

# Market prices for water in the semiarid West of the United States

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[1] Market prices contain information about supply and demand, the institutions that influence both these elements, and the operation of the market. Prices also allocate scarce resources to higher-valued uses. In this paper we analyze the price history of three water markets in the arid Southwest: Arizona's Central Arizona Project, Colorado's Colorado Big Thompson Project, and New Mexico's Middle Rio Grande Conservancy District. Using water transfers over 11 years, we estimate a simultaneous system of market equations, one for price and the other for quantity demanded. Comparison of the institutional characteristics of each market reveals that Colorado's market is well developed, with many trades and rising prices that respond to market conditions, and New Mexico's market is developing well, with lower prices, but showing some response to supply and demand factors. Arizona's market is the least developed, with few trades and very low prices. Our empirical findings support our claim that markets are becoming more efficient in these regions despite the considerable institutional and historical impediments to the evolution of water markets.

*INDEX TERMS:* 1884 Hydrology: Water supply; 1899 Hydrology: General or miscellaneous; 6314 Policy Sciences: Demand estimation; 6699 Public Issues: General or miscellaneous;  
*KEYWORDS:* markets, prices, semiarid Southwest, water, water rights

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## 1. Markets for Water

[2] Faced with limited water supplies and ever increasing populations, all western states are looking for ways to allocate and manage their water more effectively. Although few would disagree that water is a commodity, water markets and related institutions have been slow to evolve because of a combination of inexperience and social and political resistance. There are many vested interests in the historical distribution of water rights and usage patterns of water in the western United States, and new interests are emerging all the time. Despite the most compelling arguments that water right markets will increase the efficiency with which this scarce and valuable resource is allocated, such a change necessitates a redistribution of rights and the associated wealth they represent. There is evidence, however, from the increasing number of water rights transfers that markets are emerging and will continue to develop to meet the needs of the region.

[3] In principle, markets form to facilitate the efficient allocation of goods and services among producers and consumers. With relatively few, simple conditions, buyers and sellers pursuing their own self-interest will pay a single price that fully compensates sellers and provides

the commodity to those who value it highest. Unfortunately, these simple conditions are rarely present in real world markets; however, markets can still achieve outcomes that are preferred and more efficient than without markets. While emerging water markets are often informal [Howe and Goemans, 2003, p.2], involve large institutional buyers such as municipalities or cities, and can be heavily institutionalized through regulation and legal machinations, the experience of markets reported in this study suggests that water rights prices are performing their dual role by providing information to buyers and sellers and encouraging the movement of water from lower valued uses to higher-valued uses. In the most efficient market (a perfectly competitive market), price plays a number of roles. Price acts to equate the quantity supplied to the quantity demanded. It reflects the marginal benefit enjoyed by buyers and marginal cost or production or supply by sellers. Consequently, price contains information about the value of the resource to buyers and sellers that is helpful not only to those trading in the market but also to outsiders. Using this information, we expect rights holders who are currently applying water to lower-valued uses to sell those rights to users who value the water more highly.

[4] By studying prices, we can determine if markets are becoming more efficient over time. Given the historical development and current institutional state of these markets, it is unrealistic to believe they are efficient, yet movements

**Table 1.** Summary of Water Market Studies

Study	Conditions
<i>Howe</i> [1986a, 1986b]	proportional share property rights are more conducive to market formation than priority rights
<i>Howe</i> [1986a, 1986b]	flexibility in allocation of existing water supplies security of tenure for established users users must be confronted with the real opportunity cost of water available for their use predictability of the outcome from water markets fair and equitable initial allocation water allocation process must reflect public values regarding water quality and in-stream flows
<i>Burness and Quirk</i> [1980]	prior appropriation is legally efficient but not economically efficient; inefficiency stems from the unequal sharing of risk among diverse rights holders
<i>Simpson</i> [1994]	a definable right greater demand than supply product availability societal acceptance a good administrative and regulatory structure sufficient mobility fair and equitable initial allocation a fair reallocation system
<i>Saliba</i> [1987]	all economic agents must behave as price takers all economic agents must have access to complete information on legal and hydrologic characteristics property rights must be completely specified, enforced, and transferable
<i>Easter et al.</i> [1999]	water rights need to be separated from land rights institutional arrangements to deal with third-party effects adequate management and infrastructure rights will need to be preserved for “public good” uses such as in-stream flows and recreation adequate information regarding supply and demand is a basic necessity
<i>Howe and Goemans</i> [2003]	low transaction costs water right is personal property, separable from land low transactions costs plentiful water for sale shares (if applicable) are homogeneous frequent small quantities are transferable few transactions draw protests

