# VALUING LONE STAR WATER: AN ANALYSIS OF PRICE DETERMINANTS IN TEXAS WATER MARKETS

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VALUING LONE STAR WATER: AN ANALYSIS

OF PRICE DETERMINANTS IN

TEXAS WATER MARKETS

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## ABSTRACT

Population growth and urban demands, combined with recurring drought conditions, have led to increased water scarcity across the western United States. This scarcity has accentuated the need for more efficient allocation of water resources to the highest value users. Water markets have proven to be an effective mechanism for promoting allocative efficiency and providing price signals that indicate the value of water. A better understanding of the market variables and water right and transaction characteristics that affect water price determination enables market participants to make more informed consumption and purchase decisions. This study uses the hedonic pricing method to analyze the price determinants of 144 water right transactions in the state of Texas occurring between 1988 and 2009. The results of the hedonic model show that rural land values and per capita income levels are positively related with the price per committed acre-foot of water; urban users pay higher prices for water rights than other users; the per unit price of water decreases as transaction volume increases, as fixed transactions costs are spread over a greater quantity; and water rights transferred within the jurisdiction of a Texas Watermaster Program exhibit lower prices than those transferred in areas where this institutional structure does not exist.

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# INTRODUCTION

Due to growing demand from residential population growth and increased industrial, commercial, and agriculture use, coupled with dwindling supplies in many drought-laden regions throughout the country and the world, the economic and financial implications of water have risen to the forefront in recent years. As these trends accelerate into the future, it is almost certain that water costs will continue an upward trajectory that will have major implications for consumers and businesses in the US and globally. While water markets are relatively undeveloped, Texas has had a fairly active market of water transfers. The price paid for water rights is affected by a multitude of determinants that vary widely based upon regional geography and regulation.

After analyzing a set of transactions from 1988-2009, a hedonic model was used to reveal the effect of water right and transaction attributes and market characteristics on the price of water in market transactions. Exploring these price determinants revealed important insights on the factors driving water value in Texas. Such information will help market participants make more informed decisions when negotiating transactions, helping to improve market efficiency. On a broader scale, a more efficient market will send better price signals that help private sector businesses and consumers make more effective economic decisions and governments more appropriately weigh the tradeoffs among economic, ecological, and societal values when developing future water resource policies.

# LITERATURE REVIEW

## Global Water Scarcity

At present, one billion people lack access to safe drinking water and three billion are without basic sanitation. In 2003, the UN warned that this number could grow to over seven billion by 2050, unless actions were taken to reverse prevailing supply and demand trends. Though predictions such as this have forced the world to confront the water issues coming in the future, the debate of how best to proceed continues to prolong implementation of long-term solutions. Participants at the Third World Water Forum recognized that there is no single method for attacking the problem, and acknowledged the merits of ideas such as dam building, water pricing, and privatization. The UN report specifically stated that better valuation of water and more private-sector involvement will be necessary aspects of a successful effort to mitigate water shortages that could affect hundreds of millions of people (Alexander, 2003).

While implementation of the aforementioned strategies have led to improvements in immediate water shortages, the need for more extensive efforts still exists. As of 2010, 783 million people continued to use unimproved sources to meet their drinking water needs (Joint Monitoring Programme 2012). In a study conducted to assess the costs and benefits of sanitation and drinking supply to meet the UN Millennium Development Goals for 2015, the total economic loss associated with inadequate drinking water supply and sanitation was estimated at $260 billion annually (Hutton, 2012). Beyond the societal and humanitarian reasons for solving global water shortages, the report provided evidence of the economic incentives for doing so. The scope of the costs assessed in this study was limited to those related to individual access to adequate sanitation and drinking water supply, so the potential economic losses to agriculture, industry, and commercial businesses would only add to the potentially catastrophic consequences.

**Water Supply and Demand Trends**

While the basic need for water is a major concern from a global perspective, with the most severe shortages impacting developing, third-world countries, developed nations are beginning to recognize the financial implications of supply constraints. Particularly in the United States, policy-makers and individuals have just recently begun to address regional water shortages manifesting from long-term trends of inefficient usage and a general disregard for conservation. Since World War II, increased industrialization and urban population growth across regions in the western half of the United States have resulted in unprecedented demand for water. Combined with dwindling supplies in drought-ridden regions, these growing demand trends have limited the availability of water resources, resulting in reduced stream flows, lowered water levels in reservoirs, and depleted underground aquifers. One of the most concerning examples is the High Plains aquifer, which covers 174,000 square miles across Colorado, Nebraska, Oklahoma, South Dakota, Texas, and Wyoming. Since 1950 this major water source has lost enough water to cover 200 million acres of land a foot deep, representing almost 8% of its total water, according to the US Geological Survey (Henderson & Akers, 2008).

The list of demands on existing supplies is only getting longer in the western portions of the US. Since the latter decades of the 20$^{th}$ century, technology developments and modern irrigation techniques have led to substantial increases in agriculture water use. Though growth in manufacturing activity has slowed since the 1980's, industrial needs remain high, especially in more water intensive industries such as petroleum, chemicals, and primary metals (Hutson, et al., 2005). Though conservation efforts have helped to slow agricultural and industrial use, the growing population has continued to increase demand for water. These populations have not only increased residential water demands, but have also increased power and energy usage. Energy consumption is an indirect form of water consumption, as the process of transforming energy sources into usable power and fuel requires substantial water inputs (Henry, 2013). Additionally, rising incomes have increased recreational water usage, adding economic incentive to the already growing support for environmental protection, spurring further demand pressures on water sources. Ultimately, the biggest surge in water demand stems from rising residential and commercial use in urban areas. With accelerating population growth expected in undersupplied states such as Colorado and Texas, procuring water supply for public use will become progressively more difficult, and expensive, for cities and municipalities (Henderson & Akers, 2008). In a recent example, over the first six months of 2013, the price for a share of Colorado's largest water-supply project nearly doubled, according to officials at the Northern Colorado Water Convservancy District. Increased profitability in the agriculture industry has incentivized farmers to retain the water they had been electing to sell to growing cities in the region for years because it was seen as more economically beneficially. But now, the tables have turned, and the fast-growing urban areas must pay record-high prices to these users in order to fulfill the needs of their residents (Greeley Tribune, 2013). As is the intention of water markets such as this one, the price acts a signal of the underlying value of the scarce resource, allocating the resource more efficiently and promoting conservation.

**Water Markets**

> *"Nothing is more useful than water: but it will purchase scarce anything; scarce anything can be had in exchange for it. A diamond, on the contrary, has scarce any use-value; but a very great quantity of other goods may frequently be had in exchange for it."*
>
> *—Adam Smith, Chapter 4, Book I, Wealth of Nations (1776).*

In an ideal, well-functioning market where the producers and consumers both experience the full benefits and costs of their activities, the greatest possible benefit to society is achieved. Markets are not well-functioning when producers do not bear all the costs of their production (i.e., negative externalities), which frequently occurs with markets for water. Due to this factor and the difficulties in determining these externalities, water markets are among the more complicated, troublesome, and cumbersome of markets (Brady & Yoder, 2013). The quote above from Adam Smith, highlights how the market price of a good can be relatively unrelated, or not fully reflective of, the full economic value of a good and its contributions to welfare, and for water, to life itself.

