PROMOTING EFFICIENT ALLOCATION OF WATER RESOURCES: THE PRICE DETERMINANTS FOR DITCH COMPANY SHARES IN COLORADO'S SOUTH PLATTE BASIN

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PROMOTING EFFICIENT ALLOCATION OF WATER RESOURCES: THE PRICE DETERMINANTS FOR DITCH COMPANY SHARES IN COLORADO'S SOUTH PLATTE BASIN

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Economics

Abstract

Water scarcity presents an obstacle to economic development in the western United States. In an attempt to accommodate the increasing levels of demand that population growth, recreation, industry, and environmental protection place on water supplies, western states frequently establish markets for water. Water markets promote efficient allocation, helping states to derive the highest possible economic benefit from available resources, and allowing western water supplies to support as much new development and population growth as possible. However, imperfect pricing information for water threatens the ability of water markets to efficiently allocate water. Correct valuation improves water right allocation by aiding market participants in negotiating and completing sensible transactions despite the limited availability of price signals.

This project will estimate the values market participants place on shares of ditch company water rights in Colorado's South Platte basin. Based on observed market activity, the hedonic will method will be used to estimate the implicit value consumers place on each characteristic of a water right, and the contribution of each characteristic to the water right's price.

The dataset analyzed in this project includes price, quantity, reliability, location, and type of use information for 254 transfers of ditch company shares. Because these data are proprietary and difficult to collect, this dataset represents one of the most comprehensive collections of water transaction information in existence for Colorado's South Platte basin. It is predicted that the Ordinary Least Squares estimation of the hedonic price model developed in this project will reveal that reliable water supplies located near municipalities attract higher prices than variable water supplies situated downstream from cities. In addition, economies of scale and water price appreciation are predicted to exist in the South Platte basin.

KEYWORDS: (Water Markets, Water Transfers, Ditch Company Shares)

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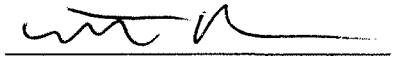

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I would like to thank Clay Landry and Harry Seely at WestWater Research for facilitating my initial understanding of water markets through a summer internship, for encouraging me to conduct a water valuation study, and for the technical and financial support they made available for this project. Because compiling datasets of water transactions is difficult and expensive, water valuation studies are often nonviable. This project would not have been possible without the dataset provided by Mr. Landry. In addition, Mr. Seely's technical advice regarding independent variables and regression analysis improved my description of the South Platte basin water market.

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Headwaters that he suggested for background reading, helped me to better understand the complex details of Colorado water law. Thank you Justice Hobbs.

CHAPTER 1

INTRODUCTION

Statement of Purpose

Water markets represent a water resource allocation mechanism frequently used by western states[1]. Several challenges associated with market failures impede the ability of water markets to efficiently allocate water. These challenges to water market efficiency also render market prices an inaccurate measure of the true value of water rights[2]. The inability of water markets to achieve efficient allocation and the imperfect price signals provided by market prices necessitate non-market methods for water right valuation.

The hedonic pricing method represents one non-market technique for valuating water rights. This project will use the hedonic method to accurately estimate the values market participants place on water in Colorado's South Platte basin.

Importance of Research

In western states population growth, economic development, recreation,

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[1] Terry L. Anderson and Pamela Snyder, *Water Markets: Priming the Invisible Pump* (Washington, DC: Cato Institute, 1997), 34.

[2] Bonnie C. Saliba and David B. Bush, *Water Markets in Theory and Practice: Market Transfers, Water Values, and Public Policy* (Boulder: Westview Press, 1987), 25-26.

agriculture, and protection of endangered species[3] place an increasing level of demand on scarce water resources. However, because significant portions of water resources in the West are fully appropriated to historic agricultural, municipal, and industrial uses, water supply struggles to satisfy rising demands[4], hindering development. The inability of water supplies to meet the increasing demands of water users results in competition for water. This competition necessitates recognizing water as an economic good and managing it accordingly to achieve efficient allocation[5]. Efficient allocation of water means deriving the highest possible economic benefit from available resources by appropriating water to its most socially valued uses[6]. Many western states, recognizing water shortage problems, use water markets as a resource allocation mechanism in an attempt to maximize economic gains and accommodate increasing demand.

Water markets hold the potential to achieve efficient allocation, allowing western water supplies to support as much new development and population growth as possible. However, imperfect pricing information for water threatens the ability of water markets to efficiently allocate water[7]. Accurate valuation of water rights based on observed market behavior can be accomplished through hedonic estimation. Correct valuation

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[3] *Carson-Truckee Water Conservancy District v. Clark*, 741 F.2d 257 (9th Cir. 1984).

[4] Clay J. Landry, "Giving Color to Oregon's Gray Water Market: An Analysis of Price Determinants for Water Rights" (M.S. diss., Oregon State University, 1995).

[5] Robert A. Young, *Determining the Economic Value of Water* (Washington, DC: Resources for the Future, 2005).

[6] Jan P. Crouter, "Hedonic Estimation Applied to a Water Rights Market," *Land Economics* 63, no. 3 (August 1987).

[7] Landry, 1995

helps market participants to negotiate and complete sensible transactions despite the limited availability of price signals[8], promoting efficient allocation.

Specific Question

Differentiated goods are comprised of a variety of attributes. Consumers identify and place a value on these attributes, but cannot purchase them separately from the differentiated good[9]. Water rights are differentiated goods. A water right's individual qualities lend it value. These qualities include priority date (a measure of the reliability of the right), source (the origin of diverted water and a second indicator of reliability), location (stating the point of diversion for the water from the stream), and historic nature of beneficial use (the type of use previously assigned to the diverted water). What effect do these attributes of water rights have on water right prices?

Based on observed market activity, this project will use the hedonic method to estimate the implicit value consumers place on each characteristic of a water right, and the contribution of each characteristic to the water right's price[10].

The question regarding the effects of water right characteristics on price will be analyzed within the context of Colorado's South Platte basin. This region is characterized by one of the most active water markets in the western United States[11], with water transfers frequently occurring in the form of ditch company share sales. A ditch

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[8] Young, 2005

[9] Sherwin Rosen, "Hedonic Prices and Implicit Markets: Product Differentiation in Perfect Competition," *Journal of Political Economy*, 82 (1974).

[10] Laura O. Taylor, "The Hedonic Method," in *A Primer on Nonmarket Valuation*, Ian J. Bateman ed. (Dordrecht: Kluwer Academic Publishers, 2003).

[11] Thomas C. Brown, "Trends in Water Market Activity and Price in the Western United States," *Water Resources Research*, 42 (2006).

company share entitles the owner to a pro rata percentage of the ditch company's total water supply each year[12]. While most water markets in the west facilitate transfers of water rights, ditch companies control the most valuable water rights in the South Platte basin. Purchasing shares in these companies represents a viable way for water users to acquire new water supplies.

A hedonic analysis will be conducted for a dataset listing the prices of ditch company shares in the South Platte basin, along with the ditch company share characteristics and market attributes predicted to influence prices. A hedonic analysis uses multiple regression to identify the effects of the independent variables (water market and share characteristics) on the dependent variable (share price). The basic functional form for this analysis is:

$$P=f(\text{market attributes, share attributes}) + e$$

where:

- P represents sale price
- f is the function of best fit estimated through regression
- market attributes are the independent variables that determine supply and demand
- share attributes represent the individual qualities of ditch company shares
- e is an error term.

The basic elements of a share, including reliability of water supply, quantity yielded, and location, are predicted to influence prices in the South Platte basin. The unique market conditions of the South Platte basin are predicted to further influence share prices. The market attributes this project examines are previous use of transferred water, new use of transferred water, and the year in which the sale takes place.

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[12] Leonard Rice and Michael D. White, *Engineering Aspects of Water Law* (New York: John Wiley & Sons, Inc., 1987).

Overview of Relevant Theory

Previous research using the hedonic method for water right valuation has been completed in two ways. First, hedonic analyses applied to real estate transactions that include appurtenant water rights estimate the implicit value consumers attach to water rights, and calculate the value that water rights contribute to the land. Second, researchers use the hedonic method to examine sales of water rights as an individual commodity to identify the determinants water right prices in specific water markets.

Byrd[13] and Faux[14] examine real estate transactions including appurtenant water rights in the Northern High Plains and Oregon, respectively, to assess the value that water rights contribute to property values. Byrd analyzes groundwater, while Faux examines surface water irrigation rights. Both studies conclude that water rights add to the value of property, and describe the attributes of these water rights that consumers value.

In contrast to the Byrd and Faux studies analyzing real estate data, Landry[15], Colby et al.[16], and Goodman and Howe[17] use data sets comprised of water right transactions to identify the price determinants of water rights.

In his analysis of Oregon's water market, Landry concludes that quantity and water right price are inversely related. This means that as quantity increases, price per acre-foot decreases. Duty, defined as the maximum annual volume of water for an acre

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[13] Heath A Byrd, "Estimating the Value of Groundwater Rights to Irrigated Agriculture: An Application of the Hedonic Price Model in the Northern High Plains" (M.S. diss., Colorado State University, 2004).

[14] John Faux, "Hedonic price analysis to reveal value of water in irrigation: an application to northern Malhuer County, Oregon" (M.S. diss, Oregon State University, 1996).

[15] Landry, 1995

[16] Bonnie G. Colby, Kristine Crandall, and David B. Bush, "Water Right Transactions: Market Values and Price Dispersion," *Water Resources Research*, 29 (1993).

[17] D. Jay Goodman and Chuck Howe, "Determinants of Ditch Company Share Prices in the South Platte River Basin." *American Journal of Agricultural Economics,* Vol. 79, No. 3 (Aug., 1997), pp. 946-951.

of irrigated land[18], and price are also inversely related, an unexpected result attributed to market segmentation and the strong influence of a small set of results. Senior priority dates also command higher prices, and a significant relationship exists between location and price.

Colby et al. found that senior priority dates, geographic flexibility (the ability to transfer water to alternate uses[19]), and purchases for non-agricultural purposes are associated with higher water right prices in New Mexico's Gila-San Francisco basin. In addition, sales of large quantities of water attract lower unit prices than smaller transfers in the Gila-San Francisco basin.

Goodman and Howe examined transfers of ditch company shares to cities in the Denver metropolitan area. This study concluded that a share's yield (quantity of water provided by the share) and the reliability of the water supply associated with a share hold positive relationships with share prices. The quantity of water lost due to evaporation during the transportation process is inversely related to share prices.

While some hedonic analyses addressing water rights attempt to estimate the value of water rights by examining real estate transaction data, the most accurate way to estimate the value of water rights is to analyze water market information[20]. The lack of research using up-to-date data sets comprised of observed water market activity calls for further valuation studies analyzing this market information[21].

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[18] Landry, 1995

[19] Colby et al., 1993

[20] Landry, 1995

[21] Colby et al., 1993

Statement of Method

This project employs the hedonic pricing method to determine which independent variables influence the price of water rights. The hedonic pricing method is a revealed preference approach to non-market valuation[22]. Similar to other revealed preference techniques, the hedonic method statistically infers values market participants place on attributes of goods based on observed choices participants make within markets[23]. The hedonic method applies to differentiated goods, or goods that possess multiple attributes that cannot be separated when purchasing the good. Purchasers recognize these attributes, and their preferences vary according to each product's individual qualities. The hedonic hypothesis, asserting that consumers value a good based on the amount of utility each of the good's individual characteristics provides, forms the basis for the hedonic pricing method[24].

Description of Data

The data set analyzed in this project lists observed transactions of ditch company shares. The data set includes price, the dependent variable, and independent variables including reliability, location, type of use, and quantity transferred for each share purchase. All of these data will be analyzed quantitatively. Qualitative data for independent variables such as location and type of use will be adapted to a form conducive to quantitative analysis.

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[22] Young, 2005

[23] Kevin J. Boyle, "Introduction to Revealed Preference Methods," in *A Primer on Nonmarket Valuation*, ed. Ian J. Bateman (Dordrecht: Kluwer Academic Publishers, 2003).

[24] Rosen, 1974

WestWater Research, an economic consulting firm working in water markets, agreed to make its data available for this project. The private nature of water transaction information renders market price data difficult to locate, but several viable collection methods exist. Sale deeds identify the occurrence of transactions, and phone calls to buyers and sellers may be used to gather details regarding transactions. This process for data collection was used to build the data set for this project.

Expected Outcomes

In the South Platte basin, water supply reliability, quantity, and location are predicted to have a significant effect on price. Consistent water supplies will have a positive association with price, and quantity will be negatively associated with price per acre-foot. Shares in ditch companies with upstream water rights and located in close proximity to buyers are expected to attract high prices. Shares previously used for irrigation and transferred to municipal use will be highly valuable, and water prices in the basin are predicted to appreciate over time.

CHAPTER 2

THEORY

Introduction

Accurate valuation of water rights increases the ability of water markets to efficiently allocate scarce water resources by helping market participants to make pragmatic purchasing and selling decisions. In many commodity markets, market price information provides correct valuation and the market operates efficiently, with prices reflecting the value of the commodity's positive and negative qualities. However, collecting market price data for water rights is challenging as a result of the proprietary nature of water transaction information. In addition, water markets are affected by imperfect competition, hydrological and institutional uncertainty, and price-setting by a few market participants. These market failures cause market prices to inaccurately reflect the value of water rights' individual characteristics[1]. The proprietary and erroneous qualities of market price data result in a lack of price signals, causing water markets to function inefficiently. Non-market valuation techniques hold the potential to aid market participants in negotiating and completing sensible transactions, increasing the efficiency of water markets.

[1] Bonnie C. Saliba and David B. Bush, *Water Markets in Theory and Practice: Market Transfers, Water Values, and Public Policy* (Boulder: Westview Press, 1987).

Hedonic pricing is the non-market valuation method used in this project to estimate the true values market participants place on water. This chapter begins by explaining the evolution and execution of the hedonic method, then details previous applications of the hedonic method to the water sector.