toward greater efficiency indicate that markets for water will continue to develop and flourish. In this paper we study the prices paid for the transfer of water rights in three major markets in three basins that dominate the three semiarid states of Arizona, Colorado, and New Mexico. The three water markets and the corresponding basins in which they lie are the Central Arizona Project (CAP) in the Lower Colorado basin that covers Arizona, the Colorado Big Thompson (CBT) market associated with the Northern Colorado Water Conservancy District (NCWCD) in the Upper Colorado Basin that covers the western half of Colorado, and the Middle Rio Grande Conservancy District (MRG) market in the Rio Grande basin that covers New Mexico. We chose these three markets primarily for pragmatic reasons, yet they all herald and reflect a trend in the development of western water markets that makes them worthy of study. The pragmatic consideration was the availability of data in sufficient numbers and with adequate control variables to conduct an empirical analysis. These markets provide a relatively long history of market transactions compared to other western regional markets.

[5] Research into water rights prices has been hampered by the general paucity of price data, even though

quantity data are readily available. *Howe and Goemans* [2003] provide a recent example of research into water markets that uses quantity data but is unable to provide analysis of the price-quantity relationship. While there are many studies promoting water markets, most argue on the theoretical grounds of improved efficiency. This study offers a focused look at the price history in three exemplary markets but represents only the beginning of this line of research, which ultimately could provide both a retrospective explanation of price determination and trends and a model capable of predicting water rights prices for use by administrators, policy makers, and buyers and sellers of water in the West.

[6] Although a large number of transactions may define a well-developed market, this does not necessarily imply an efficient market, nor is a market with few transactions necessarily inefficient. The efficiency of a market depends on the market structure, the number of buyers and sellers, the ease of entry to and exit from the market, and transaction costs. In their review of the operation of the NCWCD, for example, *Howe and Goemans* [2003] argue that this market works well because the rights being traded are homogeneous shares, there are many buyers and sellers, and transaction costs are low: the fundamental

