 | 18.16 | <.0001 |
| *SPI 12 six month lag*** | -0.01280 | 0.02236 | 0.33 | 0.5671 |
| *Trend* | 0.09135 | 0.01041 | 77.05 | <.0001 |
| *Population%Change* | -0.20814 | 0.02670 | 60.79 | <.0001 |
| *Munuse* | 0.52104 | 0.07365 | 50.05 | <.0001 |
| *Envuse* | -0.66938 | 0.22581 | 8.79 | 0.0030 |
| *Interstatecompuse*** | -0.00825 | 0.57444 | 0.00 | 0.9885 |
| *Rural*** | 0.64156 | 0.41491 | 2.39 | 0.1220 |
| *Lkmeredith* | -3.69912 | 0.54156 | 46.66 | <.0001 |
| Observations | 1150 | | | |
| R-Squared | 0.6124 | | | |

**Insignificant at the 10% level

The two models explored have good explanatory power with an r-squared of 0.61. The variable *qhat* represents the predicted values for quantity of water transferred. The results for the explanatory variable *qhat* indicate economies of scale in both models. This means that as the volume of the water right increases the price of that water right decreases.

The Colorado Full Model examined two models, one that explored the 12 month SPI with a six month lag and one that explored the 12 month SPI without a lag. The 12 month SPI without a lag is statistically significant at the 1% level while the 12 month SPI with a six month lag is not significant. The parameter estimates of -0.06 for the 12 month SPI without a lag indicates that as a region becomes wetter, the price of a water right decreases. This is the result one would expect in the region.

Several independent variables other than the drought indices and the quantity variable exhibit expected results. The time trend variable is significant at the 1% level and the parameter estimate in both models indicates that over time water rights become more expensive. The variable *population%change* is statistically significant in both models with a negative parameter estimate. This is not the result one would expect. The result indicates that as the population percent change of an area increases the price of a water right decreases.

Several binary variables are included that explored the new use of the water right and the location that the transaction occurred. The binary variables that examined the new use of the water right include: *munuse, envuse,* and *interstatecompuse.* These three uses are compared to the new use being agricultural purposes. If the water right is being purchased for municipal use it is more expensive than if that same water right is purchased for agricultural purposes. On the other hand if a water right is purchased for environmental reasons then it is significantly less than if being purchased for agriculture. The binary variable *interstatecompuse* is not statistically significant, which indicates that there is no statistical difference in price between water being purchased for agriculture and interstate compact agreements.

Two other binary variables are included that represent the location the transaction occurred. These binary variables are *rural* and *lkmeredith.* The binary variable *lkmeredith* is statistically significant when compared to water transactions occurring along the Front Range. If the purchase of a water transaction occurred in a rural region of Colorado when compared to the Front Range, there is no statistical difference in the price. The results also indicated that water transactions coming from the Lake Meredith reservoir cost much less than purchases of water rights in the Front Range region. This likely is due to particular institutional arrangements involving water stored in Lake Meredith.

### 5.5.2 Colorado Big Thompson Results

The Colorado Big Thompson Model examines all the purchases of water rights that occurred during the study period 1987 to 2004. Colorado Big Thompson water is Colorado River water that is brought across the mountains for use in the northeastern corner of Colorado. Colorado Big Thompson transactions make up a large majority of all transactions in Colorado. Since all Colorado Big Thompson transactions involve surface water, the 12 month SPI with and without a six month lag are examined in separate models while holding all other variables constant. The econometric models analyzed exhibited heteroskedasticity of an unknown nature as a result and the corrected robust standard errors are reported in the tables below. These econometric models attempt to explain the price variation in purchases of water rights in the Colorado Big Thompson water market.

When correcting for heteroskedasticity in the Colorado Big Thompson Model, all explanatory variables retained the same level of significance. The endogenous variable quantity remained significant and negative after applying the instrumental variable approach to produce consistent estimators.

Table 5.7 Colorado Big Thompson Model with SPI 12
Dependent Variable: Natural Log of Adjusted Price per acre-foot

| **Variable Name** | Parameter Estimate | Robust Standard Error | Chi-Square | Pr > Chi-Square |
|---|---|---|---|---|
| *Intercept* | 12.22830 | 0.50382 | 589.08 | <.0001 |
| *Qhat* | -1.36635 | 0.14339 | 90.80 | <.0001 |
| *SPI12*** | -0.00737 | 0.01559 | 0.22 | 0.6364 |
| *Trend* | 0.04585 | 0.01179 | 15.13 | 0.0001 |
| *Population%Change* | -0.16415 | 0.01084 | 229.38 | <.0001 |
| *Munuse*** | 0.02552 | 0.02673 | 0.91 | 0.3398 |
| Observations | 946 | | | |
| R-Squared | 0.8802 | | | |

**Insignificant at the 10% level

Table 5.8 Colorado Big Thompson Model with SPI 12 six month lag
Dependent Variable: Natural Log of Adjusted Price per acre-foot

| **Variable Name** | Parameter Estimate | Robust Standard Error | Chi-Square | Pr > Chi-Square |
|---|---|---|---|---|
| *Intercept* | 12.62666 | 0.51176 | 608.76 | <.0001 |
| *Qhat* | -1.47598 | 0.14626 | 101.84 | <.0001 |
| *SPI12 six month lag* | 0.08589 | 0.01638 | 27.51 | <.0001 |
| *Trend* | 0.03544 | 0.01223 | 8.40 | 0.0037 |
| *Population%Change* | -0.18578 | 0.01108 | 281.11 | <.0001 |
| *Munuse** | 0.05290 | 0.02741 | 3.72 | 0.0536 |
| Observations | 946 | | | |
| R-Squared | 0.8762 | | | |

*Insignificant at the 5% level
**Insignificant at the 10% level

The Colorado Big Thompson Models have excellent explanatory power with over 87% of the variation in price being explained in the models that examined the 12 month SPI with and without a six month lag. Nearly all the explanatory variables are significant at the 1% level, with only the new use of the water right being insignificant at the 10% level in the model that examined the SPI 12 without a lag. The SPI 12 with a six month lag is statistically significant at the 1% level while the SPI 12 without a lag is a statistically insignificant variable.

As seen in the previous Colorado model discussed, economies of scale also exist in the Colorado Big Thompson region. The negative parameter estimate of the variable *qhat* suggests that as the quantity of a water right increases the price that water right sells for decreases. This is as one would expect in a well developed water market, such as the Colorado Big Thompson market.

Several derived demand variables are examined and all are statistically significant at the 1% level. The year the transactions occurred is a significant variable and the results indicate that over time the price of a water right increases. The percent change in population of the region the transaction occurred is an important variable in determining the price of a water right. The negative parameter estimate suggests that as the population increases, the price of a water right becomes less expensive.

Binary variables are examined that denote the new use of the water right. In the Colorado Big Thompson region, water is mainly used for municipal or agricultural purposes. The binary variable *munuse* was created to estimate the price difference between water purchased for municipal use and water purchased for agricultural purposes. The results suggest that there is no difference in the price paid for the different uses in the model that examines the SPI 12 without a lag. In the model that examines the SPI 12 with a six month lag, the variable *munuse* is significant at the 10% level with a positive parameter estimate. The result is not what one would expect due to the insignificance of municipal water rights in the SPI 12 model without a lag and the relatively small parameter estimate in the SPI 12 model with a six month lag.

### 5.5.3 Front Range Results

The majority of Colorado's population lives along the Front Range. The Front Range begins in the north in the Fort Collins/Greenly area and continues south through Boulder and Denver ending in Colorado Springs. The population of this area is increasing at an astounding rate which has helped to encourage the development of water markets. One very well developed market was discussed earlier, the Colorado Big Thompson market, these water transactions are included in the Front Range Model. The econometric models analyzed in this section examine all the purchases of water rights that have occurred along the Front Range from 1987 to 2004. The 12 month SPI with and without a six month lag are explored as independent variables in two separate models. The Colorado Front Range Model displays heteroskedasticity of an unknown nature and the corrected standard errors are reported.

When adjusting for heteroskedasticity in the Front Range Model, all explanatory variables retain their level of significance. The endogenous variable quantity is also still statistically significant and negative after applying the instrumental variable approach to produce consistent estimators.

Table 5.9 Front Range Model with SPI 12
Dependent Variable: Natural Log of Adjusted Price per acre-foot

| **Variable Name** | Parameter Estimate | Robust Standard Error | Chi-Square | Pr > Chi-Square |
|---|---|---|---|---|
| *Intercept* | 8.64103 | 0.36413 | 563.15 | <.0001 |
| *Qhat* | -0.36168 | 0.09263 | 15.25 | <.0001 |
| *SPI12* | -0.07055 | 0.01956 | 13.01 | 0.0003 |
| *Trend* | 0.09365 | 0.01035 | 81.82 | <.0001 |
| *Population%Change* | -0.18279 | 0.02254 | 65.75 | <.0001 |
| *Munuse* | 0.53190 | 0.07396 | 51.72 | <.0001 |
| *Envuse* | -0.72102 | 0.23479 | 9.43 | 0.0021 |
| Observations | 1132 | | | |
| R-Squared | 0.6015 | | | |

Table 5.10 Front Range Model with SPI 12 six month lag
Dependent Variable: Natural Log of Adjusted Price per acre-foot

| **Variable Name** | Parameter Estimate | Robust Standard Error | Chi-Square | Pr > Chi-Square |
|---|---|---|---|---|
| *Intercept* | 8.81190 | 0.36474 | 583.67 | <.0001 |
| *Qhat* | -0.40338 | 0.09298 | 18.82 | <.0001 |
| *SPI12 six month lag*** | -0.02219 | 0.01996 | 1.24 | 0.2663 |
| *Trend* | 0.08977 | 0.01042 | 74.20 | <.0001 |
| *Population%Change* | -0.19414 | 0.02270 | 73.18 | <.0001 |
| *Munuse* | 0.52889 | 0.07295 | 52.56 | <.0001 |
| *Envuse* | -0.69881 | 0.23582 | 8.78 | 0.0030 |
| Observations | 1132 | | | |
| R-Squared | 0.6012 | | | |

**Insignificant at the 10% level

The Front Range Models, which include CBT transactions, have good explanatory power with over 60% of the variation in price being explained by the variables included in the model. The variable *qhat* is statistically significant at the 1% level which indicates economies of scale within the Front Range water markets. This result indicates that has the volume associated with the water right increases the price of that water right decreases.

The 12 month SPI without a six month lag is statistically significant at the 1% level with a parameter estimate of -0.07. This result indicates that as a region becomes wetter the price of a water right decreases. For a one unit increase in the 12 month SPI the price of a water right decreases by 7%.

The significance of the time trend variable indicates that water rights increase in price over time. This holds with the expectation that water prices increase over time after adjusting for inflation. The percent change in the population of the region where the water transaction occurred is also a significant variable in determining the price of a water right. The negative parameter estimate on the *population%change* variable indicates that as population increases the price of water rights decrease.

Binary variables denote the new use of the water right. The variables *munuse* and *envuse* look at water rights purchased for municipal and environmental purposes and compares them to water rights purchased for agricultural purposes. Both variables *munuse* and *envuse* are significant at the 1% level in both models. The positive parameter estimate on *munuse* indicates that water purchased for municipal uses are more expensive than that same water right purchased for agricultural purposes. The negative parameter estimate of -0.70 on the binary variable *envuse* indicates that water rights purchased along the Front Range for environmental purposes cost less that water rights purchased for agricultural uses.

## *5.6 Conclusion*

As in Arizona the results from the Colorado water market models suggest that water markets within Colorado are influenced by the characteristics of the water right and demand factors. The econometric results presented in this chapter indicate that there is a statistically significant relationship between the price of a water right and the quantity transferred, the year the transaction took place, the drought index, the percent change in population, and the new use of the water right.

Unlike Arizona, the statistic summary shows that a large number of transactions have occurred throughout the State of Colorado. A large majority of these transactions occurred in the Colorado Big Thompson region. The Colorado Big Thompson water market is a well established and exhibits the traditional characteristics of a market: numerous transactions, easy market entry and exit, and price transparency. The political means and infrastructure are available throughout the State of Colorado to support well developed water markets such as the Colorado Big Thompson market. Several water markets exist in Colorado but they do not involve water transaction activity to the same extent as the CBT market. With time and increased pressure on water supplies we may see a progression of these immature markets developing into well functioning markets.

The results indicate that drought conditions play a significant role in determining the price of a water right. The results of each model illustrate that the long-term drought index, 12 month SPI, is an appropriate measures for assessing drought conditions on the market price of water. The year the transactions took place is also significant in almost every model analyzed. This result holds with ones expectation that the price of water rights increase over time.  Several derived demand variables are significant in nearly all the models examined the percent change in population greatly influences the price of water rights.  In every model except the Colorado Big Thompson Model the results indicated that the new use of the water right played a role in determining the market price of water rights.

As in Arizona, drought has been a significant problem throughout the study period in Colorado.  The importance of climate variability on the market price of water is suggested in the significance of the drought indices included in each econometric model. Historic records show that drought is a common occurrence in the State of Colorado and throughout the western United States.   As drought conditions continue and or become more severe one will likely see increased water market activity throughout Colorado with increases in water market prices.  Projected population estimates continue to show significant growth along the Front Range region of Colorado.  This increasing population along the Front Range has contributed to the establishment of water markets and better management of statewide water supplies.  Water markets may be one strategy for handling this expected increase in demand for municipal water supplies.

# Chapter 6: Modeling Transaction Prices in New Mexico

## *6.1 Introduction*

New Mexico, like much of the western United States is characterized by population growth, a large agricultural sector, an increasing pressure on water supplies, and susceptibility to drought conditions.  All of these factors have contributed to the development of water markets in select areas of the state. New Mexico’s current population is just under 2 million with a large majority living in the Albuquerque area. The US Census Bureau has predicted a 15% increase in the state-wide population by the year 2030.  New Mexico withdrew 4.2 million acre feet of water during 1990 (New Mexico Water Use).  New Mexico relies on two sources: groundwater and surface water to satisfy their demand.  Of the 4.2 million acre feet withdrawn nearly half was from groundwater sources.

Agriculture is the primary user of water in the State of New Mexico.  76% of the total water supplied is used by the agricultural sector.  Another 5% is used for livestock watering, mining operations and other industrial purposes.  Municipal use only accounts for 9% of the total water use within New Mexico and approximately 10% of water loss is due to evaporation (New Mexico Office of the State Engineer).  Municipal water use in the state is primarily supported by groundwater use with less than 20% of total domestic water supplies coming from surface water supplies.

New Mexico treats surface water and groundwater under the prior appropriation doctrine.  Prior appropriation is the common doctrine governing water rights throughout the western United States. Prior appropriation is often referred to as “first in time, first in right”. This means that the first user in time is allowed the first right to the use of the water. The first user is assigned a priority date of when the water was put to beneficial use each user after receives a later priority date. Priority dates are used to determine who legal receives water in times of shortage. The earlier the priority date the more senior the water rights.

The State of New Mexico is similar to the diverse hydrological conditions found in Arizona. They both have regions that range from dry desert to alpine mountains. Like Arizona, New Mexico is dependent on high elevation snowfall and rain. New Mexico, unlike Arizona, has several major rivers that supply surface water throughout the state. New Mexico depends on both groundwater and surface water supplies to meet its demand. Drought conditions are a common occurrence in New Mexico, and when these conditions occur they create an increased pressure on supplies.

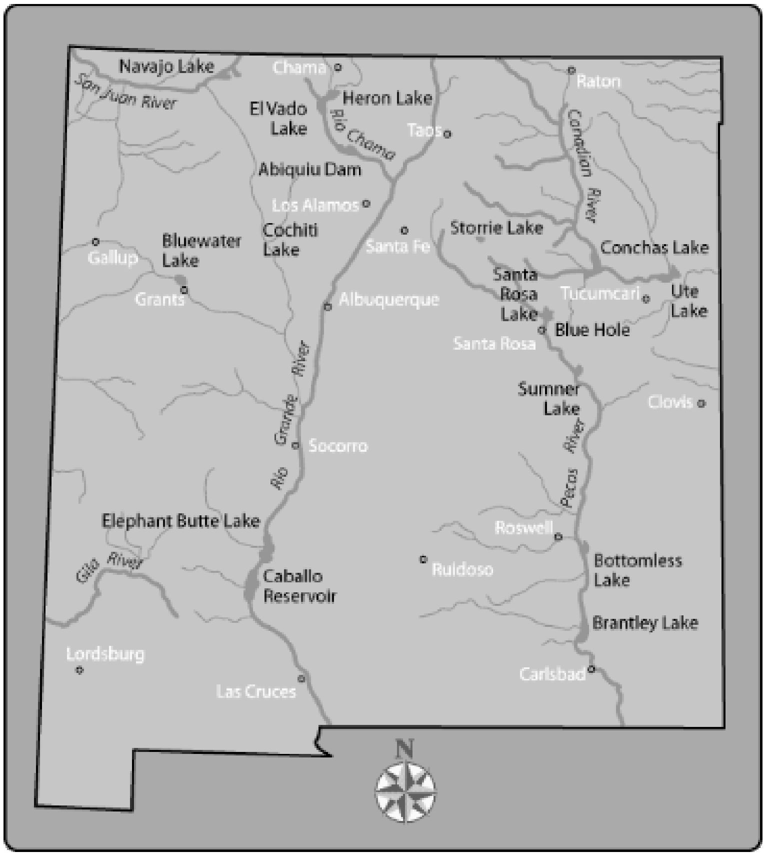
## *6.2 Types of Water Sources in New Mexico*

New Mexico has two primary sources of water: Surface water and groundwater. Each source accounts for approximately half of the total water use in New Mexico. Both sources of water in New Mexico were initially supplied from precipitation. This precipitation may have been in the form of rain or snow and may have fallen within the State of New Mexico or in the mountainous region of Colorado that lies just north of New Mexico. New Mexico depends on Colorado precipitation for some of its surface water supplies.  Both surface and groundwater supplies are discussed in further detail in the following sections.

### 6.2.1 Surface Water

Surface water comes from either rainfall or snow in the higher elevations of New Mexico and Southern Colorado.  New Mexico, like Arizona and Colorado, receives an annual allotment of Colorado River water.  New Mexico is not dependent on their Colorado River allocation as they have other surface water supplies and groundwater to draw upon.  Other major surface water supplies in New Mexico include: the Rio Grande, Pecos and San Juan River.  Several smaller rivers and tributaries are also located throughout the state.  Figure 6.1 illustrates the surface water supplies located in New Mexico.

Figure 6.1 New Mexico Surface Water Sources

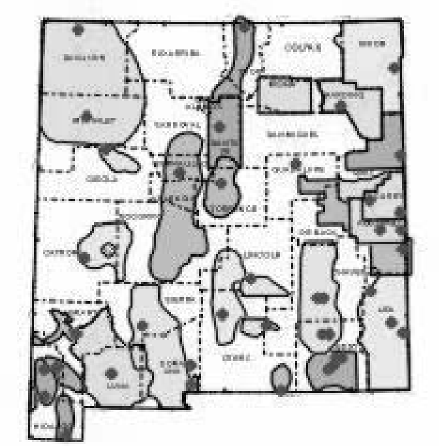


* New Mexico Land of Enchantment Tourism Webpage, accessed at http://www.newmexico.org/index2.php

### 6.2.2 Groundwater

Throughout the State of New Mexico, groundwater is relied heavily upon by water users. Groundwater is replenished in the form of rain, snow, and river water seeping into the aquifer. There are 32 recognized aquifers located throughout New Mexico. Figure 6.2 illustrates these groundwater basins. Groundwater accounts for nearly half of the water used in New Mexico. As with most western states groundwater is not being replenished at the same rate it is being withdrawn creating declining groundwater levels throughout New Mexico.