Hedonic Pricing

The hedonic pricing method is a revealed preference approach to non-market valuation. Similar to other revealed preference techniques, the hedonic method statistically infers values market participants place on attributes of goods based on observed choices participants make within markets[2]. Sherwin Rosen introduced the hedonic pricing method in his seminal 1974 article[3]. The hedonic method applies to differentiated goods, or goods that possess multiple attributes that cannot be separated when purchasing the good. Differentiated goods are always purchased as a bundle of attributes, and changing these characteristics is impossible because they are fundamental aspects of the good. Buyers recognize these attributes, and their preferences vary according to each product's individual qualities. The hedonic hypothesis, asserting that consumers value a good based the amount of utility each of the good's individual characteristics provides, forms the basis for the hedonic pricing method[4].

Hedonic pricing employs multiple regression to determine which attributes of a differentiated good, the independent variables, influence the price of the good. The implicit value consumers place on each of a good's characteristics and the contribution of

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[2] Kevin J. Boyle, "Introduction to Revealed Preference Methods," in *A Primer on Nonmarket Valuation*, ed. Ian J. Bateman (Dordrecht: Kluwer Academic Publishers, 2003).

[3] Sherwin Rosen, "Hedonic Prices and Implicit Markets: Product Differentiation in Perfect Competition," *Journal of Political Economy*, 82 (1974).

[4] Rosen, 1974

each characteristic to the good's overall price are estimated. The hedonic pricing method is most commonly applied to real estate transaction data to determine how characteristics of properties affect price[5]. For example, consider 100 identical houses with the same neighborhood quality and lot size. Fifty of these houses are located 10 miles from a lake, while the remaining 50 houses are situated on lakefront property. Assuming that consumers prefer houses on the lake, higher levels of demand exist for lakefront property than property 10 miles away from the lake. This greater level of demand results in a higher equilibrium price for the lakefront properties. Based on these observed differences in price, the value consumers attach to a property's proximity to the lake may be estimated using the hedonic method.

While most applications of the hedonic method analyze the price determinants of real estate, Young[6] outlines its use for water valuation. For water rights, a hedonic analysis estimates the effects of water market and water right characteristics on water right price. The basic functional form for these analyses is:

$$P = f(\text{market attributes, right attributes}) + e$$

where:

- P represents sale price
- f is the function of best fit estimated using regression
- market attributes are the independent variables that determine supply and demand
- right attributes represent the individual qualities of water rights
- e is an error term.

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[5] Laura O. Taylor, "The Hedonic Method," in *A Primer on Nonmarket Valuation*, ed. Ian J. Bateman (Dordrecht: Kluwer Academic Publishers, 2003).

[6] Robert A. Young, *Determining the Economic Value of Water* (Washington, DC: Resources for the Future).

This function varies in each study based the specific question addressed and the independent variables included in the datasets analyzed by each study.

Applications of the Hedonic Method to the Water Sector

Previous research using the hedonic method for water right valuation has been completed in three ways. First, hedonic analyses applied to real estate transactions that include appurtenant water rights (rights connected to the land on which they are put to use) estimate the implicit value consumers attach to water rights, and calculate the value that water contributes to land prices (Crouter 1987, Faux 1996, Byrd 2004). Second, researchers conduct meta-analyses of water right transaction data across several markets to determine if consumers in different markets place similar value on the attributes of water rights (Brown 2006, Brewer et al. 2008). Third, the hedonic method is applied to water right transaction data within a single market to identify the determinants of water rights prices in specific water markets (Brookshire et al. 2004, Landry 1995).

Crouter[7], a 1980 graduate of the Colorado College Economics and Business Department, attempted to assess the allocative efficiency of the water market in Weld County, Colorado by constructing a hedonic price function for real estate transaction data in the area. The inclusion of appurtenant water rights in a real estate transaction represents one variable analyzed in the hedonic price function. Because the hedonic function was unable to explain prices when split into separate equations for land and water, Crouter concluded that the distinct market for water in Weld County is not functioning efficiently. This lack of a competitive, efficient water market is attributed to prohibitively high transactions costs. While Crouter's aim was not to valuate water, her

[7] Jan P. Crouter, "Hedonic Estimation Applied to a Water Rights Market," *Land Economics* 63, no. 3 (August 1987).

application of the hedonic method to real estate data formed the foundation for future studies estimating the value that appurtenant water rights add to real estate prices.

Building on Crouter's work, Byrd[8] and Faux[9] examined real estate transactions including appurtenant water rights in the Midwest and Oregon, respectively, to assess the value that water rights contribute to property values. Byrd analyzed groundwater, concluding that aquifer flow capacity, certainty regarding the future availability of water supply, and good soil quality are positively related to price. Faux examined surface water irrigation rights and found that water rights add to the value of property, and water rights applied to high quality soil hold the most value.

While these studies attempted to valuate water rights by applying the hedonic method to real estate transaction data, the most direct way to estimate the value of water rights is to analyze water market information because different markets exist for real estate and water[10]. The following studies used the hedonic method to examine transfers of water rights as an individual commodity to identify the determinants of water right prices.

Brown[11] conducted a meta-analysis of water right transaction data between 1990 and 2003 for the 14 western states. This analysis examined the influence of year, drought conditions, parcel size, county population, water source, and buyer type on price. Brown

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[8] Heath A Byrd, "Estimating the Value of Groundwater Rights to Irrigated Agriculture: An Application of the Hedonic Price Model in the Northern High Plains" (M.S. diss., Colorado State University, 2004).

[9] John Faux, "Hedonic price analysis to reveal value of water in irrigation: an application to northern Malhuer County, Oregon" (M.S. diss, Oregon State University, 1996).

[10] Clay J. Landry, "Giving Color to Oregon's Gray Water Market: An Analysis of Price Determinants for Water Rights" (M.S. diss., Oregon State University, 1995).

[11] Thomas C. Brown, "Trends in Water Market Activity and Price in the Western United States," *Water Resources Research*, 42 (2006).

found that buyer type and population significantly affect price. Water purchased for municipalities and environmental purposes draws higher prices than irrigation water rights. In addition, water purchased in counties with high population levels attracts lower prices than purchases in rural counties, a surprising result that emphasizes the need to understand the unique traits of individual markets.

Brewer et al.[12] developed a similar study of water transaction data between 1987 and 2005 from 12 western states. This hedonic analysis of meta-data revealed that, as a result of market heterogeneity, prices and trading activity vary based on location and individual characteristics of local water markets. However, two patterns persist among all markets. Agriculture-to-urban trades demand higher prices than transactions among agricultural water users, and sales and leases for terms longer than one year have become increasingly common over time.

Brookshire et al.[13] created a hedonic model to analyze a data set consisting of water transfers over eleven years in Arizona's Central Arizona Project (CAP) market, Colorado's Colorado Big Thompson (CBT) project market, and New Mexico's Rio Grande Conservancy District (MRG). This analysis indicated that characteristics of the market, such as buyer type and drought conditions, influence water right prices. While common price determinants exist among these different markets, the authors concluded that the markets are heterogeneous, and the meta-analysis lacks the specificity required to provide meaningful insight into water right prices. Hedonic analysis applied to water

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[12] Jedidiah Brewer, Robert Glennon, Alan Ker, and Gary Libecap, "Water Markets in the West: Prices, Trading, and Contractual Forms," *Economic Inquiry*, 46 (2008).

[13] David S. Brookshire, Bonnie Colby, Mary Ewers, and Philip Ganderton, "Market Prices for Water in the Semi-Arid West," *Water Resources Research*, 40 (2004).

right transaction data within a single market are required to identify the determinants of water rights prices.

To gain increased insight into the attributes of water markets that affect price, Brookshire et al. used an alternate hedonic model to examine each market individually. The independent variables analyzed in this model were agricultural output, price of irrigated agricultural land, population, personal income, and employment in mining and manufacturing. For Arizona's CAP market, no statistically significant relationships were found between these variables and price. In the Colorado CBT market, value of agricultural output, land price, and population are negatively related to water price. Employment in manufacturing holds a significant, positive relationship with price in the Colorado CBT market. Applying the model to New Mexico's MRG market revealed a significant, negative association between price and population. Overall, the researchers concluded that applying this second model to individual markets instead of multiple markets provides more meaningful conclusions regarding the price determinants of water rights.

Similar to the second model developed by Brookshire et al. analyzing individual water markets, Landry[14] conducted a hedonic analysis of transactions in Oregon's water market. Landry used the hedonic method to assess the effects of duty, priority date, parcel size, and market segmentation on price.

Duty, defined as the maximum annual volume of water an irrigator may use for an acre of land, was predicted to be positively related to price. However, following the completion of the analysis, duty was found to hold a significant negative relationship

[14] Landry, 1995

with price. This surprising result was attributed to the effects of four outlying observations on the small data set[15].

Priority date serves as a measure of the reliability of the water supply allocated by a water right. Landry predicted that senior priority dates would command higher prices, and the model corroborated this prediction.

Parcel size describes the quantity of water transferred. Landry hypothesized that economies of scale exist as a result of the fixed costs incurred in transferring water rights, meaning that transactions involving large quantities of water command lower unit prices than smaller transactions. This prediction was confirmed by the hedonic analysis.

Landry also tested the effects of market segmentation on price. Market segmentation results from institutional or geographic constraints on inter-basin transfers. In many areas, state laws prohibit inter-basin transfers, creating a separate market in each basin. Geographic features, such as mountain ranges, may also cause market segmentation by rendering physical transport of water between basins impossible. Oregon's Cascade Mountains separate the water market in eastern Oregon from western Oregon. Landry tested for price differences between the western and eastern markets. The hedonic model showed that water rights in the eastern portion of Oregon attract higher prices than western water rights.

These results revealed that a water right's attributes affect its sale price. While Brookshire et al. limited their analysis to characteristics of water markets, Landry's study demonstrates that estimations of water values should account for water right characteristics as well as market variables.

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[15] Landry, 1995

In another study investigating the effects of water right characteristics on prices and water market attributes on price dispersion, Colby et al.[16] constructed a hedonic model to analyze water right transactions from 1971 to 1987 in New Mexico's Gila-San Francisco basin. Priority date, geographic flexibility, buyer type, parcel size, and date were examined for their impact on price. Priority date, a measure of the water right's reliability, was found to affect price, with senior priority dates commanding higher prices than junior priorities. Geographic flexibility reflects the variety of purposes and places of use to which the water right may be transferred. As a result of rapid growth in the Gila subbasin and laws prohibiting inter-basin transfers, a higher level of demand exists for water rights in the Gila subbasin than San Francisco subbasin water. The ability of water users in the Gila subbasin to transfer rights to higher-value uses results in higher water right prices than the San Francisco subbasin. The analysis also revealed that buyers classified as "high profile," including municipalities, mining operations, and utility companies, pay more for water than agricultural buyers. In addition, larger parcels of water sell for lower unit prices, reflecting the economies of scale common in water markets. Colby et al. concluded that accounting for water right and water market characteristics in hedonic analyses allows for more accurate estimations of water values.

Goodman and Howe[17] conducted a water valuation study examining a small portion of the South Platte basin, a study area similar to the region analyzed in this project. A data set of 400 ditch company share purchases involving several communities in the Denver metropolitan area was analyzed for relationships between price paid per

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[16] Bonnie G. Colby, Kristine Crandall, and David B. Bush, "Water Right Transactions: Market Values and Price Dispersion," *Water Resources Research*, 29 (1993).

[17] D. Jay Goodman and Chuck Howe, "Determinants of Ditch Company Share Prices in the South Platte River Basin." *American Journal of Agricultural Economics,* Vol. 79, No. 3 (Aug., 1997), pp. 946-951

share and volume of water diverted per share, the quantity of water lost during transportation, crop prices, population of the purchasing city, and interest rate. Goodman and Howe found that quantity of water provided by the share, reliability of the water supply provided by the share, and transportation losses significantly influenced share prices.

Conclusion

Prior applications of the hedonic pricing method to the water sector provide insight into the specific price determinants of water rights. Two categories of price determinants, market characteristics and water right attributes, were analyzed to estimate the value of water. Analyses of real estate data (Byrd 2004, Faux 1996) found that water rights increase property values, that water rights applied to high quality soil hold the most value, and that reliable water sources are associated with higher prices. Meta analyses of water market transactions (Brown 2006, Brewer et al. 2008) revealed that buyer type significantly affects price, with agricultural buyers paying less for water than municipalities or organizations purchasing water for environmental enhancement. Studies examining specific water markets (Landry 1995, Colby et al. 1993, Goodman and Howe 1997) arrived at more detailed conclusions regarding the water right and market characteristics that impact prices. These studies found that buyer type significantly affects price, senior priority dates attract higher prices, parcel size is negatively related to price, and that market segmentation can result in a price differences among individual water markets. This price information is important for aiding water market participants in negotiating and conducting sensible transactions, increasing the allocative efficiency of water markets.

In addition to analyzing the price determinants of water rights, previous water valuation studies set standards for effective applications of the hedonic method to water rights research. Hedonic analyses of water market information offer more detailed price information than analyses of real estate data. Also, analyses of specific markets instead of multiple markets provide more useful information on the price determinants of water rights. These hedonic analyses of single markets must account for water right attributes in addition to market characteristics. Further research examining datasets of water right transfers in specific water markets is needed to fully understand the relationships between water right characteristics, market characteristics, and water prices.

CHAPTER 3

BACKGROUND

Introduction

Water rights are bought and sold throughout the western United States. These transactions take the form of both leases and sales. Water right sales permanently transfer the entitlement to divert a fixed quantity of water. In a water lease, the lessor agrees to allow the lessee access to a specific amount of water for a predetermined length of time[1]. These sales and leases create markets for water that promote efficient allocation by shifting water appropriations to high-value uses. The first part of this chapter describes water transfers in the West, buyers of water, sellers of water, the impacts of water markets on water prices, and the characteristics of water rights that affect sale price. The second part of this chapter details the water market in Colorado's South Platte Basin.

Water Right Transfers

Water right sales and leases transfer water rights from agricultural applications to other, high-value purposes. Water as a factor of production in agriculture holds less value than water put to municipal, industrial, environmental, or recreational use. For example, an acre-foot of water applied to cotton fields in California generates $60 in state

[1] Thomas C. Brown, "Trends in Water Market Activity and Price in the Western United States," *Water Resources Research*, 42 (2006).

revenue, while the same acre-foot used for semi-conductor production yields $980,000 in revenue[2]. Transferring water to high-valued uses benefits both parties involved: farmers gain more income selling water rights than they earn from applying the water to crops, and water buyers procure water supplies at low costs. Water acquisitions also represent a viable alternative to other water supply-enhancing projects, such as construction of new dams, that incur high economic and environmental costs. As a result of these shared benefits, water transactions promote efficient allocation. Efficient allocation of water means deriving the highest possible economic benefit from available resources by appropriating water to its most socially valued uses, and is the aim of water transfers and water markets[3].

