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Abstract

This research extends the analysis of De Mouche et al. (2011) and Colby et al. (1993) relating price differentials in per acre-foot terms to the priority date of water rights and hydrologic conditions using experimental economic data. This study investigates the effect that priority date, or the year the right was established, can have on the price of leases in the market for water rights and will expand on the existing literature by using an experimental data set to test the relationship. It is hypothesized that senior water rights, those with an older priority date, will have higher prices, while junior water rights, those that have been more recently established, will have lower prices. A cross-sectional analysis using an Ordinary Least Squares (OLS) model will be conducted to test this hypothesis. If the expected relationship is observed and found to be significant, this study may have policy implications that could impact decisions to regulate the market for temporary water rights transfers more strictly in the Western United States. Ultimately, since water scarcity and water rights are a growing economic and environmental concern in regions around the globe, extensions of this work may lead to new policies and regulations on a global level.

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I. Introduction and Background

In the Western Region of the United States, where water is a scarce resource, various water-trading schemes, both temporary and permanent, have been attempted over the years. Under the Doctrine of Prior Appropriations (DPA), the property rights regime that was established in the late 1860s and dominates the Western half of the U.S., the first user to claim a source of water and put that water to beneficial use has the indefinite right to use the source exclusively. These rights can be inherited from one generation to another, or transferred between parties in a marketplace.

Today, more than 100 years after the DPA was established, the population of the western region continues to boom at a rate of 2% per year in urban areas, and agricultural production in this region is becoming increasingly crucial to the national economy (DeMouche et al., 2011). Denser urban populations and intensive agricultural production both require water, a limited resource. Increased stress on water resources in the region have resulted in a need for trade, but permanent transfers are not incentivized as there is more value to the original user in holding the right in perpetuity. Because of the infeasibility of permanent transfers, markets for temporary transfers, or leases, of water rights have been employed in an attempt to meet the needs of water consumers, primarily agricultural users. These transfers occur when the permanent rights holder leases the right to their priority of use to another user temporarily. A lease is beneficial for both parties as it fulfills the immediate need for water and allows the original rights holder to profit while still maintaining the right to use the water in the future (Shupe et al., 1989).

The term of any individual lease is negotiable and can range from one month to several years. Despite growing use of these markets, they remain inefficient because little is known about the willingness to pay of demanders, the willingness to accept of consumers, priority, and the impact of environmental and hydrologic conditions on these factors. The lack of information and scramble to acquire water rights has resulted in an array of trade prices over time and across markets.

De Mouche et al. (2012) investigated what factors affect the price of temporary water rights using data from transfers occurring from 1987 to 2005. When urban municipalities were the consumers the average price of the transfer is $4400.00 per acre/foot, compared to only $1700.00 per acre/foot when the resource is going to crops (De Mouche et al., 2012). This price discrepancy represents inefficiency in the market for temporary water rights, a problem that has occurred because the owners of the permanent rights do not know the value of the temporary rights to demanders, and vice versa. A number of other factors, both environmental and economic, affect the price of a temporary water rights transfer in the west. The identity of the demander plays an important role, as

does the presence of drought, and the ability of agricultural demanders to stack multiple leases and use more than the legal limit of water in an effort to reap higher yields or produce more water intensive crops (De Mouche et al., 2011).

The seminal theoretical work on the subject by Ciriacy-Wantrup (1956) connects the three major property rights regimes in the United States, riparian doctrine, appropriative doctrine, and a third system blending the features of these two systems, with the economic concepts of security, transferability, and welfare. The theoretical analysis in the literature has been extended to include measures of welfare, potential third party effects, and suggested implementation of markets for temporary transfers of water rights to increase efficiency (Gould, 1989). Using the principle of use-value, and assuming that the buyer of a right has a higher use-value for the right than the seller, Libecap (2005) offers a more recent refinement to the theoretical basis for markets for temporary transfers of water rights under the Doctrine of Prior Appropriations (DPA) established by Ciriacy-Wantrup (1956) and Gould (1989). He suggests that a senior right should have a higher value because it comes with a greater guarantee of receiving an allotment of water (Libecap, 2005). It has greater security because the right's holder is guaranteed to receive the water they are entitled to before any junior user via diversion of the source or a bulk water transfer (Gould, 1989). As Ciriacy-Wantrup (1956) describes, "under natural conditions a senior appropriative right is more secure than a junior appropriative right against physical uncertainty." The holder of a junior right may have a higher use-value for water because of the potential value of their crop yield, and thus, a higher willingness to pay for the senior right and security that comes with it. Because reliability of the right is directly linked to the right's priority date, if a right is more senior, it should receive a higher price in the market (Libecap, 2005).