Figure 6.2 New Mexico Groundwater Basins



* New Mexico Groundwater locations, USGS New Mexico Current Drought Conditions Webpage, accessed at http://nm.water.usgs.gov/drought/index.html

## *6.3 Types of Water Entitlement in New Mexico*

In New Mexico both groundwater and surface water sources are involved in market transactions. New Mexico's water markets are primarily segmented by geographic location. A market exists for Pecos River water but sufficient data is not available for meaningful statistical analysis. Market transactions occur in northern New Mexico but these are not numerous enough to create a statistical model for this region. The water markets that do provide enough data for analysis are the Gila-San Francisco Basin, the Albuquerque area, and a State-wide model. Table 6.1 illustrates the number of water purchases that occurred during the study period in the State of New Mexico. Each region is discussed in further detail in the following sections.

Table 6.1 New Mexico Water Transaction Totals

| **Type of Water** | **# of Transactions** | **Average # of Acre Feet Transferred** | **Average Price ($2004 dollars)** |
|---|---|---:|---:|
| New Mexico | 119 Purchases | 280.25 | 2,641.43 |
| Albuquerque | 31 Purchases | 159.56 | 2,316.77 |
| Gila/San Fran | 65 Purchases | 20.68 | 3,049.03 |

### 6.3.1 Albuquerque

Albuquerque is the only major city located in the State of New Mexico. With a population of just under half a million, nearly a third of New Mexico's population lives in the Albuquerque area. Nearly all of Albuquerque's water use comes from groundwater pumping. In 1993, the USGS released a study indicating depleted groundwater levels in the aquifers surrounding the Albuquerque area (USGS). The City of Albuquerque has implemented several conservation programs to decrease groundwater use such as: charging summer surcharges to customers when exceeding 300% of their winter use average and importing more surface water supplies (City of Albuquerque).

Leases and purchases of water rights have occurred in the Albuquerque region for a variety of purposes. It is not uncommon to see water transactions occurring for landscape irrigation, given the restrictions in place on landscape watering. Transactions also occur for municipal, agricultural and environmental purposes. During the study period, water market activity has begun to increase in the Albuquerque region. As this region continues to grow, an increase in water market activity is likely.

### 6.3.2 Gila-San Francisco Basin

The Gila-San Francisco Basin is located in southwestern New Mexico's Grant County which has a population of 29,842 (Sonoran Institute). The Basin is a diverse region in which water is used for mining, agricultural, municipal, environmental and recreational purposes. This basin has a growing demand for municipal water supplies, which exerts economic pressure for water to be transferred out of other uses. Much of the Gila-San Francisco Basin lies within the Gila National Forest and Gila Wilderness Area. The basin is divided into two sub-basins, the Gila and the San Francisco.

The major population center in the area is Silver City. Historically mining and ranching were the dominant land and water uses in the Basin. Over the years, both industries have declined and their water rights have been sold for other uses. Water used in the Gila-San Francisco Basin comes primarily from surface water sources, but groundwater pumping is also widespread. The Gila-San Francisco Basin was closed to additional groundwater appropriations during the mid-1960s.

Water market activity began in the Gila-San Francisco Basin when the basin was closed to additional appropriation in the 1960s. Water rights were primarily held by ranchers and farmers, but in the 1960s mining interests purchased large quantities of water rights from irrigators. Water rights are now held by a variety of interests: individual homeowners, irrigators, small water service organizations, Silver City, mining corporations, and others. Water transactions that occur now typically involve much smaller quantities of water rights than mining interests purchased from farmers decades ago.

## *6.4 New Mexico Water Transaction Models*

Six econometric models are analyzed in this chapter. First, a model that explores all New Mexico purchases is examined with and without a lagged drought index. Binary variables are created to capture any regional affects of specific transaction locations. The Albuquerque Models examine only those purchases which occurred in the Albuquerque area. Two Albuquerque Models are explored one with a lagged drought index and one without. Finally a model that examines the water transactions that occurred in the Gila-San Francisco Basin is explored. Other water market activity has occurred in the State of New Mexico, but due to limited data, a statistical analysis of these models would not be meaningful.

A two stage lease squares derived demand equation is used to explain the price variation in water rights. Several explanatory variables are included in the model such as: the number of acre feet transferred, location of the transaction, and the new use of the water right. Since water market prices are not only influenced by their own characteristics but also by a combination of other factors demand variables are included in the model. These demand factors include: population percent change of the region, the drought index, and the year the transaction occurred. Price and quantity are endogenous variables in all New Mexico water markets. An instrumental variable approach is applied to produce consistent estimators. The instrumental variables included in the quantity equation are: the type of seller, the average per capita income of the state, the drought index, and agricultural output prices. Not all variables are included in each model, as some variables are not relevant to the model analyzed.

New Mexico relies on precipitation that has occurred in the southern Colorado Mountains for a majority of their surface water supplies. Much of this surface water flows into New Mexico by means of the Rio Grande. The Rio Grande supplies water to a large majority of the State. Two separate climate regions are explored for the drought indices included in each model. A drought index that links the climate region to the location of the transaction is examined as in the previous models discussed in the Arizona and Colorado Chapters. A drought index that uses the southern Colorado climate region is also explored due to locations within New Mexico's dependence on the climate of this region. Both climate regions are examined on a long-term scale that would reflect hydrological drought conditions. Results from the southern Colorado climate region are discussed in the appendix.

Hydrological drought conditions indicate a decline in both surface and groundwater supplies. The 24 Standard Precipitation Index is the logical choice for reflecting long-term drought patterns in either climate region and is examined with and without a six month lag. Figures 6.3 and 6.4 illustrate the difference in the 3 month SPI and 24 month SPI response to precipitation patterns in the Albuquerque climate region. As the figures display the 3 month SPI fluctuates on a short-term scale while the 24 month SPI is slow to react to changing conditions. All New Mexico models are also analyzed using the 12 month SPI these results are presented in the Appendix. Each model and the effect of the particular climate region are discussed in the subsequent sections.

Figure 6.3 3 month Standard Precipitation Index Climate Division 5 New Mexico

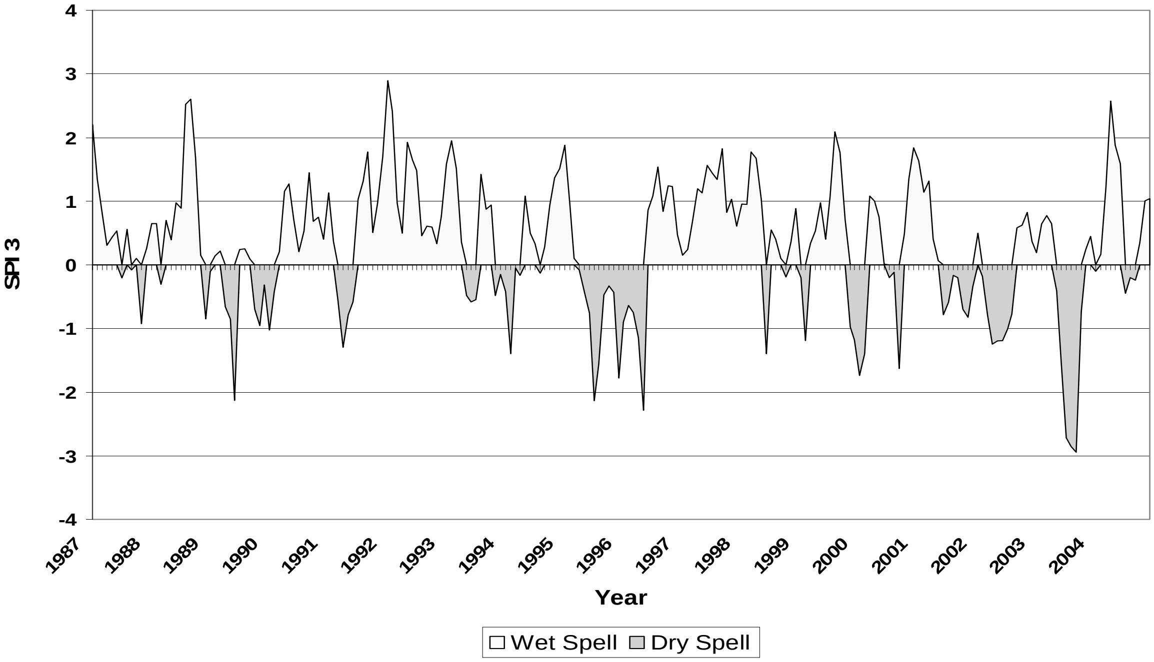
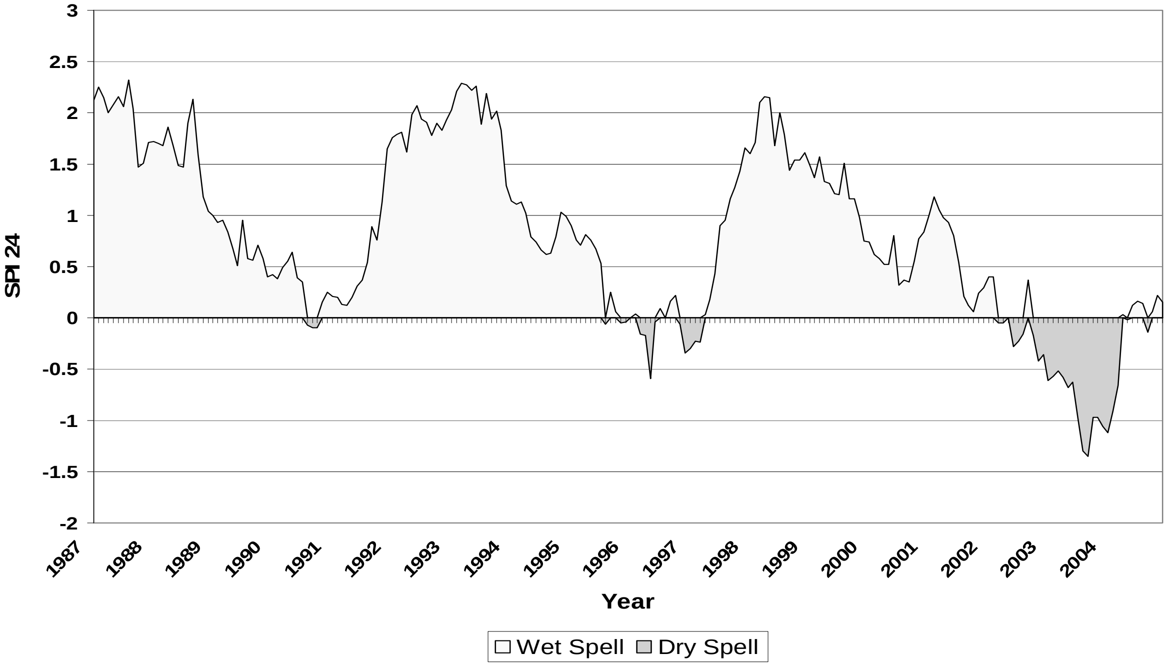


Figure 6.4 24 month Standard Precipitation Index Climate Division 5 New Mexico



## 6.4.1 New Mexico Full Model

A total of 119 purchases occurred in New Mexico during the study period. The average price paid for the purchase of a water right is $2,641 (2004 dollars) per acre foot. The average volume transferred for the purchase of a water right is 280 acre feet. This econometric model examines the price variation for the purchase of a water right in the State of New Mexico.

A Two-Stage Least squares approach is used for the analysis of the New Mexico Full Model:

Price Equation: lnAdjustedPrice = β0 + β1* qhat + β2*SPI + β3*trend + β4*Population%Change + β5*munuse + β6*interstatecompuse + β7*silvercity + β8*north + β9*rural

Instrumental Variable Equation: $lnaf = \beta0 + \beta1*SPI + \beta2* lnavgpercap + \beta3*agseller + \beta4*lnalfalfa$

Table 6.2 Description of variables included in the New Mexico Full Model

| **Variable:** | **Description:** |
|---|---|
| *lnAdjustedPrice* | The natural log of the price per acre-foot in the transaction adjusted to year 2004 dollars |
| *lnAF* | The natural log of the volume of water per acre-foot purchased |
| *Qhat* | The predicted values for quantity from the instrumental variable equation |
| *SPI* | The Standard Precipitation Index |
| *Trend* | The year the transaction occurred minus 1987 |
| *Population%Change* | Percent change in population for the region the transaction occurred each year |
| *Munuse* | Binary variable equal to one if the water purchased is to be used for municipal purposes compared to agriculture |
| *Interstatecompuse* | Binary variable equal to one if the water purchased is to be used for interstate compact agreements compared to agriculture |
| *Silvercity* | Binary variable equal to one if the water transaction occurred in the Silver City area compared to Albuquerque |
| *North* | Binary variable equal to one if the water transaction occurred in northern New Mexico compared to Albuquerque |
| *Rural* | Binary variable equal to one if the water transaction occurred in a rural region of New Mexico compared to Albuquerque |
| *Lnavgpercap* | The natural log of the average per capita income for the county where the transaction occurred |
| *Agseller* | Binary variable equal to one if agriculture is the supplier of the water right compared to all other types of sellers |
| *Lnalfalfa* | The natural log of the three month average price as dollars/ton for dry alfalfa for each state |

### 6.4.2 Albuquerque Model

A total of 31 purchases occurred in the Albuquerque area during the study period. The average price paid for the purchase of a water right in the Albuquerque area is $2,316 and the average quantity transferred is just less than 160 acre feet. This econometric model explores all the purchases of water right in the Albuquerque area.

A Two-Stage Least squares approach is used for the analysis of the Albuquerque Model:

Price Equation: $lnAdjustedPrice = \beta0 + \beta1 * qhat + \beta2 * SPI + \beta3 * trend + \beta4 * Population\%Change + \beta5 * munuse$

Instrumental Variable Equation: $lnaf = \beta0 + \beta1 * SPI + \beta2 * lnavgpercap + \beta3 * agseller + \beta4 * lnalfalfa$

Table 6.3 Description of variables included in the Albuquerque Model

| **Variable:** | **Description:** |
|---|---|
| *lnAdjustedPrice* | The natural log of the price per acre-foot in the transaction adjusted to year 2004 dollars |
| *lnAF* | The natural log of the volume of water per acre-foot purchased |
| *Qhat* | The predicted values for quantity from the instrumental variable equation |
| *SPI* | The Standard Precipitation Index |
| *Trend* | The year the transaction occurred minus 1987 |
| *Population%Change* | Percent change in population for the region the transaction occurred each year |
| *Munuse* | Binary variable equal to one if the water purchased is to be used for municipal purposes compared to agriculture |
| *Lnavgpercap* | The natural log of the average per capita income for the county where the transaction occurred |
| *Agseller* | Binary variable equal to one if agriculture is the supplier of the water right compared to all other types of sellers |
| *Lnalfalfa* | The natural log of the three month average price as dollars/ton for dry alfalfa for each state |

### 6.4.3 Gila-San Francisco Model

The Gila-San Francisco Model examines all the purchases of water rights that have occurred in the Gila and San Francisco Basins. A total of 65 purchases occurred during the study period from 1977 to 2004. The average price paid for the purchase of a water right in this region is $3,049. This is a bit higher than seen in other regions of New Mexico. The average quantity transferred is 20 acre feet. This is significantly lower than the volume transferred in purchases of water rights in other regions of the state.

A Two-Stage Least squares approach is used for the analysis of the Gila-San Francisco Model:

Price Equation: $\ln AdjustedPrice = \beta 0 + \beta 1 * qhat + \beta 2 * SPI + \beta 3 * trend + \beta 4 * Population\%Change + \beta 5 * gila + \beta 6 * \ln COMEXcopper + \beta 7 * \ln Calf$

Instrumental Variable Equation: $\ln af = \beta 0 + \beta 1 * SPI + \beta 2 * \ln avgpercap + \beta 3 * agseller + \beta 4 * \ln alfalfa$

Table 6.4 Description of variables included in the Gila-San Francisco Model

| **Variable:** | **Description:** |
|---|---|
| *lnAdjustedPrice* | The natural log of the price per acre-foot in the transaction adjusted to year 2004 dollars |
| *lnAF* | The natural log of the volume of water per acre-foot purchased |
| *Qhat* | The predicted values for quantity from the instrumental variable equation |
| *SPI* | The Standard Precipitation Index |
| *Trend* | The year the transaction occurred minus 1987 |
| *Population%Change* | Percent change in population for the region the transaction occurred each year |
| *Gila* | Binary variable equal to one if the water transaction occurred in the Gila sub-basin |
| *Lncomexcopper* | The natural log of the New York commodity index price for copper |
| *Lncalf* | The natural log of the sale price of calves in the State of New Mexico |
| *Lnavgpercap* | The natural log of the average per capita income for the county where the transaction occurred |
| *Agseller* | Binary variable equal to one if agriculture is the supplier of the water right compared to all other types of sellers |
| *Lnalfalfa* | The natural log of the three month average price as dollars/ton for dry alfalfa for each state |

## *6.5 Econometric Results*

As in the Colorado Chapter, a double-log two stage least squares equation is used to estimate all New Mexico water market models. Several different functional forms are examined. These include: linear, log-linear, linear-log, and double-log specifications.

The results of the Box-Cox transformation indicated a double-log model for all of the New Mexico models. The double-log model is a commonly used functional form and the interpretation of the results is straightforward. A two-stage least squares method is necessary because price and quantity are endogenous variables in all New Mexico water markets.

All New Mexico models are tested for heteroskedasticity using White's General Test and the Breusch-Pagan Lagrange Multiplier Test. The New Mexico Model that examined all the purchases of water rights exhibited heteroskedasticity of an unknown nature, as did the Albuquerque Model and the Gila-San Francisco Model. All of the New Mexico water market models displayed heteroskedasticity their robust standard errors are reported in the results.

### 6.5.1 New Mexico Full Model Results

The New Mexico Full Model examines the purchases of water rights that occurred during the study period. This model displayed heteroskedasticity of an unknown nature. The robust standard errors are displayed in the results. Water transactions that occurred in the New Mexico Full Model are a combination of both surface and groundwater. Groundwater supplies are much slower to react to changing precipitation patterns than surface water supplies. Therefore a longer-term drought index such as the SPI 24 is more appropriate in estimating long term hydrological conditions that may potential affect water prices. The SPI 24 is examined with and without a six month lag and the results are compared below. The long-term SPI 12 drought index is also explored and the results are presented in the appendix.

When adjusting for heteroskedasticity, all but one of the explanatory variables included in the New Mexico Full Model remained significant. The binary variable *silvercity* was originally an insignificant variable but after correcting for heteroskedasticity is significant at the 10% level. The endogenous variable quantity remained an insignificant variable in the New Mexico Full Model after applying an instrumental variable approach.

Table 6.5 New Mexico Full Model with SPI 24
Dependent Variable: Natural Log of Adjusted Price per acre-foot

| **Variable** | Parameter Estimate | Robust Standard Error | Chi-Square | Significance Level |
|---|---|---|---|---|
| *Intercept* | 8.07391 | 0.42578 | 359.58 | <.0001 |
| *Qhat*** | -0.14860 | 0.17051 | 0.76 | 0.3835 |
| *SPI_24*** | 0.02391 | 0.11316 | 0.04 | 0.8327 |
| *Trend* | 0.04134 | 0.01867 | 4.90 | 0.0268 |
| *Population%Change*** | -0.00311 | 0.05699 | 0.00 | 0.9564 |
| *Munuse*** | -0.26106 | 0.16573 | 2.48 | 0.1152 |
| *Interstatecompuse* | -1.43181 | 0.57456 | 6.21 | 0.0127 |
| *Silvercity** | 0.39694 | 0.20793 | 3.64 | 0.0563 |
| *North*** | 0.42220 | 0.33253 | 1.61 | 0.2042 |
| *Rural*** | -0.40291 | 0.27493 | 2.15 | 0.1428 |
| Observations<br>R-Squared | 119<br>0.2765 | | | |

*Insignificant at the 5% level
** Insignificant at the 10% level

Table 6.6 New Mexico Full Model with SPI 24 six month lag
Dependent Variable: Natural Log of Adjusted Price per acre-foot

| **Variable** | Parameter Estimate | Robust Standard Error | Chi-Square | Significance Level |
|---|---|---|---|---|
| *Intercept* | 8.03023 | 0.42080 | 364.17 | <.0001 |
| *Qhat*** | -0.10259 | 0.16225 | 0.40 | 0.5272 |
| *SPI_24 six month lag*** | -0.03569 | 0.10899 | 0.11 | 0.7433 |
| *Trend* | 0.03879 | 0.01735 | 5.00 | 0.0253 |
| *Population%Change*** | -0.01643 | 0.06109 | 0.07 | 0.7880 |
| *Munuse** | -0.28427 | 0.15924 | 3.19 | 0.0742 |
| *Interstatecompuse* | -1.47796 | 0.56266 | 6.90 | 0.0086 |
| *Silvercity** | 0.39067 | 0.19556 | 3.40 | 0.0651 |
| *North*** | 0.42318 | 0.34242 | 1.53 | 0.2165 |
| *Rural*** | -0.39471 | 0.27670 | 2.03 | 0.1537 |
| Observations<br>R-Squared | 119<br>0.2785 | | | |

*Insignificant at the 5% level
** Insignificant at the 10% level

The New Mexico Full Model has very poor explanatory power with less than 30% of the variation in price explained by the independent variables included in the model. The variable *qhat* represents the predicted values for quantity of water transferred. The insignificance of this variable indicates that quantity does not play a role in determining the market price of water. Both drought indices are insignificant indicating that precipitation patterns do not influence the price of water rights in the New Mexico Full Model.