Water transactions occur in response to water scarcity. In many areas throughout the West, water supplies are fully appropriated to historical agricultural uses, meaning that new water supplies are not available to accommodate increasing demand. In addition, storage projects intended to expand water supplies, such as dams, are difficult to implement. Constructing water storage facilities is expensive, and obtaining permits for these facilities is difficult as a result of environmental protection laws and environmental quality standards[4]. Because western water supplies are fully appropriated and storage facilities that would increase supplies are impractical, rising levels of demand for water

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[2] Jedidiah Brewer, Robert Glennon, Alan Ker, and Gary Libecap, "Water Markets in the West: Prices, Trading, and Contractual Forms," *Economic Inquiry*, 46 (2008).

[3] Jan P. Crouter, "Hedonic Estimation Applied to a Water Rights Market," *Land Economics* 63, no. 3 (August 1987).

[4] *Alameda Water & Sanitation Dist. v. Reilly*, 930 F. Supp. 486, 488 (D. Colo. 1996).

intensify water scarcity[5]. Competition among water users grows constantly in response to this scarcity, necessitating increased water market activity.

While water transfers encourage efficient allocation and accommodate increasing demand for water by shifting water use to high-value applications, negative externalities can ensue from water sales and leases. Externalities, defined as third-party effects of two-party transactions, undermine the economic gains derived from water transactions. The third parties most directly affected by water right transfers are appropriators downstream of the transferred water right. Water transfers hold the potential to decrease return flows. Return flows are the unused portion of diverted water that flows back to the stream following beneficial use[6]. Downstream diverters depend on return flows to fulfill their appropriation. Laws exist protecting water users from this third party effect of water transactions[7]. Water buyers are required to file applications with the state to change the purchased water right's type of use and point of diversion. Based on the "no-injury" policy stating that a water transfer must not compromise the reliability of other appropriations, state water administrators can disallow water transfers. Water users are entitled to protest any water transfer that undermines their right[8]. This "no-injury" rule represents an important safeguard, granting water right holders legal standing to protect their water appropriations as property rights.

Rapid population growth, economic development in industry and manufacturing sectors, environmental protection, and recreation place increased levels of demand on

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[5] Mark G. Smith, "The Water Market in the Southern Front Range of Colorado," *Proceedings of the Symposium on International and Transboundary Water Resource Issues* (March 1990).

[6] David H. Getches, *Water Law in a Nutshell* (St. Paul, MN: West Publishing Co., 1997).

[7] *Strickler v. Colorado Springs*, 16 Colo. 61, 70, 26 P. 313, 316 (1891).

[8] Getches, 1997

fully appropriated water supplies in the West. Because water supplies cannot be expanded, municipal water suppliers, environmental protection organizations, and industrial plants purchase or lease water from irrigation users to accommodate their needs. These transactions result in water markets.

Water Markets

Water markets are established as buyers and sellers transfer water from low-value agricultural uses to high-value municipal, industrial, and environmental purposes. Throughout the West, states encourage the formation of water markets to promote efficient allocation and satisfy increased demand on water supplies. Water right transactions occur most frequently in areas experiencing high demand on scarce water supplies, and in areas with few institutional and geographic constraints on transferring water to high-value uses. As a result of the high level of trading that prevails, these areas are classified as having active water markets. The most active water markets in the west are the market in Colorado's South Platte basin, California's Central Valley market, and the Lower Rio Grande Valley market in Texas[9] (see figure 3.1). Heavy competition for limited water supplies is prevalent in these markets, and the legal systems and geographic settings of these markets facilitate water transfers to high-value purposes.

Each individual water market is characterized by specific attributes that influence the price of water rights transferred among its buyers and sellers. The market attributes that contribute to water right prices include buyer type, seller type, drought conditions, geographic flexibility, and the value of crops cultivated in the area.

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[9] Brown, 2006

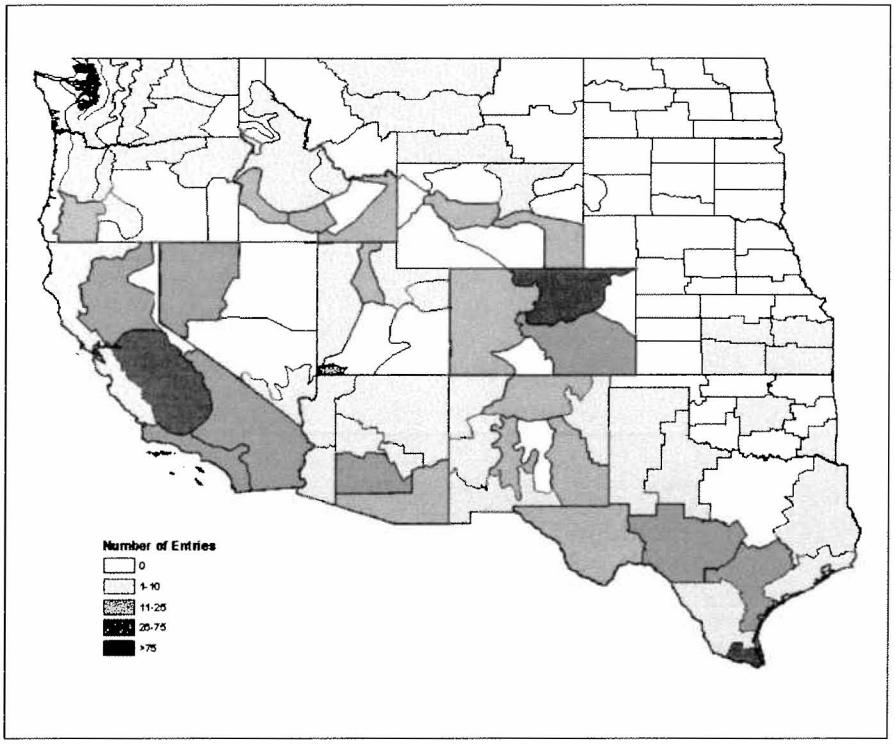

FIGURE 3.1. Western Water Markets by Level of Market Activity, from Thomas C. Brown, "Trends in Water Market Activity and Price in the Western United States," *Water Resources Research*, 42 (2006).

The predominant buyer type within a water market affects water prices. Previous research indicates that municipal and environmental buyers pay more for water than agricultural buyers[10]. In a market characterized by transfers from agricultural to municipal uses, water prices will be higher than in a market dominated by agricultural purchases.

Similarly, seller type influences water prices. Water rights historically used for irrigated agriculture attract lower prices than municipal or environmental rights. Markets characterized by transfers from agriculture to alternate uses reflect lower prices than a market facilitating transfers between various high-value purposes.

[10] Brewer et al., 2008

Drought conditions influence water scarcity. A drought decreases water supply while demand remains constant, driving prices higher. The presence of drought conditions at the time of a water right transaction results in a higher sale price.[11]

The geographic flexibility of water supplies in an area refers to the ability of buyers to physically transport water for alternative uses. In a market with few geographic barriers to transferring water to high-value uses, water right prices are high. If a market's geographic features make transporting water to municipalities or industrial purposes impossible, water rights are relegated to low-value irrigation uses, decreasing water values[12].

Water rights applied to valuable crops are worth more to farmers than water used for irrigating low-value crops, such as alfalfa. Transferring irrigation water rights entails forgoing crop production. The opportunity cost of fallowing crops is higher for farmers cultivating valuable crops than for farmers growing low-value crops. Therefore, in a market producing valuable agricultural products, water right prices are higher than in a market specializing in low-value agricultural production.[13]

Every water market in the United States is characterized by unique attributes. These unique market attributes impact the sale prices of water rights transferred within the market. A thorough understanding of a market's characteristics is necessary for estimating water right values in the market.

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[11] Ellen Hanak, "California's Water Market, By the Numbers," *Public Policy Institute of California* (2002).

[12] Bonnie G. Colby, Kristine Crandall, and David B. Bush, "Water Right Transactions: Market Values and Price Dispersion," *Water Resources Research*, 29 (1993).

[13] Clay J. Landry, "Giving Color to Oregon's Gray Water Market: An Analysis of Price Determinants for Water Rights" (M.S. diss., Oregon State University, 1995).

Water Rights

While water market characteristics significantly impact water right prices, each individual water right possesses attributes that further affect its price. Upon approval from state water administrators, a water right is assigned a priority date, source, quantity, location, and type of use. These qualities of a water right influence its value.

The doctrine of prior appropriation forms the foundation of water law in the western United States[14]. Allocating water based on the "first in time, first in right" principle represents the key premise of the prior appropriation doctrine[15]. A water user gains a water right by diverting water. The user must also demonstrate intentions to apply diverted water to a beneficial use. When a water right is awarded, a priority date is assigned to the right. The first water rights established on a stream hold "senior" priority dates, while subsequent appropriations have "junior" priority dates. Water appropriations are fulfilled in order of seniority. In times of scarcity when insufficient water is available to supply water to all right-holders, junior water users must forfeit their appropriations so that senior appropriations may be completely satisfied. Junior rights are forfeited in descending order from most recent priority dates to oldest priorities. As a result of this "first in time, first in right" principle of western water law, priority dates represent an important indicator of a water right's reliability. Senior priorities are more likely to receive appropriations than water rights with junior priorities. Because water buyers attach value to a water right's reliability, rights with senior priority dates attract higher prices than junior rights[16].

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[14] Getches, 1997

[15] *Coffin et al. v. Left Hand Ditch Co.*, 6 Colo. 443 (1882).

[16] Colby et al., 1993

A water right's source serves as a second indicator of reliability. A water appropriation from a large river that runs permanently is more likely to be fulfilled than a right on a stream that holds water ephemerally. Water rights diverting water from reliable sources are more valuable than water appropriations from streams that run intermittently[17].

Every water right specifies a quantity of water that the right holder is entitled to divert. A water right's quantity affects its value significantly; water rights allocating larger quantities of water are worth more than smaller appropriations, ceteris paribus. However, the effects of quantity on water prices are variable. Many water valuation studies reveal the existence of economies of scale in water right transactions, meaning that as quantity increases, price per unit decreases[18]. These economies of scale are attributable to the transactions costs that accompany water transfers. Transactions costs associated with water transfers arise from obtaining technical advice and completing the legal processes necessary for court approval of the sale[19]. These fixed transactions costs remain consistent among water sales, regardless of the quantity of water transferred. Therefore, in transactions of large quantities of water, transactions costs for each acre-foot are lower than in smaller sales, resulting in economies of scale.

The location of a water appropriation refers to the point of diversion specified by the right. Each right describes the exact location where the water user is permitted to remove water from the source. Water diversion is only permitted at the point listed in the

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[17] Smith, 1990

[18] Colby et al., 1993

[19] Jay R. Lund, "Transaction Risk versus Transaction Costs in Water Transfers," *Water Resources Research, 29* (1993).

right. A water right transaction involves altering the point of diversion, enabling the new owner to use the water. A point of diversion change requires filing a transfer application with the state water administrator. Moving a water right's location downstream of the previous location is more commonly approved than moving the location upstream due to the effects of the change on other water users. Upstream location changes reduce the quantity of water available to other diverters, a third-party effect prohibited by the "no-injury" rule[20]. As a result of this restriction on changing points of diversion, upstream water rights are usually more valuable than rights diverting water further downstream[21].

Water rights are assigned an approved type of use. If a water buyer intends to use the water appropriation for an alternative use, the state water administrator must approve a change of use application. This approval process results in uncertainty for the buyer. The state water administrator may disapprove transfers based on the new use, and may allow the buyer to use only a portion of the water allotted by the right. This uncertainty regarding the transferability of the water and quantity of water purchased makes water transfers risky for the buyer. Because buyers are risk-averse, the risk associated with changing a right's type of use results in lower prices for agricultural water rights purchased for alternate purposes[22].

Water rights are characterized by individual attributes that affect sale prices. Attributes of water markets also influence water right prices. However, achieving

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[20] Rice and White, 1987

[21] Smith, 1990

[22] Rice and White, 1987

meaningful analysis of the specific effects of market and right attributes on prices is impossible without in-depth knowledge of the specific water market.

Colorado's South Platte Basin

The South Platte basin encompasses over 27,600 square miles of Northeastern Colorado (see figure 3.2). The South Platte River runs from its mountain origins southwest of Denver to Northern Colorado's high plains region. Several major streams flow from the mountains into the South Platte, including Clear Creek, St. Vrain Creek, the Big Thompson River, and the Cache la Poudre River. Stream flows in the South Platte and its tributaries are primarily determined by snowmelt runoff and rainstorms, rendering the basin's surface water supply highly variable.[23]

Irrigated agriculture represents an important economic activity in the South Platte basin, with over 30% of the basin's land area and 68% of the basin's water dedicated to crop cultivation. In addition, the South Platte basin is home to Colorado's largest urban areas, including the Denver metropolitan area and Fort Collins. While native flows and water imported from other basins provide 1,800,000 AF/year of water to the South Platte basin, approximately 4,000,000 AF/year of surface water rights have been appropriated to accommodate the area's high municipal and irrigation water demands.[24] Because water users need more water than is available, competition for scarce water supplies exists, resulting in market transfers of water[25]. As Denver suburbs develop and metropolitan

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[23] Colorado Water Conservation Board, *Statewide Water Supply Initiative* (Colorado: Colorado Department of Natural Resources and Colorado Water Conservation Board, 2004).

[24] Dick Wolfe, *Regulation of Well Pumping in the South Platte River Basin* (2005, accessed 27 January 2009); available from http://water.state.co.us/pubs/presentations/dwolfe_100705_b.pdf

[25] Greg Hobbs, Colorado Supreme Court Justice, interview by author, 20 January 2009, Denver, CO.

populations grow, this competition for water intensifies, and sales of water from agricultural uses to municipal purposes occur with greater frequency[26].