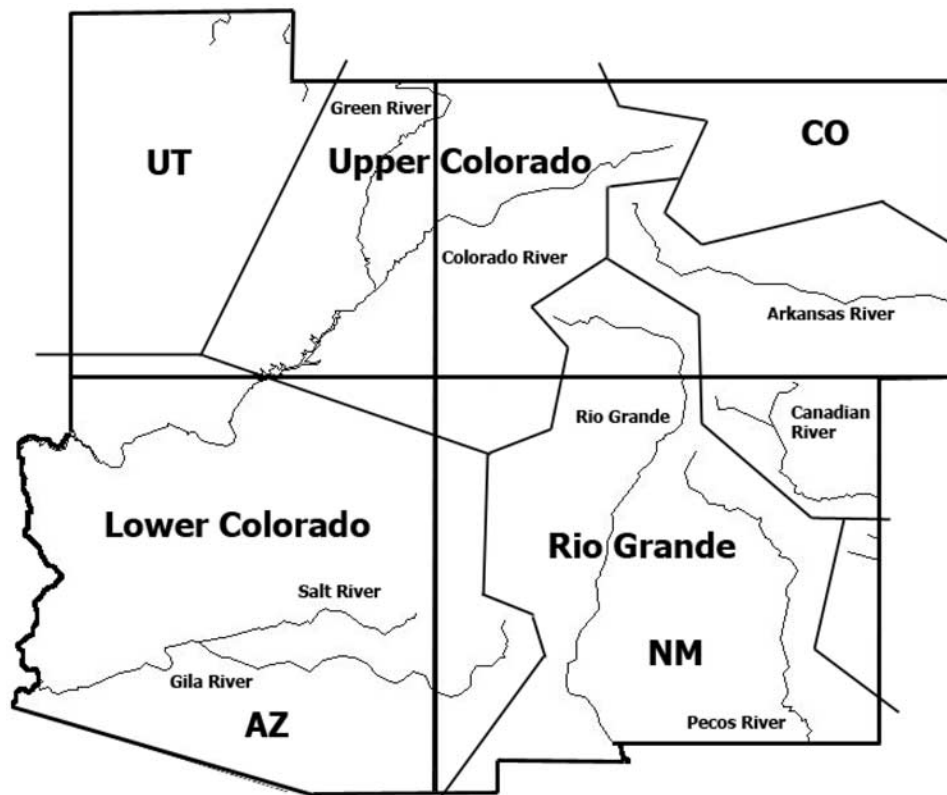


Figure 1. Major basins and rivers of three states in study.

features of an efficient market. In Table 1 we provide a summary of the features identified as critical to the operation of water markets in previous studies.

## 2. Water and Water Markets in Three Semi-arid States

[7] We concentrate on three major water markets, each dominating three water basins, each of which, with one exception, covers a state: (1) the Central Arizona Project in the Lower Colorado basin in Arizona, (2) the Colorado Big Thompson Project in the Upper Colorado basin in Colorado, and (3) the Middle Rio Grande Conservancy in the Rio Grande basin in New Mexico. As Figure 1 shows, only the western half of Colorado is covered by the Upper Colorado basin, yet a significant amount of water collected from the western slopes of the Rocky Mountains under the CBT project is conveyed to the eastern slopes and Front Range of the Rockies for use by communities located in the Missouri and Arkansas basins.

[8] Within these three states we chose the largest basins, and within these basins we chose one representative market. Table 2 shows that U.S. Bureau of Reclamation (BOR) projects are largely responsible for establishing the infrastructure on which water markets can be built. Accordingly, the three markets studied here emerged from BOR projects: the Central Arizona Project in 1968, Colorado Big Thompson started in 1938, and the Middle Rio Grande Conservancy District formed in 1923. Below we consider some necessary elements for water

markets to form and increase the efficient allocation of water in these three regions.

### 2.1. Project Infrastructure

[9] While each project differs by local conditions, geography, climate, history, and the regulatory environment of each state, the existence of the federal BOR program ensures a high level of physical infrastructure that can enable markets to form and flourish. Reclamation projects “reclaimed” arid western land for the specific purposes of irrigation. CAP uses 336 miles (1 mile = 1.609 km) of lined ditches to irrigate 560,000 acres (1 acre = 4047 m<sup>2</sup>) of land with water from the Colorado River. In 1971, the Central Arizona Water Conservation District (CAWCD) was created to contract CAP water with the U.S. Bureau of Reclamation. CAWCD coordinates water deliveries to over 20 irrigation districts. The Colorado Big Thompson project first diverted water from the western slope of Colorado to the eastern slope for irrigation in 1947. CBT water irrigates 600,000 acres of land in 30 cities; 95 miles of canals were constructed for water delivery. The original cost per acre-foot unit (1 acre-foot = 1234 m<sup>3</sup>) of CBT water was \$1.50 in 1937 when applications were first accepted. The Colorado Big Thompson project lies within the Northern Colorado Water Conservancy District, which was formed in the 1930s specifically to contract water from the U.S. Bureau of Reclamation [Wahl, 1989]. It is the board of the NCWCD that approves all transfers of CBT water. Starting in 1923, New Mexico’s MRGCD built dams and over 800 miles of irrigation canals connecting to over 200 miles of existing canals, but inadequate finance led to a crisis by the late 1940s. Federal assistance through the BOR