The *trend* variable is significant at the 5% level in both models which suggest water right prices increase over time. Other significant variables include if the transaction occurred for municipal purposes, interstate compact agreements, or in the Silver City area. The binary variable *interstatecompuse* has a negative parameter estimate suggesting that water rights purchased for interstate compact agreements, when compared to agricultural uses, sell for significantly less. The variable *silvercity* has a positive parameter estimate of approximately 0.39, this indicates that water rights in the Silver City area sell for a significantly higher price than water rights purchased in the Albuquerque area.

### 6.5.2 Albuquerque Model Results

The Albuquerque Models examine the purchases of water rights that occurred in the Albuquerque metropolitan area. The Albuquerque Models displayed heteroskedasticity of an unknown nature. The robust standard errors are reported in the results of the Albuquerque Models. Water transactions that occurred in the Albuquerque Model are a combination of both surface and groundwater. Groundwater supplies are much slower to react to changing precipitation patterns than surface water supplies. Therefore a longer-term drought index such as the SPI 24 is more appropriate in estimating long term hydrological conditions that may potential affect water prices. The SPI 24 is examined with and without a six month lag and the results are compared below. The long-term SPI 12 drought index is also explored and the results are presented in the appendix.

When adjusting the Albuquerque Model for heteroskedasticity, all explanatory variables retained their original level of significance. The endogenous variable quantity remains an insignificant variable after applying an instrumental variable approach to produce consistent estimators.

Table 6.7 Albuquerque Model with SPI 24
Dependent Variable: Natural Log of Adjusted Price per acre-foot

| **Variable** | Parameter Estimate | Robust Standard Error | Chi-Square | Significance Level |
|---|---|---|---|---|
| *Intercept* | 8.01791 | 0.33652 | 567.69 | <.0001 |
| *Qhat*** | -0.12621 | 0.08019 | 2.48 | 0.1155 |
| *SPI_24* | 0.14803 | 0.05434 | 7.42 | 0.0065 |
| *Trend* | 0.09392 | 0.00732 | 164.48 | <.0001 |
| *Population%Change* | -0.30293 | 0.05625 | 29.01 | <.0001 |
| *Munuse*** | -0.17724 | 0.13044 | 1.85 | 0.1742 |
| Observations<br>R-Squared | 31<br>0.8657 | | | |

** Insignificant at the 10% level

Table 6.8 Albuquerque Model with SPI 24 six month lag
Dependent Variable: Natural Log of Adjusted Price per acre-foot

| **Variable** | Parameter Estimate | Robust Standard Error | Chi-Square | Significance Level |
|---|---|---|---|---|
| *Intercept* | 8.06599 | 0.38538 | 438.05 | <.0001 |
| *Qhat*** | -0.12498 | 0.08685 | 2.07 | 0.1501 |
| *SPI_24 six month lag*** | 0.08978 | 0.05534 | 2.63 | 0.1047 |
| *Trend* | 0.08727 | 0.00767 | 129.50 | <.0001 |
| *Population%Change* | -0.27652 | 0.05751 | 23.12 | <.0001 |
| *Munuse*** | -0.16740 | 0.17036 | 0.97 | 0.3258 |
| Observations<br>R-Squared | 31<br>0.8480 | | | |

** Insignificant at the 10% level

The Albuquerque Models have good explanatory power, despite only a few statistically significant variables. The R-Squared of approximately 0.85 indicates that 85% of the variation in price is explained by the variables included in the models. The predicted values for quantity of water transferred do not explain any variation in price. The drought index is significant in the model that examines the drought index without a lag. The positive parameter estimate of the drought index suggests that as the

Albuquerque region becomes wetter the price of water rights increase. This is not the result one would expect.

The population percent change variable is significant in both models. The negative parameter estimate of this variable suggests that for a one unit increase in the population percent change the price of a water right will decrease. In other words, an increase in population will decrease the price that water rights sell for. The other significant variable included in the Albuquerque Models is the time trend. The variable *trend* is significant in both the model that examines drought with and without a six month lag. The significance of this variable indicates that in this model the price of water rights increases over time.

### 6.5.3 Gila-San Francisco Model Results

The Gila-San Francisco Model examines all the purchases of water rights in the Gila and San Francisco Basins. This model did display heteroskedasticity of an unknown nature and the corrected standard errors are reported. The Gila-San Francisco Models consist of primarily surface water transactions. Therefore, the 12 month SPI is examined with and without a six month lag. The 12 month SPI reflects hydrological drought conditions and surface water levels.

When adjusting for heteroskedasticity in the Gila-San Francisco Model all variables except one retain their original level of significance. The variable *qhat* is the predicted values for the quantity of water transferred in the Gila-San Francisco region. This variable is originally insignificant in the model that examines the drought index without a lag but after correcting for heteroskedasticity it becomes significant at the 10%

level. Prior to applying the instrumental variable approach to the endogenous variable quantity, quantity was insignificant in determining water prices.

Table 6.9 Gila-San Francisco Model with SPI 12
Dependent Variable: Natural Log of Adjusted Price per acre-foot

| **Variable** | Parameter Estimate | Robust Standard Error | Chi-Square | Significance Level |
|---|---|---|---|---|
| *Intercept* | 14.99237 | 1.69870 | 77.89 | <.0001 |
| *Qhat** | 0.16513 | 0.08487 | 3.79 | 0.0517 |
| *SPI_12*** | -0.09358 | 0.07824 | 1.43 | 0.2317 |
| *Trend* | 0.05166 | 0.01705 | 9.18 | 0.0025 |
| *Gila* | 0.92126 | 0.12116 | 57.82 | <.0001 |
| *Population%change* | 0.20383 | 0.03562 | 32.74 | <.0001 |
| *lnCopper* | -3.66605 | 0.44019 | 69.36 | <.0001 |
| *lnCalve* | 1.80570 | 0.28267 | 40.81 | <.0001 |
| Observations<br>R-Squared | 65<br>0.6989 | | | |

*Insignificant at the 5% level
** Insignificant at the 10% level

Table 6.10 Gila-San Francisco Model with SPI 12 six month lag
Dependent Variable: Natural Log of Adjusted Price per acre-foot

| **Variable** | Parameter Estimate | Robust Standard Error | Chi-Square | Significance Level |
|---|---|---|---|---|
| *Intercept* | 14.19718 | 1.53356 | 85.70 | <.0001 |
| *Qhat*** | 0.07520 | 0.07447 | 1.02 | 0.3126 |
| *SPI_12 six month lag* | -0.28155 | 0.09761 | 8.32 | 0.0039 |
| *Trend* | 0.06440 | 0.01601 | 16.17 | <.0001 |
| *Gila* | 0.91211 | 0.11646 | 61.34 | <.0001 |
| *Population%change* | 0.15337 | 0.04023 | 14.54 | 0.0001 |
| *lnCopper* | -3.54348 | 0.41856 | 71.67 | <.0001 |
| *lnCalve* | 1.93309 | 0.26658 | 52.58 | <.0001 |
| Observations<br>R-Squared | 65<br>0.7231 | | | |

** Insignificant at the 10% level

The Gila-San Francisco Models have good explanatory power with approximately 70% of the variation in price being explained by the variables included in the models. The *qhat* variable is in the model that examines drought with a six month lag. Also, *qhat* is only significant at the 10% level in the other model. This indicates that larger quantities of water rights do not sell for a significantly lower price per acre foot than do smaller quantities of water rights, suggesting that economies of scale are not evident in the Gila-San Francisco Basin's water market.

The longer-term *12 month SPI with a six month lag* is found to be statistically significant at the 1% level. The marginal effect of the *24 month SPI with a six month lag* is -0.28. The marginal effect for the longer-term drought model is consistent with the hypothesis that as drought intensifies the price for water increases. The parameter estimate of the *24 month SPI with a six month lag* indicates that for a one unit increase in the *SPI,* the price of water decrease by 28%. The results indicate that buyers and sellers of water rights react to long-term hydrological conditions. The *12 month SPI without a lag* is an insignificant variable. This result is likely attributed to the time delay associated with changing water right ownership in New Mexico.

The binary variable *Gila* is statistically significant at the 1% level. This variable measures the difference between water purchased in the Gila sub-Basin and water transactions that occurred in the San Francisco sub-Basin. The significant coefficient of the *Gila* variable is approximately .91 and the marginal effect is 1.50. This result can be interpreted to mean that if the water rights transaction occurred in the Gila sub-Basin when compared to the San Francisco sub-Basin, the price is approximately 91% higher.

This result is consistent with the rapid and extensive development in the Gila sub-Basin, compared to the San Francisco sub-Basin.

The change in population over the years is a statistically significant variable in determining the price of a water right. The variable *population%change* is statistically significant at the 1% level. The estimate for the variable *population%change* is interpreted as the following, holding all other variables constant an increase in the population percent change of the Gila-San Francisco area will result in an increase in the price of water rights.

The natural log of the annual average price of copper is a significant variable in determining the price a water right sells for. The variable *lncopper* has a large test statistic and is statistically significant at the 1% level. The results indicate that the elasticity of the variable *lncopper* is -3.6. This result illustrates that for a one percent increase in the average annual price of copper the price of a water right decreases by over 3%. As the price of copper becomes more expensive, the price of water rights declines. This result is counterintuitive, given the prominence of copper mining as a water use in this region. However, the mining industry in Grant County New Mexico (Sonoran Institute) has declined significantly over the study period and this decline appears unrelated to copper prices.

The natural log of the annual average calf price variable is statistically significant at the 1% level. The result of 1.85 is an elasticity measure and indicates, that for a one percent increase in the annual average calf price, the price of a water right will sell for nearly 2% more.

## 6.6 Conclusion

The results presented for New Mexico water markets suggest that water market activity located throughout New Mexico is more sporadic and less developed when compared to the Front Range of Colorado. Econometric analysis indicates that precipitation patters do not play a large role in determining the price at which water rights sell. With the exception of the Gila-San Francisco area, both the New Mexico Models and the Albuquerque Models indicated that only a few variables are responsible for the price variation in water rights. The results did indicate that there is a statistically significant relationship between the price of a water right and the year the transaction occurred, the percent change in population, where the transaction occurred, and the new use of the water right.

The emerging water markets in New Mexico do not exhibit that same characteristics of the well developed water markets discussed in the Colorado Chapter. The water markets currently occurring in New Mexico do not display a large number of transactions, price transparency, or easy market entry and exit. As New Mexico's water markets continue to develop, we may see price decisions based on a larger range of characteristics. Increased pressure on water supplies that may be related to population growth and/or drought conditions, likely will encourage the expansion of existing markets in other areas of the state and intensify the degree of activity within the current markets.

# Chapter 7: Modeling Transaction Prices across States and Urban Areas

## *7.1 Introduction*

The intermountain region of the southwestern United States consists of: Arizona, Colorado, New Mexico, Nevada and Utah. These states are all characterized by rapid population growth, large agricultural sectors, dependence on Colorado River water, and declining groundwater sources. Several large and growing metropolitan areas exist in each of these states, creating a pressure for increased municipal water supplies. These states depend on several sources for their water supply: Colorado River water, groundwater, effluent, and surface water supplies other than the Colorado River.

Each state has unique hydrological conditions that vary from desert to high alpine. The headwaters of many rivers that provide water supplies to the southwestern United States begin in the intermountain region. Precipitation provides water supplies in the form of rain, snowfall, and runoff. A significant portion of the water supplied is stored in the form of snow in the mountains during the winter and contributes to the groundwater and surface water supplies as the snow melts.

Throughout the intermountain region of the southwestern United States, surface water rights are determined by the doctrine of prior appropriation. Arizona, Colorado, New Mexico, Nevada, and Utah all follow variations of the prior appropriation doctrine. This doctrine is often referred to as “first in time, first in right”. Several states in the intermountain region treat groundwater rights in a similar manner. Groundwater and surface water rights are often thought of as separate entities. Often groundwater rights are determined by ownership of the land. An individual may withdrawal any and all water that lies beneath their property. Colorado, New Mexico, Utah and Nevada manage both groundwater and surface water under the prior appropriation system, with each state having unique modifications. As discussed previously, Arizona has a bifurcated water law. Colorado considers all water surface or ground to be tributary to the stream unless determined otherwise.

## *7.2 Types of Water Entitlement*

The intermountain and urban water transaction models examine all the reported water transactions that have occurred in: Arizona, Colorado, and New Mexico, Nevada and Utah. The Intermountain Model analyzes water transactions throughout each state while the Urban Model explores only the transactions that occurred in large metropolitan areas. This chapter explores the impact that drought has had on the purchases of water rights that occurred in the intermountain region. Table 7.1 illustrates the number of transactions, the average quantity transferred, and the average price paid in each state during the study period. Table 7.1 illustrates that there is a significant difference between each state. In some states the average number of acre feet transferred in extremely low while the average price per acre foot is quite high. In other cases the opposite occurs. The intermountain and urban water markets are discussed in detail in the following section.

Table 7.1 Intermountain Water Transaction Totals

| **State** | **# of Transactions** | **Average # of Acre Feet Transferred** | **Average Price ($2004 Dollars)** |
|---|---|---|---|
| Arizona | 92 | 3,840.72 | 1,161.18 |
| Colorado | 1151 | 129.42 | 7,152.27 |
| New Mexico | 119 | 280.25 | 2,641.43 |
| Nevada | 198 | 485.98 | 4,566.09 |
| Utah | 45 | 3,751.07 | 1,580.76 |
| Total: | 1605 | 1697.49 | 3,420.35 |

## *7.3 Intermountain Water Transaction Model*

The Intermountain Model analyzes all the purchases of water rights that occurred in the intermountain region during the study period 1987 to 2004. A total of 1,605 transactions occurred during the study period with, over half transpiring in the state of Colorado. Two econometric models with be examined in this section. The first model will analyze all the water transactions that occurred using a long term drought index, the 24 month SPI. This model will then be compared to a model that analyzes the water transaction data using the 24 month SPI lagged six months. The lag accounts for the time delay associated with the change of ownership of water rights. All other explanatory variables will remain constant while, changing only the drought index.

Several explanatory variables other than the Standard Precipitation Index (SPI) are included in the models examined. A two stage least squares derived demand equation is used to explain price variation in water rights. Variables that explain the characteristics of the water right are included such as: the quantity of acre feet transferred, the new use of the water right, and the state that the transaction occurred. Demand variables are also included in the model such as: the drought index, the year the transaction occurred, and the percent change in population of the region where the transaction took place. Price and quantity are endogenous variables in the intermountain region. Therefore an instrumental variable equation is applied. The instrumental variables included in the quantity equation are: the type of seller, the average per capita income of the state, the drought index, and agricultural output prices.

## *7.4 Urban Water Transaction Model*

The Urban Model is very similar to the Intermountain Model in that it explores all the water transactions that occurred in Arizona, Colorado, New Mexico, Nevada, and Utah. The only difference is that the Urban Model only examines the purchases that occurred in the large metropolitan areas of these states. As in the Intermountain Model, we see a significant portion of the transactions occurring in Colorado. Several metropolitan areas are included in this model. In Arizona transactions that occurred in Tucson and Phoenix are included, all transactions that occurred along the Front Range of Colorado are examined and the major metropolitan area for New Mexico is Albuquerque. In Nevada all transactions occurring in Las Vegas and the Reno/Sparks area are included, and finally in Utah all transactions that occurred in the Salt Lake City, Provo, and Park City area are analyzed.

As in the Intermountain Model several explanatory variables explain the variation in price per acre foot. In the Intermountain Model the state dummy variable indicates the state where the transaction took place, but in the Urban Model the actual city denotes the location of the transaction. All other variables included are the same as in the intermountain region model. As in the Intermountain Model, price and quantity are endogenous. A two stage least squares derived demand equation is applied in the estimation. Using an instrumental variable approach, quantity becomes a function of the drought index, average per capita income, the type of seller, and agricultural output prices.

Several drought indices are measured to examine the impact that drought has had on the market price of water. The SPI 12 and 24 are the logical choices when exploring hydrological drought conditions. Groundwater and surface water levels react to longer-term dry conditions. Both the SPI 12 and 24 are examined with and without a six month lag. The results for the SPI 12 are reported in the appendix and the SPI 24 with and without a six month lag are presented below. As in the Intermountain Model, the Urban Model included water transactions that include both groundwater and surface water transactions. The SPI 24 represents a long-term cumulative index that indicates changes in both surface water and groundwater.

### 7.4.1 Intermountain Model

A total of 1,605 transactions are included in the intermountain econometric model. Of those 1,605 transactions, over 1,100 occurred in Colorado. The average quantity transferred in the intermountain region is just less than 1,700 acre feet but this amount ranged significantly from just 129 acre feet in Colorado to nearly 4,000 acre feet in Arizona and Utah. The average price paid for an acre foot of water in the intermountain region of the western United States during the 17 year study period is $3,420 (2004 dollars). As with quantity, price also ranged significantly within the intermountain region from just \$1,160 in Arizona to \$7,150 in Colorado. This econometric model explores all the purchases of water rights that occurred in the intermountain region.

A Two-Stage Least squares approach is used for the analysis of the Intermountain Model:

Price Equation: $lnAdjustedPrice = \beta0 + \beta1 * qhat + \beta2 * SPI + \beta3 * trend + \beta4 * Population\%Change + \beta5 * munuse + \beta6 * envuse + \beta7 * recuse + \beta8 * az + \beta9 * nm + \beta10 * nv + \beta11 * ut$

Instrumental Variable Equation: $lnaf = \beta0 + \beta1 * SPI + \beta2 * lnavgpercap + \beta3 * agseller + \beta4 * lnalfalfa$

Table 7.2 Description of variables included in the Intermountain Model

| **Variable:** | **Description:** |
|---|---|
| *lnAdjustedPrice* | The natural log of the price per acre-foot in the transaction adjusted to year 2004 dollars |
| *lnAF* | The natural log of the volume of water per acre-foot purchased |
| *Qhat* | The predicted values for quantity from the instrumental variable equation |
| *SPI* | The Standard Precipitation Index |
| *Trend* | The year the transaction occurred minus 2004 |
| *Population%Change* | Percent change in population for the region the transaction occurred each year |
| *Munuse* | Binary variable equal to one if the water purchased is to be used for municipal purposes compared to agriculture |
| *Envuse* | Binary variable equal to one if the water purchased is to be used for environmental purposes compared to agriculture |
| *Recuse* | Binary variable equal to one if the water purchased is to be used for recreational purposes compared to agriculture |
| *Az* | Binary variable equal to one if the water transaction occurred in the state of Arizona compared to Colorado |
| *Nm* | Binary variable equal to one if the water transaction occurred in the state of New Mexico compared to Colorado |
| *Nv* | Binary variable equal to one if the water transaction occurred in the state of Nevada compared to Colorado |
| *Ut* | Binary variable equal to one if the water transaction occurred in the state of Utah compared to Colorado |
| *Lnavgpercap* | The natural log of the average per capita income for the county where the transaction occurred |
| *Agseller* | Binary variable equal to one if agriculture is the supplier of the water right compared to all other types of sellers |
| *Lnalfalfa* | The natural log of the three month average price as dollars/ton for dry alfalfa for each state |

### 7.4.2 Urban Model

A total of 1,447 transactions took place in the metropolitan areas of Arizona, Colorado, New Mexico, Nevada, and Utah. A significant portion of these water transactions are for municipal use, nearly 70%. The average quantity transferred in the metropolitan areas is 364 acre feet and the average price paid is $6,370. The average quantity transferred in the urban areas is much smaller than in the Intermountain Model. This is likely due to the large number of municipal water transactions that occurred. Most agricultural transactions involve larger quantities and often occur in more rural locations. The average price paid in the urban region is also much higher than in the Intermountain Model. This again is likely due to the large number of municipal transactions. The urban econometric model explores all the purchases of water rights that occurred in the large metropolitan areas of the intermountain region.