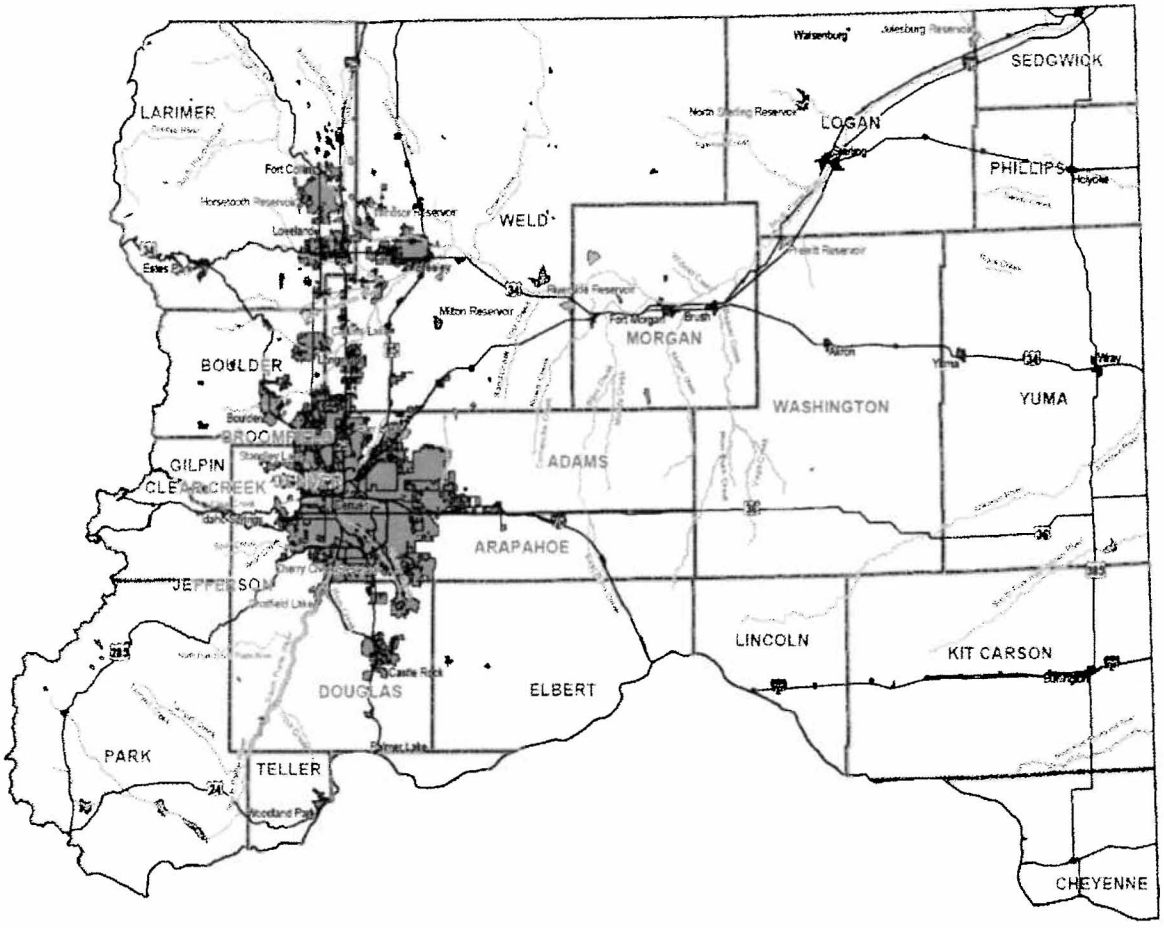

FIGURE 3.2. The South Platte Basin, from Colorado Water Conservation Board, *Statewide Water Supply Initiative* (Colorado: Colorado Department of Natural Resources and Colorado Water Conservation Board).

Ditch companies control the most senior water rights in the South Platte basin, with priority dates as early as 1861[27]. Neighboring farmers originally established mutual

[26] D. Jay Goodman and Charles W. Howe, "Determinants of Ditch Company Share Prices in the South Platte River Basin," *American Journal of Agricultural Economics,* 79 No. 3 (August 1997): 946.

[27] Goodman and Howe, 1997.

ditch companies by combining financial resources to purchase or establish water rights and to construct water delivery infrastructure. Farmers bought shares of company water, with each share representing a pro rata percentage of the company's annual water supply. Assessment fees were imposed on each share to fund the acquisition of new water supplies and infrastructure development projects.[28] The majority of surface water rights in the South Platte basin is currently allocated to agricultural use[29], with significant portions of these rights controlled by mutual ditch companies.

Market Participants

The Denver metropolitan area, located at the convergence of the plains and the Rocky Mountains in the southwest corner of the South Platte basin, has historically depended on large groundwater aquifers to satisfy its water needs. However, as the population of this urban area grows and new suburbs develop, municipal demand for water increases, and acquiring new water supplies becomes necessary (See Table 3.1).

TABLE 3.1

DENVER METRO AREA POPULATION GROWTH AND WATER DEMAND PROJECTIONS

	2000	*2030*
Population	1,432,700	2,157,200
Gross Water Demand (AF)	366,000	513,400

Source: Colorado Water Conservation Board, *Statewide Water Supply Initiative* (Colorado: Colorado Department of Natural Resources and Colorado Water Conservation Board)

[28] Terry L. Anderson and Pamela Snyder, *Water Markets: Priming the Invisible Pump* (Washington, D.C.: Cato Institute, 1997).

[29] Colorado Foundation for Water Education, *Headwaters: South Platte Edition* (Denver: Colorado Foundation for Water Education, 2009).

The Denver metropolitan area is not the only urban area experiencing rapid growth in the South Platte Basin. Populations throughout the basin are projected to rise[30]. One viable way for cities to expand water supplies is to purchase ditch company shares from farmers, and transfer the shares to municipal use. Municipalities purchase ditch company shares frequently. One example of a city acquiring ditch company water is the City of Westminster purchasing shares of the Farmers' Highline Canal and Reservoir Company. Westminster is a suburb of Denver located in the northern portion of the Denver metropolitan area. The Farmers' Highline Canal runs through Westminster, allowing purchased water to enter the city system cheaply. Westminster currently owns 550 shares of Farmers' Highline Canal and Reservoir Company, and purchases new shares for approximately $20,000/AF once the water supply associated with the shares is deemed sufficiently reliable.[31] While cities purchase more shares for higher prices than other water buyers in the basin, other buyers remain active in the water market[32].

Agricultural water users transfer water among themselves. If one agricultural activity is considerably more valuable than another, water is transferred to the more valuable use. However, the value differentials among agricultural activities in the basin usually are not large enough to justify water sales among farmers[33]. In addition, new

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[30] Colorado Foundation for Water Education, 2009.

[31] Josh Nims, City of Westminster, CO. interview by author, 5 November 2008, Westminster, CO, phone conversation.

[32] Hobbs, 2009

[33] Charles Howe, Professor Emeritus of Economics at University of Colorado-Boulder, interview by author, 23 January 2009, Boulder, CO.

markets for agricultural water are forming; land trusts buy irrigation water for permanent dedication to farmland in an attempt to preserve farming culture and communities[34].

Most water purchases by non-municipal users occur to fulfill augmentation requirements. If a farmer removes groundwater for irrigation, and surface water supplies are depleted as a result of this groundwater pumping, the farmer must add surface water to the affected stream to prevent injury to more senior water appropriations[35]. Groundwater users or groundwater districts often buy ditch company shares and leave the water instream to fulfill this augmentation obligation[36]. Purchases of ditch company shares for augmentation purposes constitute a significant portion of the water transactions that occur in the South Platte basin[37], and 4% of the basin's water is used for augmentation[38].

Price Determinants of Ditch Company Shares

A variety of factors influences the prices for which ditch company shares are bought and sold in the South Platte basin. These factors include the buyer type, volume transferred, reliability of the share, and the costs of delivering purchased water to the buyer's system.

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[34] Hobbs, 2009

[35] Colorado Foundation for Water Education, *Citizen's Guide to Colorado Water Law* (Denver: Colorado Foundation for Water Education, 2004).

[36] Howe, 2009

[37] Larry MacDonnell, Ph.D. – Porzak, Browning & Bushong, interview by author, 20 January 2009, Boulder, CO.

[38] Wolfe, 2009.

The primary buyers of ditch company shares in the South Platte basin are irrigators and municipalities. Higher economic gains are derived from putting water to municipal use than from applying water to agriculture. Therefore, cities pay more than farmers for ditch company shares.

The volume of water transferred in a share purchase influences share prices. According to Colorado water law, only the consumptive use portion of a ditch company share may be transferred in a sale if the water source is native to the basin[39]. The consumptive portion of the share refers to the water that is permanently removed from the stream due to evaporation, plant, or animal consumption, and does not include the water that traditionally returns to the stream after use (return flows)[40]. Higher levels of consumptive use associated with an individual share results in higher total prices for the share because the buyer is able to receive more water.[41] However, as a result of economies of scale, transfers of large quantities of water are expected to attract lower prices per acre-foot of consumptive use than small transfers.

A share's price reflects its level of reliability. A reliable share yields a consistent quantity of water each year with little variation. The yield of an unreliable share varies significantly each year, with some unreliable shares receiving no water in drought years. Buyers pay more for reliable shares. For a city to sell a tap to a developer, the city must be confident that water will always be available for the tap. Municipalities are unwilling to purchase unreliable ditch company shares that leave water supply uncertain. Because

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[39] Greg Hobbs, Colorado Supreme Court Justice, "A Decade of Colorado Supreme Court Water Decisions: 1996-2006." *Headwaters*, Special Report, Fall 2006.

[40] Colorado Foundation for Water Education, 2004.

[41] Eric Hecox, Manager of the Office of Interbasin Compact Negotiations, interview by author, 23 January 2009, Denver, CO.

water buyers are risk-averse, reliable shares garner higher sale prices. Ditch companies offering reliable shares are characterized by early priority and adjudication dates, and have reservoir storage to boost company water supply in dry years.

The costs associated with delivering purchased water to the buyer's new point of use also affect price. For example, if a city must construct pipelines and pumps to deliver purchased water to its system, it will pay less than it would pay for water that enters its system cheaply. Ditch companies diverting long distances downstream from municipalities are expected to have less valuable shares than shares from ditch companies that divert near cities and use ditches that run through cities.[42]

While buyer type, volume transferred, reliability of the share, and the costs of delivering purchased water to the buyer's system are predicted to influence the prices of ditch company shares in the South Platte Basin, the extent to which each element influences prices are unknown. Chapter Four will use regression to estimate the effect of these factors on share prices.

[42] MacDonnell, 2009

CHAPTER 4

DATA ANALYSIS

Introduction

To determine which characteristics of ditch company shares influence share prices and to estimate the magnitude of each characteristic's effect on prices, a complete data set containing information about the shares and transfers is needed. Information regarding transfers of ditch company shares is proprietary and difficult to collect, rendering this type of analysis challenging. Data for this project were provided by WestWater Research, LLC., the leading transaction and asset-valuation advisory company to the water sector[1]. An econometric model was then developed based on the hedonic pricing method to explain share prices. This chapter describes the data set used in this project and the hedonic price model developed to analyze these data.

Data

The data set analyzed in this project includes 254 observations of completed ditch company share transfers in the South Platte basin between 2002 and 2008. The data collection process began by gathering "quit claim" and "special warranty" deeds from

[1] Company Profile, available from www.waterexchange.com/; internet; accessed 5 February 2009. The author worked as an intern with WestWater Research during the summer of 2008. After this internship was completed, managing director Clay Landry offered technical support for this project, including the use of one of WestWater's valuable and proprietary data sets. Because these data sets are expensive and time-consuming to compile, the opportunity to use WestWater's data set allowed this project to effectively address a significant issue in water resource economics. This project would not have been possible without these data.

county clerk offices in the South Platte basin to identify share sales. While these deeds indicate that a transaction occurred and name the parties involved, they rarely list details about the terms of the transaction. The buyers and sellers listed on the deeds were contacted to gain information regarding the specific shares that were transferred and details about the terms of the sale. The information acquired for each transfer included price, volume transferred (consumptive use), number of shares sold, previous use of water, new use, share reliability, the storage capabilities of each ditch company, and water district where each company is located. All transfers included in this analysis occurred in Larimer, Morgan, Weld, Park, Douglas, Arapahoe, Adams, Jefferson, Boulder, Gilpin, or Clear Creek County (see Figure 4.1).

Water sales included in this project's data set transferred a total of approximately 12,408 acre-feet consumptive use (AF CU). Transfers of shares in Farmers Reservoir and Irrigation Company (FRICO), Standley Lake Division, amounted to 1,026 AF CU, the most water transferred from any single company in the data set (see Figure 4.2). However, while sales of FRICO Standley Lake shares accounted for the highest volume of water transferred, shares of Riverside Reservoir and Land Company were traded more frequently than shares of any other company in the data set (33 trades, see Figure 4.3). Municipalities purchased more acre-feet of water and participated in more transactions than the other buyer types included in the data set; cities acquired approximately 7,692 AF CU in 139 transfers, comprising 55% of the sales and 62% of the total volume of transfers included in the data set (see Figure 4.4). While 75 purchases involved shares of ditch companies located downstream from the confluence of the Cache la Poudre River and the South Platte River, 179 sales transferred shares of companies situated upstream

from this confluence. Municipalities primarily purchased shares of upstream ditch companies, while the majority of downstream purchases were for irrigation purposes.