**Table 2.** Three Basin Descriptive Statistics<sup>a</sup>

	Basin		
	Lower Colorado	Upper Colorado	Rio Grande
Main state	Arizona	Colorado	New Mexico
Population (thousands)	5131	4418	1829
Average annual precipitation, inches	9 (22.86 cm)	16 (40.64 cm)	8 (20.32 cm)
Major rivers	Colorado, Gila, Salt, Little Colorado	Colorado, South Platte, Rio Grande	Rio Grande, Pecos
Major cities	Phoenix, Tucson, Prescott	Denver, Fort Collins	Albuquerque, Las Cruces, Santa Fe
Bureau of Reclamation (BOR) projects	Central Arizona Project, Parker Davis, Palo Verde, Salt River, Gila, Yuma	Colorado/Big Thompson, Armel, Silt, San Luis Valley, Fruitgrowers Grand Valley, Mancos Florida, Bostwick Park	MRGCD, Navajo, San Juan, Chama, Tukumcari, Fort Sumner, Rio Grande, Pecos, Carlsbad, McMillan Delta
Major BOR Project	CAP	CBT	MRGCD
Miles of Ditches	336	95	834
Project Acreage	7,296,000	1,900,000	278,000
Irrigated Acres	560,000	720,000	128,787
Groundwater priority dates	1975–1980	1972	1931, 1956
Surface water priority dates	1919	continuous dates	1907

<sup>a</sup>Sources for data are Bureau of Economic Analysis: Regional Economic Accounts, NOAA National Climatic Data Center, U.S. Geological Survey, U.S. Bureau of Reclamation, New Mexico State Engineer, Colorado Division of Water Resources, and Arizona Department of Water Resources.

helped rejuvenate the district, and since then, it has provided water to agriculture, supported the 30,000 acres of bosque lining the river's edge, and provided recreational opportunities for Albuquerque's growing population. Irrigation and conservancy districts were initially formed to serve agricultural interests and protect agriculture from the cyclic and episodic fluctuations of surface water supplies. While agricultural interests remain the priority for these projects, increased recreational use and protection of habitats and species is placing additional burdens on these projects. At the same time, alternative uses of project water by municipalities and industries are increasing in value compared to the relatively steady or falling value of the agricultural produce generated by traditional project users.

## 2.2. Property Right Schemes

[10] The right to divert and consume water is a private property right, of value and transferable. Water in these regions is governed by the doctrine of prior appropriation. Under this doctrine a water right is created as soon as water is diverted from the river and put to beneficial use. Attached to the right created by this diversion is a "priority date" which is usually the date of first diversion. The priority date establishes a valuable status to the right in times of drought or when demand for water exceeds supply. Despite many commonalities, there are sufficient idiosyncratic differences between states and basins to warrant a more detailed look at each state in our study.

### 2.2.1. Arizona Surface Water Rights

[11] Surface water rights in Arizona are categorized by their priority date in comparison to the year 1919. Surface water rights with a priority date prior to 1919 are marketable. Priority dates after 1919 are permitted rights and are not marketable. In 1974 the Arizona State Legislature passed the Water Rights Registration Act. The act required all surface water rights not granted by the state water code (pre-1919 rights) to be registered by filing a claim with the state of Arizona. The final deadline for filing a claim was

1 October 1990, after which no other claims were accepted. This effectively fixes the total supply of surface water that can be traded in the state; however, the supply of water rights available on the market may still be responsive to price, especially as the price increases over time.

### 2.2.2. Colorado Surface Water Rights

[12] Colorado surface water rights are administered by the Colorado Division of Water Resources (CDWR) in conjunction with the water courts. The water courts are District Courts that hear matters related only to water. Surface water is appropriated according to priority dates. Some priorities date back to the 1890s. CDWR administers the surface water rights up to the head gate of the main ditch where water diverts from the river. Allocation to individual shareholders along the ditch is governed by the ditch company. To obtain a surface water right, an individual must show intent to divert water and put it to beneficial use. The individual fills out an application and submits it to the water courts. If there is no opposition, the water right may be signed into a decree. The Colorado Constitution states that the right to appropriate the unappropriated waters of the state "shall never be denied."

[13] Federal exemptions can override the administrative rules of the state outlined above, especially for BOR projects within the state. Specifically, in the Colorado Big Thompson there is a "proportional" rights system of surface water rights. NCWCD was established to build the CBT project, and all rights within the district are administered by NCWCD. Their authority stems from the Water Conservancy Act which created water districts with the same power and authorization as a state agency. Therefore the NCWCD may administer water within its boundaries separate from the CDWR.