A Two-Stage Least squares approach is used for the analysis of the Urban Model:

Price Equation:
$\text{lnAdjustedPrice} = \beta_0 + \beta_1 * \text{qhat} + \beta_2 * \text{SPI} + \beta_3 * \text{trend} + \beta_4 * \text{Population\%Change} +$
$\beta_5 * \text{munuse} + \beta_6 * \text{envuse} + \beta_7 * \text{recuse} + \beta_8 * \text{phx} + \beta_9 * \text{tuc} + \beta_{10} * \text{alb} + \beta_{11} * \text{saltlkcity} +$
$\beta_{12} * \text{reno} + \beta_{13} * \text{lasvegas}$

Instrumental Variable Equation:
$\text{lnaf} = \beta_0 + \beta_1 * \text{SPI} + \beta_2 * \text{lnavgpercap} + \beta_3 * \text{agseller} + \beta_4 * \text{lnalfalfa}$

Table 7.3 Description of variables included in the Urban Model

| **Variable:** | **Description:** |
|---|---|
| *lnAdjustedPrice* | The natural log of the price per acre-foot in the transaction adjusted to year 2004 dollars |
| *lnAF* | The natural log of the volume of water per acre-foot purchased |
| *Qhat* | The predicted values for quantity from the instrumental variable equation |
| *SPI* | The Standard Precipitation Index |
| *Trend* | The year the transaction occurred minus 2004 |
| *Population%Change* | Percent change in population for the region the transaction occurred each year |
| *Munuse* | Binary variable equal to one if the water purchased is to be used for municipal purposes compared to agriculture |
| *Envuse* | Binary variable equal to one if the water purchased is to be used for environmental purposes compared to agriculture |
| *Recuse* | Binary variable equal to one if the water purchased is to be used for recreational purposes compared to agriculture |
| *Phx* | Binary variable equal to one if the water transaction occurred in the city of Phoenix compared to Colorado’s Front Range |
| *Tuc* | Binary variable equal to one if the water transaction occurred in the city of Tucson compared to Colorado’s Front Range |
| *Alb* | Binary variable equal to one if the water transaction occurred in the city of Albuquerque compared to Colorado’s Front Range |
| *Saltlakecity* | Binary variable equal to one if the water transaction occurred in the cities of Salt Lake, Park, or Provo compared to Colorado’s Front Range |
| *Lasvegas* | Binary variable equal to one if the water transaction occurred in the city of Las Vegas compared to Colorado’s Front Range |
| *Reno* | Binary variable equal to one if the water transaction occurred in the city of Reno/Sparks compared to Colorado’s Front Range |
| *Lnavgpercap* | The natural log of the average per capita income for the county where the transaction occurred |
| *Agseller* | Binary variable equal to one if agriculture is the supplier of the water right compared to all other types of sellers |
| *Lnalfalfa* | The natural log of the three month average price as dollars/ton for dry alfalfa for each state |

## 7.5 Econometric Results

A double log two-stage least squared model is used to estimate both the intermountain and urban water market models. As in the state models, several different functional forms are estimated a linear, log-linear, linear-log and double-log model. The results of the Box-Cox transformation indicated a double-log model for both the intermountain and urban models. A two-stage least squares method is necessary because price and quantity are endogenous variables in the intermountain and urban water markets.

Both the intermountain and urban models are tested for heteroskedasticity using White's General Test and the Breusch-Pagan Lagrange Multiplier Test. The intermountain and urban model both exhibit heteroskedasticity of an unknown nature. The models are corrected for heteroskedasticity and their robust standard errors reported in the results.

Water transactions that occurred in the intermountain and urban models are a combination of both surface and groundwater. Groundwater supplies are much slower to react to changing precipitation patterns than surface water supplies. Therefore a longer-term drought index such as the SPI 24 is more appropriate in estimating long term hydrological conditions that may potential affect water prices. The SPI 24 is examined with and without a six month lag and the results are compared below. The long-term SPI 12 drought index is also explored and the results are presented in the appendix.

### 7.5.1 Intermountain Results

The Intermountain Model examines all the purchases of water rights in Arizona, Colorado, New Mexico, Nevada, and Utah. The model displays heteroskedasticity, so the corrected standard errors are reported in the results. Results are presented for two models, one that examines the SPI 24 drought index without a lag and one that explores a six month lag. This econometric model attempts to explain price variation in the intermountain region of the western United States.

When adjusting for heteroskedasticity, a few variables changed in significance. The binary variable “recreational use” went from being significant at the 1% level to being significant at only the 5% level in both the SPI 24 models. The only other variable that changed in significance is the binary variable that represents the state of New Mexico. Prior to adjusting for heteroskedasticity, the New Mexico variable is significant at the 5% level in both models after adjusting for heteroskedasticity the variable is only significant at the 10% level. All other variables remained the same after the heteroskedasticity correction. The endogenous variable “quantity” remained significant and negative after applying an instrumental variable approach to produce consistent estimators.

Table 7.4 Intermountain Model with SPI 24
Dependent Variable: Natural Log of Adjusted Price per acre-foot

| **Variable Name** | Parameter Estimate | Robust Standard Error | Chi-Square | Pr > Chi-Square |
|---|---|---|---|---|
| *Intercept* | 8.82601 | 0.22267 | 1571.15 | <.0001 |
| *Qhat* | -0.28768 | 0.05005 | 33.04 | <.0001 |
| *SPI 24*** | -0.02960 | 0.01965 | 2.27 | 0.1319 |
| *Trend* | 0.06676 | 0.00574 | 135.14 | <.0001 |
| *Population%Change* | -0.14841 | 0.02236 | 44.04 | <.0001 |
| *Munuse* | 0.31586 | 0.05761 | 30.06 | <.0001 |
| *Envuse* | -1.36791 | 0.16927 | 65.31 | <.0001 |
| *Recuse** | -2.34937 | 1.10222 | 4.54 | 0.0330 |
| *AZ* | -1.14291 | 0.14062 | 66.06 | <.0001 |
| *NM*** | -0.14839 | 0.10641 | 1.94 | 0.1632 |
| *NV* | 0.59005 | 0.11221 | 27.65 | <.0001 |
| *UT* | -1.49621 | 0.15765 | 90.07 | <.0001 |
| Observations<br>R-Squared | 1604<br>0.5529 | | | |

* Insignificant at the 5% level
**Insignificant at the 10% level

Table 7.5 Intermountain Model with SPI 24 six month lag
Dependent Variable: Natural Log of Adjusted Price per acre-foot

| **Variable Name** | Parameter Estimate | Robust Standard Error | Chi-Square | Pr > Chi-Square |
|---|---|---|---|---|
| *Intercept* | 8.80763 | 0.22138 | 1582.84 | <.0001 |
| *Qhat* | -0.28529 | 0.04991 | 32.68 | <.0001 |
| *SPI 24 six month lag* | 0.03746 | 0.01900 | 3.89 | 0.0487 |
| *Trend* | 0.06830 | 0.00567 | 145.31 | <.0001 |
| *Population%Change* | -0.16289 | 0.02280 | 51.06 | <.0001 |
| *Munuse* | 0.31623 | 0.05721 | 30.55 | <.0001 |
| *Envuse* | -1.37266 | 0.17125 | 64.25 | <.0001 |
| *Recuse* | -2.38826 | 1.11591 | 4.58 | 0.0323 |
| *AZ* | -1.10581 | 0.14052 | 61.93 | <.0001 |
| *NM** | -0.18029 | 0.10677 | 2.85 | 0.0913 |
| *NV* | 0.68393 | 0.11396 | 36.02 | <.0001 |
| *UT* | -1.48652 | 0.15825 | 88.24 | <.0001 |
| Observations<br>R-Squared | 1604<br>0.5532 | | | |

* Insignificant at the 5% level
**Insignificant at the 10% level

Both models have respectable explanatory power with an R-Square of 0.55. This means that 55% of the variation in price in the intermountain region is explained by the variables included in the model. The variable *qhat* represents the predicted values for quantity of water transferred. The parameter estimate of -0.28 is an elasticity measure that can be interpreted as the following, holding all other variables constant a 1% increase in the quantity purchases will result in a 0.28% decrease in the price of a water right. This result reflects economies of scale in the intermountain region. This result is consistent across the two different SPI 24 models.

Two intermountain models are examined, one that explores the SPI 24 and the SPI 24 with a six month lag. All other variables remained constant in order to explore the difference a lagged drought index would have on the price of water rights in the intermountain region. The SPI 24 without the lag is insignificant in determining the price of water rights in the intermountain region. The SPI 24 with a six month lag is significant at the 5% level with a positive parameter estimate of 0.037. This is not the result one would expect. The positive parameter estimate suggests that as the intermountain region becomes wetter, the price of a water right increases. The insignificant result found in the SPI 24 variable and the positive estimate found in the SPI 24 with a six month lag may be due to the different processing time required by each state in order to change ownership of water rights, the ability of the drought index to accurately reflect both surface and groundwater supplies, and that the severity of drought conditions varies from state to state and even inside climate divisions within a state.

The explanatory variables *trend* and *population%change* are both statistically significant at the 1% level in both models. The parameter estimate for the variable *trend* indicates that a one unit change in the year will result in a 6% increase in the price of a water right. This result holds with the expectation that the real price of water increases over time. The variable *population%change* has a negative parameter estimate of approximately -0.15 in both models. This result indicates that as population increases the price of water rights become less expensive. The sign of this parameter is counter-intuitive, but the estimated effect on price in negligible.

Several binary variables are examined in the Intermountain Model. One set of binary variables explored the impact that the new use of the water right had on the market price and the other set examined the difference in the price of water rights between states. As expected, if the new use of the water right is for municipal purposes when compared to agricultural purposes the water right is more expensive, approximately 30% more expensive. If the water right is purchased for environmental purposes when compared to agricultural purposes, that water right is less expensive. This is also the case with water rights purchased for recreational purposes. Purchases for these latter two purposes often occur under duress, with farmers motivated to sell due to pending endangered species or other litigation.

Arizona, New Mexico, Nevada, and Utah are all compared to the state of Colorado. Each state binary variable is significant at the 1% level, except New Mexico. The Arizona and Utah binary variables both have negative parameter estimates of -1.15 and -1.40 respectively this means that water rights purchased in Arizona are 115% less expensive than water rights purchased in Colorado and Utah water rights are 140% less expensive. In Nevada, on average, the price of a water right sells for 68% more than water rights in Colorado. New Mexico is statistically significant at only the 10% level in the SPI 24 model with a six month lag and not significant at all in the SPI 24 model without a lag. The small parameter estimate and insignificance of this model indicates that there is not a notable statistical difference between water prices in New Mexico and Colorado.

### 7.5.2 Urban Results

The Urban Model examines all the purchases of water rights in the large metropolitan areas of Arizona, Colorado, New Mexico, Nevada, and Utah. The model displayed heteroskedasticity, so the corrected standard errors are reported in the results. Results are presented for two models one that examines the SPI 24 drought index without a lag and one explores a six month lag. This econometric model attempts to explain price variation in the metropolitan areas of the intermountain region.

Adjusting for heteroskedasticity changed only one variable. In the urban model that examined the SPI 24 with a six month lag, the binary variable Las Vegas went from being an insignificant variable prior to the heteroskedasticity correction to being significant at the 5% level. All other variables remained the same level of significance after correcting for heteroskedasticity. Price and quantity are endogenous variables in the urban market and an instrumental variable equation is estimated to correct for the correlation between error terms. The variable quantity remains a significant and negative estimate after applying two stage least squares.

Table 7.6 Urban Model with SPI 24
Dependent Variable: Natural Log of Adjusted Price per acre-foot

| **Variable Name** | Parameter Estimate | Robust Standard Error | Chi-Square | Pr > Chi-Square |
|---|---|---|---|---|
| *Intercept* | 8.49648 | 0.25957 | 1071.48 | <.0001 |
| *Qhat* | -0.26806 | 0.05615 | 22.79 | <.0001 |
| *SPI 24*** | -0.01586 | 0.01891 | 0.70 | 0.4018 |
| *Trend* | 0.07613 | 0.00657 | 134.29 | <.0001 |
| *Population%Change* | -0.11552 | 0.02263 | 26.07 | <.0001 |
| *Munuse* | 0.44118 | 0.06223 | 50.27 | <.0001 |
| *Envuse* | -1.17000 | 0.16594 | 49.71 | <.0001 |
| *Recuse*** | 0.49636 | 0.72045 | 0.47 | 0.4909 |
| *Phoenix* | -1.26215 | 0.21481 | 34.52 | <.0001 |
| *Tucson* | -1.10889 | 0.15046 | 54.31 | <.0001 |
| *Albuquerque* | -0.52004 | 0.08523 | 37.23 | <.0001 |
| *Las Vegas*** | 0.25631 | 0.16283 | 2.48 | 0.1155 |
| *Reno* | 0.57326 | 0.11727 | 23.90 | <.0001 |
| *Salt Lake City* | -1.35817 | 0.28741 | 22.33 | <.0001 |
| Observations | 1447 | | | |
| R-Squared | 0.5766 | | | |

* Insignificant at the 5%

**Insignificant at the 10% level

Table 7.7 Urban Model with SPI 24 six month lag
Dependent Variable: Natural Log of Adjusted Price per acre-foot

| **Variable Name** | Parameter Estimate | Robust Standard Error | Chi-Square | Pr > Chi-Square |
|---|---|---|---|---|
| *Intercept* | 8.43238 | 0.25681 | 1078.14 | <.0001 |
| *Qhat* | -0.25147 | 0.05546 | 20.56 | <.0001 |
| *SPI 24 six month lag** | 0.05385 | 0.01844 | 8.53 | 0.0035 |
| *Trend* | 0.07925 | 0.00650 | 148.52 | <.0001 |
| *Population%Change* | -0.13448 | 0.02276 | 34.90 | <.0001 |
| *Munuse* | 0.43560 | 0.06161 | 49.98 | <.0001 |
| *Envuse* | -1.16664 | 0.16817 | 48.13 | <.0001 |
| *Recuse*** | 0.49885 | 0.72514 | 0.47 | 0.4915 |
| *Phoenix* | -1.25225 | 0.21186 | 34.94 | <.0001 |
| *Tucson* | -1.07931 | 0.14632 | 54.41 | <.0001 |
| *Albuquerque* | -0.57137 | 0.08091 | 49.87 | <.0001 |
| *Las Vegas** | 0.32657 | 0.15411 | 4.49 | 0.0341 |
| *Reno* | 0.65762 | 0.11753 | 31.31 | <.0001 |
| *Salt Lake City* | -1.32947 | 0.29246 | 20.66 | <.0001 |
| Observations | 1447 | | | |
| R-Squared | 0.5769 | | | |

* Insignificant at the 5%
**Insignificant at the 10% level

The Urban Models have good explanatory power with over 57% of the variation in price being explained by the variables included in the model. The variable *qhat* is statistically significant at the 1% level and represents the predicted values for the quantity of water purchased. The negative parameter estimate indicates that as quantity increases the price of water rights decrease. This result indicates economies of scale in the urban water markets. As in the intermountain region, the drought index is not significant when examined without a lag and is significant when examined with a six month lag but has a relatively small effect. This may be a result of the different processing time that occurs in order to change the ownership of water rights in each urban area, the ability of the drought index to accurately reflect both surface and groundwater supplies, and that the severity of drought conditions may vary between each metropolitan area.

As in the intermountain region, the variables *trend* and *population%change* are both statistically significant at the 1% level. The variable *trend* represents the year that the transaction occurred and the variable *population%change* examines the percent change in population in each metropolitan area. The positive parameter estimate on the variable *trend* indicates that for a one year change the price of water increases by nearly 8%. The variable *population%change* has a negative parameter estimate which in not what one would expect. The result can be interpreted as: holding all other variables constant a percent increase in the population of the area will decrease the price of water rights.

Several “new use” binary variables are examined: municipal use, environmental use, and recreational use are all compared to agricultural uses. If a water right is purchased for municipal purposes, then the price is approximately 40% more than if that same water right had been purchased for agricultural purposes. Water purchased for environmental uses are found to be less expensive than water rights purchased for agricultural purposes. Recreational water purchases are found to be insignificant so no statistical difference exists between water purchased for recreation and water purchased for agriculture.

To account for the differences that may exist across metropolitan areas binary variables are created for each city. The baseline city is the Front Range region of Colorado. Each city is statistically significant at the 1% level, except Las Vegas which is significant at the 5% level in one of the two models. Phoenix, Tucson, Albuquerque, and Salt Lake City all had negative parameter estimates indicating that water purchased in these cities cost less than water rights purchased along the Front Range of Colorado. Water rights purchased in Reno and Las Vegas are found to be more expensive when compared to the Front Range, holding all other variables constant.

## *7.6 Conclusion*

As in the state chapters, we see that water markets in the intermountain and urban regions of the western United States are influenced by demand factors and the characteristics of the water right. The econometric results indicate that there is a statistically significant relationship between the price of a water right and the quantity transferred, the year the transaction occurred, the percent change in population of an area, the new use of the water right, and the location the transaction occurred.

It is not surprising that the drought index does not play a significant role in determining the price of water rights in the intermountain and urban models. The SPI 24 and SPI 24 with a six month lag do a good job of representing hydrological drought conditions across the western United States, but drought conditions vary between states and regions within a state. It is therefore very difficult to choose an appropriate drought index to quantify all the climate variability occurring across this vast area. Another difficulty in the drought index is measuring surface water and groundwater supplies. Surface water supplies react much quicker to dry conditions than groundwater supplies. Therefore a shorter term drought index such as the SPI 12 may be more appropriate for surface water transactions, while a longer term drought index may more accurately reflect groundwater transactions. The final problem encountered with the drought index is the lag. It is known that water right transfers must be processed in order for a change of ownership to occur. This takes a few months in some states and over a year in others. It is difficult to choose an appropriate lag to account for these time differences. The lag that reflected the average time delay between each state was selected to estimate the impact.

The statistical summary indicates that the majority of transactions occurred in Colorado followed by Nevada, New Mexico, Arizona, and finally Utah. Well-developed water markets exist in several of these states and metropolitan areas. A model that combines all of these states and metropolitan areas is difficult to estimate given the considerable differences in water markets among these states. Given the complexity of water markets in general, with the added difficulty of several distinct water markets combined into one analysis, the intermountain and urban models do a good job of explaining the price fluctuation with over 55% of the variation explained. The results presented provide insight into the major distinguishing factors involved in current water transaction prices.

# Chapter 8: Concluding Remarks

The statistical summary provided in each chapter indicates that water transactions across the western Untied States vary tremendously depending on the region and state in which they occur. Water transactions occur for a variety reasons that differ considerably within the same state. Water market activity occurring in urban areas is made up significantly of municipal transactions, while agricultural water transactions make up a significant portion of the transactions occurring in rural areas. The remarks provided in this section summarize the general results observed throughout the intermountain states.

Results presented in the preceding chapters indicate that regional and state-wide water markets are strongly influenced by demand factors and the characteristics of the water right. Econometric analysis has shown a statistically significant relationship between the price of a water right and the quantity transferred, the year the transaction occurred, the percent change in population of an area, the new use of the water right, whether the transaction occurred during a drought year, and the location that the transaction occurred.