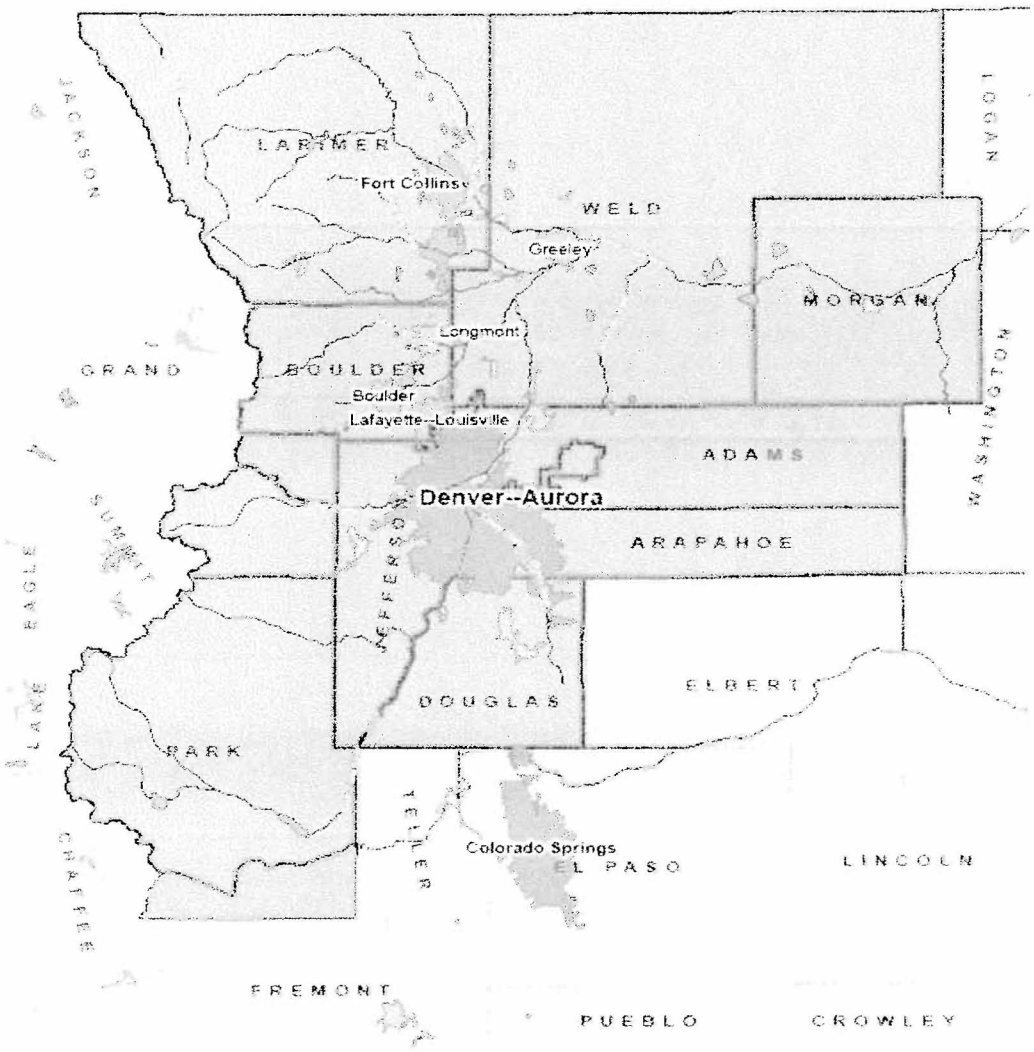

FIGURE 4.1. South Platte Basin Study Area. Created by WestWater Research, LLC., reprinted with permission.

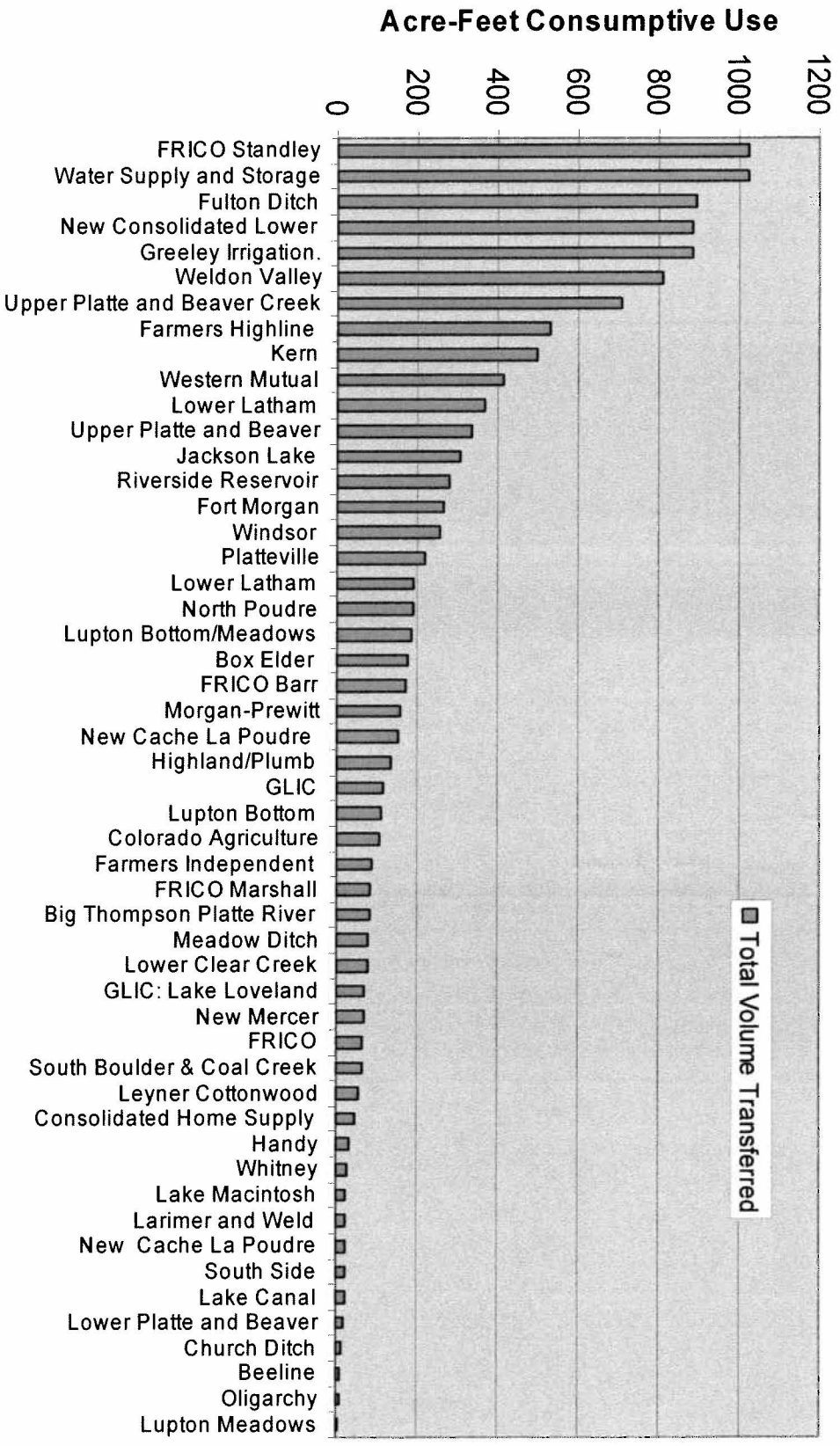

FIGURE 4.2. Volume Traded (AF CU) by Ditch Company

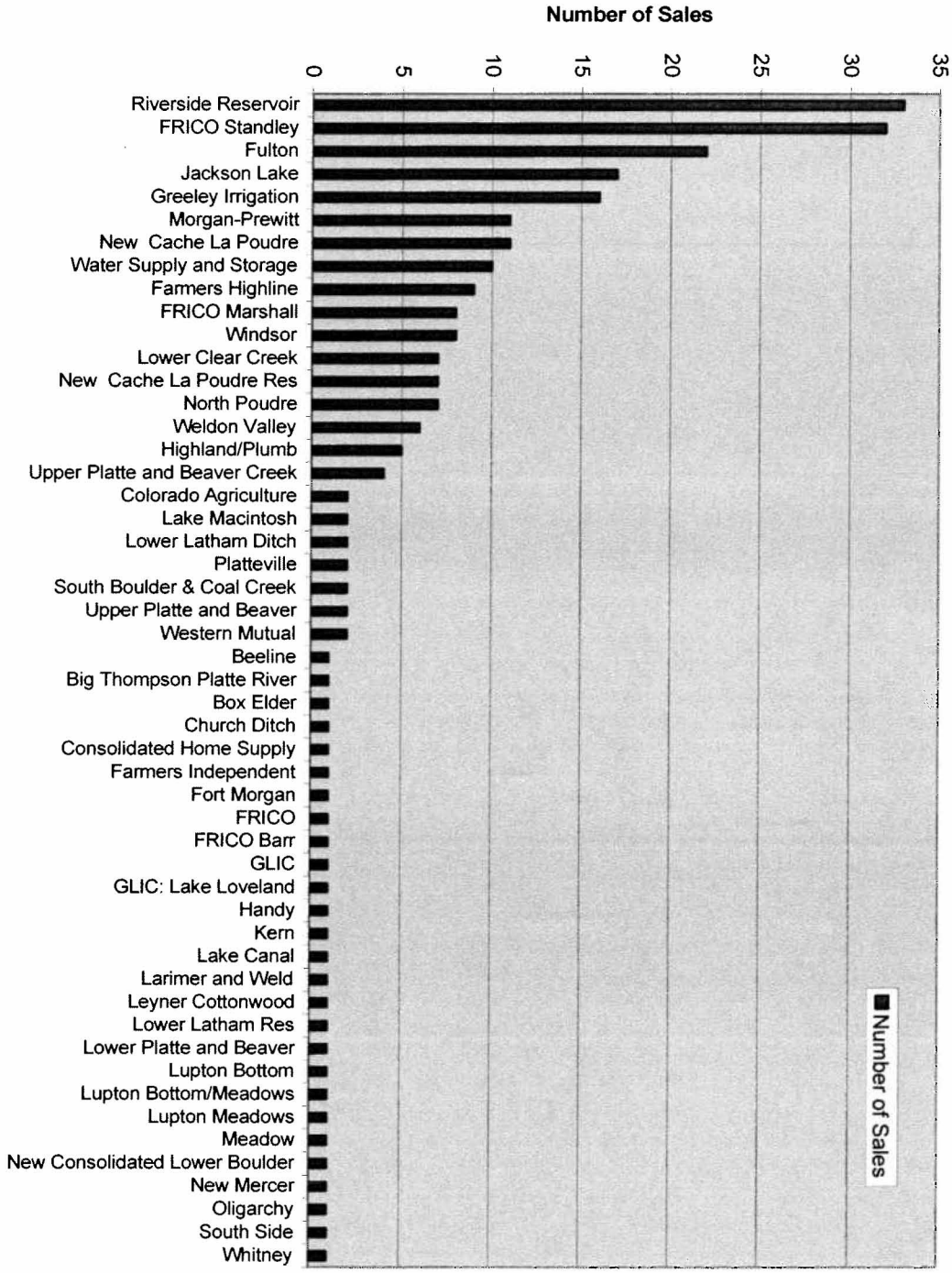

FIGURE 4.3. Sales by Ditch Company

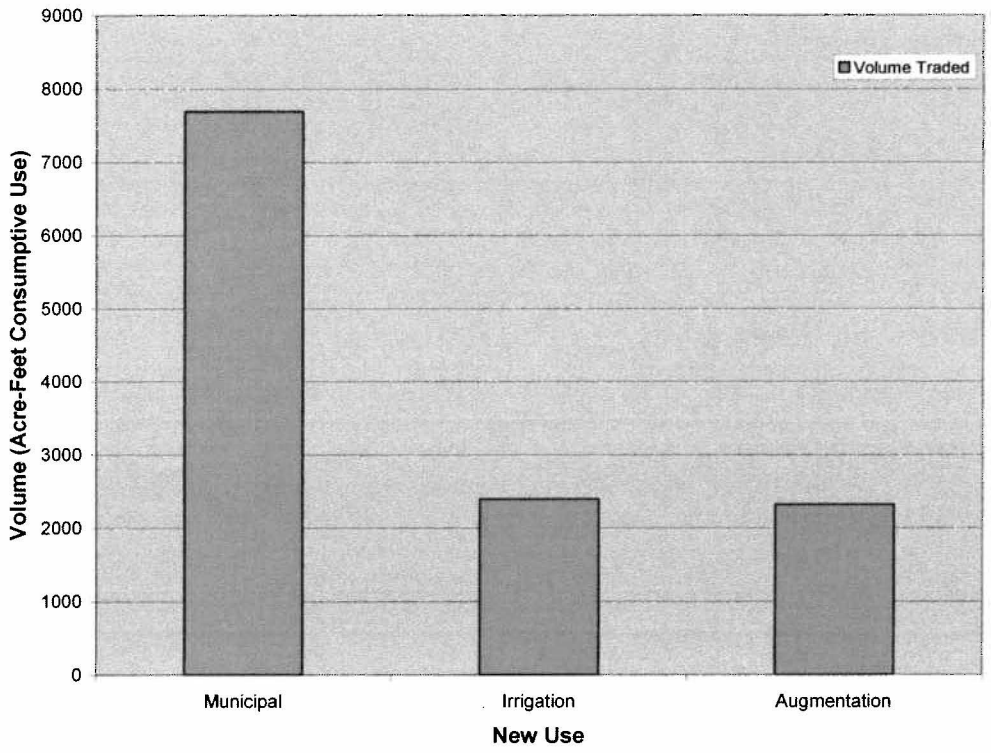

FIGURE 4.4. Volume Traded by New Use

The Model

Ditch company shares are differentiated goods, meaning that the shares of each individual company are characterized by a bundle of characteristics that cannot be separated for individual purchase. The buyer must recognize the different qualities that comprise the share and base consumption decisions on the share's attributes. A hedonic price model statistically infers the values that market participants place on each attribute of ditch company shares based on observed choices participants make within markets.[2] This project applies a hedonic price model to the data set of share sales described above to estimate the effects of share attributes and South Platte basin water market attributes

[2] Sherwin Rosen, "Hedonic Prices and Implicit Markets: Product Differentiation in Perfect Competition," *Journal of Political Economy*, 82 (1974).

on share prices. These ditch company share attributes are water supply reliability, location of the ditch, and the quantity of water purchased. The market attributes included in this analysis are previous use of the purchased water, new use, and the year the purchase occurred.