[14] Proportional surface water rights within the CBT market are traded as "shares" of a variable amount of water annually. The shares can be bought and sold separate from the land; however, the shares cannot be transferred away from the Northern Colorado Water Conservancy District. A CBT unit is defined as 1/310,000th share of the total surface

water available in a given year. All trades in the Colorado study area are for surface water. *Howe* [1986a] argues that proportional rights are better suited to markets because of lower transaction costs and because all rights are homogeneous, allowing for a single market clearing price. In comparison, a priority system creates a variety of priority dates by which rights are differentiated. The senior right has a higher priority and may attract a higher value than a junior right. The water right market may reflect differences in priority by forming submarkets in which same-priority rights are traded, or we may observe lower-priced rights trading before the more highly valued rights.

### 2.2.3. New Mexico Surface Water Rights

[15] The New Mexico Office of the State Engineer (OSE) administers New Mexico water rights. The state engineer oversees the measurement, appropriation, distribution and adjudications by the court. Surface water was declared to be public water in 1907. Surface water rights existing prior to 1907 are considered the most senior rights in New Mexico. They are transferable and can be severed from the land. Surface water rights developed after 1907 are permitted rights and cannot be transferred or sold. Many of the pre-1907 surface water rights have yet to be adjudicated, the legal process of establishing a water right. Once a pre-1907 surface water right is adjudicated, it can be legally transferred or sold. A common priority date for transferable rights of 1907 creates a homogenous right with characteristics of the proportional rights system. In times of drought, all 1907 right holders share equally in the loss of water supply. As argued earlier, although the prior appropriation doctrine creates differentiated water rights, it still lends itself well to the creation of water markets by establishing a well-defined tradable property right. Basically, to legally transfer a water right in New Mexico, the state engineer requires that the right be valid, be put to a beneficial use by the buyer, and does not impair the rights of others, including deliveries at the state border under compacts. The water rights structure in New Mexico lends itself to the formation of a market because of the homogeneity of the right, but delays in adjudication mean that only finalized rights can be traded at present.

### 2.3. Administration and Regulation

[16] Water authorities and institutions not only establish the rules by which water rights can be claimed, they also determine the rules by which they can be traded. By necessity, there are similarities but also many differences between water adjudication, appropriation, allocation, regulation, and administration in each state. Because all water is owned by the state, it is a public good that through water rights becomes a private commodity with corresponding value acquirable by the right holder. So while private agents use and trade water, public agencies administer the allocation of rights and the conditions under which they can be traded. In particular, agency oversight is required to ensure that third-party effects are acknowledged and given appropriate standing. Some states, such as New Mexico, also have public welfare clauses under which intervention in water transfers can be made by parties quite removed from the proposed trade [*Brookshire et al.*, 1996].

[17] To transfer water in Arizona, an Application to Transfer form must be completed and filed with the Arizona Department of Water Resources (ADWR). Consent of the

existing right holder must be included along with a \$500 examination fee and a copy of the recorded deed showing land ownership. Type of use, place of use, legal description, and months of beneficial use must also be given. Once the completed application is submitted, the ADWR will determine if the application should be approved or denied within 420 days. Transfers within the CBT project are handled entirely by NCWCD. In the case of a temporary rental or lease of water, only a postcard needs to be filled out and sent to NCWCD. For a permanent transfer of water, an application must be filled out and reviewed by the board of the NCWCD which meets once a month. Third-party effects, if there are any, are determined by NCWCD. The entire transfer process may take up to 45 days and includes a transfer fee of \$70. The New Mexico process for transferring a right involves a public notification period. The applicant must complete the application for transfer that includes type of use, place of use, legal description, and copies of all deeds. It may also include affidavits of a person having knowledge of the date of first appropriation. The application fee ranges from \$25 to \$50 depending of the type of transfer (e.g., surface to ground). After the application is received, it must be published in the public record. Anyone wishing to protest the transfer may file a statement by the end of 30 days. After the publication period, the transfer application is reviewed by a referee and a hearing is scheduled. At the hearing the transfer may be approved or denied. The entire process can take up to 18 months. Colorado clearly holds the advantage in having administrative rules that generate lower transactions costs.