The drought index is a statistically significant variable in some models and a poor indicator of price variation in others. This result is expected. The Standard Precipitation Index is a cumulative drought index that provides data on precipitation patterns across the United States. Due to differing hydrological patterns and water supply diversity in each state, the SPI’s indication of drought conditions varies. Several SPIs are examined for each model. The 3 and 6 month SPI are good indicators of short-term dry conditions and likely would work well for leases or temporary transactions. The longer-term 12 and 24 month SPI indicate hydrological drought conditions which reflect surface and groundwater conditions. Because this analysis focuses on permanent water transfers, the 12 and 24 month SPI is used in analyzing the price variation in water rights across the intermountain west. The 12 month SPI works well for surface water transactions, since surface water levels react quickly to precipitation patterns. Groundwater supplies react much slower than surface water to dry conditions, therefore a longer drought index such as the 24 month SPI works well. Even longer drought indices exist such as the 36 and 48 month SPI. These longer term drought indices react slowly to precipitation patterns and are sluggish in indicating changing water supplies.

In several models the drought index is significant and negative, indicating that as the region or state becomes wetter the price of water decreases. This is commonly seen across Arizona and Colorado. However, the drought index is insignificant in all New Mexico models, indicating that drought conditions do not play a statistically significant role in determining the price of water transactions there. As discussed in the Intermountain and Urban results section, drought is not a significant variable. This is likely due to the variation in drought conditions across each state and region. Several other factors may influence the significance of the drought index. These include: choosing the appropriate drought index to comprehensively quantify climate variability across regions: the difficulty in one particular drought index measuring both surface and groundwater supplies: and difficulty choosing the appropriate lag associated with each drought index, as water right transfers must be processed in order for a change of ownership to occur, which takes a few months in some locations and over a year in others. Lagging the drought index ensures that the correct drought conditions were examined at the time the price of the water right was negotiated.

Several variables are consistently significant across most models. These include: the year the transaction occurred, the population percent change of the area, the new use of the water right, the location the transaction occurred, and the quantity transferred. In all models except Arizona, the year the transaction occurred is a statistically significant variable with a positive effect on price. Indicating that over time the price of water has become more expensive in the intermountain states. However, in Arizona the time trend variable is statistically insignificant, which may be reflecting the administrative influences on CAP water transactions.

The population percent change in the area where the transaction occurred is nearly always significant in determining the price of water transactions but does not always have the expected sign. In some cases, the price of water rights decreases with increased population and in other cases the price increases. One would expect the price to increase as population increases at a higher rate. Population growth increases urban demand for water but displaces agriculture along the cities edge, which may result in a decrease of water use per unit of land. Unfortunately, the data examined in this study does not shed light on the potential explanation that higher rates of population growth sometimes has a negative effect on the price of a water right.

The new use of the water is an important variable in determining the price of water rights. The results suggest that water purchased for municipal uses are more expensive than water purchased for agriculture purposes. Water rights purchased for environmental purposes have a tendency to be less expensive than water rights purchased for agriculture. The location the transaction occurred also plays a large role in water right price variation. These results vary from model to model depending on which location variables are included.

Finally, the quantity of water transferred is statistically significant in several of the models examined. The parameter estimate is negative in all but one model, the Arizona CAP Model. The negative estimate suggests that larger quantities of water rights sell for a lower price. This result indicates that economies of scale exist throughout the intermountain region.

A well developed water market exhibits the following characteristics: numerous transactions, easy market entry and exit, and price transparency. The tables provided in each chapter indicate the number of transactions occurring throughout each state. A large number of transactions occur in the State of Colorado when compared to the other intermountain states. It is not a surprising result that Colorado has the most well-established water markets in this region. The Colorado Big Thompson water market located in Colorado’s northeast corner exhibits all the traditional characteristics of an efficient market. In addition to these traditional characteristics, the political means and infrastructure are in place throughout Colorado to support water market development and state policies consider third party impacts. In Arizona and New Mexico water market activity is occurring, but we do not see the same volume of transactions that are traded in Colorado. Water markets are extremely localized within the western United States.

Water markets are constrained to a particular region due to high transport costs to move water across regions. One would not expect an equilibrium price to occur across regions and states. A mature market would exhibit an equilibrium price between the different types of uses. In a mature water market we would not see water rights purchased for municipal purposes selling for a significant higher price than water rights purchased for agricultural purposes.

Drought has been a persistent problem across the western United States. The importance of climate variability is suggested in the significance of the drought index in the models examined. Historical records show that drought is a common occurrence in the western United States and will continue to be in the future. As drought conditions continue and or become more severe, increased water market activity is likely to be a dominant strategy used to alleviate the increasing pressure on supplies. Individuals may react to the perception and expectation that drought conditions may continue or become more severe, therefore choosing the purchase water sooner in order to avoid future price increases of water rights. Bjornlund and Rossni (2005) show that price of allocations react to short-term changes such as allocation level, evaporation and rainfall while the price of purchases reacts to long-term trends. Projected population estimates continue to show significant growth in the intermountain region of the West. With increasing population and a limited water supply, the implementation of water policies should facilitate the expansion of water markets.

Water transactions occur for a variety of reasons: planning for drought year reliability, urban growth, budgeting for acquisitions, and environmental restoration. As the population of the West increases, increases in water transactions may be one strategy for handling the expected increase in demand for water supplies. The results presented provide insight into the major distinguishing factors involved in water market activity occurring in the intermountain states of the West. Insight into the factors that influence water market activity provides policy makers and water users the ability to make more informed decisions.

# Appendices

## *Appendix A: Instrumental Variable Results for the Models Discussed in Each Chapter*

### *A.1 Colorado Instrumental Variable Results*

Table A.1 Instrumental Variable Results for Colorado Full Model with SPI 12
Dependent Variable: Natural Log of Quantity Purchased

| **Variable Name** | Parameter Estimate | Standard Error | T Value | Pr > T-Stat |
|---|---|---|---|---|
| *Intercept* | 19.4692 | 2.84183 | 6.85 | <.0001 |
| *lnavgpercap* | -1.5269 | 0.2024 | -7.54 | <.0001 |
| *ag_seller* | -1.50479 | 0.21351 | -7.05 | <.0001 |
| *Lnalfalfa* | 0.12468 | 0.28454 | 0.44 | 0.6613 |
| *SPI 12* | 0.10864 | 0.05413 | 2.01 | 0.045 |
| *lkmeredith* | 2.57967 | 1.10913 | 2.33 | 0.0202 |
| Observations | 1150 | | | |
| R-Squared | 0.1189 | | | |

Table A.2 Instrumental Variable Results for Colorado Full Model with SPI 12 six month lag
Dependent Variable: Natural Log of Quantity Purchased

| **Variable Name** | Parameter Estimate | Standard Error | T Value | Pr > T-Stat |
|---|---|---|---|---|
| *Intercept* | 18.17795 | 2.93967 | 6.18 | <.0001 |
| *Lnavgpercap* | -1.48482 | 0.20399 | -7.28 | <.0001 |
| *ag_seller* | -1.50682 | 0.21316 | -7.07 | <.0001 |
| *Lnalfalfa* | 0.30965 | 0.30217 | 1.02 | 0.3057 |
| *SPI 12 six month lag* | 0.1382 | 0.05528 | 2.5 | 0.0126 |
| *Lkmeredith* | 2.72009 | 1.10604 | 2.46 | 0.0141 |
| Observations | 1150 | | | |
| R-Squared | 0.1206 | | | |

Table A.3 Instrumental Variable Results for CBT Model with SPI 12
Dependent Variable: Natural Log of Quantity Purchased

| **Variable Name** | Parameter Estimate | Standard Error | T Value | Pr > T-Stat |
|---|---|---|---|---|
| *Intercept* | 19.0065 | 3.09987 | 6.13 | <.0001 |
| *lnavgpercap* | -1.60887 | 0.22649 | -7.1 | <.0001 |
| *ag_seller* | -0.51803 | 0.24238 | -2.14 | 0.0328 |
| *Lnalfalfa* | 0.16237 | 0.27894 | 0.58 | 0.5606 |
| *SPI 12* | 0.10117 | 0.05153 | 1.96 | 0.0499 |
| Observations | 946 | | | |
| R-Squared | 0.0790 | | | |

Table A.4 Instrumental Variable Results for CBT Model with SPI 12 six month lag
Dependent Variable: Natural Log of Quantity Purchased

| **Variable Name** | Parameter Estimate | Standard Error | T Value | Pr > T-Stat |
|---|---|---|---|---|
| *Intercept* | 17.69849 | 3.20158 | 5.53 | <.0001 |
| *Lnavgpercap* | -1.56595 | 0.228 | -6.87 | <.0001 |
| *ag_seller* | -0.52384 | 0.24188 | -2.17 | 0.0306 |
| *Lnalfalfa* | 0.35039 | 0.29828 | 1.17 | 0.2404 |
| *SPI 12 six month lag* | 0.12975 | 0.0524 | 2.48 | 0.0135 |
| Observations | 946 | | | |
| R-Squared | 0.0812 | | | |

Table A.5 Instrumental Variable Results for Front Range with SPI 12
Dependent Variable: Natural Log of Quantity Purchased

| **Variable Name** | Parameter Estimate | Standard Error | T Value | Pr > T-Stat |
|---|---|---|---|---|
| *Intercept* | 24.57742 | 2.93541 | 8.37 | <.0001 |
| *lnavgpercap* | -1.9372 | 0.2123 | -9.12 | <.0001 |
| *ag_seller* | -1.44862 | 0.21179 | -6.84 | <.0001 |
| *Lnalfalfa* | -0.07303 | 0.28169 | -0.26 | 0.7955 |
| *SPI 12* | 0.08736 | 0.0535 | 1.63 | 0.1028 |
| Observations | 1132 | | | |
| R-Squared | 0.1249 | | | |

Table A.6 Instrumental Variable Results for Front Range with SPI 12 six month lag
Dependent Variable: Natural Log of Quantity Purchased

| **Variable Name** | Parameter Estimate | Standard Error | T Value | Pr > T-Stat |
|---|---|---|---|---|
| *Intercept* | 23.23702 | 3.01772 | 7.7 | <.0001 |
| *lnavgpercap* | -1.89472 | 0.21315 | -8.89 | <.0001 |
| *ag_seller* | -1.45102 | 0.21114 | -6.87 | <.0001 |
| *Lnalfalfa* | 0.12053 | 0.29839 | 0.4 | 0.6863 |
| *SPI 12 six month lag* | 0.13448 | 0.05444 | 2.47 | 0.0137 |
| Observations | 1132 | | | |
| R-Squared | 0.1276 | | | |

## A.2 New Mexico Instrumental Variable Results

Table A.7 Instrumental Variable Results for New Mexico Full Model with SPI 24
Dependent Variable: Natural Log of Quantity Purchased

| **Variable Name** | Parameter Estimate | Standard Error | T Value | Pr > T-Stat |
|---|---|---|---|---|
| *Intercept* | 14.81413 | 16.14893 | 0.92 | 0.3609 |
| *ag_seller* | -0.45069 | 0.76109 | -0.59 | 0.5549 |
| *lnavgpercap* | 0.64176 | 1.15615 | 0.56 | 0.5799 |
| *Lnalfalfa* | -3.48814 | 1.73608 | -2.01 | 0.0469 |
| *SPI 24* | 0.1538 | 0.2593 | 0.59 | 0.5543 |
| Observations | 119 | | | |
| R-Squared | 0.0671 | | | |

Table A.8 Instrumental Variable Results for New Mexico Full Model with SPI 24 six month lag
Dependent Variable: Natural Log of Quantity Purchased

| **Variable Name** | Parameter Estimate | Standard Error | T Value | Pr > T-Stat |
|---|---|---|---|---|
| *Intercept* | 17.40066 | 15.62761 | 1.11 | 0.2679 |
| *ag_seller* | -0.43779 | 0.77229 | -0.57 | 0.5719 |
| *lnavgpercap* | 0.5013 | 1.13461 | 0.44 | 0.6595 |
| *Lnalfalfa* | -3.71691 | 1.69477 | -2.19 | 0.0303 |
| *SPI 24 six month lag* | 0.09036 | 0.25936 | 0.35 | 0.7282 |
| Observations | 119 | | | |
| R-Squared | 0.0652 | | | |

Table A.9 Instrumental Variable Results for Albuquerque Model with SPI 24
Dependent Variable: Natural Log of Quantity Purchased

| **Variable Name** | Parameter Estimate | Standard Error | T Value | Pr > T-Stat |
|---|---|---|---|---|
| *Intercept* | 5.43529 | 51.32735 | 0.11 | 0.9165 |
| *ag_seller* | 1.19133 | 0.9312 | 1.28 | 0.2121 |
| *lnavgpercap* | 0.20926 | 2.6788 | 0.08 | 0.9383 |
| *Lnalfalfa* | -0.86198 | 5.27298 | -0.16 | 0.8714 |
| *SPI 24* | 0.15108 | 0.53571 | 0.28 | 0.7802 |
| Observations | 31 | | | |
| R-Squared | 0.0855 | | | |

Table A.10 Instrumental Variable Results for Albuquerque Model with SPI 24 six month lag
Dependent Variable: Natural Log of Quantity Purchased

| **Variable Name** | Parameter Estimate | Standard Error | T Value | Pr > T-Stat |
|---|---|---|---|---|
| *Intercept* | -5.82181 | 41.06591 | -0.14 | 0.8884 |
| *ag_seller* | 1.36194 | 0.94259 | 1.44 | 0.1604 |
| *lnavgpercap* | 0.81158 | 2.13151 | 0.38 | 0.7065 |
| *Lnalfalfa* | 0.11124 | 4.39608 | 0.03 | 0.98 |
| *SPI 24 six month lag* | 0.37602 | 0.4618 | 0.81 | 0.4229 |
| Observations | 31 | | | |
| R-Squared | 0.1055 | | | |

Table A.11 Instrumental Variable Results for Gila-San Francisco Model with SPI 12
Dependent Variable: Natural Log of Quantity Purchased

| **Variable Name** | Parameter Estimate | Standard Error | T Value | Pr > T-Stat |
|---|---|---|---|---|
| *Intercept* | -97.36742 | 47.53071 | -2.05 | 0.0449 |
| *ag_seller* | 0.47495 | 1.51036 | 0.31 | 0.7543 |
| *lnavgpercap* | 9.06361 | 4.7842 | 1.89 | 0.063 |
| *Lnalfalfa* | 1.88945 | 1.52737 | 1.24 | 0.2209 |
| *SPI 12* | -0.02938 | 0.26401 | -0.11 | 0.9118 |
| Observations | 65 | | | |
| R-Squared | 0.1216 | | | |

Table A.12 Instrumental Variable Results for Gila-San Francisco Model with SPI 12 six month lag
Dependent Variable: Natural Log of Quantity Purchased

| **Variable Name** | Parameter Estimate | Standard Error | T Value | Pr > T-Stat |
|---|---|---|---|---|
| *Intercept* | -134.87702 | 45.6733 | -2.95 | 0.0045 |
| *ag_seller* | 0.58441 | 1.43604 | 0.41 | 0.6855 |
| *lnavgpercap* | 12.19047 | 4.6152 | 2.64 | 0.0105 |
| *Lnalfalfa* | 3.11504 | 1.47602 | 2.11 | 0.039 |
| *SPI 12 six month lag* | 0.48213 | 0.24948 | 1.93 | 0.058 |
| Observations | 65 | | | |
| R-Squared | 0.1729 | | | |

## A.3 Intermountain Instrumental Variable Results

Table A.13 Instrumental Variable Results for Intermountain with SPI 24
Dependent Variable: Natural Log of Quantity Purchased

| **Variable Name** | Parameter Estimate | Standard Error | T Value | Pr > T-Stat |
|---|---|---|---|---|
| *Intercept* | 31.17636 | 2.81606 | 11.07 | <.0001 |
| *ag_seller* | -1.83187 | 0.12931 | -14.17 | <.0001 |
| *lnavgpercap* | -2.16114 | 0.19235 | -11.24 | <.0001 |
| *Lnalfalfa* | -0.88278 | 0.26195 | -3.37 | 0.0008 |
| *SPI 24* | -0.01086 | 0.04787 | -0.23 | 0.8206 |
| Observations | 1604 | | | |
| R-Squared | 0.1719 | | | |

Table A.14 Instrumental Variable Results for Intermountain with SPI 24 six month lag
Dependent Variable: Natural Log of Quantity Purchased

| **Variable Name** | Parameter Estimate | Standard Error | T Value | Pr > T-Stat |
|---|---|---|---|---|
| *Intercept* | 30.88929 | 2.79645 | 11.05 | <.0001 |
| *ag_seller* | -1.85032 | 0.12754 | -14.51 | <.0001 |
| *lnavgpercap* | -2.14099 | 0.19102 | -11.21 | <.0001 |
| *Lnalfalfa* | -0.86391 | 0.26084 | -3.31 | 0.0009 |
| *SPI 24 six month lag* | 0.01671 | 0.04467 | 0.37 | 0.7084 |
| Observations | 1604 | | | |
| R-Squared | 0.1720 | | | |

## A.4 Urban Instrumental Variable Results

Table A.15 Instrumental Variable Results for Urban with SPI 24
Dependent Variable: Natural Log of Quantity Purchased

| **Variable Name** | Parameter Estimate | Standard Error | T Value | Pr > T-Stat |
|---|---|---|---|---|
| *Intercept* | 28.14296 | 3.06633 | 9.18 | <.0001 |
| *ag_seller* | -1.67533 | 0.12935 | -12.95 | <.0001 |
| *lnavgpercap* | -2.26952 | 0.21268 | -10.67 | <.0001 |
| *Lnalfalfa* | -0.0183 | 0.28205 | -0.06 | 0.9483 |
| *SPI 24* | 0.04395 | 0.04747 | 0.93 | 0.3547 |
| Observations | 1447 | | | |
| R-Squared | 0.1781 | | | |

Table A.16 Instrumental Variable Results for Urban with SPI 24 six month lag
Dependent Variable: Natural Log of Quantity Purchased

| **Variable Name** | Parameter Estimate | Standard Error | T Value | Pr > T-Stat |
|---|---|---|---|---|
| *Intercept* | 27.90708 | 3.03743 | 9.19 | <.0001 |
| *ag_seller* | -1.69749 | 0.12725 | -13.34 | <.0001 |
| *lnavgpercap* | -2.25518 | 0.21089 | -10.69 | <.0001 |
| *Lnalfalfa* | 0.00215 | 0.28002 | 0.01 | 0.9939 |
| *SPI 24 six month lag* | 0.08491 | 0.0437 | 1.94 | 0.0522 |
| Observations | 1447 | | | |
| R-Squared | 0.1797 | | | |

## *Appendix B: Other Arizona Water Market Models and their Instrumental Variable Results*

Table B.1 Arizona Full Model with SPI 12
Dependent Variable: Natural Log of Adjusted Price per acre-foot

| **Variable Name** | Parameter Estimate | Robust Standard Error | Chi-Square | Pr > ChiSq |
|---|---|---|---|---|
| *Intercept* | 6.17081 | 0.43311 | 202.99 | <.0001 |
| *lnAF*** | -0.02388 | 0.05121 | 0.22 | 0.641 |
| *SPI 12*** | 0.02759 | 0.07341 | 0.14 | 0.707 |
| *Population%change* | 0.20686 | 0.10524 | 3.86 | 0.0494 |
| *Trend*** | -0.00648 | 0.01146 | 0.32 | 0.5717 |
| *Stlanddept*** | -0.52158 | 0.38263 | 1.86 | 0.1728 |
| *Cap*** | -0.3541 | 0.38632 | 0.84 | 0.3594 |
| *Typeii* | 0.69219 | 0.28882 | 5.74 | 0.0165 |
| *Phoenix*** | -0.30608 | 0.19572 | 2.45 | 0.1179 |
| *Mun_use** | 0.32176 | 0.17131 | 3.53 | 0.0604 |
| *Env_use* | -1.90806 | 0.36422 | 27.44 | <.0001 |
| Observations | 92 | | | |
| R-Squared | 0.6402 | | | |