Water markets have carved out a significant role, particularly in the Western US, in response to exploding population growth and dwindling water supply across this predominantly arid region. Consequently, the literature on this topic has grown quite substantial. Though the term 'water market' lacks a precise definition, Brown (2006) explained that, generally, wherever a few voluntary trades of water of relatively common physical and legal characteristics occur, it is said that a water market exists. At this point it is generally accepted that there are wide gaps between the values of water for different uses, such as municipal and agricultural. Major differences in price across uses cannot be explained only by conveyance costs and water quality, suggesting that markets have not developed enough to close the gaps. Early on, Howe, Schurmeier, and Shaw (1986) highlighted the potential benefits of water markets as a mechanism for improving water allocation to higher value uses. However, as Young (1986) pointed out, the theoretical role for water markets did not take to form as quickly as might have been expected nor on a widespread basis throughout the county.

A substantial amount of the subsequent literature attempted to explain reasons for the apparent lack of market activity. These works found common recurring threads that arose from the properties of water that make effective definition and enforcement of water rights a high-cost proposition. From a technical perspective the fluidity of water--the fact that it physically connects one individual's water rights with another's--introduces difficulties in defining and enforcing water rights (Brewer, Glennon, Ker, & Libecap, 2008). Furthermore, water's role in the ecosystem adds complexities in quantifying externalities to water market transfers. These externalities, or third-party effects, involve accounting for users outside of those immediately involved in the transaction. There is tendency of private transactions to fail to fully consider social costs and benefits, which leads to suboptimal societal allocation (Brady & Yoder, 2013). Unintended third-party effects from water transfers are due to several factors, including the connection between groundwater and surface water, as well as the impact of diminished return flows. In their analysis of the Lower Rio Grande Valley in Texas, Chang and Griffin (1992) emphasized that the lack of third party return flow issues in this region was pivotal to the water market's development but that presence of these effects would complicate market transaction and impede activity. Pecuniary effects also can occur when water transfers lead to a diminished agricultural economy, lowering tax revenues and reducing rural political influence. Political opposition in response to these effects may culminate in costly litigation and ultimately alter regulatory policies (Hanak, 2005). Other equity and distributional issues have also been addressed by Howitt (1994), and Howe & Goemans (2003). In order to reduce the impact of third-party effects, states have put regulatory requirements in place; however, these often raise transactions and reduce market activity (Colby B. , 1990).

Though cumbersome regulatory systems can restrict trading and impede market development, Howitt & Hansen’s (2005) study of the Colorado-Big Thompson project demonstrated the potential for optimal institutional structures to decrease transactions costs and promote trading activity. Unique characteristics, including homogenous rights and conducive administrative bodies, in the CBT have facilitated one of the most efficient markets in the western US (Brookshire, Colby, Ewers, & Ganderton, 2004). Similar supply-demand, geographic, and regulatory environments have also proven accommodative for water transfers in California's Central Valley market, and the Lower Rio Grande Valley market in Texas (Brown, 2006).

Although water’s basic physical and societal characteristics pose unique challenges, new insights into externalities have increased interest in the use of markets to enhance the efficiency of allocating environmental goods (Eigenraam, Stoneham, Beverly, & Todd, 2005). Major benefits of the water market mechanism have been highlighted by Haddad (2000), Anderson and Snyder (1997), as well as Howe et al. (1986). Thus far, water markets have been able to overcome externalities and high transactions costs to successfully transfer water from lower-valued to higher-valued uses over time. Even at these relatively early stages of development, water markets still offer useful indications of value and determinants of prices that market participants are willing to pay.

**Water Rights and Rights Transfers**

As opposed to other property rights, water rights carry a lower intrinsic value, all other factors being equal. The reason for this lower value derives from the aforementioned physical properties of water and the legal institutions that govern it (Brewer, Glennon, Ker, & Libecap, 2008). Property rights in water require costly exclusion and collective action at multiple levels to manage interdependent private (e.g. irrigation diversions) and collective (e.g. environmental flows) water-related economic goods. The resulting property regimes and allocation rules governing water create complex system of hierarchical, yet often overlapping rights that often clash (Garrick, Whiten, & Coggan, 2013). Water rights have proven more fragile than other property rights throughout history, specifically in regard to legal protection (Sax, 1990).

Private water rights owners do not own the water, only the right to use, known as a usufruct right; while the public sector, or State, maintains “ownership” in trust for use by citizens. The prior appropriation (PA) doctrine has been the historical basis for governing surface water use in the western US. It is far different than the common law riparian water rights system, which allocates water based on the land adjoining it. The riparian system was originally brought to the American colonies from England and is still predominantly used in the eastern US (Robbins, 2007). Based on chronological seniority, the PA doctrine is a system of water rights commonly used in the Western US. The PA doctrine prioritizes the rights to extract or divert surface and groundwater based on chronological seniority, or "first in time, first in right". Given the nature of the doctrine and agrarian focus of early western economies, the most senior rights were originally appropriated to agricultural users. (Henderson & Akers, 2008). Rights are appropriated with an assigned priority date, and water is allocated first to the senior rights holders with the earliest priority date, then progressively to those junior appropriators with more recent priority dates. During times of water scarcity, junior water rights holders are at greater risk and may be left completely without water if the senior users have already drawn the available flows. When ownership of a water right is transferred, the assigned priority date is retained, as well as the allotted volume that may be withdrawn (Robbins, 2007). Given the security afforded by seniority, water rights with earlier priority dates trade at a premium, all else equal (Colby, Crandall, & Bush, 1993).

Under the PA doctrine, if rights holders fail to use their water, the right may be forfeited according to the doctrine of abandonment. Many have criticized this "use it or lose it" rule, as it incentivizes rights holders to use all water rather than conserve (Tarlock, 2001). As a result water may be arbitrarily applied to less efficient uses, such as the production of low-value crops, because there is no benefit to conservation. To combat this, some states and regulatory bodies have implemented measures to allow the conserved water to be transferred as a means of more efficient allocation (Brewer, Glennon, Ker, & Libecap, 2008). Another defining aspect of the PA system is the beneficial use doctrine, which requires that water be used for a beneficial purpose. Historically, however, this requirement has taken on a broad definition in the courts and rarely have uses been deemed unbeneficial (Robbins, 2007).

The basic physical properties of water also underscore fundamental weaknesses of water rights. The fluidity of water renders it difficult to partition and bound as property. Furthermore, due to the hydrological connections between water sources, simultaneous and sequential users of water make exclusion difficult and creates interdependencies, increasing third party effects of transfers (Brewer, Glennon, Ker, & Libecap, 2008). Measuring these effects can be complicated and time intensive, which in turn, increases transactions costs (Howitt & Hansen, 2005). Water rights in markets characterized by greater complexity and interdependency among users may be less valuable because transfers with a greater risk of third party injury are less desirable (Payne, 2009). A water right's location can also impact conveyance opportunities, or the potential for delivery to end users (Brookshire, Colby, Ewers, & Ganderton, 2004). Rights to water that is more easily and cheaply transported to major demand sources will have a higher price than similar rights with less flexibility (Colby, Crandall, & Bush, 1993). In light of third party and conveyance factors, the location of water right is of great importance when assessing its value.

On a national basis, water allocation is governed by state water compacts, agreements between states to coordinate long-term water management. These are federal law, ratified by the US Congress, and typically focus on limiting upstream state usage (Henderson & Akers, 2008). Numerous compacts exist across the US, often adding another layer of complexity on top of the PA Doctrine systems and regional authorities that govern local water transfers. Overall, the inherent physical properties of water and cumbersome legal systems that govern it, introduce a variety of difficulties in developing efficient markets and deciphering its value. In order to effectively value water rights, the legal institutions of a market and transactions costs implications must be considered.