[18] This section provides the background for our study of water rights prices in our chosen three markets. The history and institutional setting of these markets suggest a plethora of remaining impediments to the achievement of a perfectly efficient distribution of water resources. However, in the analysis to follow, we attempt to explain water rights prices by variation in as many characteristics of the markets, both supply and demand factors, for which we can obtain data. Our analysis does not provide a complete description of the market forces determining price since we do not have all the data we would wish. For example, since these markets are predominantly informal, we would like to include the number of water brokers in each market, yet this information is not available. Despite this limitation, our analysis provides a first look at price determination in these important regional water markets.

## 3. Analysis of Water Prices

[19] Water transaction data for the three basin markets in this study were obtained from the "Yearly Transaction Summary" published in the *Water Strategist*, from 1990 to 2001. Yearly population and yearly income data were collected from the U.S. Bureau of Economic Analysis, and all prices are deflated with the 1996 Gross domestic product deflator. Monthly mean temperature and the monthly Palmer drought severity index were obtained from National Oceanic and Atmospheric Administration (NOAA). Substantially more observations come from trades in the CBT market (490) with only 55 trades recorded with price data from Arizona's CAP and 94 with prices for New Mexico's MRGCD market. All data are pooled, but a dummy variable indicating the market is included.

**Table 3.** Selected Sample Statistics for the Three Markets Under Study: 1990–2001<sup>a</sup>

Measure	Lower Colorado (AZ)	Rio Grande (NM)	Upper Colorado (CO)
Number of Trades	35	89	490
Average traded volume, acre feet	96,830 (298,317)	195 (969)	81 (463)
Average Price, 1996 \$, \$/acre feet	613 (926)	2,118 (1,232)	5,312 (4275)
Proportion government buyer	0.20	0.05	0
Proportion municipal buyer	0.63	0.95	0.92

<sup>a</sup>Only trades with price are included in the data set. Entries in parentheses are standard deviations of measure.

[20] Three buyer types are identified: federal or state governments, irrigation districts, or municipal buyers including both residential and commercial/industrial buyers. This is included as an explanatory variable since a large number of trades involve the transfer of water rights from agricultural uses to municipal buyers wanting water to meet the increasing demands of residential and commercial users. To capture the changing demands from population movement, we include the annual change in basin population each year of the transaction. Another demand variable included is yearly per capita income. The possible impact of regional weather conditions, in particular drought, is included through the monthly Palmer index, a measure that takes on negative values for drought and positive values in wet years. Another set of variables captures the supply side of the market to the extent that most trades involve the transfer of rights from agricultural users. We include the value of agricultural output and the value of agricultural land.

[21] Selected summary statistics for the sample data are given in Table 3. While CBT trades provide the lion's share of observations, they also have the highest average price for a right. Average prices vary considerably across basins, as do the average volumes transferred, with an inverse relationship between size and price. The empirical model we estimate is a reduced form simple market model. The structural equations define the quantity supplied and the quantity demanded, as a function of price, and other factors. A system of structural supply and demand equations was also estimated, but only the demand equation is identified in this system (results available on request). Consequently, the two-stage least squares method is used to estimate the demand equation (quantity) while instrumenting for the endogenous price. Tables 4 and 5 show the estimated parameters of a system of price and quantity equations.

[22] The estimated price equation has good performance measured by  $R^2$ , and most coefficients are statistically different from zero at the 1% level. In general, coefficients are found to have signs consistent with our expectations but with some exceptions. Compared to Arizona's CAP basin, both Colorado and New Mexico have higher prices, with Colorado prices substantially higher than both other basins. This reflects what we observed in the descriptive statistics earlier, that these markets represent three stages of market maturity and that Colorado's higher prices reflect a more efficient market than the others. The buyer-type coefficient estimates suggest that agricultural and municipal buyers pay the same price for water rights but that government buyers pay lower prices. This could reflect the monopsony

power of the government sector, especially since many purchases of water rights are to satisfy mandated protection of species and habitat. As the statistics in Table 3 reveal, government buyers represent a relatively small part of the market in Arizona (20%), only 5% in Colorado, and 0% in New Mexico. Reassuringly, estimates for the Palmer index coefficient reveal that water prices are lower in wetter periods throughout the region. The change in the basin population over the previous year shows no statistical effect on prices, implying that population growth is not a major driving force in water demand, but the highly significant positive coefficient on per capita income indicates that demand comes from the increasing demands for water from the population as it becomes wealthier.