Table B.2 Arizona Full Model with SPI 12 six month lag
Dependent Variable: Natural Log of Adjusted Price per acre-foot

| **Variable Name** | Parameter Estimate | Robust Standard Error | Chi-Square | Pr > ChiSq |
|---|---|---|---|---|
| *Intercept* | 6.24267 | 0.48339 | 166.78 | <.0001 |
| *lnAF*** | -0.02372 | 0.0509 | 0.22 | 0.6412 |
| *SPI 12 six month lag*** | 0.04964 | 0.10788 | 0.21 | 0.6454 |
| *Population%change*** | 0.17735 | 0.1363 | 1.69 | 0.1932 |
| *Trend*** | -0.00524 | 0.01209 | 0.19 | 0.665 |
| *Stlanddept*** | -0.51892 | 0.38209 | 1.84 | 0.1744 |
| *Cap*** | -0.33981 | 0.39444 | 0.74 | 0.389 |
| *Typeii* | 0.68876 | 0.29449 | 5.47 | 0.0193 |
| *Phoenix*** | -0.30836 | 0.19784 | 2.43 | 0.1191 |
| *Mun_use** | 0.33202 | 0.1906 | 3.03 | 0.0815 |
| *Env_use* | -1.94674 | 0.36126 | 29.04 | <.0001 |
| Observations | 92 | | | |
| R-Squared | 0.6408 | | | |

Table B.3 CAP Model with SPI 24
Dependent Variable: Natural Log of Adjusted Price per acre-foot

| **Variable Name** | Parameter Estimate | Standard Error | T-Value | Pr > T Stat |
|---|---|---|---|---|
| *Intercept*** | 2.41132 | 2.99982 | 0.8 | 0.4333 |
| *lnAF*** | 0.21252 | 0.13942 | 1.52 | 0.147 |
| *SPI 24*** | -0.046 | 0.32695 | -0.14 | 0.8899 |
| *Trend** | -0.18189 | 0.10031 | -1.81 | 0.0886 |
| *Population%Change*** | 0.74451 | 0.47549 | 1.57 | 0.137 |
| *Mun_use* | 1.73124 | 0.80334 | 2.16 | 0.0467 |
| *Env_use*** | 0.09889 | 0.90656 | 0.11 | 0.9145 |
| *Phx*** | 0.02072 | 0.78943 | 0.03 | 0.9794 |
| Observations | 24 | | | |
| R-Squared | 0.6870 | | | |

Table B.4 CAP Model with SPI 24 six month lag
Dependent Variable: Natural Log of Adjusted Price per acre-foot

| **Variable Name** | Parameter Estimate | Standard Error | T-Value | Pr > T Stat |
|---|---|---|---|---|
| *Intercept*** | 2.50881 | 3.02867 | 0.83 | 0.4197 |
| *lnAF*** | 0.20526 | 0.13573 | 1.51 | 0.15 |
| *SPI 24 six month lag*** | -0.06819 | 0.28126 | -0.24 | 0.8115 |
| *Trend** | -0.18389 | 0.10029 | -1.83 | 0.0854 |
| *Population%Change*** | 0.73872 | 0.46363 | 1.59 | 0.1306 |
| *Mun_use** | 1.67165 | 0.84159 | 1.99 | 0.0644 |
| *Env_use*** | 0.03174 | 0.96299 | 0.03 | 0.9741 |
| *Phx*** | 0.07787 | 0.7685 | 0.1 | 0.9205 |
| Observations | 24 | | | |
| R-Squared | 0.6878 | | | |

Table B.6 Type II Model with SPI 12
Dependent Variable: Natural Log of Adjusted Price per acre-foot

| **Variable Name** | Parameter Estimate | Robust Standard Error | Chi-Square | Pr > ChiSq |
|---|---|---|---|---|
| *Intercept* | 7.71987 | 0.17678 | 907.07 | <.0001 |
| *lnAF* | -0.04309 | 0.01939 | 4.94 | 0.0263 |
| *SPI 12*** | 0.05854 | 0.03685 | 2.52 | 0.1122 |
| *Trend*** | -0.00916 | 0.00596 | 2.36 | 0.1243 |
| *Population%Change* | -0.10523 | 0.04255 | 6.12 | 0.0134 |
| *tuc_ama* | 0.43574 | 0.06618 | 43.35 | <.0001 |
| *other_ama** | 0.36183 | 0.20682 | 3.06 | 0.0802 |
| *Golf_use*** | -0.04946 | 0.09513 | 0.27 | 0.6031 |
| Observations | 43 | | | |
| R-Squared | 0.7293 | | | |

Table B.7 Type II Model with SPI 12 six month lag
Dependent Variable: Natural Log of Adjusted Price per acre-foot

| **Variable Name** | Parameter Estimate | Robust Standard Error | Chi-Square | Pr > ChiSq |
|---|---|---|---|---|
| *Intercept* | 7.62529 | 0.19024 | 606.65 | <.0001 |
| *lnAF* | -0.0514 | 0.02066 | 6.19 | 0.0129 |
| *SPI 12 six month lag* | -0.07531 | 0.03757 | 4.02 | 0.045 |
| *Trend* | -0.01613 | 0.00545 | 8.75 | 0.0031 |
| *Population%Change*** | -0.02284 | 0.04978 | 0.21 | 0.6464 |
| *tuc_ama* | 0.33974 | 0.07058 | 23.17 | <.0001 |
| *other_ama*** | 0.25591 | 0.1886 | 1.84 | 0.1748 |
| *Golf_use*** | -0.10311 | 0.07905 | 1.7 | 0.1921 |
| Observations | 43 | | | |
| R-Squared | 0.7437 | | | |

** Insignificant at the 10% level
* Insignificant at the 5% level

# *Appendix C: Other Colorado Water Market Models and their Instrumental Variable Results*

Table C.1 Colorado Full Model with SPI 24
Dependent Variable: Natural Log of Adjusted Price per acre-foot

| **Variable Name** | Parameter Estimate | Robust Standard Error | Chi-Square | Pr > ChiSq |
|---|---|---|---|---|
| *Intercept* | 8.80218 | 0.42387 | 431.23 | <.0001 |
| *Qhat* | -0.4158 | 0.10637 | 15.28 | <.0001 |
| *SPI 24*** | -0.00724 | 0.02263 | 0.1 | 0.7491 |
| *Trend* | 0.09438 | 0.01044 | 81.73 | <.0001 |
| *Population%Change* | -0.1984 | 0.02728 | 52.88 | <.0001 |
| *Mun_use* | 0.52822 | 0.07479 | 49.88 | <.0001 |
| *Env_use* | -0.66689 | 0.22481 | 8.8 | 0.003 |
| *interstatecomp_use*** | -0.00927 | 0.57619 | 0 | 0.9872 |
| *Rural*** | 0.63663 | 0.4127 | 2.38 | 0.1229 |
| *lkmeredith* | -3.86517 | 0.5293 | 53.32 | <.0001 |
| Observations | 1150 | | | |
| R-Squared | 0.6081 | | | |

Table C.2 Instrumental Variable Results for Colorado Full Model with SPI 24
Dependent Variable: Natural Log of Quantity Purchased

| **Variable Name** | Parameter Estimate | Standard Error | T-Value | Pr > T-Stat |
|---|---|---|---|---|
| *Intercept* | 19.43886 | 2.8296 | 6.87 | <.0001 |
| *lnavgpercap* | -1.53481 | 0.20154 | -7.62 | <.0001 |
| *ag_seller* | -1.52862 | 0.21401 | -7.14 | <.0001 |
| *Lnalfalfa* | 0.1502 | 0.28479 | 0.53 | 0.598 |
| *SPI 24* | 0.1258 | 0.05245 | 2.4 | 0.0166 |
| *lkmeredith* | 2.46971 | 1.11096 | 2.22 | 0.0264 |
| Observations | 1150 | | | |
| R-Squared | 0.1202 | | | |

Table C.3 Colorado Full Model with SPI 24 six month lag
Dependent Variable: Natural Log of Adjusted Price per acre-foot

| **Variable Name** | Parameter Estimate | Robust Standard Error | Chi-Square | Pr > ChiSq |
|---|---|---|---|---|
| *Intercept* | 8.67846 | 0.42266 | 421.6 | <.0001 |
| *Qhat* | -0.36836 | 0.10537 | 12.22 | 0.0005 |
| *SPI 24* | 0.09057 | 0.02281 | 15.76 | <.0001 |
| *Trend* | 0.09997 | 0.01033 | 93.63 | <.0001 |
| *Population%Change* | -0.23584 | 0.02774 | 72.3 | <.0001 |
| *Mun_use* | 0.49484 | 0.07374 | 45.03 | <.0001 |
| *Env_use* | -0.68888 | 0.23133 | 8.87 | 0.0029 |
| *interstatecomp_use*** | -0.04718 | 0.57519 | 0.01 | 0.9346 |
| *Rural*** | 0.55991 | 0.41163 | 1.85 | 0.1738 |
| *lkmeredith* | -4.20671 | 0.53314 | 62.26 | <.0001 |
| Observations | 1150 | | | |
| R-Squared | 0.6072 | | | |

Table C.4 Instrumental Variable Results for Colorado Full Model with SPI 24 six month lag
Dependent Variable: Natural Log of Quantity Purchased

| **Variable Name** | Parameter Estimate | Standard Error | T-Value | Pr > T-Stat |
|---|---|---|---|---|
| *Intercept* | 19.81991 | 2.81382 | 7.04 | <.0001 |
| *lnavgpercap* | -1.55433 | 0.20114 | -7.73 | <.0001 |
| *ag_seller* | -1.51878 | 0.21382 | -7.1 | <.0001 |
| *Lnalfalfa* | 0.11105 | 0.28274 | 0.39 | 0.6946 |
| *SPI 24 six month lag* | 0.10749 | 0.04839 | 2.22 | 0.0265 |
| *lkmeredith* | 2.59909 | 1.10788 | 2.35 | 0.0191 |
| Observations | 1150 | | | |
| R-Squared | 0.1196 | | | |

Table C.5 CBT Model with SPI 24
Dependent Variable: Natural Log of Adjusted Price per acre-foot

| **Variable Name** | Parameter Estimate | Robust Standard Error | Chi-Square | Pr > ChiSq |
|---|---|---|---|---|
| *Intercept* | 12.2117 | 0.50868 | 576.31 | <.0001 |
| *Qhat* | -1.38283 | 0.14724 | 88.21 | <.0001 |
| *SPI 24* | 0.0581 | 0.01935 | 9.01 | 0.0027 |
| *Trend* | 0.04335 | 0.01204 | 12.97 | 0.0003 |
| *Population%Change* | -0.15098 | 0.01214 | 154.64 | <.0001 |
| *Mun_use* | 0.05768 | 0.02741 | 4.43 | 0.0354 |
| Observations | 946 | | | |
| R-Squared | 0.8748 | | | |

Table C.6 Instrumental Variable Results for CBT Model with SPI 24
Dependent Variable: Natural Log of Quantity Purchased

| **Variable Name** | Parameter Estimate | Standard Error | T-Value | Pr > T-Stat |
|---|---|---|---|---|
| *Intercept* | 18.8106 | 3.07033 | 6.13 | <.0001 |
| *lnavgpercap* | -1.61067 | 0.22436 | -7.18 | <.0001 |
| *ag_seller* | -0.56701 | 0.24308 | -2.33 | 0.0199 |
| *lnalfalfa* | 0.21314 | 0.2786 | 0.77 | 0.4444 |
| *SPI 24* | 0.13981 | 0.0497 | 2.81 | 0.005 |
| Observations | 946 | | | |
| R-Squared | 0.0829 | | | |

Table C.7 CBT Model with SPI 24 six month lag
Dependent Variable: Natural Log of Adjusted Price per acre-foot

| **Variable Name** | Parameter Estimate | Robust Standard Error | Chi-Square | Pr > ChiSq |
|---|---|---|---|---|
| *Intercept* | 11.91183 | 0.53816 | 489.93 | <.0001 |
| *Qhat* | -1.28301 | 0.1551 | 68.43 | <.0001 |
| *SPI 24 six month lag* | 0.13672 | 0.0181 | 57.03 | <.0001 |
| *Trend* | 0.05077 | 0.0132 | 14.8 | 0.0001 |
| *Population%Change* | -0.17951 | 0.01254 | 204.77 | <.0001 |
| *Mun_use*** | 0.03982 | 0.02829 | 1.98 | 0.1593 |
| Observations | 946 | | | |
| R-Squared | 0.8592 | | | |

Table C.8 Instrumental Variable Results for CBT Model with SPI 24 six month lag
Dependent Variable: Natural Log of Quantity Purchased

| **Variable Name** | Parameter Estimate | Standard Error | T-Value | Pr > T-Stat |
|---|---|---|---|---|
| *Intercept* | 19.32492 | 3.04044 | 6.36 | <.0001 |
| *lnavgpercap* | -1.65462 | 0.22296 | -7.42 | <.0001 |
| *ag_seller* | -0.54888 | 0.24193 | -2.27 | 0.0235 |
| *lnalfalfa* | 0.1964 | 0.27662 | 0.71 | 0.4779 |
| *SPI 24 six month lag* | 0.13901 | 0.04592 | 3.03 | 0.0025 |
| Observations | 946 | | | |
| R-Squared | 0.0841 | | | |

Table C.9 Front Range Model with SPI 24
Dependent Variable: Natural Log of Adjusted Price per acre-foot

| **Variable Name** | Parameter Estimate | Robust Standard Error | Chi-Square | Pr > ChiSq |
|---|---|---|---|---|
| *Intercept* | 8.63003 | 0.36092 | 571.74 | <.0001 |
| *Qhat* | -0.36466 | 0.09255 | 15.52 | <.0001 |
| *SPI 24*** | -0.01796 | 0.0212 | 0.72 | 0.3969 |
| *Trend* | 0.09377 | 0.01034 | 82.17 | 0.0001 |
| *Population%Change* | -0.18386 | 0.02357 | 60.86 | <.0001 |
| *Mun_use* | 0.53745 | 0.07417 | 52.5 | <.0001 |
| *Env_use* | -0.69925 | 0.23433 | 8.9 | 0.0028 |
| Observations | 1132 | | | |
| R-Squared | 0.5967 | | | |

Table C.10 Instrumental Variable Results for Front Range Model with SPI 24
Dependent Variable: Natural Log of Quantity Purchased

| **Variable Name** | Parameter Estimate | Standard Error | T-Value | Pr > T-Stat |
|---|---|---|---|---|
| *Intercept* | 24.45987 | 2.91552 | 8.39 | <.0001 |
| *lnavgpercap* | -1.94168 | 0.21096 | -9.2 | <.0001 |
| *ag_seller* | -1.4738 | 0.21209 | -6.95 | <.0001 |
| *lnalfalfa* | -0.03695 | 0.2815 | -0.13 | 0.8956 |
| *SPI 24* | 0.11976 | 0.05169 | 2.32 | 0.0207 |
| Observations | 1132 | | | |
| R-Squared | 0.1270 | | | |

Table C.11 Front Range Model with SPI 24 six month lag
Dependent Variable: Natural Log of Adjusted Price per acre-foot

| **Variable Name** | Parameter Estimate | Robust Standard Error | Chi-Square | Pr > ChiSq |
|---|---|---|---|---|
| *Intercept* | 8.49287 | 0.36569 | 539.38 | <.0001 |
| *Qhat* | -0.31694 | 0.09337 | 11.52 | 0.0007 |
| *SPI 24* | 0.07985 | 0.0198 | 16.27 | <.0001 |
| *Trend* | 0.09993 | 0.0105 | 90.55 | <.0001 |
| *Population%Change* | -0.21959 | 0.02291 | 91.86 | <.0001 |
| *Mun_use* | 0.50687 | 0.07294 | 48.29 | <.0001 |
| *Env_use* | -0.71508 | 0.24163 | 8.76 | 0.0031 |
| Observations | 1132 | | | |
| R-Squared | 0.5951 | | | |

Table C.12 Instrumental Variable Results for Front Range Model with SPI 24 six month lag
Dependent Variable: Natural Log of Quantity Purchased

| **Variable Name** | Parameter Estimate | Standard Error | T-Value | Pr > T-Stat |
|---|---|---|---|---|
| *Intercept* | 24.85447 | 2.89475 | 8.59 | <.0001 |
| *lnavgpercap* | -1.967 | 0.21028 | -9.35 | <.0001 |
| *ag_seller* | -1.46636 | 0.21166 | -6.93 | <.0001 |
| *lnalfalfa* | -0.06672 | 0.27923 | -0.24 | 0.8112 |
| *SPI 24 six month lag* | 0.11465 | 0.04765 | 2.41 | 0.0163 |
| Observations | 1132 | | | |
| R-Squared | 0.1273 | | | |

** Insignificant at the 10% level
* Insignificant at the 5% level

# *Appendix D: Other New Mexico Water Market Models and their Instrumental Variable Results*

Table D.1 New Mexico Full Model with SPI 12
Dependent Variable: Natural Log of Adjusted Price per acre-foot

| **Variable Name** | Parameter Estimate | Robust Standard Error | Chi-Square | Pr > ChiSq |
|---|---|---|---|---|
| *Intercept* | 8.06819 | 0.37261 | 468.87 | <.0001 |
| *Qhat*** | -0.14323 | 0.1206 | 1.41 | 0.235 |
| *SPI 12*** | -0.00697 | 0.06413 | 0.01 | 0.9134 |
| *Trend* | 0.04189 | 0.01627 | 6.63 | 0.01 |
| *Population%Change*** | 0.00274 | 0.05005 | 0 | 0.9563 |
| *Mun_use* | -0.26544 | 0.14974 | 3.14 | 0.0763 |
| *Interstatecomp_use* | -1.44301 | 0.59006 | 5.98 | 0.0145 |
| *silvercity* | 0.4049 | 0.17822 | 5.16 | 0.0231 |
| *North*** | 0.44155 | 0.34726 | 1.62 | 0.2035 |
| *Rural*** | -0.36708 | 0.27991 | 1.72 | 0.1897 |
| Observations | 119 | | | |
| R-Squared | 0.2778 | | | |

Table D.2 Instrumental Variable Results for New Mexico Full Model with SPI 12
Dependent Variable: Natural Log of Quantity Purchased

| **Variable Name** | Parameter Estimate | Standard Error | T-Value | Pr > T-Stat |
|---|---|---|---|---|
| *Intercept* | 27.67669 | 15.19287 | 1.82 | 0.0711 |
| *ag_seller* | -0.55498 | 0.75964 | -0.73 | 0.4665 |
| *lnavgpercap* | -0.04497 | 1.11372 | -0.04 | 0.9679 |
| *Lnalfalfa* | -4.61712 | 1.67449 | -2.76 | 0.0068 |
| *SPI 12* | -0.23138 | 0.2322 | -1 | 0.3211 |
| Observations | 119 | | | |
| R-Squared | 0.0723 | | | |

Table D.3 New Mexico Full Model with SPI 12 six month lag
Dependent Variable: Natural Log of Adjusted Price per acre-foot

| **Variable Name** | Parameter Estimate | Robust Standard Error | Chi-Square | Pr > ChiSq |
|---|---|---|---|---|
| *Intercept* | 8.03848 | 0.3488 | 531.13 | <.0001 |
| *Qhat*** | -0.11891 | 0.1015 | 1.37 | 0.2414 |
| *SPI 12 six month lag*** | -0.0428 | 0.07856 | 0.3 | 0.5859 |
| *Trend* | 0.03906 | 0.01442 | 7.34 | 0.0067 |
| *Population%Change*** | -0.00482 | 0.05199 | 0.01 | 0.9261 |
| *Mun_use* | -0.26884 | 0.15432 | 3.03 | 0.0815 |
| *Interstatecomp_use* | -1.45925 | 0.58509 | 6.22 | 0.0126 |
| *silvercity* | 0.3839 | 0.16464 | 5.44 | 0.0197 |
| *North*** | 0.44602 | 0.34242 | 1.7 | 0.1927 |
| *Rural*** | -0.35982 | 0.2818 | 1.63 | 0.2017 |
| Observations | 119 | | | |
| R-Squared | 0.2782 | | | |