Dependent Variable

Price represents the dependent variable in a hedonic price model. Price is expressed as a function of the independent variables: ditch company share attributes and characteristics of the water market[3].

$$\text{Price}=f(\text{market attributes, share attributes}) + e$$

Where:

- f is the function of best fit estimated through regression analysis
- e is an error term

The dependent variable in the hedonic price model used in this project is unit price, or dollars/acre-foot consumptive use. An acre-foot of water is defined as the volume required to cover an acre of land with water one foot deep. Water used consumptively is water permanently extracted from its source as a result of evaporation, human ingestion, or crop transpiration. Under Colorado water law, only the consumptive use portion of a ditch company share, measured in acre-feet, may be transferred to alternate beneficial uses.[4] Acre-feet consumptive use quantifies the volume of water associated with ditch company shares that water users may legally buy and sell. Therefore, the dollars/acre-foot consumptive use unit for the dependent variable accurately represents the price that

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[3] Clay J. Landry, "Giving Color to Oregon's Gray Water Market: An Analysis of Price Determinants for Water Rights" (M.S. diss., Oregon State University, 1995).

[4] Colorado Foundation for Water Education, *Citizen's Guide to Colorado Water Law* (Denver, CO CFWE) 2004

buyers pay for each usable unit of water they receive. Unit prices were adjusted for inflation and changed to 2008 dollars using the GDP deflator[5].

Share Attributes

Reliability

The reliability of the water supply associated with a ditch company share affects the price buyers are willing to pay for the share. Purchasing reliable shares results in a consistent water supply for the buyer, mitigating risks related to uncertain water supplies. Most water valuation studies use priority date as a measure of a water right's reliability[6,7]. However, the data set analyzed in this study includes annual water yield information for each ditch company's shares. This annual yield information was collected from the "Colorado Decision Support Systems" online diversion records provided by the Colorado Division of Water Resources and Colorado Water Conservation Board[8]. While these diversion records are difficult to interpret and are sometimes incomplete, they represent the best available source for ditch company water supply information.

The coefficient of variation (COEFF VAR) for the water supply provided annually by each share represents the indicator of reliability used in this project. The coefficient of variation equals the ratio of the standard deviation of yearly water supply to the average yearly water supply.

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[5] Gross Domestic Product Deflator Inflation Calculator, NASA, available at http://cost.jsc.nasa.gov/inflateGDP.html; internet; accessed 9 February 2009.

[6] Landry, 1995

[7] Bonnie G. Colby, Kristine Crandall, and David B. Bush, "Water Right Transactions: Market Values and Price Dispersion," *Water Resources Research*, 29 (1993).

[8] Water Rights, available from http://cdss.state.co.us/; internet; accessed 5 February 2009

$$\text{COEFF VAR} = \frac{\text{Standard Deviation of Annual Yield}}{\text{Average Annual Yield}}$$

Shares with low coefficients of variation provide consistent and reliable water supplies. Conversely, shares with high coefficients of variation are unreliable. Because reliable shares are predicted to be more valuable, the coefficient of variation is expected to be inversely related to unit price. Shares with low coefficients of variation will attract higher sale prices than shares with high coefficients of variation.

A second measure of the reliability of water supplies provided by ditch company shares is the availability of reservoir shares. Reservoirs allow ditch companies to store excess water in wet years for use in dry years, rendering company water supplies more consistent. The variable RES SHARES is a dummy variable, and takes on a value of 1 if the ditch company offers reservoir shares, and 0 if the company does not offer reservoir shares. Because reservoirs increase the reliability of water supply associated with ditch company shares, and share buyers are predicted to pay more for reliable shares, RES SHARES is expected to hold a positive relationship with share price.

Location

The location of a ditch company in relation to share buyers affects the ability of the buyer to successfully complete a transfer for new use. Water courts more commonly approve share transfers to users downstream of the original point of diversion, because moving water rights upstream can impair other water rights, a violation of the "no-injury" provision of the prior appropriation doctrine. As a result of the risk that water courts will not allow transfers from downstream ditch companies and the high legal transactions

costs associated with moving water upstream, water buyers are predicted to pay more for shares of companies situated further upstream.[9]

After a share transfer is approved, the buyer must deliver the water to its system to benefit from the purchase. Transporting purchased water from companies located long distances from buyers is more expensive than delivering water from nearby companies. Therefore, buyers are predicted to pay more for shares of companies in close proximity to avoid high water delivery costs.[10] The model includes the variable UPSTREAM to test this prediction that location influences share prices. A zero-one dummy variable separates upstream companies from downstream companies. Ditch companies situated upstream from the confluence of the Cache la Poudre River and South Platte River are assigned a value of one, while ditch companies downstream from this confluence assume a zero value. The confluence of the Cache la Poudre and the South Platte was chosen as the demarcation between upstream and downstream companies because the major municipal areas in the South Platte basin, which account for the majority of share purchases in the data set, are located upstream from this confluence (see Figure 4.5). Ditch companies located upstream from this confluence are predicted to have more valuable shares as a result of their upstream water rights and close proximity to share buyers.

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[9] Mark G. Smith, "The Water Market in the Southern Front Range of Colorado," *Proceedings of the Symposium on International and Transboundary Water Resource Issues* (March 1990).

[10] Larry MacDonnell, Ph.D. – Porzak, Browning & Bushong, interview by author, 20 January 2009, Boulder, CO.

Volume Transferred

Previous studies demonstrate that economies of scale exist in water transfers, meaning that sales of large parcels of water are associated with lower unit prices[11,12]. The hedonic price model in this study uses the variable CU to test for economies of scale in South Platte basin water transfers. The variable CU represents the volume transferred in acre-feet of consumptive use. Economies of scale are predicted to exist in the South Platte basin water market with higher volumes transferred resulting in lower unit prices for water.

Market Attributes

Previous Use

Ditch company share sales transfer water from low-value uses to higher-value uses[13]. The revenue the seller receives for selling water outweighs the economic gains derived from continuing to use the water, while the buyer benefits economically from increasing its water supplies. Previous studies have demonstrated that in water markets throughout the western United States, agricultural water users constitute low-value water users and frequently sell irrigation water rights to municipalities. These municipalities derive higher economic returns from purchased water supplies[14]. The model developed for this project tests for the existence of this irrigation-to-municipal water transfer trend in the South Platte basin by including the variable PREV USE. This variable is a dummy

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[11] Landry, 1995

[12] Colby et al., 1993

[13] David S. Brookshire, Bonnie Colby, Mary Ewers, and Philip Ganderton, "Market Prices for Water in the Semi-Arid West," *Water Resources Research*, 40 (2004).

[14] Thomas C. Brown, "Trends in Water Market Activity and Price in the Western United States," *Water Resources Research*, 42 (2006).

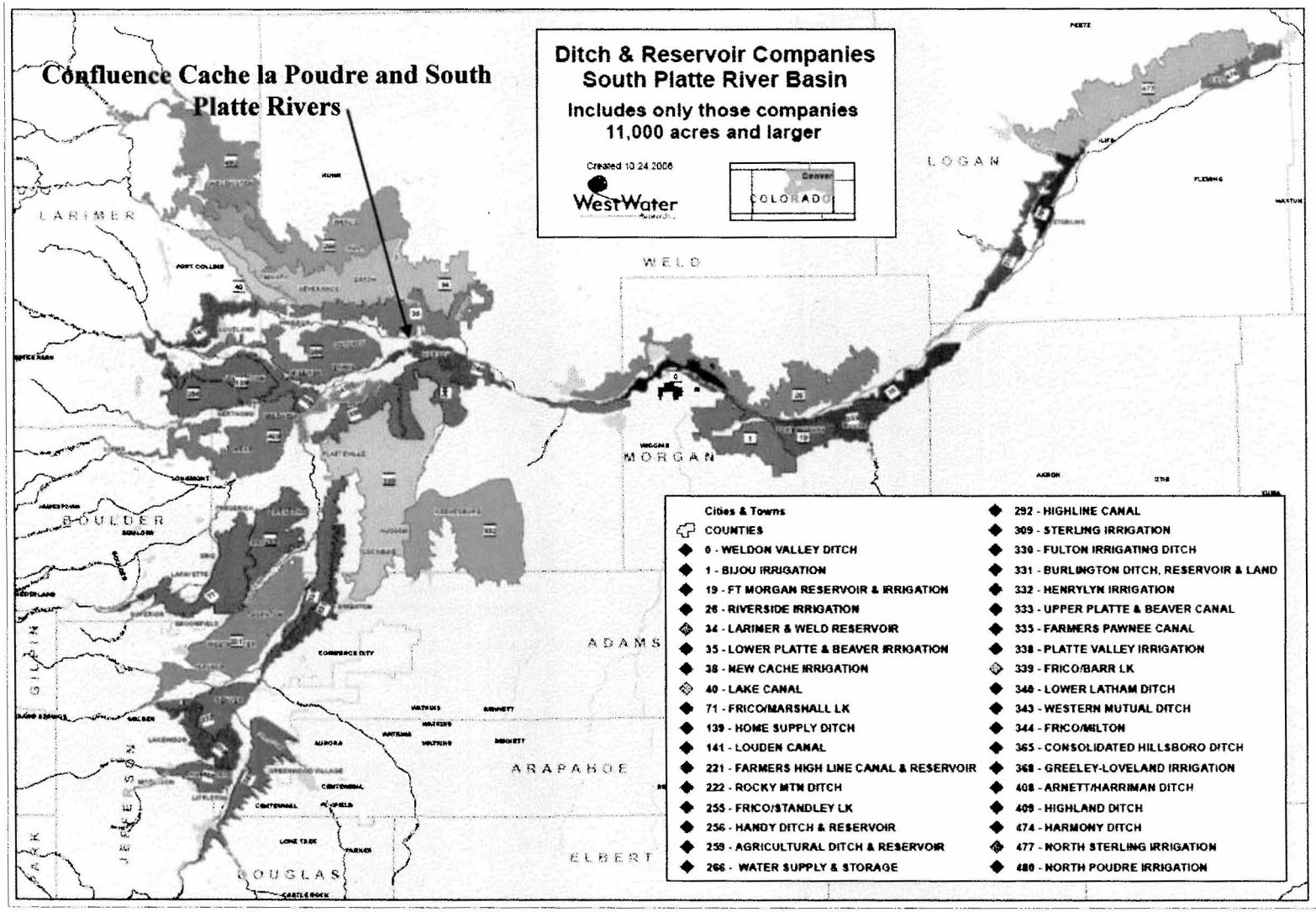

FIGURE 4.5. Locations of Ditch and Reservoir Companies with Respect to the Confluence of the Cache la Poudre and South Platte Rivers. Created by WestWater Research, LLC., reprinted with permission.

variable that takes on a value of 1 if the previous use of the ditch company share was irrigation, and 0 for shares previously owned by municipalities. While agriculture represents a valuable economic activity in the South Platte basin, water applied to irrigation is still predicted to be less valuable than municipal water. Therefore, shares previously used for irrigation are predicted to attract lower prices than shares previously used by cities.

New Use

Previous water right valuation studies indicate that municipal water use is the most valuable application of water in the western United States[15,16]. Because municipalities derive the most economic benefits from water supplies, cities are predicted to pay higher prices for ditch company shares than other buyer types in the South Platte basin. This study's data set includes share sales that transfer water to three different new uses: municipal use, augmentation, and irrigation. Two dummy variables are included in the model to account for the new use of transferred shares. The variable NEW USE MUNICIPAL assumes a value of 1 if a municipal water user purchased the share. The variable NEW USE AUGMENTATION takes on a value of 1 if the share was transferred to augmentation use. Groundwater users purchase ditch company shares and transfer them to augmentation use to replace the surface water depletions caused by groundwater pumping. If both of these variables have a 0 value, irrigators transferred the shares among themselves. The model is predicted to reveal a positive relationship between NEW USE MUNICIPAL and share prices, indicating that municipalities in the South

[15] Brown, 2006

[16] Jedidiah Brewer, Robert Glennon, Alan Ker, and Gary Libecap, "Water Markets in the West: Prices, Trading, and Contractual Forms," *Economic Inquiry*, 46 (2008).

Platte basin pay more for water than other buyers. A positive relationship between NEW USE AUGMENTATION and price is also predicted to exist, because augmentation seems to be a higher-value use than irrigation. However, the coefficient on NEW USE AUGMENTATION will be lower than the coefficient of NEW USE MUNICIPAL, indicating that augmentation water is not as valuable as municipal water.

Year

The data set analyzed in this study includes ditch company share sales occurring between 2002 and 2008. Throughout the South Platte basin, water seems to be appreciating in value[17], meaning that prices rise as time passes. This appreciation of water prices could be occurring in response to increased demand for water stemming from rising metropolitan populations[18]. The variable YEAR is included in the hedonic price model to test for appreciation, and assumes the value of the year in which the share transfer occurred. Because ditch company share price appreciation is predicted to exist in the South Platte basin, YEAR will hold a positive relationship with share price.

Summary of Model

The hedonic price model developed in this study to analyze the relationships between characteristics of ditch company shares, attributes of the South Platte basin water market, and the share prices is:

[17] Harry Seely. Principal, WestWater Research, LLC. interview by author, 6 February 2009, Telephone

[18] Colby et al., 1993

Unit Price = f(COEFF VAR, RES SHARES, UPSTREAM, CU, PREV USE, NEW USE MUNICIPAL, NEW USE AUGMENTATION, YEAR) + e

Where:

- f is the function of best fit estimated through regression analysis
- COEFF VAR is a measure of water supply reliability. A low coefficient of variation indicates a highly reliable share.
- RES SHARES represents the availability of reservoir shares from each ditch company. RES SHARES is a dummy variable that takes on a value of 1 if the ditch company offers reservoir shares, and 0 if no reservoir shares are available.
- UPSTREAM differentiates between ditch companies located upstream on the South Platte River near cities, and companies situated downstream, far from municipal areas. A value of 1 is attached to UPSTREAM if the company is located upstream, and 0 for downstream companies.
- CU represents the volume of water transferred in acre-feet of consumptive use.
- PREV USE differentiates between water transferred from agricultural uses and water originally used for municipal purposes. This variable takes on a value of 1 for previous agricultural use and 0 for previous municipal use.
- NEW USE MUNICIPAL assumes a value of 1 if the share was purchased by a city, and 0 for alternate buyer types.
- NEW USE AUGMENTATION assumes a value of 1 if the share was transferred to augmentation use, and 0 if purchased water was transferred to irrigation or municipal purposes.
- YEAR takes on the value of the year in which the transfer was completed to test for appreciation.
- e is an error term.