## Valuing Water

### *Water Valuation Models*

Similar to the physical fluidity of water as a physical substance, water valuation also is highly variable and ultimately dependent on its use. Numerous techniques have been employed in literature, often dependent on the purpose of the study and the feasibility of application given resource and information constraints. Some of the more common methods for water valuation include the sales-comparison approach, income-capitalization model, land value differencial analysis, and development-cost estimation, as well as the travel cost method and contingent valuation method (Landry, 1995) (Colby B. G., 1989).

*Sales Comparison Approach*

The sales comparison approach involves analysis of precedent sales transactions with similar qualities to the subject water right to determine the appropriate value of the right. While this is useful for providing a benchmark or range for the price, it is not considered a highly trusted mehtod on its own (Colby B. G., 1989).

*Income Capitalization Model*

The income capitalization model is most applicable to valuing water as a factor of production in the agricultural setting, and usually derives the value of water from differences in income at varying levels of irrigation water supply. Farmers expect to be compensated for this lost income and thus this is the price at which they will sell (Henderson & Akers, 2008). There are several methods for identifying the value of this irrigation, including optimization models that analyze the impact of water supplies on crop yields and mix, and comparisons of cash rents for irrigated and non-irrigated cropland (Young, 2005). While this model is fairly straightforward and useful for the agricultural sector, it often fails to consider the links between the farm and nonfarm economic activity in a given region.

*Land-Differential Method*

The land-differentials method looks at the spread between prices paid for similar irrigated and non-irrigated lands to determine the value of water, but depends heavily on reliable data and existence of relevant comparable sales (Colby B. G., 1989).

*Development-Cost Approach*

Finally, the development-cost approach assumes that the costs of alternatives to water rights purchase, such as recycling or conservation measures, reflects the price a party is willing to pay for water rights. While other methods are based on the benefits derived from or willingness to pay for water, development cost fails to account for this and should be considered only as a point of reference (Colby B. G., 1989).

*Travel-Cost Method*

When looking at the recreational value of water, such as the impact of major lakes on the local economy, the travel cost method is often used. The travel cost method looks at travel expenditures to reveal what users are willing to pay to obtain the benefits of using recreational water sources. While other methods mentioned have focused on revealed preferences (the theory that consumer preferences are revealed by their purchase habits), the contingent valuation method relies on surveys that ask people what they would actually be willing to pay for a water assuming a hypothetical market existed (Landry, 1995).

*Hedonic Pricing Method*

The hedonic pricing method is a revealed preference method, relying on observed market participant behavior to determine their relative preferences for goods. Specifically, the hedonic method employs regression analysis to explain the value of a differentiated good as a function of the relative value users place on specific factors and characteristics of the good (Rosen, 1974). It has commonly been used in real estate to determine the extent to which amenity and environmental characteristics affect property values. The model asserts that the utility of consumption of housing services depends on several factors, including its structural characteristics, a vector of neighborhood characteristics, and location-related amenities, such as lakes or reservoirs. Using econometric methods, the incremental increase in market value of the property due to the amenity or environmental variable is isolated to determine its value as a characteristic (Booker, Howitt, Michelsen, & Young, 2012). For example, say there were ten properties, identical in regards to housing and neighborhood characteristics, but two are located on a major lake while the other 8 are at least 50 miles from the closest lake. Under the assumption that consumers prefer houses on lakes, the greater level of demand for the two properties exhibiting this quality will have higher prices. Based on the observed price differences, the value to consumers of having lakefront property can be estimated using the hedonic method (Payne, 2009). The hedonic pricing model, expressed as an equation describing the price of a heterogeneous good as function of characteristics or attributes of the good, is shown below (Rosen, 1974) (Landry, 1995):

$$P = f(W_i)$$

Where: $P$ is the observed market price of the good

$W_i$ is a vector of $_I$ characteristics of the good

The hedonic pricing method has seen increasing application to water valuation research since the late 1980's. Although there is no official method for valuing water, previous literature have shown a preference for this technique, particularly in analyzing price determinants of water rights transfers in established markets (Payne, 2009). The next section goes into further detail on water valuation studies using the hedonic pricing method.

***Hedonic Pricing Method in Water Valuation***

One of the first to apply Rosen's theory of hedonic price functions to the water market, Crouter (1987) used the model to show water rights as a characteristic of farm parcel prices in attempt to measure the efficiency of water markets in Weld County, Colorado. Her findings revealed that competitive markets had yet to fully develop, possibly impeded by transactions costs. Faux & Perry (1999) furthered the application of the hedonic pricing analysis to real estate transactions to reveal the implicit market price for irrigation in the Treasure Valley of Oregon, finding that water rights add to the value of property. Torell et al. (1990) used a hedonic function to estimate the market value of water in the Ogallala Aquifer, specifically analyzing the differentials between irrigated and non-irrigated agricultural land sales to reveal the implicit value of specific groundwater characteristics. While the literature applying the hedonic method to real estate transactions to find the implied value of water provided some valuable insight, they have inherent limitations due to the difficulty in separating the real estate market from the distinct market for water.

To gain further insight into specific characteristics that affect prices in water market, numerous studies have applied the hedonic price method directly to water rights transactions data. While some have focused on broader geographies and the comparison of regional water markets, others have narrowed the scope to find specific value drivers within individual markets. These studies have revealed several common trends in preferred market characteristics and specific water rights attributes that affect transfer prices.

A growing set of studies have analyzed water markets and price determinants on a macro level. Brookshire et al. (2004) examined the price history of three water markets in the arid Southwest: Arizona's Central Arizona Project, Colorado's Colorado Big Thompson Project, and New Mexico's Middle Rio Grande Conservancy District. The study's data set looked at water transfers over an 11 year period in each market. A comparison of institutional characteristics revealed that the more developed Colorado market had higher volume and prices more responsive to market conditions, while the lesser developed markets in New Mexico and Arizona demonstrated less efficiency. Brookshire et al. found that the comparison of variables across markets was difficult, however, and analyzed each market individually using the hedonic method to determine water rights price determinants. Variables used in the study included water supply measures, values of agricultural land and output, population, personal income, and manufacturing employment. The most significant relationships were found in the Colorado CBT market, which Brookshire et al. attributed to the its greater maturity. The results showed that the value of agricultural output, land price, and population are negatively related to water price, whereas manufacturing employment held a strong positive relationship.

Brown (2006) analyzed 1,380 transactions from 1990-2003 in 14 western states. He concluded with confidence that more water was transferred through leases than sales (and that leases were much larger on average) due to lower transactions costs and constraints, as well as their recurring short-term in nature. Furthermore, he found that water market activity and price are geographically variable. From an activity standpoint he observed that Water Management Organizations (public agencies) and irrigators were the most common lessors, most sales involved municipalities buying from irrigators, and municipalities tend to buy rather than lease, while other users prefer to lease. It also appeared that market leasing activity was increasing, though sales were not and that real sales prices had been increasing, as have leases in more recent years. Across all transaction data, he calculated an implicit capitalization rate (by dividing the median lease price by the median sales price) of 1.94%, suggesting that purchasers were paying a premium to obtain perpetual ownership of a water right.

In his hedonic model, Brown tested year of the transaction, drought conditions, parcel size, county population, water source, and buyer type as price determinants. His results revealed that prices for municipal water were higher than environmental and irrigation, noting the impact of subsidization effects and exceptions found in Rio Grande and CBT where competition helped to equalize price dispersion. Surprisingly, the model also showed that population was negatively related to water prices.

