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Allocating Scarce Water Resources:Examining if Price Differentials Exist in a Prior Appropriations Setting

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Abstract

This study examines the potential for a water leasing market within one singular basin in Southwestern, New Mexico. The goal of this research is to test the feasibility of a water market in the river basin and determine if price differentials are found in a prior appropriations setting. This was done through a laboratory experiment to test if participants would simulate an effective water leasing market in a basin within New Mexico. In order to assess the potential for a water leasing market, a water leasing market was designed to incorporate the hydrologic, engineering, institutional, and economic market of the Upper Mimbres Basin (Broadbent et. al., 2009). Using experimental economics, which uses computer programs and simulation to test an economic theory, the market value of water was induced through the set up of the experiment. The set up involved double auction where all bids and offers are presented publically and each bid and offer is presented simultaneously. The advantages of conducting a laboratory experiment is predominantly time, data that would usually take a year to collect can be done in a short amount of time. By simulating the water leasing market we can test participants' reactions to drought conditions, which could take years to occur in the real setting of New Mexico.

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I. INTRODUCTION

The Southwestern United States is an arid region with significantly low levels of precipitation. This region not only has a limited water supply, but also consequently has a large percentage of population growth. From 1965 to 2000 population has increased by 80 percent (Konieczki and Heilman, 2004). With the population increasing from year to year, as a result, there has also been an increase in the demand for water. This is seen in the withdrawal rate of water for domestic use, which has increased by 64 percent (Konieczki and Heilman, 2004). While a growing population increases the demand for water use among humans, a majority of the water supply still goes towards irrigation for agriculture. The demand for water is not the only increasing factor, but temperatures over the last century have increased 1.5 degrees Fahrenheit around the globe (United States Environmental Protection Agency, 2012). The warming climate has impacted, for example, the natural flow of the Colorado River, which supplies water to a large portion of the arid Southwestern region of the United States (United States Environmental Protection Agency, 2012). Future prospective droughts due to climate change and an increasing population have the potential to create conflicts over water supplies, which is amplified by the nature of the water rights in the Southwest.

The water right laws in the Southwest differ from the rest of the country (i.e. riparian rights). In the western United States the predominant water law is known as the Doctrine of Prior Appropriations. This law was a response to the arid climate and has been in existence since the settlement of the west. The concept of prior appropriations states that water can be set aside for "beneficial use", which is an ambiguous term (Fort, 2002). Prior appropriations give senior users the first claim to the water in the times of a drought. A drought is commonly referred to as a call. Therefore, leasing of water rights amongst senior users and juniors, those with secondary claims on the water source, during times of drought has been proposed. Water leasing, also known as water banking, provides a temporary transfer of water rights, which could provide a market for smaller water users who need to buy water for irrigation purposes in times of drought. One possible problem could arise in a water market under a prior appropriations setting. As a result, the price differentials occur where higher prices are paid for "senior" water rights vs. "junior" water rights as defined by Libecap (2005).

In cases of water scarcity, consideration for a water market is necessary especially if the watershed is over allocated. This is supported at the state and national level. On the national level, the Department of the Interior (2005) discussed the issue of water scarcity in their report entitled Water 2025: Preventing Crises and Conflict in the West. Many states have drafted plans to address issues in water management. These state level water plans have been drafted by: California, New Mexico, Nevada, Utah, and Wyoming. (California Department of Water Resources, 2012; New Mexico Office of the State Engineer, 2009; State of Nevada Division of Water Resources, 2011; Utah Division of Water Resources, 2001; Wyoming Water Development Office, 2007). The water scarce region of the western United States has consistently increased its demand for water despite limited water supplies. This points to a need for improved water allocation mechanisms, such as water leasing markets.

The inefficiencies of water allocation can be addressed through two market institutions: permanent water rights transfer or the leasing of water rights. Permanent transfer of water rights is an established practice in the west. Los Angeles would not exist today without the purchase and transfer of water rights from the Owens Valley. Water leasing markets, on the other hand, are a newly emerging market institution. Water leasing provides a temporary transfer of water rights, which would provide a market for smaller water users who need water for irrigation purposes (Shupe et. al., 1989).