[23] Turning to the second stage equation explaining the quantity traded, the coefficient on price is negative and statistically significant. The size of the price coefficient indicates that the demand for water rights is relatively elastic, with an absolute value of 1.1. The coefficient on the value of agricultural activity is negative, indicating that higher-valued agricultural production is associated with lower water quantities being traded on the market. The estimate of the elasticity of water quantity with respect to the value of agricultural land is positive, indicating that higher land prices reflect the higher opportunity cost of holding and maintaining agricultural land through the value of the water rights associated with the land. This supports data from the *U.S. Department of Agriculture* [2003] that the average value of irrigated cropland in New Mexico in 2003 is

**Table 4.** First Stage Market Price of a Water Right Equation: All Markets, 1990–2001<sup>a</sup>

Variable	Coefficient	<i>t</i> Statistic
CAP (AZ)	reference region	
MRGCD (NM)	3.16	20.86
CBT (CO)	2.91	23.85
Buyer = Irrign	reference buyer	
Buyer = Fed/State	-0.877	-3.98
Buyer = Muni.	-0.079	-0.83 <sup>b</sup>
Palmer Index	-0.101	-10.82
Log Population Change	0.011	0.19 <sup>b</sup>
Log PerCap Income	3.02	17.82
Constant	-25.05	-17.71
Obs	608	
Adjusted $R^2$	0.734	

<sup>a</sup>Dependent variable is log water right price.

<sup>b</sup>Not statistically significant. All other coefficients are significant at 95% or greater.

**Table 5.** Second Stage Quantity of a Water Right Transacted Equation: All Markets, 1990–2001<sup>a</sup>

Variable	Coefficient	<i>t</i> Statistic
Log real right price	−1.11	−17.60
Log Value of Ag	−0.624	−2.56
Log land prices	1.36	5.76
Constant	12.74	5.56
Obs	608	
<i>R</i> <sup>2</sup>	0.319	

<sup>a</sup>Dependent variable is log acre feet traded.

\$2610 per acre, nearly 10 times the average value of nonirrigated cropland at \$270 per acre.

#### 4. Discussion and Conclusion

[24] Analysis of the data from the three markets in Arizona, Colorado, and New Mexico reveals very different market conditions, yet these three areas have much in common. They rely on large rivers fed by large drainage areas for the majority of their surface water, but Colorado uses proportionately less groundwater than either Arizona or New Mexico. All three markets formed around large U.S. Bureau of Reclamation projects designed to ensure the delivery of water to large agricultural sectors, the primary holders of water rights under the prior appropriation system. By far, the largest share of all transfers in the sample is to municipal buyers who need water to support increased housing and commercial development brought on by increasingly wealthy populations. Structural shifts in the national and regional economies mean that water for agricultural production is an input with ever decreasing value, while its value in other uses steadily rises.

[25] Reflecting on the elements needed to establish and maintain an effective market for water identified in our study from a review of earlier theoretical work, we see many of them present in the three study markets. U.S. Bureau of Reclamation projects provide the majority of the physical infrastructure needed to allow water to physically follow the economic transfers in the market. Canals and irrigation networks have supported water transfers in Arizona and New Mexico, and even though the physical length of canals and tunnels in the CBT of Colorado is small, the significance of moving water from the western slopes of the Rocky Mountains to the eastern slopes cannot be understated. In the other two flatter areas, miles of canals are needed to move water across the thousands of acres of agriculture that use it. Even though the infrastructure in each basin differs because of local conditions, each provides the necessary means for water to follow its highest value.