Modern water transfers occur using a number of market mechanisms including water banks, bulletin board markets, double-auction markets, derivative markets, environmental leasing and purchase programs, and combinations of these systems (Hadjigeorgalis, 2009). However, large transaction costs and incomplete information result in large price differentials of temporary water rights transfers (Colby, et al., 1993; Broadbent et al., 2009; De Mouche et al., 2011). These same factors impede the markets in general and have resulted in few traded rights (De Mouche et al., 2011). While scholars have used real data and found that price differentials observed in the markets exist because of priority dates (De Mouche et al., 2011; Colby et al., 1993), transaction size, and various additional buyer, seller, and environmental characteristics, data limitations remain a chief concern (De Mouche et al., 2011; Bjornlund and Rossini, 2005).

Because real transaction data is in short supply, water resources, and environmental economists have relied on experimental economics methods to test their hypotheses regarding the temporary transfer of water rights. Over the past two decades hypothetical markets have been coupled with hydrologic models in an attempt to determine whether parties engaged in each transaction, the direction of the trade, the size of the transaction measured in acre-feet, and the impact on the physical system affect the price of the transfer (Broadbent et al., 2009). In accordance with the theoretical developments of Gould (1989) and Libecap (2005), Broadbent et al. (2009) finds that regardless of the identity of the buyer, more trades of larger overall quantity occurred when the meteorological conditions of the region were drier and the supply of water was more uncertain. An empirical study in Australia, another hotbed of water resource allocation issues, yielded similar results, showing agricultural users utilized the market more heavily when low precipitation was expected, and that higher overall prices were observed for farmers with higher use-values (i.e., dairy farmers) (Brooks and Harris, 2008).

This research extends the analysis of De Mouche et al. (2011) and Colby et al. (1993) relating price differentials in per acre-foot terms to the priority date of water rights and hydrologic conditions using experimental economic data. This study investigates the effect that priority date, or the year the right was established, can have on the price of leases in the market for water rights and will expand on the existing literature by using an experimental data set to test the relationship. It is hypothesized that senior water rights, those with an older priority date, will have higher prices, while junior water rights, those that have been more recently established, will have lower prices. A cross-sectional analysis using an Ordinary Least Squares (OLS) model will be conducted to test this hypothesis. If the expected relationship is observed and found to be significant, this study may have policy implications that could impact decisions to regulate the market for temporary water rights transfers more strictly in the Western United States. Ultimately, since water scarcity and water rights are a growing economic and environmental concern in regions around the globe, extensions of this work may lead to new policies and regulations on a global level. The remainder of this paper is organized as follows: Section two describes the experimental data and methodology used to test the relationship between price per-acre foot, priority date, and four additional explanatory variables. Section three discusses the results of the regression analysis and the fourth section discusses the implications of the relationship between priority date and price in markets for temporary water transfers in systems operating under the DPA.

II. Data and Methods

An experiment conducted at Illinois Wesleyan University (IWU) in 2012 provided the data set used to test the hypothesis that priority dates are positively related to the price of temporary water transfers. Dr. Craig Broadbent conducted the experiment over a four-week period in the fall of 2012. Thirteen Senior Economics students were paid a $50.00 show up fee, which they could add to through engaging in market transactions. Eleven students represented rights holders and engaged in the market and two students served as alternates. One student represented a senior water rights holder, meaning their right to the source was established in 1869. Eight students represented junior rights holders, meaning their rights were established in 1870, 1880, 1893, or 1894. One student represented a residential user, and the last student represented a supplemental well, or a surplus reserve of water for residential users.

During the first week of the experiment, the students were given background information about the DPA. They were introduced to the software used to conduct the trades, which was developed by Dr. Broadbent's research team at the Sandia National Laboratories and the University of Texas. The students also participated in a similar type of experimental economics activity during week two, in order to gain a better understanding of the purpose of the study and to grasp the procedure of what they would be doing in the following weeks.