This study examines the potential for a water leasing market within one singular basin in Southwestern, New Mexico. The goal of this research is to test the feasibility of a water market in the river basin and determine if price differentials are found in a prior appropriations setting. This was done through a laboratory experiment to test if participants would simulate an effective water leasing market in a basin within New Mexico. In order to assess the potential for a water leasing market, a water leasing market was designed to incorporate the hydrologic, engineering, institutional, and economic market of the Upper Mimbres Basin (Broadbent et. al., 2009). Using experimental economics, which uses computer programs and simulation to test an economic theory, the market value of water was induced through the set up of the experiment. The set up involved double auction where all bids and offers are presented publicly and each bid and offer is presented simultaneously. The advantages of conducting a laboratory experiment is predominantly time, data that would usually take a year to collect can be done in a short amount of time. By simulating the water leasing market we can test participants' reactions to drought conditions, which could take years to occur in the real setting of New Mexico.

The data from two trials (each simulating a year's worth of transactions) were studied. From these experiments, individual transactions are recorded including the stakeholders involved in the trade, the quantity of water traded, price of water traded and the impacts on the hydrologic model. It is, therefore, hypothesized that stakeholders will fulfill their assigned roles under the experimental leasing system (the market price will be equal to the expected market price) and there will be a price differential between senior and junior user's water rights during times of a call. The focus of this research is firstly is to test whether the experimental market follows realistic expectations and secondly to examine the benefits of instituting a water leasing market within the river basin.

II. LITERATURE REVIEW

Broadbent et al. (2009) summarize the literature on water leasing markets. Their article establishes the need for water leasing markets in the west, the barriers to establishing water leasing markets, and past theoretical and empirical studies on water leasing markets.

Permanent transfer of water rights, have been studied for almost forty years. Literature regarding permanent transfer of water rights has outlined criteria essential for successful water market transactions. Broadbent et al. (2009) outline the criteria as "1) well-defined, securable, and tradable property rights; 2) hydrologic and engineering reality; 3) environmental quality; 4) social/community and traditional uses; 5) transaction costs; and 6) third-party effects" (p. 713). Third party effects are resolved through the adoption of the "no-injury" rule, transactions that economically harm third parties cannot occur. Typically, transaction costs are higher in water markets and therefore addressing third party effects is necessary to create a successful water leasing market. Water markets must acknowledge traditional water uses such as Native American rights to water as well as the environmental impacts of water leasing on the watershed. Understanding the hydrologic and engineering reality of a watershed will not only determine the feasibility of trading water in specific locations but also address the impacts on the watershed. Above all, well-defined property rights encourage right holders' to act in their own self-interest.

Theoretical studies on water leasing markets have acknowledged it as "an attractive option for both parties because it maintains continuity, preserves ownership by holder of the right for future use, and accommodates an intermediate use" (Shupe et al. 1989). Empirical studies have been conducted in the Western United States (Yoskowitz, 1999; Czetwertynski, 2002; Yoskowitz, 2002; Loomis et.al., 2003; Adams et. al., 2004; Howitt, 2005; Brown, 2006; Brewer et.al., 2007), as well as southeastern Australia (Crase et.al, 2000; Bjornlund, 2003, 2004; Crase, et. al., 2004; Turra et. al., 2005), and Southern Chile (Hadjigeorgalis, 2004). These studies show that water leasing has received national and international attention. Studying the literature on water leasing markets establishes a basis to study water-leasing markets.

A recent article by Basta and Colby (2010) examine the trends of water markets for leasing and permanent transfers. Basta and Colby expand the literature on water markets through the compilation of the monthly water transactions reported from 1987 to 2007 in the journal Water Strategist. From this they establish a large dataset of many states and regional water markets. Through the analysis of water sales data, Basta and Colby ascertain trends in the water market. Trends, such as total transactions, total quantity traded, and average prices, aid in the understanding in the valuation of water rights and the water market itself. Almost all states and regions observed a general trend of an increasing number of transactions in the sale and lease of water rights, whereas New Mexico is experiencing a growing leasing market instead of the permanent sale of water rights. Leasing is a growing market within California, Colorado, New Mexico, Texas, and the Pacific Northwest Region. Prices are rising, with a variance in prices between regions. This supports the concept of the increased strain on the water supply, especially in the Western United States. It also signifies the importance to understand trends in the burgeoning water market.

Watson and Davies (2011) examine regional growth in the South Platte River Basin in Colorado to understand the incentive structures for different users if the water supply is fixed (2011). They examine the demand of both agricultural and municipal water users, finding that with an increasing population will strain the water supplies and force water to be used for urban user rather than irrigation. In addition, return flows from municipal to agricultural users provide more water for irrigation. Finally, they found the price of municipal water to increase by 25 percent where the agricultural price for water remained the same. This is likely due to the increasing population within the region, which subsequently increases the municipalities demand for water; whereas, the demand from the agricultural sector remains largely the same.