With a similarly broad scope, Brewer et al.'s (2008) study conducted meta-data analysis of transactions in 12 western states from 1987 to 2005. The study results echoed many of Brown's conclusions regarding the heterogeneity of water markets, the impact of water use type on price, and the level of long-term leases and sales. Their hedonic analysis looked at the timing of the transaction, location, quantity of water, buyer/seller use and priority of the water right. They found that water prices were higher for agricultural to urban transactions, and that agriculture is the origin of the majority of transactions. Furthermore, Brewer et al. took a different approach to measuring trade volume than previous work, which revealed that from a standpoint of term committed flows (i.e., discounting the volume of sales into perpetuity and multi-year leases over their entire term of use), total transaction volumes were increasing.

In addition to macro analysis across several markets, works by Colby et al. (1993), Landry (1995), and Payne (2009) have focused on individual markets to gain further insight into factors influencing water right prices. Because water rights are a heterogenous commodity, charactersitics of each right and transaction have implicit values that contribute to the price paid in the market. Results of these studies contributed to the better understanding of which factors determine this market price.

Colby et al. (1993) applied a hedonic pricing model in their study of New Mexico's Gila-San Fransisco basin, using price data for the period of 1971 to 1987. In an effect to reveal price dispersion factors, the model focused on water right characteristics, institutional contols on water use, the transferability of water rights, and the leverage of buyers relative to sellers. The specific variables used were priority of the water right, size of transaction, location, whether the buyer was considered high profile, and year. The model revealed that in explaining water prices each of these factors had significant relationships, all of which were positive with the exception of transaction size.

In his study of Oregon's water market, Landry (1995) used hedonic analysis of water rights prices based on annual volume allowed by the water right, priority date, quantity transferred, and market segmentation on price. As he had predicted, Landry found that priority date had a positive relationship with market prices signifying the premium attributed to seniority rights, while transaction size held a negative relationship due to the fixed nature of transactions costs.

Payne's (2009) more recent analysis of price determinants of water rights, specifically ditch company shares in Colorado's South Platte basin, incorporated both market characteristics and water right attributes into his hedonic model. The market characteristic inputs were the previous use and new use of water being transferred and the year of the transaction; specific water right attributes were reliability, volume transferred, and location. The model results showed that reliability has a positive impact on price, increased volume decreases unit prices, shares previously used for irrigation trade at lower prices, prices are increasing over time and that location has impact on price.

***Water Transaction Data Sources***

Due to the proprietary nature of private water transaction information, there is a limited amount of publicly available price data. This information deficiency underlies the lack of price signals that impede the efficiency of many water markets, and has also been a major limitation of previous water valuation research. Obtaining information for water price valuation studies has involved either the cumbersome and costly task of collecting primary data, or the use of secondary sources. The public sector often retains records of transactions, but without the key data point of price. Therefore, researchers have commonly looked to private consulting firms in the water industry that collect this type of data. Once such company, Stratecon, Inc., historically had collected and published water market transactions with price data in their monthly publication, *Water Strategist*. Brewer et al. (2007), Brookshire et al. (2004), and Brown (2006) used *Water Strategist* data in their aforementioned studies. While recognizing that the data did not represent a completely exhaustive list of transactions, it was concluded that the *Water Strategist* data was generally representative of water market activity and prices and ultimately represented the most comprehensive data source available. Other authors who have used the *Water Strategist* include Howitt and Hansen (2005) and Basta and Colby (2010).

Long viewed as the industry standard and relied on by academics for water research, the publication ended in 2010 and all data was moved to a proprietary database exclusively available to Stratecon, Inc. clients (Stratecon, Inc.). The loss of this source only increases the already difficult task of collecting recent water transaction price data. Fortunately, however, the Water Transfer Data Base, funded by the National Science Foundation and the California Water Resources Research Center, has been made available by the Bren School of Environmental Science and Management at the University of California, Santa Barbara. This database now represents the only comprehensive accounting of water trading prices between 1987 and 2009 in 12 western states that is still available to the public (Bren School of Environmental Science & Management, 2010). While it fails to capture market activity beyond 2009, this database is a useful compilation of historical market transfer data.

**Summary of Literature Review**

Water scarcity is a global issue. While third world countries feel the brunt of water shortages through a basic lack of safe drinking water, developed nations are beginning to feel the financial implications of water supply constraints. Increased industrialization and urban population growth over the past half-decade in the Western US have increased the demand for water, as recurring droughts have weakened supply. Specifically, exploding populations in states such as Colorado and Texas have greatly increased urban water use. The result has been less water in our streams, lakes, and aquifers, as well as higher prices in water markets indicating an increase in value for the scarce resource.

The literature on water markets has explored how water's unique qualities affect its value. In ideal competitive markets, producers and consumers experience the full benefits and costs of their activities, but due to factors such as negative externalities this is often not the case for water markets (Brady & Yoder, 2013). Though early research highlighted the potential allocative benefits of water markets, this theoretical role did not materialize as quickly as anticipated (Young, 1986) (Howe, Schurmeier, & Shaw Jr., 1986). Subsequent literature attempted to explain the apparent lack of progress, indicating that water's physical properties make it difficult to define and protect water rights and that its role in the ecosystem creates complex externalities (Brady & Yoder, 2013) (Brewer, Glennon, Ker, & Libecap, 2008) (Chang & Griffin, 1992). The regulatory requirements implemented to mitigate these externalities, as well as other equity and distributional issues, tended to increase transactions costs and reduce market activity (Colby B. , 1990) (Hanak, 2005) (Howitt R. E., 1994). Studies of successful water markets, such as Texas' Lower Rio Grande Valley, revealed that homogenous rights and optimal institutional structures helped to increase market activity and rationalize prices (Brown, 2006).

Water rights in the western US are based on the Prior Appropriation Doctrine, which allocates water based on a priority system of "first in time, first in right" (Robbins, 2007). Private water rights holders own the right to use water, but not the water, itself, as this is controlled by the state for the public good. Compared to other property rights, water rights generally afford less legal protection and are less valuable, all else equal (Brewer, Glennon, Ker, & Libecap, 2008) (Sax, 1990). The location of a water right has a major impact on its value, due to the impact of potential third party effects and conveyance opportunities (Colby, Crandall, & Bush, 1993) (Payne, 2009). Overall, the legal institutions of a market and transactions costs considerations are major factors when valuing water.

Several techniques have been employed to value water, including the sales comparison approach, income-capitalization model, land value differencial analysis, development-cost estimation, as well as the travel cost method and contingent valuation method (Landry, 1995) (Colby B. G., 1989). The hedonic pricing method, which is a revealed preference method, explains the value of a differentiated good as a function of the relative value users place on specific factors and charactertistics of the good and is shown below (Landry, 1995) (Rosen, 1974).

$$\boldsymbol{P} = f(\boldsymbol{W}_i)$$

Where: $\boldsymbol{P}$ is the observed market price of the good

$\boldsymbol{W}_i$ is a vector of $_I$ characteristics of the good

Since the late 1980's, the hedonic method has been used consistently in other water valuation studies, particularly in analyzing price determinants of water rights transfers in established markets (Payne, 2009). Crouter (1987), Faux and Perry (1999), and Torell et al. (1990) used the hedonic method applied to real estate transactions to value water. Numerous studies have applied the hedonic price method directly to water rights transactions data. Some have focused on broader geographies and the comparison of regional water markets, while others have narrowed the scope to find specific value drivers within individual markets. These studies have revealed several common trends in preferred market characteristics and specific water rights attributes that affect transfer prices. The table below summarizes these studies and applications of the hedonic theory.