During weeks three and four the actual experiments were conducted. Experiments one and two were conducted in week three and simulated a situation in which there was a call on the water source. A call occurs in times of drought, usually during the summer months, and is when a senior user indicates that they have not received their allotment of water and places a "call" which stops junior users from diverting water. In experiment one, a call on the source of water occurred during the months of June and July, impacting 7 of the 44 accepted trades. In experiment two, a call occurred during June only, and affected 6 of the 45 accepted trades. Experiments three and four were conducted in the final week and simulated a situation in which stacking was allowed. Stacking is the ability of agricultural users to irrigate their land with more than the legally allotted volume of water per acre, currently 2.7 acre-feet of water per acre over the growing season. When stacking was allowed,

every trade in the experiment received a 1 for stacking. In experiment three, a call occurred, in addition to stacking, during the months of July and August with 12 of the 51 accepted trades in this experiment affected. These two conditions were included in the experimental model in order to gauge the effect of hydrologic conditions on the price of temporary water transfers.

The data from these four experiments is cross-sectional and yielded 201 accepted temporary transfers with a fixed term of one month. Experiment one produced 44 trades, experiment two yielded 45 accepted trades, experiment three produced 51 accepted trades, and experiment four yielded 61 trades for a total of 201 trades. For each individual trade, the seller's name, the buyer's name, the total price paid in U.S. Dollars, and the quantity, measured as the number of acre-feet traded was recorded. The price per acre-foot was calculated from the recorded information for each accepted transfer by dividing the total price paid from the buyer to the seller in U.S. Dollars by the total number of acre-feet traded. Five dummy variables were created and recorded to indicate the month of a call, if stacking was allowed, and the type of trade that occurred (i.e. senior to junior user, junior to junior user, or agricultural user to residential user). Trades were given a value of one if the factors measured by the dummy variables were present or applicable to the trade, so, if a call occurred, a trade was given a value of one for the call variable. There are three potential categories for the type of trade: senior agricultural user to junior agricultural user trades, junior agricultural user to junior agricultural user trades, and agricultural user, which can be senior or junior users, to residential user trades. For any given trade, only one of these categories is applicable, so the trades received a one for the dummy variable measuring the category in which they best fit and a zero for all other dummy variables excluding junior to junior trades.

The average price per acre-foot across all 201 accepted trades is $3.71. The maximum price per acre-foot in an accepted trade was $7.00, and the minimum was $2.00. For each priority date, there is a wide dispersion of prices per acre-foot. Most trades were accepted at a price per acre-foot of $2.00 to $5.00, with a few outliers that occurred at $6.00 or $7.00 per acre-foot. The general trend is that in trades from senior users and higher priority date junior users, the prices per acre-foot are higher, as pictured in Figure 1 in Appendix A. The average price of trades of 1869 priority date rights is $4.02; for trades of rights with an 1870 priority date the average price is $4.38. The prices for the three more junior dates, 1880, 1893, and 1894 averaged at $3.76, $3.55, and $3.28, respectively.

An Ordinary Least Squares Regression (OLS) in Eviews software was used to test this hypothesis and determine the relationship between price per acre-foot (price per quantity) and the priority date of the water right. Equation 1 shows the model with price per acre-foot as the dependent variable, and priority date, occurrence of a call, presence of stacking, senior to junior user trade, and agricultural to residential user trade as the independent variables. Trades occurring between any agricultural user, regardless of seniority, to either the residential user or the supplemental well were given a value of one for agricultural to residential trades. The expected relationship between these variables, summarized in Table 1 in Appendix A, is positive for priority date, meaning that the older the water right, the higher the price paid, positive for a call, negative for stacking, positive for Senior to Junior trades, and negative for Agricultural to Residential user trades.

Equation 1:

$$\text{Price Per Acre-Foot} = \alpha + \beta 1(\text{Priority Date}) + \beta 2(\text{Call}) + \beta 3(\text{Stacking}) + \beta 4(\text{Senior to Junior}) + \beta 5(\text{Agricultural User to Residential User}) + e$$

III. Results

The empirical model tests the relationship between prices per acre-foot of temporarily

transferred water rights and the priority date of the right being traded (Equation 1). Four additional variables are included in the model. Occurrence of a call, stacking, and two dummy variables which capture the nature of the trading parties and gauge the effect of the identities of the traders on price per acre-foot. The first is senior user to junior user and the second is agricultural user to residential user transactions. For both variables, a value of one indicates that the trade falls into the category of the trade that is measured by the variable. Thus, the final expression is given in equation 1. Using the cumulative data from all four of the individual experiments, or trading rounds, an Ordinary Least Squares regression produced the expected results, summarized in Table 2 in Appendix A.