Yoskowitz (2001) looks at existing price differentials in water market transactions in the Rio Grande Valley in Texas. In order to understand this phenomenon the article addresses the institutional nature of the water markets. This is done by statistics to show price differentials converging and diverging over time among agricultural users and urban users. In addition, Yoskowitz hypothesizes possible reasons why price differentials occur. The results support a differential price among different water users, and price convergence has yet to occur. Yoskowitz (2001) attributes price differentials to asymmetries in information and the price elasticity of different water users. Yoskowitz (2001) looks at price differentials between consumers and represents the empirical model used to test if price differentials occur.

A. Summary of Literature

There are many challenges facing the current water leasing markets. Broadbent et al. (2009) outlined requirements necessary to ensure water-leasing markets are efficient. These included well-defined water rights, markets based upon hydrologic and engineering reality, markets that protect environmental quality, community and traditional uses, acknowledge transactions costs, and address third-party effects. Basta and Colby (2010) survey the current trends of water markets in the Western United States and find a general increase in the number of transactions of water rights through both leasing and sales. While there have been many studies done examining water leasing markets in the Western United States (Yoskowitz 1999; Czetwertynski, 2002; Yoskowitz, 2002; Loomis et al., 2003; Adams et al., 2004; Howitt, 2005; Brown, 2006; Brewer et. al., 2007), very few have examined the occurrence of price differentials (Yoskowitz, 2001; Watson, 2011). These studies have found price differentials occurring between agricultural users and urban users.

III. THEORY

The design of the hypothetical water leasing market draws upon experimental economics. Experimental economics uses laboratory techniques to test an economic theory. Essentially, experimental economics induces values through the use of participants to test a hypothesis. The data for this paper was collected through a double auction experiment. A double auction means that all bids and offers are presented publicly and each bid and offer is presented simultaneously.

Basic supply and demand theory is the conceptual framework where the demand function is a step demand function (Smith, 1982). The step demand function occurs due to a differing market price value between irrigators and municipalities. The flat region of the demand curve in Figure 1 refers to the irrigators demand for water. The marginal utility for municipalities is higher than irrigators and therefore the left flat region on the demand curve represents municipalities demand for water (See Figure 1). Municipalities value water rights at a higher price than irrigators because there are a fixed number of water rights based upon the hydrology of the basin and the supply of water is perfectly inelastic. Users are not able to draw more than their allotment of water, even when flows are high. In times of a call the supply moves left and water prices rise (See Figure 1). Water is only supplied to senior users during a drought. Senior users are those with the oldest claim to the water. Junior users are those with newer claims to the water and are the first to have their water cut off during times of a drought. Therefore junior users as well as the municipalities' willingness to pay for these rights will increase in times of drought.

Based upon the step demand function, during times of a drought a price differential will occur between senior and junior users if prices depend upon the users' willingness to pay. Price differentials occur as a result of differing marginal values between users. According to Libecap (2005) price differentials still exist within the water leasing market because of the infrequency of trades. Libecap states, "Water trades take place and are growing in frequency and magnitude, but they are not sufficient to cause water prices to equalize on the margin, adjusting for transport costs" (p. 39). Water markets still face heavy regulations on the transfer of water rights due to the interconnectedness of water uses (Libecap, 2005).

IV. DATA

The data for this study comes from an experimental water leasing market that was designed for the Upper Mimbres Basin in southwestern New Mexico. The two treatments used in this paper to understand the impacts of a call under a prior appropriations setting. The data collected from each experiment measures a full years worth of transactions. Conducting an experiment to test the feasibility of a water leasing market was chosen primarily because of a lack of data for the region. This data is appropriate to measure the hypothesis because the experiment induced values in which stakeholders first learned about the subject matter and had a monetary incentive to act in their best interest. In the Upper Mimbres Basin there are eleven stakeholders.

The oldest priority date is 1869, which has a yearly allocation of 789 acre-feet of water. This is the senior user who has the most favorable water rights during periods of drought, since they will be the last to get their water cut off. There are four users with the priority date of 1870 with an average allotment of 18 acre-feet of water. Following the four users of 1870, there is one user with a priority date of 1880 with a yearly allocation of 99 acre-feet. Then there is one user with an 1893 priority date with a yearly allocation of 132 acre feet and two users with an 1894 priority date with an average of 117 acre feet of water. The previously mentioned users are currently using their water for irrigation purchases but there are two municipalities in the region interested in leasing water rights. The water leasing market allows users to trade water each month to address inefficiencies in the current water allocation. Each trading round, which represents one trading round, users are able to buy or sell water to other users since this experiment is a double auction and all prices posted to buy and sell water are visible to all users. These trading decisions are then applied to the hydrologic model, which factors in the affects on water flow within the basin. Each month individual transactions are recorded including the stakeholders involved in the trade, the quantity of water traded, price of water traded and the impacts on the hydrologic model.

