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Efficiency Gains from Transferable Water Rights

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EFFICIENCY GAINS FROM TRANSFERABLE WATER RIGHTS

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ABSTRACT

In times of drought, mandatory water restrictions are a popular option for local governments to prevent water shortages. The state of South Carolina has had mandatory water restrictions in various counties for nearly a third of the past decade. If there are heterogeneous consumers with varying marginal valuations for water, these mandatory restrictions may be economically inefficient. I calculate what welfare gains could be achieved for the state by allowing prices to fluctuate instead of imposing mandatory restrictions.

To perform this calculation, I assume a basic quadratic demand function for water with constant income elasticity. The water restrictions force all consumers down the demand curves to a lower quantity than they would otherwise consume. The percentage of this movement along the demand curves is taken from previously calculated reductions in water usage due to restrictions shown in the literature. I estimate the net welfare loss for the state by the mandatory restrictions. I then calculate the estimated welfare gains of allowing trade across counties.

To perform these calculations, I have gathered data on residential water usage in every county within South Carolina for 2005. In addition, I have per capita income and population values for each county. I use the income elasticity of demand for water of .25 based on studies in North Carolina. I use data from Agthe and Billings 1987 paper to estimate a functional relationship between income and price elasticity, which is then applied to each county to estimate the county's price elasticity. Based on pricing data obtained across the state, I use a fixed price for water.

My analysis finds a welfare loss of around 20% of the overall expenditures on water. I calculate the gains from trade to be initially around only 3% of the overall welfare loss. Subsequent

evaluations reveal that this value is sensitive to the overall variance among the counties' price elasticities. If demand for water varies enough among counties or trades among individuals are feasible, then welfare recovery appears to be a viable option. However, if the costs to create such a market are high, then such an effort appears inefficient.

DEDICATION

This is dedicated to my wonderful wife, Kristin, who has always been my biggest supporter in everything.

ACKNOWLEDGEMENTS

Firstly, my thanks go to Dr. Maloney who encouraged and directed what has been a very rewarding project. Thanks for taking the time needed to help me complete this Mike.

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Thanks you also Dr. Sauer for assisting on my committee. I appreciate your leadership over the department and your level of involvement with students, which is not nearly as common as it ought to be among department chairs.

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Bobby, whether you prefer being an economist or an environmentalist, you'll always be one of my greatest friends. I appreciate most your humbleness and generosity. You truly are the kind of man I'd want with me in a bad meeting or a foxhole.

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INTRODUCTION

Throughout the eastern United States, rainfall has been at record-setting lows from 2007 to 2009. In fact, according to Ryan Broyles, North Carolina's state climatologist, the Carolinas experienced what may have been the worst drought in nearly 800 years based on tree ring data. (Shapley) In many instances, the response of local governments has been to impose either mandatory or voluntary water restrictions. Although, rationing of a scarce good is rarely economically efficient, many governments choose to ration water during times of shortages and drought.

It is interesting (if unsurprising) that voluntary restrictions have been shown to provide little in terms of actual reductions in water consumption. In their study of counties that implemented voluntary restrictions during the 2002 drought in Colorado, Kenney, Klein, and Clark found reductions of less than 10% in expected use and only 4% in actual per capita use. (Kenney) In their same study, mandatory restrictions served to reduce consumption by substantially more - between 18 and 56 percent. However, while mandatory rationing does succeed in reducing consumption, it is not clear what sorts of inefficiencies are introduced as a result of the rationing.

As of February 7, 2008 approximately 9% of South Carolina's population was under mandatory restrictions and 60% was under voluntary restrictions. (South Carolina State Climatology Office) I will use a model to estimate the loss of surplus to the state of South Carolina for similar water restrictions in times of drought. To do so I will look at existing studies of the price elasticity of demand for water, income elasticity of demand for water, and a basic demand curve. After estimating the loss from restrictions, I will discuss what sort of steps could be taken to attempt to recover these costs.

LITERATURE REVIEW

Much work has been done in the past estimating elasticities of water prices. Howe and Linaweaver were some of the original water resource economists to estimate the demand for water in 1967. (Howe) They used multi-city cross-sectional data to determine the demand for indoor and outdoor water use. Among their conclusions, they discovered that indoor (domestic) demand was relatively price inelastic while outdoor was price elastic. Outdoor demand was not as elastic in the Western U.S. as in the East. They also estimated the weighted average of elasticity of total demand to be -0.4.

In 1997, Espey, Espey, and Shaw performed a meta-analysis to determine what factors systematically affected price elasticity estimates of US residential water demand. (Espey) They used 124 price elasticity estimates as the dependent variable and included many explanatory variables, such as functional form, location, water price specification, season, etc. The average price elasticity estimate among their data sets was -0.51.

Their conclusions are that income, rainfall, evapotranspiration, pricing structure, and season all influence the estimate of price elasticity. Significant impacts were seen as summer demand was much more elastic than average demand (and vice versa for winter). Pricing structure proved to be one of the most significant factors in their study as models using average price, D price, or Shin price or in areas of increasing block rates found significantly more elastic demand. They also find that commercial demand is more elastic than residential demand. In addition, discussions with Molly Espey provided information on additional studies showed an income elasticity of water of .25 in North Carolina.