The unit price of ditch company shares is predicted to hold a positive relationship with the year the transaction occurred, municipal and augmentation new uses, the availability of reservoir shares, and upstream locations. Negative relationships are expected between agricultural previous use, the coefficient of variation for annual water supply, and the volume transferred and price (See Table 4.1).

TABLE 4.1

PREDICTED RELATIONSHIPS BETWEEN SHARE ATTRIBUTES, MARKET ATTRIBUTES, AND PRICE

Variable	Predicted Relationship with Unit Price
COEFF VAR	Negative
RES SHARES	Positive
UPSTREAM	Positive
CU	Negative
PREV USE	Negative
NEW USE MUNICIPAL	Positive
NEW USE AUGMENTATION	Positive
YEAR	Positive

Results

The Ordinary Least Squares (OLS) method was employed to estimate the hedonic price model described above. The initial estimation of this hedonic price model failed to explain more than 20% of price variation, and revealed several unexpected trends, including a strong correlation between high prices and unreliable water supplies. After plotting share prices against the coefficient of variation for share reliability (see Figure 4.6), sales of FRICO Standley Lake Division shares appeared to be causing these unexpected trends. Despite low levels of reliability, FRICO Standley Lake is characterized by several desirable traits that keep its share prices high. Standley Lake, an important water storage reservoir for FRICO, is located near the cities of Westminster, Northglenn, and Thornton, and represents the primary source of water for these

municipalities[19]. The relatively high elevation of the reservoir (5,506 ft.[20]) enables cheap transportation of its water, because gravity allows the water to flow naturally to municipalities situated at lower elevations. Westminster, Northglenn, and Thornton are actively acquiring new water supplies, including ditch company shares, as a result of rising levels of demand for water stemming from rapid population growth[21]. In response to this population growth and the cost-effectiveness of delivering water from Standley Lake, these cities pay high prices for FRICO Standley Lake shares regardless of inconsistent annual yields.[22]

To more accurately explain ditch company share prices in the South Platte basin, the hedonic price model developed in this project needed to account for the unique characteristics of FRICO Standley Lake shares that attract higher prices. Therefore, the dummy variable FRICO STANDLEY was added to the model to separate FRICO Standley Lake shares from shares of other companies. This variable assumes a value of 1 for transfers of FRICO Standley Lake shares and 0 for sales of other shares. A positive correlation is expected between this variable and unit price.

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[19] Ourwater.org, Standley Lake Cities get $50,000 for water quality protection planning, Spring 2008, available from http://www.ourwater.org/econnection/connection29/standleylake.html; Internet; accessed 8 February 2009

[20]Bill Jeffery, City of Westminster, August 2008, available from http://gis.esri.com/library/userconf/proc08/papers/papers/pap_1777.pdf; Internet; accessed 7 February 2003

[21] D. Jay Goodman and Chuck Howe, "Determinants of Ditch Company Share Prices in the South Platte River Basin." *American Journal of Agricultural Economics,* Vol. 79, No. 3 (Aug., 1997), pp. 946-951.

[22] Mark Smith, Professor of Economics, Colorado College. Interview by author, 5 February 2009, Colorado Springs, CO.

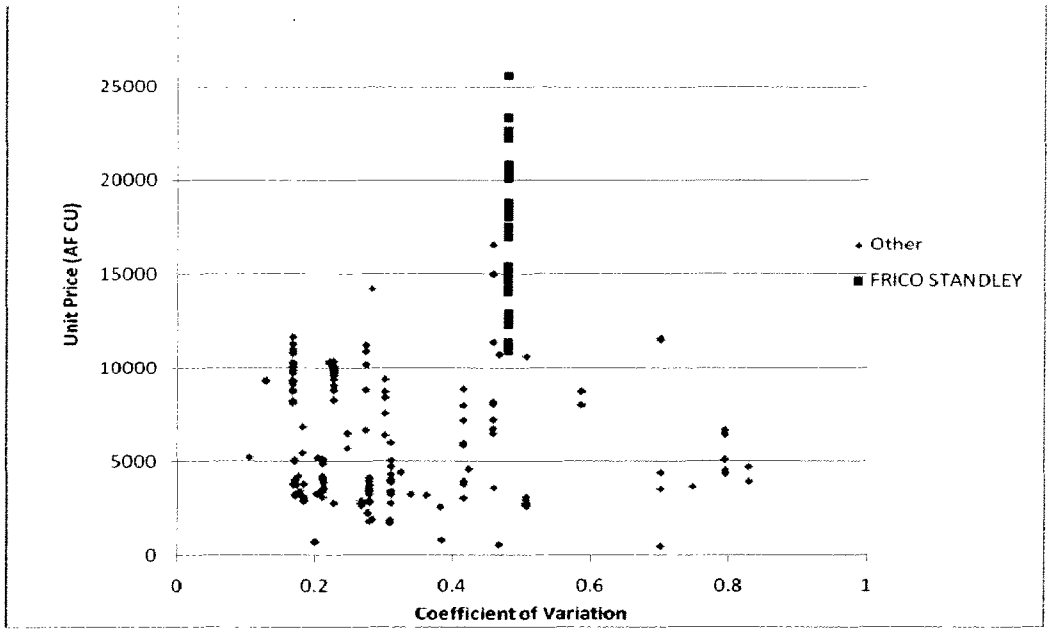

FIGURE 4.6. Unit Prices by Reliability

Following the addition of the FRICO STANDLEY variable to the model, a Jarque-Bera test revealed an uneven distribution of errors, violating the assumption of normality for OLS estimations[23]. Further examination of the original model indicated that problems with the variables UPSTREAM and NEW USE AUGMENTATION, along with one outlying observation, caused this uneven distribution. Alterations were made to this original model to generate an even distribution of errors.

The Revised Model

After recognizing the abnormal distribution of errors problem, a histogram of residuals was created to identify the cause of this uneven distribution. This histogram was characterized by severe bimodality, indicating that many of the share transfers listed

[23] A.H. Studenmund, *Using Econometrics: A Practical Guide* (Reading, MA: Addison-Wesley, 1997).

in the data set attracted systematically higher prices than the original econometric model predicted. In addition, several transfers commanded systematically lower prices.

A thorough analysis of the variables included in the original econometric model suggested that the variable UPSTREAM did not adequately differentiate low-value downstream ditch company shares from highly valuable upstream shares. The sales associated with systematically higher prices than predicted by the original model involved shares of ditch companies located downstream from the confluence of the Cache la Poudre and South Platte rivers. The demarcation between upstream companies and downstream companies represented by the variable UPSTREAM was moved to the town of Masters (see Figure 4.7). Masters is a small community located downstream of the confluence of the Cache la Poudre and South Platte rivers. In the revised model, the variable UPSTREAM assumes a value of 1 for sales of shares in ditch companies situated upstream from the town of Masters, and 0 for sales transferring shares of downstream companies. This change to the variable UPSTREAM increased the coefficient of determination (R Square) by .10 and helped to normalize the distribution of errors.

Further examination of the original model indicated that the variable NEW USE AUGMENTATION caused the negative residuals associated with several sales. In the revised model, NEW USE AUGMENTATION was replaced by NEW USE IRRIGATION. The variable NEW USE IRRIGATION takes on a value of 1 for sales transferring water among irrigators, and a value of 0 for transfers to municipal or augmentation purposes. This alteration further normalized the distribution of errors.

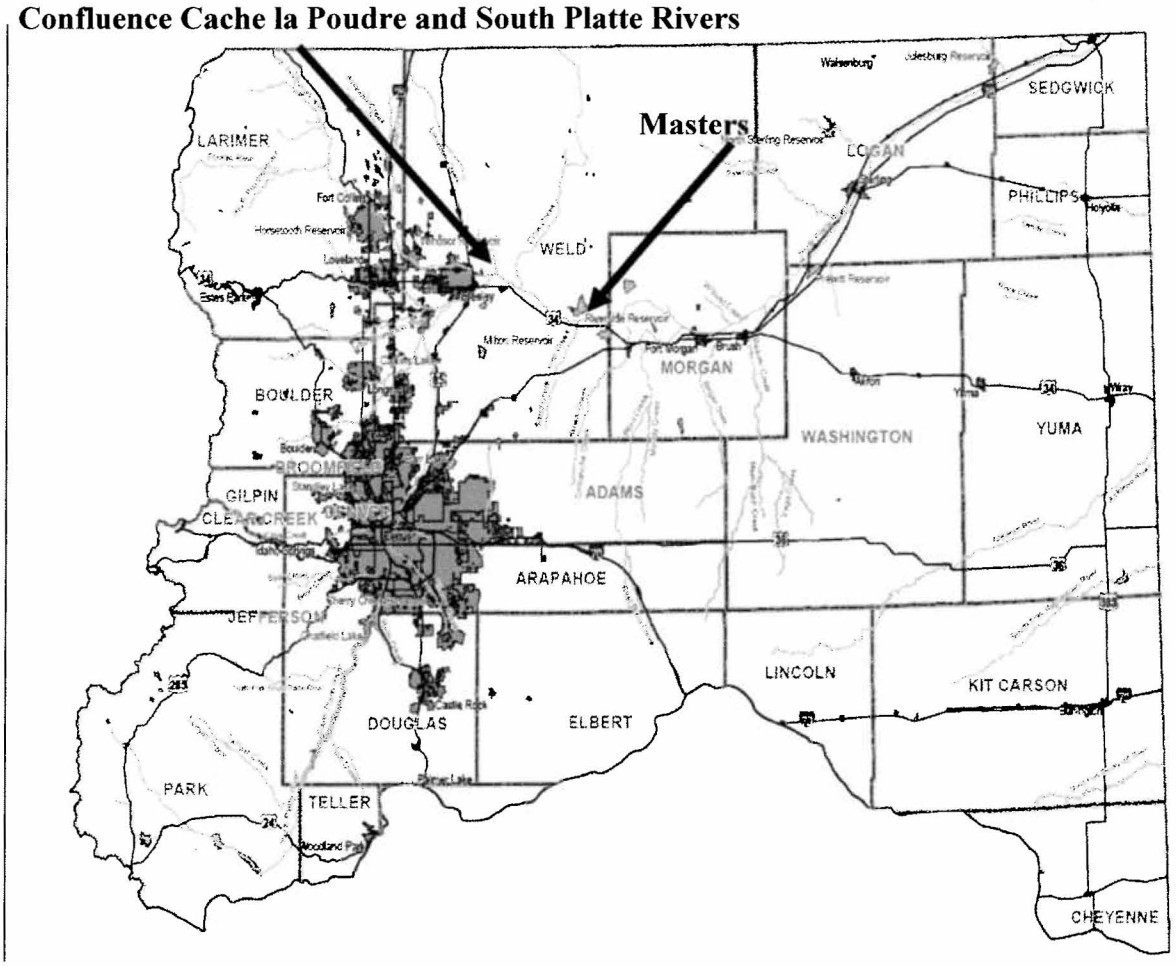

FIGURE 4.7. The Revised UPSTREAM Variable, from Colorado Water Conservation Board, *Statewide Water Supply Initiative* (Colorado: Colorado Department of Natural Resources and Colorado Water Conservation Board, 2004).

The histogram of residuals displayed one outlying observation. The unit price of the share transfer represented by this observation held a value over four standard deviations away from the value estimated by the model. This outlying observation was eliminated from the data set on the basis of suspected entry error.

After the addition of the FRICO STANDLEY variable, the change to the UPSTREAM variable, the addition of the NEW USE IRRIGATION variable, and the

removal of the NEW USE AUGMENTATION variable, the revised hedonic price model was:

Unit Price = f(COEFF VAR, RES SHARES, UPSTREAM, FRICO STANDLEY, CU, PREV USE, NEW USE MUNICIPAL, NEW USE IRRIGATION, YEAR) + e

Where:

- f is the function of best fit estimated through regression analysis
- COEFF VAR is a measure of water supply reliability. A low coefficient of variation indicates a highly reliable share.
- RES SHARES represents the availability of reservoir shares from each ditch company. RES SHARES is a dummy variable that takes on a value of 1 if the ditch company offers reservoir shares, and 0 if no reservoir shares are available.
- UPSTREAM differentiates between ditch companies located upstream on the South Platte River near cities, and companies situated downstream, far from municipal areas. A value of 1 is attached to UPSTREAM if the company is located upstream from Masters, and 0 for downstream companies.
- CU represents the volume of water transferred in acre-feet of consumptive use.
- PREV USE differentiates between water transferred from agricultural uses and water originally used for municipal purposes. This variable takes on a value of 1 for previous agricultural use and 0 for previous municipal use.
- NEW USE MUNICIPAL assumes a value of 1 if the share was purchased by a city, and 0 for alternate buyer types.
- NEW USE IRRIGATION assumes a value of 1 if the share was transferred to irrigation use, and 0 if purchased water was transferred to augmentation or municipal purposes.
- YEAR takes on the value of the year in which the transfer was completed to test for appreciation.
- e is an error term.

This new hedonic price model was estimated using the Ordinary Least Squares method. See Table 4.2 for the results of this estimation.

TABLE 4.2.

REGRESSION RESULTS

	Coefficients	*Standard Error*	*t Stat*	*P-value*
YEAR	799.68**	107.73	7.4232	1.92E-12
CU	-3.9913*	1.9543	-2.0423	0.0422
PREV USE	-7461.2**	1272.7	-5.8624	1.48E-08
RES SHARES	1710.6**	422.07	4.0530	6.81E-05
COEFF VAR	-3692.7**	1026.8	-3.5962	0.0004
FRICO STANDLEY	11130**	581.30	19.147	1.93E-50
UPSTREAM	4414**	485.89	9.0845	3.74E-17
NEW USE MUNICIPAL	457.86	664.09	0.6895	0.4912
NEW USE IRRIGATION	585.11	701.92	0.8336	0.4053

R Square = 0.7207 Adj. R Square = 0.7103 n = 253 F Statistic = 69.66

* signifies statistical significance at a 95% confidence level
**represents statistical significance at a 99% confidence level

The R Square of 0.7207 indicates that the hedonic price model succeeds in explaining 72.07% of the unit price variation in the data set. While some of the price variation remains unexplained, this R Square provides an adequate description of the data[24]. The high t-statistics and low p-values for the YEAR, PREV USE, RES SHARES, COEFF VAR, FRICO STANDLEY, and UPSTREAM independent variables signify that these variables are statistically significant at a 99% confidence level. The variable CU is statistically significant at a 95% confidence level.