IV. EMPIRICAL MODEL

In this study, two T-tests are done to measure whether there is a statistical difference between the following groups. Firstly, to investigate whether the data collected reflects the expected market price. Market price is determined through the experiment in each round of trading. For each round of trading the average price per quantity of water or market price was determined. Expected price is the price per quantity of water that should be elicited from the trading rounds given the unique payout of each participant. The expected market price was three dollars per acre-foot of water as shown in Figure 1; the null hypothesis was that market prices would not be equivalent to expected prices. To test whether market prices were equivalent to three dollars the following T-test was done.

$$T - Test = \frac{Market\ Price - Expected\ Price}{\frac{Se}{\sqrt{n}}}$$

$$\alpha = 0.10$$

$$\alpha = 0.05$$

$$Tcrit\ dF\ (n-1) = \frac{\alpha}{2}$$

Secondly, the study determines if a price differential between senior and junior users during times of a drought exists. Senior users' price per quantity of water should be higher than junior users in times of a drought. To accomplish this, the average price per quantity of the senior user's water (1869 priority date) in each round was compared to the price per quantity of all other users (all other priority dates). Both experiments were aggregated in an effort to increase the sample size. The null hypothesis is: price is not dependent upon priority date. The following T-test was done to see if there was a statistical significance between priority dates.

$$T - Test = \frac{W.A.1869 - W.A.18..}{\sqrt{\frac{SE^2 1869}{n_{1869}} + \frac{SE^2\ 18..}{n_{18..}}}}$$

$$\alpha = 0.10$$

$$\alpha = 0.05$$

$$dF(n_1 + n_2 - 2) = 0.05$$

V. RESULTS

The results proceed in four sections. First, results are presented that compare the expected price with the market price. Secondly, price differentials allow for the comparison between priority dates. Thirdly, the total number of transactions and, fourthly, the call results of both experiments. These are necessary comparisons when looking at the feasibility of a water leasing market for any basin operating under the setting of prior appropriations.

A. Market Prices

Descriptive statistics were used on the experimental data to determine the average price per acre-foot sold in every trading month (See Table 1). As well as each priority dates average price per acre-foot (See Table 1). A T-test calculated to see whether market prices were equivalent to the expected market price of three dollars per acre-foot. Overall both experiments found the market prices were equivalent to the expected market price, except in times of a call (See Table 1 and 2). Rejecting the null in times of drought could be an indicator that price differentials exist. In the first few months of both experiments the null hypothesis can be accepted this is likely due to the fact that users were adjusting to the market as well as preemptively purchasing water in case of a call. This means that participants for the most part did take on their assigned role.

B. Price Differentials

The results of the first T-test indicate the potential for price differentials. To determine whether price differentials occur between the oldest priority date and the rest of the priority dates, a second T-test was performed. The T-test found that there was a statistical difference between priority dates (See Table 4) and that there was a lag in price differentials during times of a drought. The high prices for the oldest priority date occurred in the month following the beginning of the drought and remained high the month after the drought ended. The small sample size did affect the ability to test certain months, even with the aggregation of data between the two experiments (See Table 3).

C. Total Number of Transactions

The total number of transactions in both experiment one and two is displayed in Table 3. Table 3 illustrates how minute the water leasing market is within the Upper Mimbres Basin, New Mexico. In some rounds, there were only one or two transactions. The small sample statistics indicate that an alternative method may be needed to further test the hypothesis. This can be done using a Willcoxon rank sum test.

D. Call Results

For both experiments, one and two, the expected drought given the hydrologic model is seen in Table 2. Without a water leasing market, the drought was expected to occur in the months of July and August. The drought in July would affect 1880, 1893, 1894, and in August it would affect 1994 users. In both experiments there is a decline in the severity and longevity of the drought (See Table 2). In experiment one the drought occurred in July and August and affected 1894 users and the drought in experiment one occurred in July and affected 1894 users. These results show that the water leasing market allowed the participants to minimize the impacts of a call and therefore trading was beneficial.