TABLE 1. APPLICATIONS OF HEDONIC METHOD TO WATER VALUATION

| **Application** | **Literature** |
|---|---|
| Implicit value of water as characteristic of real estate | Crouter (1987); Faux & Perry (1999); Torell et al. (1990) |
| Multiple market analysis of water rights | Brookshire et al. (2004); Brown (2006); Brewer et al. (2008) |
| Single market analysis of water rights | Colby et al. (1993); Landry (1995); Payne (2009) |

Brookshire et al.'s (2004) study of the price history of three water markets in the arid southwest found that more developed markets had greater market activity and prices that were more responsive to market conditions. Their hedonic model showed that the value agricultural output was negatively related to water price while manufacturing employment held a strong positive relationship. From his study applying the hedonic method to transactions across 14 western states, Brown (2006) concluded that water market prices are geographically variable, municipal water users pay higher prices, and that population was negatively related to water prices. Also applying a hedonic model to meta-data across multiple states, Brewer et al. (2008) confirmed the heterogeneity of water markets and the positive relationship between urban use and price.

Studies using the hedonic pricing model on data from specific markets provided further insight into price determinants of water rights (Colby, Crandall, & Bush, 1993) (Landry, 1995) (Payne, 2009). Model results for each these studies confirmed that the seniority and reliability of a water right held positive relationship with its price, while transaction volume and unit price were negatively related due to economies of scale impacting transactions costs. Also, there was a consensus among the results that location had a significant relationship with water price, as did buyer and seller characteristics. Both Colby et al. (1993) and Payne (2009) concluded that water prices were appreciating over time.

Because of the proprietary nature of private water transaction information, finding publicly available price data for market transfers is a difficult task. Previous studies have found this lack of information to be a major limitation. However, many turned to the *Water Strategist*, published by Stratecon, Inc., concluding it is the most comprehensive source of water market transaction price data available to the public. Authors using this data source include Basta and Colby (2010), Brewer et al. (2007), Brookshire et al. (2004), Brown (2006), Howitt and Hansen (2005). Though the publication ended in 2010, past transaction data was compiled in the Water Transfer Data Base and made available to the public by the Bren School at the University of California, Santa Barabara. The database is the only comprehensive source of water transfer price data available for the western US, documenting transactions from 1987 to 2009 for 12 states.

# METHODOLOGY

## Data Collection

This paper uses the database from the Bren School of Environmental Science and Management at the University of California, Santa Barbara, which compiled water transfers in 14 western states, including Texas, from 1987-2009 recorded in the publication, *Water Strategist*. The monthly publication provided information on transfers before its discontinuation in 2010.

Information in the database is comprehensive and includes the year, state, amount, price, type and tenor of contract, prior and post transaction use, a description of the buyer and seller, as well as the issue of the *Water Strategist* in which it was reported. The dataset contains over 4,400 total transactions, reporting price data for 2,915 of these. It is important to note that each observation does not necessarily represent a single water transaction. Instead, observations may represent a bundle of transactions. Often the *Water Strategist* reports transactions that are a summation of two or more water transactions made by a single entity, such as a buyer or seller, or in a single location, such as a state or water basin (Donohew & Libecap, 2010). Transactions not reported in the *Water Strategist* are not included in this dataset.

The quantity information includes minimum, maximum, and average amounts in annual acre-feet and committed acre-feet[1]. The price information includes nominal and inflation-adjusted total prices (in 1987 dollars), as well as on an annual acre-foot and

[1] As described in the earlier discussion of Brewer et al. (2008), the committed variable discounts the flow of water over time into the year the water was first transferred. For permanent transfers of water rights, the committed amount of water is determined the same way as finding the present value of a perpetual bond—by dividing the annual flow of water by the discount rate. For leases, the committed amount of water is found the same way as finding the present value of an ordinary annuity. A 5% discount rate was used in the original database (Donohew & Libecap, 2010).

committed acre-foot basis. The type of transfer is classified as either sale, exchange (gift), or lease (for which duration is given). The classification of agricultural, urban (municipal and industrial), or environmental describes the transferor's prior use and the transferee's new use of the water[2]. If the use could not be determined it was classified as unknown, and if the use could not be effectively distinguished as only one of these options, it was labeled combination. The buyer and seller descriptions were drawn from the *Water Strategist*, and due to the previously described bundling of certain transactions, the descriptions listed were unspecified or vague or in some cases this information was simply unknown. The buyer and seller descriptions are of particular importance to the analysis conducted in this study, as they are used to determine the approximate location of the transaction.

From the transactions listed in the database, there were 346 reported for the state of Texas. Of these entries, 229 included the price data necessary for the analysis of this paper. Though the information provided in the original database was useful, the geographic location of the transfer (assumed to also be that of the water right) needed to be determined with greater specificity in order to test for market characteristics and attributes specific to the transactions. From the buyer and seller descriptions, location was recorded by county. In the event that these descriptions led to conflicting county locations, the seller county was used. Where the seller county could not be determined, the buyer county was used. If a location could not be determined from either party's

[2] From the *Water Strategist*'s transaction descriptions, variables were created to describe the transferor's prior use of a water right and also the transferee's new use of the water right. Each transfer was assigned to one, and only one, of these classifications. If the water use before or after a transaction was not explicitly stated in the *Water Strategist*, the category was inferred if possible from the description of the transaction (Donohew & Libecap, 2010).

description, or the parties were listed as unknown, these transactions were excluded. At the conclusion of this process, 156 transactions remained in the data set[3]. Due to a lack of activity (only two entries reported) and difficulty in collecting information for one of the independent variables in the hedonic model, transactions for the year 1987 were also removed. After analyzing the remaining data, additional outliers and anomalies (a few leases with much higher prices) were removed to avoid disrupting the model[4]. After all adjustments had been made, the final data set for application of the hedonic model included 144 observations.

**Hedonic Model**

The hedonic model constructed for this study aims to show the influence of selected market characteristics and water right attributes on the price paid for the water right in the market. The data set of 144 water rights transactions in Texas is used for the model estimation. The per unit price of water is hypothesized to be a function of the attributes of the water right and transaction, and the characteristics of the market in which it was transferred:

$$\boldsymbol{P} = f(\boldsymbol{W}_{RT}, \boldsymbol{W}_{M})$$

Where: $\boldsymbol{P}$ is the observed market per unit price of water

$f$ is the function of best fit estimated through regression analysis

$\boldsymbol{W}_{RT}$ represents water right and transactions attributes

[3] In total, 73 transactions were removed: 6 due to buyer/seller descriptions being "unknown"; 67 due to an inability to determine county location. A common theme in the process was that descriptions provided for urban users generally were better indicators of location (e.g. "City of Laredo"), whereas the agricultural users (often individuals or simply listed as "irrigators"). The grouped transactions also led to a lack of specificity (e.g. "7 irrigation districts, 3 municipalities") that indicated conflicting locations or rendered location undeterminable

[4] Transactions with prices more than two standard deviations from the mean price of the sample set were removed (9), as well as one additional entry which was considered an anomaly and between the same parties as another transaction already eliminated.