[26] While based on the prior appropriation doctrine, the CBT system of shares appears to provide the simplest property rights structure to support market trades. The homogeneity of the right is the key characteristic that separates the water right from location, owner type, and historical use. The most heterogeneous right structure applies to Arizona's CAP water, and the relative paucity of trades, low prices, and general immaturity of this market are due in part to the restrictions imposed by the property rights system. One factor hampering the growth of the market in the Middle Rio Grande is the backlog of water

rights that must be adjudicated through the court system. Combining with the rights structure is the administration of water transfers in each basin market. The fact that the state engineer is a political appointee means that OSE administrations can change every 4 years or might remain for 8 years. Although the bureaucracy remains, changes in administrative personnel can alter priorities and policies sufficiently to cause uncertainty of administration among those interested in trading water. Clear rules, consistently applied, are an essential element needed for the smooth operation of water markets. In this regard, again the CBT appears to offer a model for other regions developing systems to support water markets.

[27] Transactions costs arise from a combination of the other factors as well as the legal and institutional need to involve brokers in transactions. One problem with informal markets is that brokers earn rents by taking advantage of informational asymmetries. As a market matures, mechanisms develop to provide information quickly and cheaply, and the need for brokers lessens. In this regard, we can expect water brokers to act more like real estate brokers and investment brokers, competing with each other for business and lowering transactions costs in the process. The evidence from the sample of trades studied here suggests that transactions costs are lowest in the CBT market, with the most trades at the highest average price, and highest in the CAP market, where trades are few and prices very low.

[28] The empirical analysis using a system of demand and supply equations shows the significance of the buyer type in determining the price of water. Federal and state governments pay significantly lower prices for water than do municipal water buyers. However, these buyers have a relatively small share of the trades, and most trades are driven by the needs of regulations such as the Endangered Species Act. As markets mature, governments will likely have to pay the same price as private buyers. Sufficient evidence exists to reiterate *Saliba's* [1987] assessment that water markets in the southwest United States are here to stay and develop. The data presented here indicate substantial variation in water rights market activity and price level across basins and time. A large part of this can be explained by differences in institutional arrangements in each market. Although we were unable to estimate a supply function, the success in estimating the demand function supports our contention that water rights markets are active and, through prices, provides both suppliers and buyers of the marginal value of water in its higher-valued uses. It is reasonable to predict that as the value of water in nonagricultural uses increases, water will continue to move toward commercial, industrial, and municipal users and, while traditional users can expect protection by administrations for the foreseeable future, markets will keep exerting pressure for change.

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#### References

Brookshire, D., P. T. Ganderton, and M. McKee (1996), Evolving entitlements and intervening to prevent a collective harm, *J. Agric. Resour. Econ.*, 21(1), 160–173.

- Burness, H. S., and J. P. Quirk (1980), Water law, water transfers, and economic efficiency, the Colorado River, *J. Law Econ.*, 23(1), 111–134.
- Easter, W. R., W. Mark, and A. Dinar (1999), Formal and informal markets for water: Institutions, performance, and constraints, *World Bank Obs.*, 14(1), 99–116.
- Howe, C. (1986a), Innovations in water management: Lessons from the Colorado-Big Thompson Project and Northern Colorado Water Conservancy District, in *Scarce Water and Institutional Change*, pp. 171–200, Resour. for the Future, Washington, D. C.
- Howe, C. (1986b), Innovative approaches to water allocation: The potential for water markets, *Water Resour. Res.*, 22(4), 439–445.
- Howe, C. W., and C. Goemans (2003), Economic efficiency and equity considerations in regional water transfers: A comparative analysis of two basins in Colorado, report, Dep. of Econ., Univ. of Hawaii at Manoa, Honolulu. (Available at <http://www.economics.hawaii.edu/research/seminars/02-03/01-17.htm>)
- Saliba, B. C. (1987), Do water markets work?, *Water Resour. Res.*, 23(7), 1113–1122.
- Simpson, L. D. (1994), Are water markets a viable option?, *Finan. Dev.*, 31(2), 30–32.
- U.S. Department of Agriculture (2003), Agricultural land values and cash rents, report, Natl. Agric. Stat. Serv., Aug. (Available at <http://usda.mannlib.cornell.edu/reports/nassr/other/plr-bb/land0803.pdf>)
- Wahl, R. W. (1989), *Markets for Federal Water: Subsidies, Property Rights, and the Bureau of Reclamation*, Resour. for the Future, Washington, D. C.
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