Table D.4 Instrumental Variable Results for New Mexico Full Model with SPI 12 six month lag
Dependent Variable: Natural Log of Quantity Purchased

| **Variable Name** | Parameter Estimate | Standard Error | T-Value | Pr > T-Stat |
|---|---|---|---|---|
| *Intercept* | 30.2763 | 15.06116 | 2.01 | 0.0468 |
| *ag_seller* | -0.42611 | 0.75485 | -0.56 | 0.5735 |
| *lnavgpercap* | -0.25514 | 1.12595 | -0.23 | 0.8211 |
| *lnalfalfa* | -4.73733 | 1.63346 | -2.9 | 0.0045 |
| *SPI 12 six month lag* | -0.313 | 0.22703 | -1.38 | 0.1707 |
| Observations | 119 | | | |
| R-Squared | 0.0795 | | | |

Table D.5 Albuquerque Model with SPI 12
Dependent Variable: Natural Log of Adjusted Price per acre-foot

| **Variable Name** | Parameter Estimate | Robust Standard Error | Chi-Square | Pr > ChiSq |
|---|---|---|---|---|
| *Intercept* | 7.69689 | 0.33837 | 517.43 | <.0001 |
| *Qhat*** | -0.0164 | 0.07697 | 0.05 | 0.8313 |
| *SPI 12* | 0.06947 | 0.0333 | 4.35 | 0.037 |
| *Trend* | 0.08174 | 0.00531 | 236.82 | <.0001 |
| *Population%Change* | -0.30247 | 0.0602 | 25.25 | <.0001 |
| *Mun_use*** | -0.16707 | 0.14967 | 1.25 | 0.2643 |
| Observations | 31 | | | |
| R-Squared | 0.8516 | | | |

Table D.6 Instrumental Variable Results for Albuquerque Model with SPI 12
Dependent Variable: Natural Log of Quantity Purchased

| **Variable Name** | Parameter Estimate | Standard Error | T-Value | Pr > T-Stat |
|---|---|---|---|---|
| *Intercept* | 15.3013 | 38.55946 | 0.4 | 0.6947 |
| *ag_seller* | 1.21995 | 0.97686 | 1.25 | 0.2228 |
| *lnavgpercap* | -0.32632 | 1.8855 | -0.17 | 0.8639 |
| *Lnalfalfa* | -1.74471 | 4.41926 | -0.39 | 0.6962 |
| *SPI 12* | 0.02589 | 0.33652 | 0.08 | 0.9393 |
| Observations | 31 | | | |
| R-Squared | 0.0829 | | | |

Table D.7 Albuquerque Model with SPI 12 six month lag
Dependent Variable: Natural Log of Adjusted Price per acre-foot

| **Variable Name** | Parameter Estimate | Robust Standard Error | Chi-Square | Pr > ChiSq |
|---|---|---|---|---|
| *Intercept* | 7.22886 | 0.3146 | 27.99 | <.0001 |
| *Qhat*** | 0.10066 | 0.07563 | 1.77 | 0.1832 |
| *SPI 12 six month lag*** | 0.02309 | 0.03898 | 0.35 | 0.5537 |
| *Trend* | 0.0733 | 0.00545 | 80.61 | <.0001 |
| *Population%Change* | -0.31378 | 0.06026 | 27.11 | <.0001 |
| *Mun_use*** | -0.09974 | 0.15169 | 0.43 | 0.5108 |
| Observations | 31 | | | |
| R-Squared | 0.8429 | | | |

Table D.8 Instrumental Variable Results for Albuquerque Model with SPI 12 six month lag
Dependent Variable: Natural Log of Quantity Purchased

| **Variable Name** | Parameter Estimate | Standard Error | T-Value | Pr > T-Stat |
|---|---|---|---|---|
| *Intercept* | 45.89708 | 39.35307 | 1.17 | 0.2541 |
| *ag_seller* | 1.31571 | 0.91743 | 1.43 | 0.1635 |
| *lnavgpercap* | -1.76367 | 1.93358 | -0.91 | 0.3701 |
| *Lnalfalfa* | -4.96096 | 4.49623 | -1.1 | 0.28 |
| *SPI 12 six month lag* | -0.42309 | 0.38259 | -1.11 | 0.2789 |
| Observations | 31 | | | |
| R-Squared | 0.1239 | | | |

Table D.9 Gila-San Francisco Model with SPI 24
Dependent Variable: Natural Log of Adjusted Price per acre-foot

| **Variable Name** | Parameter Estimate | Robust Standard Error | Chi-Square | Pr > ChiSq |
|---|---|---|---|---|
| *Intercept* | 15.10993 | 1.67266 | 81.6 | <.0001 |
| *Qhat* | 0.17464 | 0.06674 | 6.85 | 0.0089 |
| *SPI 24*** | -0.20434 | 0.12626 | 2.62 | 0.1056 |
| *Trend* | 0.0673 | 0.02043 | 10.86 | 0.001 |
| *Gila* | 0.92964 | 0.12729 | 53.34 | <.0001 |
| *Population%Change* | 0.19663 | 0.05353 | 13.49 | 0.0002 |
| *lnCOMEX_Copper* | -3.67674 | 0.44854 | 67.19 | <.0001 |
| *lnCalve_Price* | 1.78209 | 0.29281 | 37.04 | <.0001 |
| Observations | 65 | | | |
| R-Squared | 0.7109 | | | |

Table D.10 Instrumental Variable Results for Gila-San Francisco Model with SPI 24
Dependent Variable: Natural Log of Quantity Purchased

| **Variable Name** | Parameter Estimate | Standard Error | T-Value | Pr > T-Stat |
|---|---|---|---|---|
| *Intercept* | -125.42552 | 41.32279 | -3.04 | 0.0036 |
| *ag_seller* | 0.99423 | 1.3941 | 0.71 | 0.4785 |
| *lnavgpercap* | 10.69281 | 4.2299 | 2.53 | 0.0141 |
| *lnalfalfa* | 4.03994 | 1.48306 | 2.72 | 0.0084 |
| *SPI 24* | 0.65218 | 0.22305 | 2.92 | 0.0049 |
| Observations | 65 | | | |
| R-Squared | 0.2310 | | | |

Table D.11 Gila-San Francisco Model with SPI 24 six month lag
Dependent Variable: Natural Log of Adjusted Price per acre-foot

| **Variable Name** | Parameter Estimate | Robust Standard Error | Chi-Square | Pr > ChiSq |
|---|---|---|---|---|
| *Intercept* | 14.11007 | 1.56962 | 80.81 | <.0001 |
| *Qhat* | 0.19356 | 0.06492 | 8.89 | 0.0029 |
| *SPI 24* | -0.24229 | 0.11781 | 4.23 | 0.0397 |
| *Trend* | 0.07013 | 0.02053 | 11.67 | 0.0006 |
| *Gila* | 0.91089 | 0.11766 | 59.93 | <.0001 |
| *Population%Change* | 0.17476 | 0.04806 | 13.22 | 0.0003 |
| *lnCOMEX_Copper* | -3.55464 | 0.40451 | 77.22 | <.0001 |
| *lnCalve_Price* | 1.89105 | 0.31636 | 35.73 | <.0001 |
| Observations | 65 | | | |
| R-Squared | 0.7132 | | | |

Table D.12 Instrumental Variable Results for Gila-San Francisco Model with SPI 24 six month lag
Dependent Variable: Natural Log of Quantity Purchased

| **Variable Name** | Parameter Estimate | Standard Error | T-Value | Pr > T-Stat |
|---|---|---|---|---|
| *Intercept* | -110.68882 | 41.91716 | -2.64 | 0.0105 |
| *ag_seller* | 0.7777 | 1.43179 | 0.54 | 0.589 |
| *lnavgpercap* | 9.55118 | 4.33094 | 2.21 | 0.0313 |
| *lnalfalfa* | 3.42648 | 1.50636 | 2.27 | 0.0265 |
| *SPI 24 six month lag* | 0.48026 | 0.22479 | 2.14 | 0.0367 |
| Observations | 65 | | | |
| R-Squared | 0.1835 | | | |

** Insignificant at the 10% level
* Insignificant at the 5% level

# *Appendix E: Other Intermountain and Urban Water Market Models and their Instrumental Variable Results*

Table E.1 Intermountain Model with SPI 12
Dependent Variable: Natural Log of Adjusted Price per acre-foot

| **Variable Name** | Parameter Estimate | Robust Standard Error | Chi-Square | Pr > ChiSq |
|---|---|---|---|---|
| *Intercept* | 8.83238 | 0.22242 | 1576.85 | <.0001 |
| *Qhat* | -0.28734 | 0.04986 | 33.21 | <.0001 |
| *SPI 12* | -0.07341 | 0.01947 | 14.22 | 0.0002 |
| *Trend* | 0.06618 | 0.00577 | 131.54 | <.0001 |
| *Population%Change* | -0.14333 | 0.02179 | 43.26 | <.0001 |
| *Mun_use* | 0.31464 | 0.05776 | 29.67 | <.0001 |
| *Env_use* | -1.36569 | 0.16837 | 65.79 | <.0001 |
| *rec_use* | -2.34072 | 1.09439 | 4.57 | 0.0324 |
| *Az* | -1.16963 | 0.14011 | 69.69 | <.0001 |
| *nm*** | -0.1362 | 0.10605 | 1.65 | 0.199 |
| *Nv* | 0.54306 | 0.10893 | 24.85 | <.0001 |
| *Ut* | -1.51969 | 0.15755 | 93.05 | <.0001 |
| Observations | 1604 | | | |
| R-Squared | 0.5553 | | | |

Table E.2 Instrumental Variable Results for Intermountain Model with SPI 12
Dependent Variable: Natural Log of Quantity Purchased

| **Variable Name** | Parameter Estimate | Standard Error | T-Value | Pr > T-Stat |
|---|---|---|---|---|
| *Intercept* | 31.26184 | 2.80146 | 11.16 | <.0001 |
| *ag_seller* | -1.82529 | 0.12858 | -14.2 | <.0001 |
| *lnavgpercap* | -2.16705 | 0.1913 | -11.33 | <.0001 |
| *lnalfalfa* | -0.88894 | 0.26133 | -3.4 | 0.0007 |
| *SPI 12* | -0.02293 | 0.0511 | -0.45 | 0.6536 |
| Observations | 1604 | | | |
| R-Squared | 0.1720 | | | |

Table E.3 Intermountain Model with SPI 12 six month lag
Dependent Variable: Natural Log of Adjusted Price per acre-foot

| **Variable Name** | Parameter Estimate | Robust Standard Error | Chi-Square | Pr > ChiSq |
|---|---|---|---|---|
| *Intercept* | 8.82559 | 0.22307 | 1565.36 | <.0001 |
| *Qhat* | -0.28722 | 0.05016 | 32.79 | <.0001 |
| *SPI 12 six month lag*** | -0.01743 | 0.01949 | 0.8 | 0.3711 |
| *Trend* | 0.06707 | 0.00574 | 136.77 | <.0001 |
| *Population%Change* | -0.15332 | 0.02196 | 48.76 | <.0001 |
| *Mun_use* | 0.31517 | 0.05744 | 30.11 | <.0001 |
| *Env_use* | -1.36762 | 0.17029 | 64.5 | <.0001 |
| *rec_use* | -2.37271 | 1.10971 | 4.57 | 0.0325 |
| *Az* | -1.12993 | 0.14025 | 64.91 | <.0001 |
| *nm*** | -0.16425 | 0.10596 | 2.4 | 0.1211 |
| *Nv* | 0.61916 | 0.11026 | 31.53 | <.0001 |
| *Ut* | -1.48369 | 0.15774 | 88.47 | <.0001 |
| Observations | 1604 | | | |
| R-Squared | 0.5524 | | | |

Table E.4 Instrumental Variable Results for Intermountain Model with SPI 12 six month lag
Dependent Variable: Natural Log of Quantity Purchased

| **Variable Name** | Parameter Estimate | Standard Error | T-Value | Pr > T-Stat |
|---|---|---|---|---|
| *Intercept* | 31.67635 | 2.8845 | 10.98 | <.0001 |
| *ag_seller* | -1.82037 | 0.12709 | -14.32 | <.0001 |
| *lnavgpercap* | -2.18852 | 0.19453 | -11.25 | <.0001 |
| *lnalfalfa* | -0.9309 | 0.27 | -3.45 | 0.0006 |
| *SPI 12 six month lag* | -0.03734 | 0.04977 | -0.75 | 0.4532 |
| Observations | 1604 | | | |
| R-Squared | 0.1722 | | | |

Table E.5 Urban Model with SPI 12
Dependent Variable: Natural Log of Adjusted Price per acre-foot

| **Variable Name** | Parameter Estimate | Robust Standard Error | Chi-Square | Pr > ChiSq |
|---|---|---|---|---|
| *Intercept* | 8.50849 | 0.25942 | 1075.72 | <.0001 |
| *Qhat* | -0.26998 | 0.056 | 23.24 | <.0001 |
| *SPI 12* | -0.06511 | 0.01807 | 12.98 | 0.0003 |
| *Trend* | 0.0752 | 0.00659 | 130.38 | <.0001 |
| *Population%Change* | -0.10735 | 0.022 | 23.81 | <.0001 |
| *Mun_use* | 0.44162 | 0.06234 | 50.19 | <.0001 |
| *Env_use* | -1.16555 | 0.16431 | 50.32 | <.0001 |
| *rec_use*** | 0.47303 | 0.73263 | 0.42 | 0.5185 |
| *Albuq* | -0.49892 | 0.08807 | 32.09 | <.0001 |
| *Lasvegas*** | 0.21814 | 0.16542 | 1.74 | 0.1873 |
| *Reno* | 0.5141 | 0.116 | 19.64 | <.0001 |
| *Saltlkcity* | -1.39414 | 0.28008 | 24.78 | <.0001 |
| *Phx* | -1.28075 | 0.21431 | 35.71 | <.0001 |
| *Tuc* | -1.14628 | 0.15125 | 57.43 | <.0001 |
| Observations | 1447 | | | |
| R-Squared | 0.5806 | | | |

Table E.6 Instrumental Variable Results for Urban Model with SPI 12
Dependent Variable: Natural Log of Quantity Purchased

| **Variable Name** | Parameter Estimate | Standard Error | T-Value | Pr > T-Stat |
|---|---|---|---|---|
| *Intercept* | 28.07303 | 3.06526 | 9.16 | <.0001 |
| *ag_seller* | -1.67605 | 0.12827 | -13.07 | <.0001 |
| *lnavgpercap* | -2.26475 | 0.21266 | -10.65 | <.0001 |
| *lnalfalfa* | -0.01352 | 0.28184 | -0.05 | 0.9617 |
| *SPI 12* | 0.05459 | 0.05147 | 1.06 | 0.289 |
| Observations | 1447 | | | |
| R-Squared | 0.1782 | | | |

Table E.7 Urban Model with SPI 12 six month lag
Dependent Variable: Natural Log of Adjusted Price per acre-foot

| **Variable Name** | Parameter Estimate | Robust Standard Error | Chi-Square | Pr > ChiSq |
|---|---|---|---|---|
| *Intercept* | 8.50814 | 0.25737 | 1092.86 | <.0001 |
| *Qhat* | -0.27063 | 0.05583 | 23.49 | <.0001 |
| *SPI 12 six month lag*** | -0.00623 | 0.01869 | 0.11 | 0.7389 |
| *Trend* | 0.0761 | 0.00656 | 134.49 | <.0001 |
| *Population%Change* | -0.11765 | 0.02198 | 28.64 | <.0001 |
| *Mun_use* | 0.43696 | 0.06174 | 50.08 | <.0001 |
| *Env_use* | -1.16712 | 0.16595 | 49.46 | <.0001 |
| *rec_use*** | 0.48708 | 0.72015 | 0.46 | 0.4988 |
| *Albuq* | -0.51658 | 0.08471 | 37.19 | <.0001 |
| *Lasvegas** | 0.2752 | 0.16413 | 2.81 | 0.0936 |
| *Reno* | 0.58917 | 0.11439 | 26.53 | <.0001 |
| *saltlkcity* | -1.35685 | 0.28633 | 22.46 | <.0001 |
| *Phx* | -1.24834 | 0.21507 | 33.69 | <.0001 |
| *Tuc* | -1.10862 | 0.14938 | 55.08 | <.0001 |
| Observations | 1447 | | | |
| R-Squared | 0.5774 | | | |

Table E.8 Instrumental Variable Results for Urban Model with SPI 12 six month lag
Dependent Variable: Natural Log of Quantity Purchased

| **Variable Name** | Parameter Estimate | Standard Error | T-Value | Pr > T-Stat |
|---|---|---|---|---|
| *Intercept* | 26.73633 | 3.15298 | 8.48 | <.0001 |
| *ag_seller* | -1.68819 | 0.12598 | -13.4 | <.0001 |
| *lnavgpercap* | -2.20408 | 0.21481 | -10.26 | <.0001 |
| *lnalfalfa* | 0.14031 | 0.29459 | 0.48 | 0.6339 |
| *SPI 12 six month lag* | 0.10302 | 0.04997 | 2.06 | 0.0394 |
| Observations | 1447 | | | |
| R-Squared | 0.1800 | | | |

** Insignificant at the 10% level
* Insignificant at the 5% level

# *Appendix F: Nevada Water Market Models and their Instrumental Variable Results*

Table F.1 Nevada Full Model with SPI 12
Dependent Variable: Natural Log of Adjusted Price per acre-foot

| **Variable Name** | Parameter Estimate | Robust Standard Error | Chi-Square | Pr > ChiSq |
|---|---|---|---|---|
| *Intercept* | 7.00275 | 0.64488 | 117.92 | <.0001 |
| *Qhat*** | -0.10585 | 0.11236 | 0.89 | 0.3462 |
| *SPI 12*** | 0.01462 | 0.05654 | 0.07 | 0.796 |
| *Trend* | 0.04599 | 0.00852 | 29.11 | <.0001 |
| *Population%Change*** | 0.00851 | 0.04076 | 0.04 | 0.8346 |
| *Mun_use* | 1.29532 | 0.18351 | 49.82 | <.0001 |
| *Env_use*** | 0.08252 | 0.26488 | 0.1 | 0.7554 |
| *Lasvegas* | -0.4339 | 0.09681 | 20.09 | <.0001 |
| *Rural* | -1.17211 | 0.36084 | 10.55 | 0.0012 |
| Observations | 198 | | | |
| R-Squared | 0.5850 | | | |

Table F.2 Instrumental Variable Results for Nevada Full Model with SPI 12
Dependent Variable: Natural Log of Quantity Purchased

| **Variable Name** | Parameter Estimate | Standard Error | T Value | Pr > T-Stat |
|---|---|---|---|---|
| *Intercept* | 3.05465 | 14.72537 | 0.21 | 0.8359 |
| *ag_seller* | 0.87914 | 0.39095 | 2.25 | 0.0257 |
| *lnavgpercap* | 0.39364 | 0.96422 | 0.41 | 0.6835 |
| *Lnalfalfa* | -0.59302 | 1.19856 | -0.49 | 0.6213 |
| *SPI 12* | 0.45235 | 0.1525 | 2.97 | 0.0034 |
| Observations | 198 | | | |
| R-Squared | 0.0767 | | | |

Table F.3 Nevada Full Model with SPI 12 six month lag
Dependent Variable: Natural Log of Adjusted Price per acre-foot

| **Variable Name** | Parameter Estimate | Robust Standard Error | Chi-Square | Pr > ChiSq |
|---|---|---|---|---|
| *Intercept* | 6.98555 | 0.61961 | 27.11 | <.0001 |
| *Qhat*** | -0.10457 | 0.10982 | 0.91 | 0.341 |
| *SPI 12 six month lag*** | -0.00881 | 0.03021 | 0.09 | 0.7704 |
| *Trend* | 0.04506 | 0.00875 | 26.51 | <.0001 |
| *Population%Change*** | 0.00833 | 0.03972 | 0.04 | 0.8339 |
| *Mun_use* | 1.30464 | 0.17597 | 54.97 | <.0001 |
| *Env_use*** | 0.09314 | 0.26125 | 0.13 | 0.7214 |
| *Lasvegas* | -0.43293 | 0.09099 | 22.64 | <.0001 |
| *Rural* | -1.14959 | 0.36203 | 10.08 | 0.0015 |
| Observations | 198 | | | |
| R-Squared | 0.5852 | | | |