$\boldsymbol{W_M}$ represents water market characteristics

**Dependent Variable**

The dependent variable in this analysis is the unit price in inflation-adjusted 1987 dollars per committed acre-foot. Inflation-adjustments were made to allow for comparisons across time and reveal real changes in price. The committed acre-foot calculation is described above. While the original database entry calculated this volume measure using a 5% discount rate, adjustments were made so that the volume committed acre-feet reflects a 4.3% discount rate[5]. The change resulted in a relative decrease in sales prices and multi-year leases depending upon tenor, so that sales and longer-term leases were most affected. This measure provided a more appropriate means of comparing one-year leases to longer-term leases and sales.

**Independent Variables**

Based upon the empirical literature, it was determined that water right and transaction attributes as well as market characteristics should be included as independent variables[6]. The input variables included in the model, and their predicted relationship with the dependent variable, price, are listed in the table below and described in the following sections.

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[5] Rather than using the arbitrary discount rate applied to the original data, this discount rate reflected the Implicit Capitalization Ratio (ICR) of the sample data set used in the regression. This ICR was calculated as the median one-year lease price per acre-feet divided by the median sales price per annual acre-feet (Brewer et al. 2008).

[6] A vast pool of sources impacted the decision making process behind the selection of these variables and should be acknowledged for this even if not explicitly addressed in the discussion of variables (Colby, Crandall, & Bush, 1993) (Howe & Goemans, 2003) (Brewer, Glennon, Ker, & Libecap, 2008) (Brookshire, Colby, Ewers, & Ganderton, 2004) (Landry, 1995) (Young, 2005) (Crouter, 1987) (Payne, 2009) (Khan, Dassanayake, Mushtaq, & Hanjra, 2010). Data limitations were also a factor.

| TABLE 2. PREDICTED RELATIONSHIP BETWEEN VARIABLES AND PRICE | |
|---|---|
| Independent Variable | Predicted Relationship |
| ***SUPPLY*** | Negative |
| ***RURAL LAND*** | Positive |
| ***POP GROWTH*** | Positive |
| ***INCOME*** | Positive |
| ***URBAN USE BUY*** | Positive |
| ***TRANS VOL*** | Negative |
| ***WATERMASTER*** | Positive |
| ***YEAR*** | Positive |

*Water Supply*

To measure water supply and more specifically, the presence of drought conditions, this model used the Palmer Drought Severity Index (PSDI) for the climate division based upon location of the transfer. The PDSI attempts to measure the duration and intensity of the long-term drought-inducing circulation patterns. Long-term drought is cumulative, so the intensity of drought during the current month is dependent on the current weather patterns plus the cumulative patterns of previous months. Since weather patterns can change almost literally overnight from a long-term drought pattern to a long-term wet pattern, the PDSI can respond fairly rapidly (National Climatic Data Center, 2013). In order to attain a more long-term measure of scarcity, annualized measures of the PDSI were used. The purpose of this variable is to represent regional supply differences across the 10 Texas Climate divisions[7]. This study predicts that during instances of severe drought and supply shortage, water prices rise (Brown, 2006).

[7] Climate Divisions based on county location, according to boundaries established by the National Weather Service (USDA National Agricultural Statistics Service).

*Rural Land Values*

The value of rural land within the state's 7 Regional Land Markets was measured based on a deflated weighted average price per acre index for rural land.[8] Ideally, this variable would have used a more refined geographic measure (i.e. county) to more accurately reflect the real estate market; also, this is for all rural lands, not just those used for farmland. However, because it is a weighted average, it should take into effect agriculture of irrigated land in the area. The purpose of this variable is to serve as a proxy for value of agricultural uses. Higher land values would indicate a greater derived value from agricultural water use and therefore lessen the incentive to transfer water rights. In order for a seller to engage in a transfer, a buyer must pay a higher price. For this reason, it is hypothesized that this variable will have a positive relationship with water right prices.

*Population Growth*

While previous studies have used population measures to reflect demand for water in the market, most have focused on total population figures (Brown, 2006). This study uses population growth because it is believed to more accurately reflect demand pressures. Markets with high population levels, yet static growth, may already have secured adequate water supplies, whereas markets with high growth rates are presumed to be faced with more accentuated demand pressures. Data for this variables includes county population growth rates from census data for the periods 1990-2000 and 2000-2010. The

[8] Regional Land Markets and price index sourced from the Characteristics of Texas Land Markets- A Regional Analysis, published by the Real Estate Center at Texas A&M.

decade growth rates were then converted to CAGR to be applied to each year.[9] The purpose of this variable was to capture the presence of fast growing cities that have urgent needs for water rights, and it is predicted to have a positive relationship with water prices.

*Income*

For this input, per capita income by county was drawn from the BEA regional database and adjusted for inflation using 2009 dollars.[10] Other studies have used per capita income measures as a demand determinant of water prices (Brookshire, Colby, Ewers, & Ganderton, 2004). However, there may be limitations as this is a very broad measure and may fail to account for the effect of increased income on investments in more efficient water use. Also, county may not appropriately encompass the economic demand area for the water right. This independent variable attempts to reflect that higher income levels lead to greater demand for water and is predicted to have a positive relationship with water prices. As water users, particularly urban, have increased income, they buy higher water use items and engage in higher use activity.

*New Use*

To quantify the transferee's intended use, the model used a dummy variable for urban use = 1, other = 0. Buyer use information was drawn from database, and determined as described in the data section. Other options included agricultural, environmental or combination. A vast majority of the water transfers were to municipal water users, in line with trends across the Western US. This may leave less to explain

[9] For 1988-1999 transfers, 1990-2000 CAGR was used; for 2000-2009 transfers, 2000-2010 CAGR was used. Growth rate data was sourced from the United States Census Bureau and the Census 2000 analyzed by the Social Science Data Analysis Network (SSDAN)

[10] Per capita personal income was computed using Census Bureau midyear population estimates.

price and more to explain the occurrence of the transfer. This study predicts that the urban users pay higher prices for water due to higher end use values. Water rights approved for this use will carry a greater value. Also, the environmental and agricultural users' purchases are often indirectly subsidized as a result of government policies.

*Transaction Volume*

The transaction volume, or amount of water transferred, was measured in committed average acre-feet. As Brewer et al. (2008) concluded this committed volume better reflects the total amount of water being transferred over the term of the transactions. The high transactions costs associated with water transfers will be spread out over a larger sum of variable costs paid for water. This should reduce the impact of transactions costs on a per unit basis and therefore, transaction volume is predicted to have a negative relationship with water price.

*Watermaster Program*

In Texas, Watermaster Programs have been implemented to better facilitate water trading in active markets (Texas Commision on Environmental Quality, 2014). A dummy variable was used to quantify the presence of a Watermaster Program as a regulatory institution facilitating the transfer, where 1= Watermaster Program and 0 = none. If the transaction occurred under jurisdiction of a Watermaster (there are 3 in Texas, but only the Rio Grande and South Texas occurred in dataset), the right should be better protected and the market should be operating more efficiently so that prices are more rational (Howe & Goemans, 2003). Due to more developed markets and more strictly enforced rights, prices should be higher for transfers in Watermaster regions.

*Year*

In order to test for overall appreciation in the Texas water market, the variable year is included. While the literature seems to suggest that the price of water across the western US is increasing, past studies have failed to draw this conclusion for the Texas water market (Brewer, Glennon, Ker, & Libecap, 2008). While research and anecdotal evidence appears to show that recent Texas water prices have been increasing, the data used in this study only includes reported transactions through 2009 and may fail to capture this recent trend. Nevertheless, this paper predicts that the variable year will have a positive relationship with per unit price, suggesting price appreciation over the 21-year period studied.