The estimated coefficient for priority date was negative, which is consistent with the predicted outcome as a lower numbered year (i.e., 1860) is more senior than a higher numbered year (i.e., 1893) (De Mouche et al, 2011). The relationship observed is a direct relationship indicating that earlier years or older rights demand higher prices per acre-foot. Additionally, a dummy variable was included to denote trades occurring between the senior user, whose right was established in 1869, and any of the various junior users. The sign for the coefficient indicating a senior to junior transfers was positive, indicating that a senior to junior trade earned a higher price per acre-foot than a trade between two junior users.

The magnitude of the coefficients for each of these variables was small, 0.0199 and 0.4641, respectively. For a one-year decrease in seniority, the price per acre-foot falls by about $0.02. The most senior right was established in 1869, and the most junior, in 1894, so, the predicted difference in price between the most senior and most junior rights is approximately $0.50. Similarly, the difference in price between a senior to junior transfer and a transfer between junior uses is $0.46. It is crucial to consider that in this set of experimental data, the average price per acre-foot was $3.73. The impact of seniority on price is 12.3% of the average price.

As expected, the presence of a call, captured through a dummy variable, was positively related to the price per quantity. The coefficient for this variable, 0.3202, was significant at the 1% level. This result is not surprising because when there is a shortage of a scarce resource such as water, the price of that resource, in this case the per acre-foot, rises. Stacking, an indicator of a surplus of water at a particular water source had the opposite impact on the price of one-month temporary transfers. Stacking was also indicated by a dummy variable in the same fashion as the call variable. This coefficient, -0.2230, indicated that the presence of stacking resulted in a decrease in the price per acre-foot of water of $0.22. In essence, this indicates that there is not as great of a need to trade water rights in times of surplus because it is likely that all users, even those most junior, will gain access to the water that they need regardless of priority. If rights holders are trading to new users who have never before held their own water rights, the price demanded will remain low because there is more competition to lease that right and rights holders with no use for the water may undercut other rights holders in order to transfer their right and avoid losing it under the DPA's beneficial use clause. Transfers between agricultural users and residential users in which the residential user purchases the right resulted in a negative coefficient of -0.3939, indicating that when water is transferred from an agricultural user to a residential user it sells for less than agricultural to agricultural trades.

The adjusted R squared for this regression was .3536, indicating that approximately 35.4% of the variation in price per acre-foot across transactions was explained by these five factors. The F-statistic for the regression is 22.8842 and is significant at the 1% level indicating that as a group these explanatory variables are able to explain the variance in price per acre-foot.

IV. Conclusions

This paper examines the relationship between the price of temporary water rights transfers and the priority date of the right in order to extend the body of literature that seeks to influence the design and regulation of water leasing markets and to provide fuller information to buyers and sellers. Using an Ordinary Least Squares regression, this study tests the relationship between the price, in dollars, per acre-foot of water traded in an experimental market and the priority date of the right. Four additional explanatory variables were used: the presence of a call, stacking, and the parties that the transfer occurs between, senior to junior transfers, and agricultural user to residential user transfers.

The results of the regression were consistent with the predicted outcomes. Each of the coefficients for the five independent variables was significant at a high level and had the predicted sign. Priority date was observed to be correlated with price in an inverse fashion, which, considering that the actual year was used in each observation for the variable, means that the older or more senior a right, the higher the price it will sell for. This is consistent with the literature on the topic that suggests the more secure, less risky senior rights will sell at higher prices because the purchasing party is willing to pay more for a lower risk of not receiving the water they purchased, even in times of drought.

The results of this regression, which show with a high degree of certainty that senior water rights held under the Doctrine of Prior Appropriations will command higher prices than their junior counterparts when traded temporarily for a period of one month, could be used to inform buyers and sellers in similar markets in the western United States. With more complete information about the effects of seniority and environmental conditions on the demand and willingness to pay for water rights, sellers and buyers should be able to come to an agreement on price more quickly. In turn, this increased efficiency could increase the number of trades that occur making these markets a reasonable solution for the problem of water allocation in the West. The results of this research may also be used by regulatory agencies to set prices or restrictions in the markets in an effort to increase efficiency and improve water allocation.