VI. CONCLUSIONS

Increased populations are adding pressure on the already scarce water resources of the Western United States. Establishing water-leasing markets within basins that are well established in the hydrological and engineering reality have the potential to increase efficiencies. Through this experimental market, which was modeled after an actual basin in New Mexico, the benefits of water leasing can be seen. However, this experiment data does reflect the expected outcome of a water leasing market in terms of average price per quantity of water.

In this study market prices overall were equivalent to expected prices, with the exception of months when there was a drought. Price differentials between the oldest priority dates and the rest of the priority dates do occur. Price differentials are a limiting factor in implementing a water leasing market. Water is not homogenous and thus price differentials might slow the transaction process down and result in less water allowed to the market, which in turn results in increased prices and making the market less efficient. The results of this study support results of previous studies

(Yoskowitz, 2001; Libecap, 2005; Watson, 2011) of which found price differentials between agricultural users and urban users. Libecap (2005) explains "the persistence of large price differentials between agricultural, urban, and environmental users reflects the lack of extensive, routine market trades that would otherwise arbitrage to narrow the differences" (p. 4). Promoting widespread use of water leasing markets should help eliminate price differentials between users.

This study had very few transactions in certain trading rounds. The thin market impacted the ability to calculate a significance level as well as to compare between priority dates. This led to an aggregation of both experiments in order to test whether price differentials occur between junior and senior users. A Wilcoxon Rank Sum Test eliminates the concern for a small sample size because it is a nonparametric distribution free test. This would be an ideal way to extend this study.

Establishing a water leasing market within this particular basin has shown environmentally beneficial. Due to the nature of the experiments, both trials had the same expected outcome in terms of a drought. In both experiments the length and severity of the expected drought was reduced due to the reallocation of water from the leasing of water. This displays the potential for water leasing markets to reallocate resources in a more efficient manner in regions where the Doctrine of Prior Appropriations is the predominant water law.

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Figure 1: Step Demand Function