**Summary of Model**

The hedonic price model used for this study measures the effect of market characteristics and attributes of the water right and transaction on the per unit price paid for water rights.

***P** = f(**SUPPLY, RURAL LAND, POP GROWTH, INCOME, MUN USE BUY, TRANS VOL, WATERMASTER, YEAR**)*

Where: ***P*** is the observed market per unit price of water

*f* is the function of best fit estimated through regression analysis

***SUPPLY*** is a measure of water supply based on the annualized PDSI in the climate division where the transfer occurred

***RURAL LAND*** is a measure of annual rural land values in the regional land market where the transfer occurred

***POP GROWTH*** is a measure of annualized population growth for the county in which the transfer occurred

***INCOME*** is a measure of annual per capita income for the county in which the transfer occurred

***URBAN USE BUY*** assumes a value of 1 if the water right was transferred to an urban user

***TRANS VOL*** represents the volume of water transferred in committed acre-feet

***WATERMASTER*** differentiates between water transfers that occurred in the jurisdiction of a Texas Watermaster Program

***YEAR*** takes on the value of the year in which the transfer was completed

The table below summarizes the expected relationships between the dependent variable, unit price, and the respective independent variables.

TABLE 3. PREDICTED RELATIONSHIP BETWEEN VARIABLES AND PRICE

| Independent Variable | Predicted Relationship |
|---|---|
| ***SUPPLY*** | Negative |
| ***RURAL LAND*** | Positive |
| ***POP GROWTH*** | Positive |
| ***INCOME*** | Positive |
| ***URBAN USE BUY*** | Positive |
| ***TRANS VOL*** | Negative |
| ***WATERMASTER*** | Positive |
| ***YEAR*** | Positive |

# RESULTS

## Model Results

| TABLE 4. REGRESSION RESULTS | | | | |
|---|---|---|---|---|
| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* |
| ***SUPPLY*** | -1.6180 | 1.1118 | -1.4553 | 0.1479 |
| ***RURAL LAND**** | 0.1021 | 0.0277 | 3.6907 | 0.0003 |
| ***POP GROWTH*** | 332.3610 | 241.2292 | 1.3778 | 0.1706 |
| ***INCOME**** | 0.0015 | 0.0004 | 4.0623 | 0.0001 |
| ***URBAN USE BUY**** | 12.2339 | 7.2049 | 1.6980 | 0.0918 |
| ***TRANS VOL**** | -1.36E-05 | 3.74E-06 | -3.6449 | 0.0004 |
| ***WATERMASTER**** | -28.5389 | 9.4423 | -3.0224 | 0.0030 |
| ***YEAR*** | -0.2559 | 0.6357 | -0.4026 | 0.6879 |
| $R^2 = 0.4327$ | Adj. $R^2 = 0.3990$ | | n = 144 | F Stat = 11.38 |

** signifies statistical significance at a 90% confidence level*
*** signifies statistical significance at a 99% confidence level*

The Ordinary Least Squares (OLS) regression method was used to test the hedonic price model for determinants of water rights transfer prices, returning the results seen in the table above. The $R^2$ of 0.4327 indicates that the model successfully explains 43.27% of the unit price dispersion in the data set. Though more than half of the price variance remains unexplained, this is common for hedonic price models using data across multiple regions (Colby, Crandall, & Bush, 1993) (Landry, 1995). The F Statistic of 11.38 also indicates an overall significance of the regression. High t-statistics and low p-values for the RURAL LAND, INCOME, TRANS VOL, and WATERMASTER independent variables indicate that these variables are significant at a 99% confidence level; the variable URBAN USE BUY is statistically significant at the 90% confidence level. The variables SUPPLY, POP GROWTH, and YEAR do not hold statistically significant relationships with the dependent variable. All statistically significant variables demonstrate the expected relationship with the per unit price of the water right with the exception of WATERMASTER. The following sections discuss the specific independent variable results.

**Variable Relationships**

*Water Supply*

The independent variable SUPPLY attempted to show regional supply differences across the 10 Texas Climate divisions measured by the Palmer Drought Severity Index (PDSI). It was expected that a significant negative relationship between this variable and the per unit price of water rights would reflect that during instances of severe drought and supply shortage, water prices rise (Brookshire, Colby, Ewers, & Ganderton, 2004) (Brown, 2006). Given the lack of statistical significance of this variable in the model, the existence of this trend across the Texas water market cannot be confirmed. A possible explanation is that the supply variable used was not appropriate for testing the relationship between water supply and price. The PDSI is more of a short-term measure, and a measure to reflect the long-term deficit in a region would better reflect long run supply impacts in the water market. Further, climate divisions encompass fairly large areas that span across multiple river basins and aquifers, so a more narrowly defined geographic unit would better measure the supply applicable to the particular water right. Had more specific location information been available for the particular water rights involved in the transfers in this data set, reservoir levels or city-specific water shortages could have been quantified to more effectively reflect the water supply most relevant to the individual water right and the market in which it was transferred.

*Rural Land Values*

The coefficient on RURAL LAND is 0.1021, which indicates that per unit water rights prices increase as rural land values increase. Specifically, for every $100 increase in rural land values, the price per acre-foot for water rights increases by $10.21. This result supports the hypothesis that higher rural land prices reflect greater value potential for agricultural uses of water. Therefore, water right sellers demand higher prices.

*Population Growth*

The independent variable POP GROWTH does not show a statistically significant relationship with the per unit price for water rights. It was expected that higher population growth for the county in which the transfer of the water right occurred would lead to higher prices (Brown, 2006). However, Brookshire et al. (2004) also failed to demonstrate that population growth has a significant impact on water prices. This variable may have been limited because rather than using population growth data for each year, which may have varied greatly over the decade, it employed a CAGR measure that smoothed these trends. Also, the county may not have been the most appropriate geographic unit to encompass the population demand pressures on a water right. In general, the majority of water rights transfers reported were all in high growth areas (as would have been expected), so this may be more of a qualifying characteristic for market transfers to occur rather than a major factor in price determination.

*Income*

As expected, the highly significant coefficient of 0.0015 indicates that the variable INCOME has a positive relationship with the per unit price of water. Water rights transferred in counties with higher per capita income levels demand higher prices per acre-foot, all other factors being equal. Specifically, for every $1,000 increase in per capita income, the per unit price of the water right transferred increases by $1.50.

Demand for water is higher in areas with wealthier populations, which drives up prices in the water market (Brookshire, Colby, Ewers, & Ganderton, 2004).

*New Use*

The positive coefficient of URBAN USE BUY is statistically significant at the 90% confidence level, indicating that water rights purchased for urban use demand higher prices than those transferred for other uses. Past studies have demonstrated similar results, supporting the assertion that water applied to urban uses has a higher value than water applied to agricultural or environmental uses (Brown, 2006) (Brewer, Glennon, Ker, & Libecap, 2008). The coefficient of 12.2339 indicates that water rights transferred to urban users are $12.23 more expensive per acre-foot.

*Transaction Volume*

Previous research has confirmed that as the volume of water transferred increases, the per unit price decreases due to economies of scale related to transactions costs (Colby, Crandall, & Bush, 1993) (Landry, 1995) (Brown, 2006) (Payne, 2009). The statistically significant negative coefficient of TRANS VOL indicates that the same assertion can be applied to the Texas water market. The coefficient of -1.36E-05 shows that for every additional 100,000 committed acre-feet of water transferred, the price per unit decreases by $1.36. As the fixed transactions costs are spread out over a greater volume of water transferred, the impact on the per unit price decreases.