The results of this study can be used as the groundwork for more extensive research into the impact of priority on price in the face of other external conditions. With more extensive experimental data, additional scenarios could be tested to better understand the market for temporary water transfers. In this experiment, the term of the lease was fixed at one month and was non-negotiable. Giving the players in the experiment the freedom to decide to buy or sell the rights for longer periods of time would allow future researchers to test whether or not seniority has an effect on the length of the lease negotiated, and if the length of the lease has an impact on the price per acre-foot per month. A second option for further research would be to jointly test the impact of variables such as seniority and a call or seniority and stacking using a multivariate analysis. More extensive data is required to run such a test as this experiment contained only a handful of observations that would have met the necessary criteria. Finally, further extensions of this research could include testing the impact of priority date on the price of permanent transfers of the right. Admittedly, a number of practical problems would present themselves in a permanent transfer situation because there is no incentive to sell a right that you could otherwise lease month after month or year after year to produce a steady stream of income if you hold the most senior right. However, such an experiment may provide insight into the transfer of rights between junior users or between current rights holders and parties that do not currently own the rights to a water source.

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Appendix

Figure 1

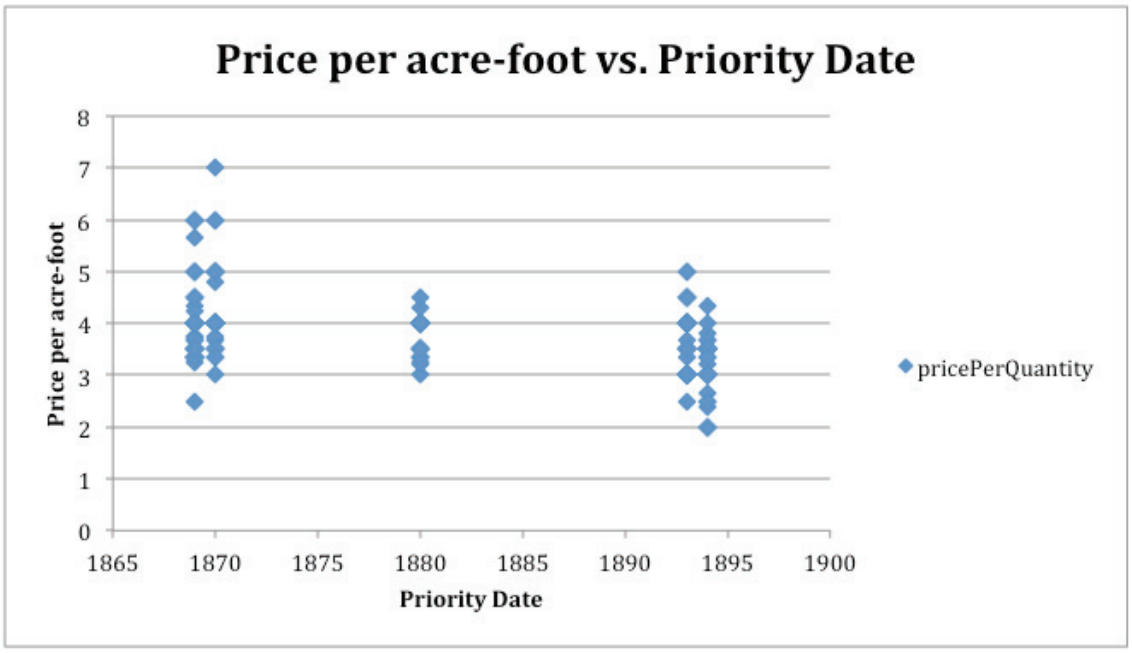

Table 1: Expected signs

Variable	Expected Sign
Priority	-
Call (1 = call; 0 = no call)	+
Agricultural to Residential User (1 = agricultural to residential user; 0 = no)	-
Stacking (1 = stacking; 0 = no stacking)	-
Senior to Junior (1 = Senior to Junior user; 0 = no)	+

Table 2: Estimation Results of the relationship between price per acre-foot and priority date

Variable	Coefficient
Priority	-0.0199*** (4.6014)
Call (1 = call; 0 = no call)	0.3202*** (2.7479)
Agricultural to Residential User (1 = agricultural to residential user; 0 = no)	-0.3909*** (4.3044)
Stacking (1 = stacking; 0 = no stacking)	-0.2230** (2.5447)
Senior to Junior (1 = Senior to Junior user; 0 = no)	0.4641*** (2.6837)
Adjusted R-Squared	0.3536
F-Statistic	22.884**

Values in parentheses are absolute statistics
***Significant at the 1% level
**Significant at the 5% level
*Significant at the 10% level