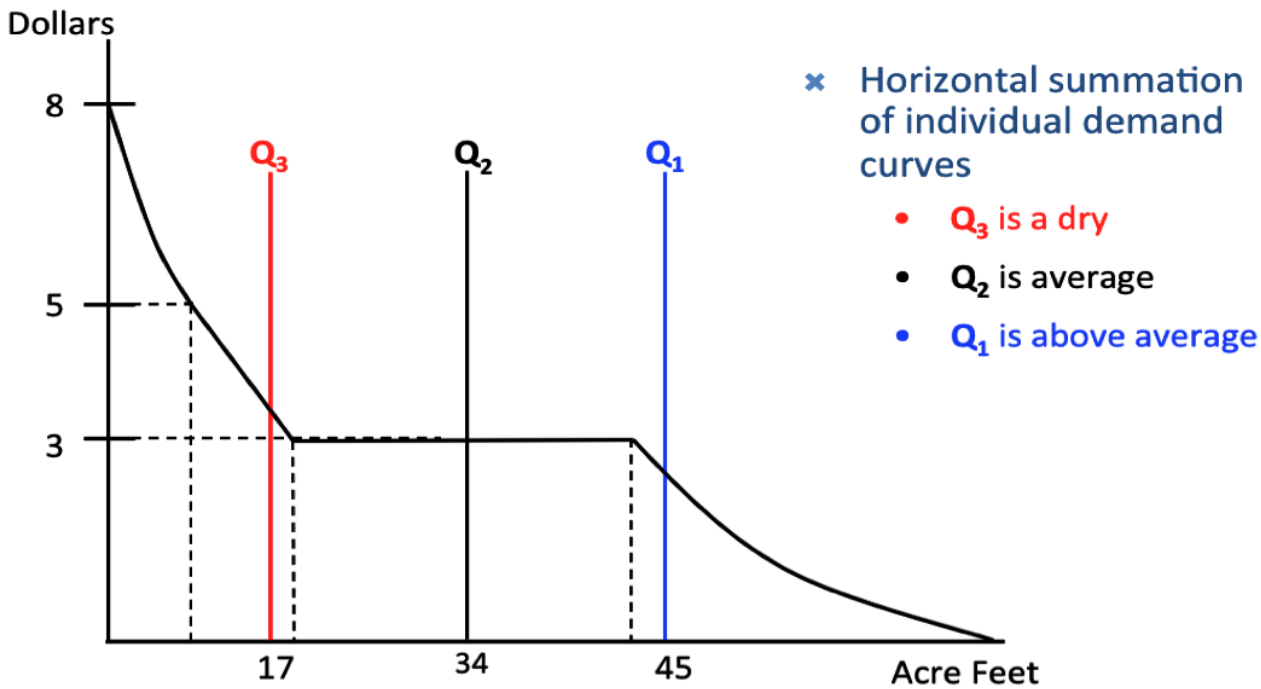

Table 1: Weighted Average Market Prices

Trading Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Experiment 1												
Market Price	3.89**	3.91*	2.59+	4.5+	4	4.71**	5.5**	5.33*	3.71*	3.61	5+	0
	-1.06	-0.89	-0.65	0	-1	-1.29	-1.15	-0.88	-0.25	-0.67	0	0
1894	2	3	2	0	0	0	0	4.333	3.5	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
1893	3.5	2.5	3.4	0	5	0	0	0	4	4	0	0
	-0.7	0	-0.29	0	0	0	0	0	0	0	0	0
1880	4.29	3.5	3.5	0	3	4	4	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
1870	5	3	0	0	4	7	6	0	0	0	5	0
	0	-1.06	0	0	0	0	0	0	0	0	0	0
1869	4	4.43	0	4.5	0	5.4	6	5.83	3.6	3.56	0	0
	0	-0.12	0	0	0	-0.71	0	-0.23	-0.12	-0.75	0	0
Experiment 2												
Market Price	4.63*	3.9*	3.59*	3.5++	3.17	3.61*	2.6+	2.8+	3++	3.33	0	0
	-0.82	-0.2	-0.27	0	-0.25	-0.32	-0.3	-0.19	0	-0.35	0	0
1984	3.5	3.5	3.6	3.5	0	0	2.4	2.75	3	0	0	0
	0	0	-0.3	0	0	0	-0.07	-0.23	0	0	0	0

Table 1: Weighted Average Market Prices												
1893	4.5	4	3.5	3.5	3	3.33	3	3	3	3.33	0	0
	-0.71	0	0	0	0	-0.47	0	0	0	-0.35	0	0
1880	4	4	0	0	0	4	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
1870	5.5	0	0	0	0	3.6	0	0	0	0	0	0
	-0.71	0	0	0	0	-0.12	0	0	0	0	0	0
1869	4	4	0	0	3.5	3.5	0	0	0	0	0	0
	0	0	0	0	0	-0.47	0	0	0	0	0	0

*Denotes 0.05 +Denotes only one transaction
**Denotes 0.10 ++ More than one transaction, no standard error

Table 2: Expect Versus Actual Affects of Drought			
Year	Expected Affects of Drought		
	June	July	August
1869			
1870			
1880		X	
1893		X	
1894		X	X
Drought in Experiment 1			
1869			
1870			
1880			
1893			
1894	X	X	
Drought in Experiment 2			
1869			
1870			
1880			
1893			
1894	X		

Table 3: Total Number of Trades												
	Trading Month											
Scenario	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
No Stack/ Call #1	6	7	5	1	3	4	3	3	7	5	1	0
1894	1	1	0	0	0	0	1	1	1	0	0	0
1893	2	1	3	0	1	0	0	0	4	1	0	0
1880	1	1	1	0	1	1	1	0	0	0	0	0
1870	1	2	0	0	1	1	1	0	0	0	1	0
1869	1	2	0	1	0	2	1	2	2	4	0	0
No Stack/ Call #2	8	6	6	2	4	6	5	3	3	2	0	0
1894	1	2	5	1	0	0	2	2	1	0	0	0
1893	2	1	1	1	3	2	3	1	2	2	0	0
1880	2	1	0	0	0	1	0	0	0	0	0	0
1870	2	0	0	0	0	2	0	0	0	0	0	0
1869	1	3	0	0	1	1	0	0	0	0	0	0

Table 4: Weighted Average Price by Priority Dates												
	Trading Month											
Weighted Avg. Price	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1869 Priority	4	4.25*	0	4.5*	3.5+	4.86	6*	5.83*	3.6	3.56	0	0
	0	-0.236	0	0	0	-1.258	0	-0.236	-0.118	-0.74	0	0
All Other Priorities	4.35	3.71	3.09	3.5	3.5	3.88	3	3.38	3.58	3.6	5	0
	-1.047	-0.744	-0.499	0	-0.837	-1.315	-1.252	-0.739	-0.496	-0.5	0	0
Transactions by Priority Date												
1869	2	5	0	1	1	3	1	2	2	4	0	0
All Other Priorities	12	9	10	2	6	7	8	4	8	3	1	0

* Denotes 0.05 significance + Denotes only one transaction
** Denotes 0.10 significance