*Watermaster Program*

Because Watermaster Programs in Texas facilitate the state's more developed markets, this study hypothesized that transfers in these areas would trade at relatively higher prices (Howe & Goemans, 2003) (Brookshire, Colby, Ewers, & Ganderton, 2004).

However, the negative coefficient of the variable WATERMASTER is an unexpected result that contradicts this assertion. In fact, a coefficient of -28.5389, indicates that a water right transferred in a Watermaster Program trades at a significant discount to an otherwise similar water right transferred outside the jurisdiction of this regulatory institution. A possible explanation for this revelation is that the existence of a Watermaster mitigates the impact of transactions costs by facilitating easier, more uniform transfers of better protected water rights. When transactions costs are lowered, the per unit price of the water right decreases.

*Year*

The variable YEAR (the year in which the transfer took place) was included in the model to test for water price appreciation over the period of the data set. Given the results of previous studies, it was expected that the model would show an increasing trend water rights prices over time (Colby, Crandall, & Bush, 1993) (Brown, 2006) (Payne, 2009). The coefficient of YEAR is not statistically significant, however, so this trend cannot be confirmed. Though this result is surprising, it may be explained by the fact that other independent variables included in the model, such as INCOME, better captured factors causing the price of water to increase over time. Also, because the data included transactions across multiple markets, the model results may fail to reflect price increases that occurred within specific geographic areas. Finally, because the data set only includes transfers through 2009, more recent trends in water price appreciation are not tested in this model.

**Summary of Results**

The hedonic pricing model used in this study explained approximately 43% of the market price variation for water rights transfers in Texas from 1988 to 2009 included in the data set. Other than SUPPLY, POP GROWTH, and YEAR, all independent variables tested in the model showed statistically significant relationships with the dependent variable, price per committed acre foot. As hypothesized, the unit price of water rights was shown to have a positive relationship with the value of rural land, level of per capita income, and transfer of water to urban use. Also as expected, the unit price of water rights was shown to be negatively related to the volume of water transferred. An unexpected negative relationship was revealed between the price paid per unit of water and the existence of a Watermaster. The table below summarizes these conclusions.

| TABLE 5. RELATIONSHIPS BETWEEN VARIABLES AND PRICE | |
|---|---|
| Independent Variable | Relationship |
| ***SUPPLY*** | Uncertain |
| ***RURAL LAND*** | Positive |
| ***POP GROWTH*** | Uncertain |
| ***INCOME*** | Positive |
| ***URBAN USE BUY*** | Positive |
| ***TRANS VOL*** | Negative |
| ***WATERMASTER*** | Negative |
| ***YEAR*** | Uncertain |

**Limitations**

The model used in this study was limited by the availability of data pertaining to water rights transfers and prices. While the data set used provided a basis for exploring trends in the Texas water market, it was far from an exhaustive list of transactions that occurred from 1988 to 2009. The majority of reported market activity was concentrated in the lower Rio Grande region of Texas. Consequently, this geographic dominance could have skewed results. Further, the nature in which the data source reported water transfers prevented the inclusion of information specific to individual water rights in the model. Most notably, the model did not include an independent variable describing the seniority of the water right. Despite these limitations, the model remains effective in revealing key trends that affect price determination in the Texas water market.

## DISCUSSION AND IMPLICATIONS

The results from this study revealed several key variables that explain almost half of the price variation of market prices for water rights in Texas. Urban users pay higher prices for water rights in Texas, which suggests that the trend of reallocation of water from agricultural users to cities continues to move water to higher value uses. As water markets facilitate better allocative efficiency, this should produce overall economic gains for the Texas economy (Brewer, Glennon, Ker, & Libecap, 2008). Over time, this price differential should diminish, signaling a move toward equilibrium in the market. However, we should expect a portion of this discrepancy to remain given the subsidization of agricultural and environmental users through government policies and regulatory measures.

The establishment of water market conditions conducive to increasing transfer activity will be key to attaining greater allocative efficiency (Brookshire, Colby, Ewers, & Ganderton, 2004). As evidenced by the negative relationship between transaction volume and per unit water price, transactions costs are prevalent in the Texas market. However, the study results also suggest that the Watermaster program has been successful in mitigating these costs. Applying similar institutional structures and regulatory policies on a statewide basis could greatly increase the efficiency of the overall Texas market.

With a booming economy and expanding population, water prices should be expected to increase over the long-term in Texas. Rising rural land values as cities extend their reach farther have the potential to be a major driver behind this trend. Further, increases in per capita income driven by economic growth should also push prices higher. Areas of the state experiencing the most robust growth in business activity, particularly those benefitting from the booming energy sector, should expect the highest price levels.

Given that the model failed to explain over half of the price variation, it is important to explore what factors might account for this unexplained portion. As mentioned previously, water right seniority is expected to be a major contributor to the value of a water right. Further, the reliability of the hydrological source of the water guaranteed by the right should also impact its price. Prices vary across the different regions within Texas, so more location-specific factors most likely played a significant role as well. Finally, given the heterogeneity of water rights and transfer policies, there are likely numerous transaction-specific variables that would explain the remaining price dispersion.

**Concluding Remarks**

Understanding the factors that influence the value of Texas water will have significant implications for participants in the water market. Businesses need to understand how to value the water they use as inputs and realize the potential impact of higher water prices on the bottom line. From a public policy perspective, governments have become keenly aware of water issues following years of drought and scarcity. As state agencies develop long term plans for allocating water, they must consider factors that affect its value. Further, municipalities and other water providers should be mindful of the underlying value drivers of water when determining the rates charged to end users. Also, as water gains popularity as a long-term investment, the results of this study will help water investors target water rights with the highest potential for price appreciation. Finally, and most importantly, as the true value of water is better understood it will help to promote the conservation of a scarce resource that is essential for the existence of humanity and our planet.

**Suggestions for Further Research**

While this study analyzed a significant number of variables, there are numerous other factors that may be affecting the price of water in the Texas market. In order to further explain the price dispersion, subsequent research should focus on exploring additional variables, particularly those relating to the water right, itself. Also, for additional studies it could be useful to narrow the geographic scope, analyzing specific markets within Texas. For example, there is a burgeoning market developing in the center of the state involving transfers of Edwards Aquifer water that has yet to be sufficiently studied. As mentioned previously, the scope of this study does not include data within the past five years. Analyzing more recent market activity will be important for identifying new trends in the water market and shifts in price determinants for water rights.

While this project focused on the hedonic pricing method, additional research could be done exploring other applications of other economic and financial valuation to water. For example, how can water-input commodities that trade on public markets (e.g. corn, wheat, or cattle) be used to inform the value of water? As the market price for raw water becomes better understood, further analysis should focus on how well the price paid by households for delivered water reflects this raw value.

There is an increasing need for better water price information so that Texans can make more informed decisions when using and purchasing water. If a comprehensive public water right transaction price database was developed, it would greatly benefit Texas water market participants. Further, using such a database combined with existing water demand and supply factor forecasts would allow for the development of detailed valuation models to project long-term prices. Ultimately, attaining greater visibility of future market prices will be pivotal to ensuring long term allocative efficiency, as well as the sustainability of Texas water.

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