White's test for heteroscedasticity indicated that no heteroscedasticity is present in the hedonic price model, meaning that the error term has a constant variance[25]. A Jarque-Bera statistic of 0.7507 signifies that residuals are normally distributed.

[24] Landry, 1995

[25] Studenmund, 1997

Water Price Appreciation

The independent variable YEAR (the year the share sale was completed) has a coefficient of 799.68**. This coefficient reveals a positive relationship with unit price of ditch company shares, implying that appreciation of ditch company share prices exists in the South Platte basin. As each year goes by, the price of an acre-foot (consumptive use) of water increases by $799.68. This high level of appreciation can be attributed to increasing levels of demand for water in the South Platte basin stemming from population growth. This population growth occurs primarily in cites, where water prices are thought to be highest. For example, the Denver Metropolitan Area grew at an average rate of 1.9% annually between 1998 and 2008[26]. Rising demand for high-priced water over time results in increased water prices over time.

Volume Transferred

The coefficient on CU (volume of water transferred in acre-feet consumptive use) of -3.9913* shows a negative relationship with unit price. This coefficient indicates that with each additional acre-foot of water purchased, the price per acre-foot decreases by $3.99. This negative relationship implies that economies of scale exist in the South Platte basin water market. Previous studies have shown that economies of scale exist in water markets throughout the western United States[27,28] and the water market in Colorado's South Platte basin follows the same trend.

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[26] Metro Denver Economic Development Corporation, Demographics: Population, available from http://www.metrodenver.org/demographics-communities/demographics/population.html; Internet; accessed 9 March 2009.

[27] Colby et al., 1993

Previous Use of Ditch Company Shares

The majority of ditch company share sales in the South Platte basin transfer water from irrigation use to alternate uses. Because irrigation constitutes a low-value use of water[29], shares previously used for irrigation may be acquired for lower prices than shares applied to higher-value purposes. The coefficient of -7,461.2**on the independent variable PREV USE indicates that an acre-foot of water previously applied to irrigation in the South Platte basin is $7,461.20 cheaper than an acre-foot used for other purposes.

New Use of Transferred Ditch Company Shares

Previous water valuation studies have shown that cities pay more for water than agricultural water users[30,31]. Because the coefficients of NEW USE IRRIGATION and NEW USE MUNICIPAL are not statistically significant, the existence of this trend in the South Platte basin cannot be confirmed. It is unclear how the new use of transferred ditch company shares influences unit prices. The failure of the shares' new use to affect prices can be explained by the importance and value of agriculture to the local economy in the South Platte basin. Agriculture in Weld County, a small portion of the South Platte basin, adds a $1.1 billon per year to Colorado's economy[32]. Because agriculture is so valuable in the South Platte basin, irrigators may be willing to pay as much for water as municipalities.

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[28] Landry, 1995

[29] Brookshire et al., 2004

[30] Brown, 2006

[31] Brewer et al., 2008

[32] South Platte Basin Roundtable, Colorado Water Conservation Board. Available from http://ibcc.state.co.us/Basins/SouthPlatte/; internet; accessed 8 February 2009.

A correlation matrix was created to test for multicollinearity in the hedonic price model. A high correlation between the NEW USE IRRIGATION and NEW USE MUNICIPAL was identified, indicating that multicollinearity exists in the model. However, because multicollinearity does not affect the predictive power of the model, neither variable was eliminated from the analysis.

Reliability of Ditch Company Water Supplies

The coefficient of 1,710.6** on the variable RES SHARES shows a positive relationship between the prices buyers are willing to pay for water and the availability of reservoir shares from a ditch company. If a ditch company offers reservoir shares to water users, buyers pay $1,710.60 more per acre-foot for shares in the company. Reservoir storage allows ditch companies to provide more consistent water supplies for each share, rendering the share more reliable. This result indicates that water buyers in the South Platte basin value shares that provide reliable water supplies.

A more direct measure of the reliability of ditch company shares is the coefficient of variation for the annual water supply of each company's shares. A high coefficient of variation means that the company provides an inconsistent volume of water each year. Low coefficients of variation indicate a reliable water supply. The coefficient -3,692.7** on the variable COEFF VAR reveals that unit prices are higher for shares of ditch companies offering more reliable water.

FRICO Standley Lake Division

The coefficient of 11,130** on the variable FRICO STANDLEY indicates that shares in Farmers' Reservoir and Irrigation Company (Standley Lake Division) are worth

$11,130.00 per acre-foot more than shares of other ditch companies. FRICO Standley Lake is characterized by unique qualities that allow its shares to command high prices despite the company's inconsistent water supplies. The cities of Westminster, Thornton, and Northglenn are acquiring new water supplies to accommodate their growing populations[33]. These municipalities pay high prices for shares of FRICO Standley Lake because the water can be cheaply delivered to their city water systems[34]. This cheap and easy water delivery is possible as a result of the location of Standley Lake. The lake lies in close proximity to the cities and is situated at a higher elevation, so the water can flow naturally to the cities without expensive pumping systems.

Ditch Company Location

Shares of ditch companies located upstream from the town of Masters command higher prices than share of companies situated downstream from this point. The majority of share buyers are upstream of this community, and legal and physical barriers exist to upstream transfers. Water courts often disapprove upstream transfers from downstream ditch companies because upstream transfers can injure other water rights[35]. In addition, ditch companies located downstream from Masters are a long distance from most Front Range municipalities. These cities are the buyers in a large portion of the water sales in the South Platte basin. Transporting water long distances is expensive, and water purchasers pay less for shares providing water that is costly to deliver to their systems. The variable UPSTREAM has a coefficient of 4,414**, meaning that shares of ditch

[33] Goodman and Howe, 1997

[34] Smith, 2009

[35] Smith, 1990

companies located upstream from the confluence of the Cache la Poudre and South Platte are worth $4,414.00 per acre-foot more than shares of downstream ditch companies.

Summary of Findings

The Ordinary Least Squares estimation of the hedonic price model explained approximately 72% of the variation of ditch company share prices in the South Platte basin. The year the share sale was completed was found to influence price, with share prices increasing over time. The volume of water transferred has a negative relationship with price, indicating that large transfers are associated with lower unit prices for water. Shares previously used for irrigation attract lower sale prices than shares previously applied to municipal use. The reliability of the water supply provided by a ditch company share influences price; shares yielding consistent quantities of water each year command higher prices. Shares of FRICO Standley Lake Division are worth more than shares of other ditch companies. A ditch company's location affects the price of its shares; shares of companies located upstream from the town of Masters attract higher sale prices than shares of downstream ditch companies.

CHAPTER 5

CONCLUSION

Water markets throughout the western United States shift water appropriations from low-value uses to higher-valued uses. By transferring water to more valuable uses, water markets promote efficient allocation of water, allowing states and citizens to derive the highest possible economic benefits from scarce water supplies[1]. In many areas throughout the west, insufficient water supplies are available to meet the needs of all water users. Water markets represent a free-market mechanism for accommodating the water demands of many diverse water users by facilitating purchases and sales of water rights. However, as a result of incomplete price information for water appropriations, buyers and sellers cannot make informed decisions, causing water markets to operate inefficiently. To address this problem of incomplete information, this project analyzed four characteristics of transferred ditch company shares and five attributes of the water market in Colorado's South Platte basin for their effects on ditch company share prices. A ditch company share provides its owner with a pro-rata portion of the ditch company's water supply each year. The South Platte basin is one of the most active water markets in

[1] Jan P. Crouter, "Hedonic Estimation Applied to a Water Rights Market," *Land Economics* 63, no. 3 (August 1987).

the United States[2], and ditch company shares are frequently transferred among water users in the basin, rendering the South Platte basin and ditch company shares useful subjects for analysis.

To evaluate the determinants of water prices in the South Platte basin, a hedonic price model was developed to estimate the effects of market attributes and characteristics of ditch company shares on share prices. Price per acre-foot in 2008 dollars for water provided by ditch company shares represented the dependent variable in the model. The independent variables analyzed in the model for their influence on price were reliability of water supply, location of company, FRICO Standley Lake shares versus other shares, volume of water transferred, previous use of water, new use of water, and the year the transfer occurred. The hedonic price model developed for this analysis is:

[2] Thomas C. Brown, "Trends in Water Market Activity and Price in the Western United States," *Water Resources Research*, 42 (2006).

Unit Price = f(COEFF VAR, RES SHARES, FRICO STANDLEY, UPSTREAM, CU, PREV USE, NEW USE MUNICIPAL, NEW USE IRRIGATION, YEAR) + e

Where:

- f is the function of best fit estimated through regression analysis
- COEFF VAR is a measure of water supply reliability. A low coefficient of variation indicates a highly reliable share.
- RES SHARES represents the availability of reservoir shares from each ditch company.
- FRICO STANDLEY separates shares of Farmer's Reservoir and Irrigation Company (Standley Lake Division) from shares of alternate companies.
- UPSTREAM differentiates between ditch companies located upstream on the South Platte River near cities, and companies situated downstream, far from municipal areas.
- CU represents the volume of water transferred in acre-feet of consumptive use.
- PREV USE differentiates between water transferred from agricultural uses and water originally used for municipal purposes.
- NEW USE MUNICIPAL assumes a value of 1 if the share was purchased by a city, and 0 for alternate buyer types.
- NEW USE AUGMENTATION assumes a value of 1 if the share was transferred to augmentation use, and 0 if purchased water was transferred to irrigation or municipal purposes.
- YEAR takes on the value of the year in which the transfer was completed to test for appreciation.
- e is an error term.

Applied to a data set of 253 share transfers and estimated using the Ordinary Least Squares method, this model revealed relationships between share attributes, market attributes, and prices displayed in Table 5.1.

TABLE 5.1

RELATIONSHIPS BETWEEN SHARE ATTRIBUTES, MARKET ATTRIBUTES, AND PRICE

Variable	**Relationship with Unit Price**
COEFF VAR	Negative
RES SHARES	Positive
FRICO STANDLEY	Positive
UPSTREAM	Positive
CU	Negative
PREV USE	Negative
NEW USE MUNICIPAL	Uncertain due to insignificant correlation with unit price
NEW USE IRRIGATION	Uncertain due to insignificant correlation with unit price
YEAR	Positive

This hedonic price model successfully explains approximately 72% of the price variation among ditch company shares, contributing significantly to knowledge of the determinants of ditch company share prices in the South Platte basin.

The significant negative relationship between the coefficient of variation for annual water supply provided by ditch company shares (COEFF VAR) and unit price indicates that share buyers value reliable water supplies. Shares providing consistent quantities of water each year attract higher prices than unreliable shares.

The positive relationship between availability of reservoir shares (RES SHARES) and unit price shows that share buyers pay more for shares of ditch companies that have

reservoir storage systems. Companies offering reservoir shares provide more consistent water supplies than companies without reservoir shares. The positive relationship between price and RES SHARES represents a second indication that share buyers in the South Platte basin place a higher value on reliable water supplies.

This analysis shows that shares of FRICO Standley Lake attract higher prices than shares of other companies, despite the inconsistent water supplies associated with FRICO Standley Lake shares. Shares of FRICO Standley Lake are thought to command high prices as a result of the company's location, which permits cheap delivery of water to municipal share buyers. The positive effects of FRICO STANDLEY on share prices indicate that municipal water buyers in the South Platte basin place high values on shares associated with inexpensive water delivery regardless of the reliability of ditch company water supplies.

This study found that shares of ditch companies located upstream of the town of Masters attract higher prices than shares of ditch companies situated downstream from this point. Water from upstream ditch companies is delivered cheaply to municipal buyers, and water courts more commonly approve transfers of upstream water appropriations. The positive correlation between UPSTREAM and share prices provides further evidence that water delivered to buyers at low costs is more valuable than water that must be transported long distances for use.

In several water markets in the western United States, economies of scale exist in water transfers[3]. The significant negative relationship between volume transferred (CU) and unit prices for ditch company shares shows that economies of scale exist in the South

[3] Bonnie G. Colby, Kristine Crandall, and David B. Bush, "Water Right Transactions: Market Values and Price Dispersion," *Water Resources Research*, 29 (1993).

Platte basin water market. Sales of large parcels of water are associated with lower unit prices than sales transferring smaller quantities.

The previous use of transferred ditch company shares influences prices. Shares previously applied to agricultural use attract lower prices than shares used by cities. This result demonstrates that municipal water use is more valuable than irrigation water use, and that transfers of water to cities promotes efficient allocation of water resources in the South Platte basin.

The significant positive relationship between the year ditch company share sales occurred (YEAR) and share prices reveals that share price appreciation exists in the South Platte basin. As time passes, ditch company shares increase in price. This trend could be a reaction to increases in demand for water in the basin stemming from rapidly growing municipal populations.

Suggestions for Further Research

The dataset analyzed in this project consisted of 253 transfers of ditch company shares in the South Platte basin. While this dataset is one of the most complete water transfer datasets that exists for the South Platte basin, analyzing a data set containing more sales would allow researchers to draw more accurate conclusions regarding the determinants of share prices. However, as a result of the proprietary nature of share sale information, compiling large datasets of water transfers is expensive and time consuming. Legislation making this information public would allow for better analyses of water prices and help market participants to make more informed consumption decisions.

The reliability data for each ditch company's shares used in this study were collected from online diversion records maintained by the Colorado Division of Water

Resources and the Colorado Water Conservation Board[4]. These records can be imperfect and are difficult to interpret. Annual yields per share listed in the dataset for this project were inferred from these diversion records. A more accurate analysis of the effects of reliability on share prices would be possible with better data on the quantity of water provided by ditch company shares each year. Ditch companies maintain these records of annual water yields per share. However, because ditch companies insisted on keeping records private, online diversion records represented the best available source of reliability data for this study. A more accurate study could be conducted if ditch companies allowed researchers access to their records.

[4] Diversion Records, available from http://cdss.state.co.us/; internet; accessed 5 February 2009

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