Table F.4 Instrumental Variable Results for Nevada Full Model with SPI 12 six month lag
Dependent Variable: Natural Log of Quantity Purchased

| **Variable Name** | Parameter Estimate | Standard Error | T Value | Pr > T-Stat |
|---|---|---|---|---|
| *Intercept* | 2.86938 | 16.47817 | 0.17 | 0.8619 |
| *ag_seller* | 0.91414 | 0.39843 | 2.29 | 0.0228 |
| *lnavgpercap* | 0.27681 | 1.0544 | 0.26 | 0.7932 |
| *Lnalfalfa* | -0.3386 | 1.35764 | -0.25 | 0.8033 |
| *SPI 12 six month lag* | 0.17112 | 0.13287 | 1.29 | 0.1993 |
| Observations | 198 | | | |
| R-Squared | 0.0429 | | | |

Table F.5 Nevada Full Model with SPI 24
Dependent Variable: Natural Log of Adjusted Price per acre-foot

| **Variable Name** | Parameter Estimate | Robust Standard Error | Chi-Square | Pr > ChiSq |
|---|---|---|---|---|
| *Intercept* | 7.05188 | 0.62192 | 128.57 | <.0001 |
| *Qhat*** | -0.10309 | 0.10962 | 0.88 | 0.347 |
| *SPI 24*** | -0.02306 | 0.03079 | 0.56 | 0.4537 |
| *Trend* | 0.04333 | 0.00856 | 25.66 | <.0001 |
| *Population%Change*** | 0.00203 | 0.03954 | 0 | 0.9591 |
| *Mun_use* | 1.26617 | 0.1768 | 51.29 | <.0001 |
| *Env_use*** | 0.04859 | 0.25506 | 0.04 | 0.8489 |
| *Lasvegas* | -0.42748 | 0.09202 | 21.58 | <.0001 |
| *Rural* | -1.17284 | 0.34734 | 11.4 | 0.0007 |
| Observations | 198 | | | |
| R-Squared | 0.5871 | | | |

Table F.6 Instrumental Variable Results for Nevada Full Model with SPI 24
Dependent Variable: Natural Log of Quantity Purchased

| **Variable Name** | Parameter Estimate | Standard Error | T Value | Pr > T-Stat |
|---|---|---|---|---|
| *Intercept* | 2.16781 | 16.46122 | 0.13 | 0.8954 |
| *ag_seller* | 0.91323 | 0.39809 | 2.29 | 0.0229 |
| *lnavgpercap* | 0.37304 | 1.0708 | 0.35 | 0.7279 |
| *Lnalfalfa* | -0.39175 | 1.32138 | -0.3 | 0.7672 |
| *SPI 24* | 0.18758 | 0.13557 | 1.38 | 0.1681 |
| Observations | 198 | | | |
| R-Squared | 0.0441 | | | |

Table F.7 Nevada Full Model with SPI 24 six month lag
Dependent Variable: Natural Log of Adjusted Price per acre-foot

| **Variable Name** | Parameter Estimate | Robust Standard Error | Chi-Square | Pr > ChiSq |
|---|---|---|---|---|
| *Intercept* | 7.02397 | 0.61315 | 131.23 | <.0001 |
| *Qhat*** | -0.09911 | 0.10708 | 0.86 | 0.3547 |
| *SPI 24 six month lag*** | -0.02474 | 0.02924 | 0.72 | 0.3974 |
| *Trend* | 0.0436 | 0.00864 | 25.44 | <.0001 |
| *Population%Change*** | 0.00172 | 0.03974 | 0 | 0.9654 |
| *Mun_use* | 1.27803 | 0.17287 | 54.66 | <.0001 |
| *Env_use*** | 0.05601 | 0.25425 | 0.05 | 0.8256 |
| *Lasvegas* | -0.43426 | 0.08553 | 25.78 | <.0001 |
| *Rural* | -1.16475 | 0.35532 | 10.75 | 0.001 |
| Observations | 198 | | | |
| R-Squared | 0.5881 | | | |

Table F.8 Instrumental Variable Results for Nevada Full Model with SPI 24 six month lag
Dependent Variable: Natural Log of Quantity Purchased

| **Variable Name** | Parameter Estimate | Standard Error | T Value | Pr > T-Stat |
|---|---|---|---|---|
| *Intercept* | 5.20304 | 15.73579 | 0.33 | 0.7413 |
| *ag_seller* | 0.92284 | 0.39881 | 2.31 | 0.0217 |
| *Lnavgpercap* | 0.15401 | 1.01758 | 0.15 | 0.8799 |
| *Lnalfalfa* | -0.56314 | 1.28755 | -0.44 | 0.6623 |
| *SPI 24 six month lag* | 0.15329 | 0.11953 | 1.28 | 0.2012 |
| Observations | 198 | | | |
| R-Squared | 0.0428 | | | |

Table F.9 Reno/Sparks Model with SPI 12
Dependent Variable: Natural Log of Adjusted Price per acre-foot

| **Variable Name** | Parameter Estimate | Robust Standard Error | Chi-Square | Pr > ChiSq |
|---|---|---|---|---|
| *Intercept* | 6.90792 | 0.90376 | 58.42 | <.0001 |
| *Qhat*** | -0.12465 | 0.17319 | 0.52 | 0.4717 |
| *SPI 12*** | 0.01629 | 0.07945 | 0.04 | 0.8375 |
| *Trend* | 0.04608 | 0.00879 | 27.5 | <.0001 |
| *Population%Change*** | 0.01745 | 0.0425 | 0.17 | 0.6813 |
| *Mun_use* | 1.43366 | 0.16132 | 78.98 | <.0001 |
| *Env_use*** | 0.20288 | 0.25295 | 0.64 | 0.4225 |
| Observations | 188 | | | |
| R-Squared | 0.5215 | | | |

Table F.10 Instrumental Variable Results for Reno/Sparks Model with SPI 12
Dependent Variable: Natural Log of Quantity Purchased

| **Variable Name** | Parameter Estimate | Standard Error | T Value | Pr > T-Stat |
|---|---|---|---|---|
| *Intercept* | 5.65197 | 15.51162 | 0.36 | 0.716 |
| *ag_seller* | 0.59482 | 0.40442 | 1.47 | 0.1431 |
| *lnavgpercap* | 0.15572 | 1.02916 | 0.15 | 0.8799 |
| *Lnalfalfa* | -0.61151 | 1.23335 | -0.5 | 0.6206 |
| *SPI 12* | 0.44103 | 0.15361 | 2.87 | 0.0046 |
| Observations | 188 | | | |
| R-Squared | 0.0609 | | | |

Table F.11 Reno/Sparks Model with SPI 12 six month lag
Dependent Variable: Natural Log of Adjusted Price per acre-foot

| **Variable Name** | Parameter Estimate | Robust Standard Error | Chi-Square | Pr > ChiSq |
|---|---|---|---|---|
| *Intercept* | 6.979 | 0.8884 | 61.71 | <.0001 |
| *Qhat*** | -0.14281 | 0.17816 | 0.64 | 0.4228 |
| *SPI 12 six month lag*** | -0.00053221 | 0.04118 | 0 | 0.9897 |
| *Trend* | 0.04508 | 0.00916 | 24.21 | <.0001 |
| *Population%Change*** | 0.01756 | 0.04067 | 0.19 | 0.6659 |
| *Mun_use* | 1.4392 | 0.14924 | 93 | <.0001 |
| *Env_use*** | 0.21874 | 0.24887 | 0.77 | 0.3794 |
| Observations | 188 | | | |
| R-Squared | 0.5215 | | | |

Table F.12 Instrumental Variable Results for Reno/Sparks Model with SPI 12 six month lag
Dependent Variable: Natural Log of Quantity Purchased

| **Variable Name** | Parameter Estimate | Standard Error | T Value | Pr > T-Stat |
|---|---|---|---|---|
| *Intercept* | 2.2828 | 17.47459 | 0.13 | 0.8962 |
| *ag_seller* | 0.61974 | 0.41112 | 1.51 | 0.1334 |
| *lnavgpercap* | 0.21791 | 1.12801 | 0.19 | 0.847 |
| *Lnalfalfa* | -0.07051 | 1.41735 | -0.05 | 0.9604 |
| *SPI 12 six month lag* | 0.19883 | 0.13392 | 1.48 | 0.1393 |
| Observations | 188 | | | |
| R-Squared | 0.0303 | | | |

Table F.13 Reno/Sparks Model with SPI 24
Dependent Variable: Natural Log of Adjusted Price per acre-foot

| **Variable Name** | Parameter Estimate | Robust Standard Error | Chi-Square | Pr > ChiSq |
|---|---|---|---|---|
| *Intercept* | 6.96162 | 0.88577 | 61.77 | <.0001 |
| *Qhat*** | -0.12124 | 0.17353 | 0.49 | 0.4848 |
| *SPI 24*** | -0.0185 | 0.03718 | 0.25 | 0.6187 |
| *Trend* | 0.04343 | 0.00894 | 23.61 | <.0001 |
| *Population%Change*** | 0.00898 | 0.04095 | 0.05 | 0.8265 |
| *Mun_use* | 1.40837 | 0.15387 | 83.78 | <.0001 |
| *Env_use*** | 0.16943 | 0.24256 | 0.49 | 0.4849 |
| Observations | 188 | | | |
| R-Squared | 0.5232 | | | |

Table F.14 Instrumental Variable Results for Reno/Sparks Model with SPI 24
Dependent Variable: Natural Log of Quantity Purchased

| **Variable Name** | Parameter Estimate | Standard Error | T Value | Pr > T-Stat |
|---|---|---|---|---|
| *Intercept* | 4.44253 | 17.45572 | 0.25 | 0.7994 |
| *ag_seller* | 0.62205 | 0.41202 | 1.51 | 0.1328 |
| *lnavgpercap* | 0.14455 | 1.1466 | 0.13 | 0.8998 |
| *Lnalfalfa* | -0.36358 | 1.37453 | -0.26 | 0.7917 |
| *SPI 24* | 0.16796 | 0.13609 | 1.23 | 0.2187 |
| Observations | 188 | | | |
| R-Squared | 0.0267 | | | |

Table F.15 Reno/Sparks Model with SPI 24 six month lag
Dependent Variable: Natural Log of Adjusted Price per acre-foot

| **Variable Name** | Parameter Estimate | Robust Standard Error | Chi-Square | Pr > ChiSq |
|---|---|---|---|---|
| *Intercept* | 6.98707 | 0.88161 | 62.81 | <.0001 |
| *Qhat*** | -0.12849 | 0.17386 | 0.55 | 0.4599 |
| *SPI 24 six month lag*** | -0.01317 | 0.04192 | 0.1 | 0.7534 |
| *Trend* | 0.04384 | 0.00904 | 23.5 | <.0001 |
| *Population%Change*** | 0.0099 | 0.04081 | 0.06 | 0.8083 |
| *Mun_use* | 1.41036 | 0.15017 | 88.2 | <.0001 |
| *Env_use*** | 0.17425 | 0.24241 | 0.52 | 0.4723 |
| Observations | 188 | | | |
| R-Squared | 0.5238 | | | |

Table F.16 Instrumental Variable Results for Reno/Sparks Model with SPI 24 six month lag
Dependent Variable: Natural Log of Quantity Purchased

| **Variable Name** | Parameter Estimate | Standard Error | T Value | Pr > T-Stat |
|---|---|---|---|---|
| *Intercept* | 4.65946 | 16.66219 | 0.28 | 0.7801 |
| *ag_seller* | 0.62697 | 0.41101 | 1.53 | 0.1289 |
| *lnavgpercap* | 0.09411 | 1.0878 | 0.09 | 0.9312 |
| *lnalfalfa* | -0.30079 | 1.33939 | -0.22 | 0.8226 |
| *SPI 24 six month lag* | 0.18731 | 0.12027 | 1.56 | 0.1211 |
| Observations | 188 | | | |
| R-Squared | 0.0314 | | | |

** Insignificant at the 10% level
* Insignificant at the 5% level

## *Appendix G: Utah Water Market Models and their Instrumental Variable Results*

Table G.1 Utah Full Model with SPI 12
Dependent Variable: Natural Log of Adjusted Price per acre-foot

| **Variable Name** | Parameter Estimate | Standard Error | T-Value | Pr > T-Stat |
|---|---|---|---|---|
| Intercept | 6.90001 | 1.40844 | 4.9 | <.0001 |
| *Qhat*** | -0.10148 | 0.18334 | -0.55 | 0.5834 |
| *SPI 12*** | -0.11231 | 0.13875 | -0.81 | 0.4237 |
| *Trend** | 0.0592 | 0.03032 | 1.95 | 0.0589 |
| *Population%Change*** | 0.22775 | 0.22072 | 1.03 | 0.3092 |
| *Mun_use*** | -0.161 | 0.28719 | -0.56 | 0.5786 |
| *SLC* | -0.86923 | 0.40562 | -2.14 | 0.0391 |
| *Park*** | 0.20574 | 0.57156 | 0.36 | 0.721 |
| *StGeorge* | -1.20815 | 0.42177 | -2.86 | 0.007 |
| *CUW*** | -0.41526 | 0.48729 | -0.85 | 0.3999 |
| Observations | 45 | | | |
| R-Squared | 0.4025 | | | |

Table G.2 Instrumental Variable Results for Utah Full Model with SPI 12
Dependent Variable: Natural Log of Quantity Purchased

| **Variable Name** | Parameter Estimate | Standard Error | T Value | Pr > T-Stat |
|---|---|---|---|---|
| *Intercept* | -15.61367 | 17.20548 | -0.91 | 0.3696 |
| *ag_seller* | -1.30734 | 0.80596 | -1.62 | 0.1126 |
| *lnavgpercap* | 0.00363 | 1.10728 | 0 | 0.9974 |
| *lnalfalfa* | 4.88519 | 2.02844 | 2.41 | 0.0207 |
| *SPI 12* | -0.1419 | 0.28241 | -0.5 | 0.6181 |
| Observations | 45 | | | |
| R-Squared | 0.2728 | | | |

Table G.3 Utah Full Model with SPI 12 with six month lag
Dependent Variable: Natural Log of Adjusted Price per acre-foot

| **Variable Name** | Parameter Estimate | Standard Error | T-Value | Pr > T-Stat |
|---|---|---|---|---|
| Intercept | 7.18289 | 1.58469 | 4.53 | <.0001 |
| *Qhat*** | -0.13184 | 0.20357 | -0.65 | 0.5215 |
| *SPI 12 six month lag*** | -0.07415 | 0.16172 | -0.46 | 0.6494 |
| *Trend*** | 0.05356 | 0.03208 | 1.67 | 0.1039 |
| *Population%Change*** | 0.19118 | 0.21486 | 0.89 | 0.3797 |
| *Mun_use*** | -0.15459 | 0.2902 | -0.53 | 0.5976 |
| *SLC* | -0.84328 | 0.40741 | -2.07 | 0.0459 |
| *Park*** | 0.23222 | 0.59085 | 0.39 | 0.6967 |
| *StGeorge* | -1.15431 | 0.41254 | -2.8 | 0.0083 |
| *CUW*** | -0.39864 | 0.4891 | -0.82 | 0.4206 |
| Observations | 45 | | | |
| R-Squared | 0.3970 | | | |

Table G.4 Instrumental Variable Results for Utah Full Model with SPI 12 six month lag
Dependent Variable: Natural Log of Quantity Purchased

| **Variable Name** | Parameter Estimate | Standard Error | T Value | Pr > T-Stat |
|---|---|---|---|---|
| *Intercept* | -18.05986 | 21.03946 | -0.86 | 0.3958 |
| *ag_seller* | -1.34635 | 0.8184 | -1.65 | 0.1078 |
| *lnavgpercap* | 0.07683 | 1.24435 | 0.06 | 0.9511 |
| *lnalfalfa* | 5.27468 | 2.47271 | 2.13 | 0.0391 |
| *SPI 12 six month lag* | 0.0115 | 0.35964 | 0.03 | 0.9746 |
| Observations | 45 | | | |
| R-Squared | 0.2682 | | | |

Table G.5 Utah Full Model with SPI 24
Dependent Variable: Natural Log of Adjusted Price per acre-foot

| **Variable Name** | Parameter Estimate | Standard Error | T-Value | Pr > T-Stat |
|---|---|---|---|---|
| Intercept | 6.9027 | 1.54174 | 4.48 | <.0001 |
| *Qhat*** | -0.09549 | 0.19891 | -0.48 | 0.6341 |
| *SPI 24*** | -0.02297 | 0.15198 | -0.15 | 0.8808 |
| *Trend** | 0.05697 | 0.03234 | 1.76 | 0.0869 |
| *Population%Change*** | 0.1857 | 0.21506 | 0.86 | 0.3937 |
| *Mun_use*** | -0.13563 | 0.28881 | -0.47 | 0.6415 |
| *SLC** | -0.81313 | 0.40703 | -2 | 0.0536 |
| *Park*** | 0.30885 | 0.56861 | 0.54 | 0.5905 |
| *StGeorge* | -1.10929 | 0.40419 | -2.74 | 0.0095 |
| *CUW*** | -0.40018 | 0.4905 | -0.82 | 0.4201 |
| Observations | 45 | | | |
| R-Squared | 0.3936 | | | |

Table G.6 Instrumental Variable Results for Utah Full Model with SPI 24
Dependent Variable: Natural Log of Quantity Purchased

| **Variable Name** | Parameter Estimate | Standard Error | T Value | Pr > T-Stat |
|---|---|---|---|---|
| *Intercept* | -15.57538 | 19.64831 | -0.79 | 0.4326 |
| *ag_seller* | -1.32694 | 0.80846 | -1.64 | 0.1086 |
| *lnavgpercap* | -0.04225 | 1.21145 | -0.03 | 0.9724 |
| *Lnalfalfa* | 4.98431 | 2.25466 | 2.21 | 0.0328 |
| *SPI 24* | -0.06796 | 0.33513 | -0.2 | 0.8403 |
| Observations | 45 | | | |
| R-Squared | 0.2690 | | | |

Table G.7 Utah Full Model with SPI 24 with six month lag
Dependent Variable: Natural Log of Adjusted Price per acre-foot

| **Variable Name** | Parameter Estimate | Standard Error | T-Value | Pr > T-Stat |
|---|---|---|---|---|
| Intercept | 6.79398 | 1.38407 | 4.91 | <.0001 |
| *Qhat*** | -0.08098 | 0.17596 | -0.46 | 0.6482 |
| *SPI 24*** | 0.00386 | 0.12657 | 0.03 | 0.9758 |
| *Trend** | 0.05864 | 0.03133 | 1.87 | 0.0696 |
| *Population%Change*** | 0.18514 | 0.21649 | 0.86 | 0.3983 |
| *Mun_use*** | -0.12923 | 0.28635 | -0.45 | 0.6546 |
| *SLC** | -0.79766 | 0.39905 | -2 | 0.0534 |
| *Park*** | 0.3342 | 0.5669 | 0.59 | 0.5593 |
| *StGeorge* | -1.1045 | 0.39937 | -2.77 | 0.009 |
| *CUW*** | -0.3925 | 0.49962 | -0.79 | 0.4374 |
| Observations | 45 | | | |
| R-Squared | 0.3932 | | | |

Table G.8 Instrumental Variable Results for Utah Full Model with SPI 24 six month lag
Dependent Variable: Natural Log of Quantity Purchased

| **Variable Name** | Parameter Estimate | Standard Error | T Value | Pr > T-Stat |
|---|---|---|---|---|
| *Intercept* | -22.49251 | 18.72205 | -1.2 | 0.2367 |
| *ag_seller* | -1.33027 | 0.80255 | -1.66 | 0.1052 |
| *lnavgpercap* | 0.32595 | 1.1959 | 0.27 | 0.7866 |
| *Lnalfalfa* | 5.6975 | 2.08164 | 2.74 | 0.0092 |
| *SPI 24 six month lag* | 0.17043 | 0.29779 | 0.57 | 0.5703 |
| Observations | 45 | | | |
| R-Squared | 0.2742 | | | |

** Insignificant at the 10% level
* Insignificant at the 5% level

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