Espey, Espey, and Shaw had their work expanded on in 2003 by Dalhuisen, Florax, de Groot, and Nijkamp with another meta-analysis. (Dalhuisen) They add a substantial amount of additional data from studies since the original meta-analysis was performed as well as including income elasticities. They also find that there is a substantial effect with different pricing structures (primarily increasing block rate pricing). Higher absolute values of prices and income elasticities are found when prices different from marginal prices are used. In addition, the differences in estimated elasticities are positively correlated with differences in per capita income.

In a 1987 study, Agthe and Billings estimated a simultaneous equation model of demand for households in four income groups to determine the price elasticity of demand for each group. (Agthe) Under the existing increasing block rate pricing schedules, higher income households use more water and have lower elasticities of demand. Their groups were set up with four income brackets of $0-$10k, $10k-$20k, $20k-$35k, and $35k+. The price elasticities for these groups were found to be -.565, -.49, -.46, and -.397 respectively.

Kennedy, Klein, and Clark investigated the question of what impacts water restrictions have on actual consumption during a drought in Colorado in the summer of 2002. (Kenney) They tracked the water savings achieved by eight water providers based on comparisons of usage in 2002 to 2000 and 2001. Mandatory restrictions were highly effective at reducing water consumption and resulted in per capita savings between 18 and 56 percent. Voluntary restrictions resulted only in savings of 4 to 12 percent.

The volume of work estimating price and income elasticities of demand for water is not surprising given water's critical role in human survival. However, there is a surprising lack of work that has been done to examine the welfare costs of water rationing. I will discuss one such study that was undertaken in Sydney, Australia but have been unable to find similar research performed in the United States.

Grafton and Ward perform a demand-based analysis of the welfare impacts of mandatory water restrictions placed on over 75 percent of Australians as of March 2008. (Grafton) They attempt to measure the loss in Marshallian surplus to the city of Sydney, Australia due to restrictions over the period of 2004-2005. The restrictions they estimated reduced overall quantity consumed by approximately 14%.

They use the rainfall and temperature data for Sydney in an estimated model to predict the annual demand for these years. Based on this demand estimate, they calculate the market-clearing price at $2.35/kL that would induce the total quantity demanded to equal the quantity used under restrictions. This price allows them to integrate the inverse demand curve between the quantity consumed at the actual price and this market-clearing price to calculate the loss.

They use a choke price of $5.05/kL to cap the otherwise infinite loss, above which they assume alternate means of gathering water (such as rain barrels) will be used. The resulting estimate is a loss to the city of Sydney of about $235 million over a 12-month period. This comes to a $55 loss per capita and $150 loss per household. Based on their data, this was almost half of the average water bill in 2005.

THEORY

I begin the theoretical discussion with the understanding that water is a normal good and follows the law of demand. I also assume that there are either heterogeneous consumers (with regards to marginal valuations of water) or that there exist different marginal values of water for different uses that are restricted by the rationing. In this case, mandatory restrictions placed on water will impose a welfare cost because consumers cannot equate the marginal cost of water to its marginal benefit.

In Figure 1, I assume a single county imposes water restrictions and want to calculate the costs of these restrictions. I use an ordinary demand curve as an estimate of consumer surplus instead of compensated demand curves.

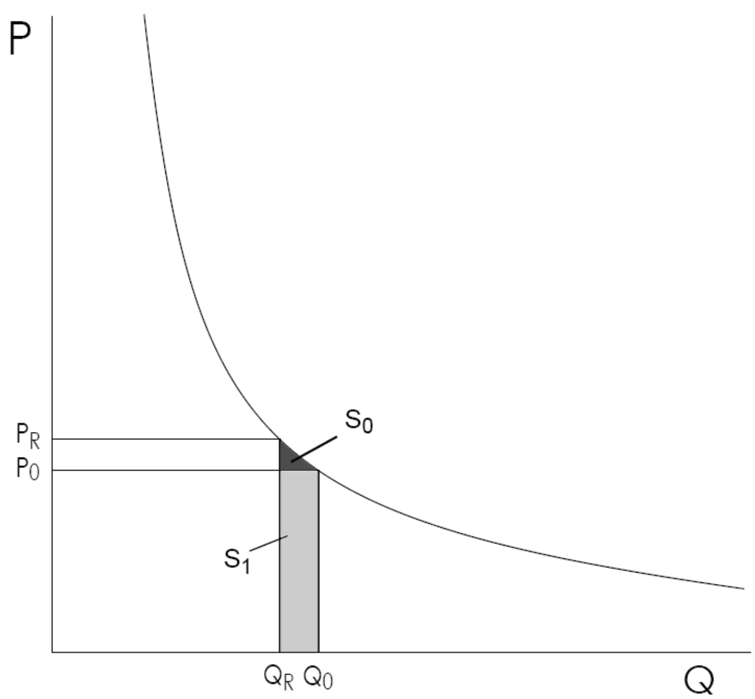

Figure 1: Demand curve and welfare loss with restrictions (One county)

In Figure 1, P_0 is the initial price of water, and Q_0 is the initial consumption. The water restriction shifts consumption back to Q_R at price P_R. Consumers will consequently spend less on water. This reduction in expenditures is shown by the area labeled S_1. However, consumers lose surplus as well as shown by the dead weight loss area, S_0. There is an additional welfare loss imposed by the costs of enforcement that is not captured here.

The shadow price of water at Q_R is the demand price or marginal valuation along the demand curve. To the extent that consumers are heterogeneous, the shadow price under water restrictions will vary across consumers. Because of this, there are potential gains-from-trade holding the total amount of water consumed to the restricted level. This is shown in Figure 2 for two consumer groups using a pair of ordinary demand curves to show consumer surplus.

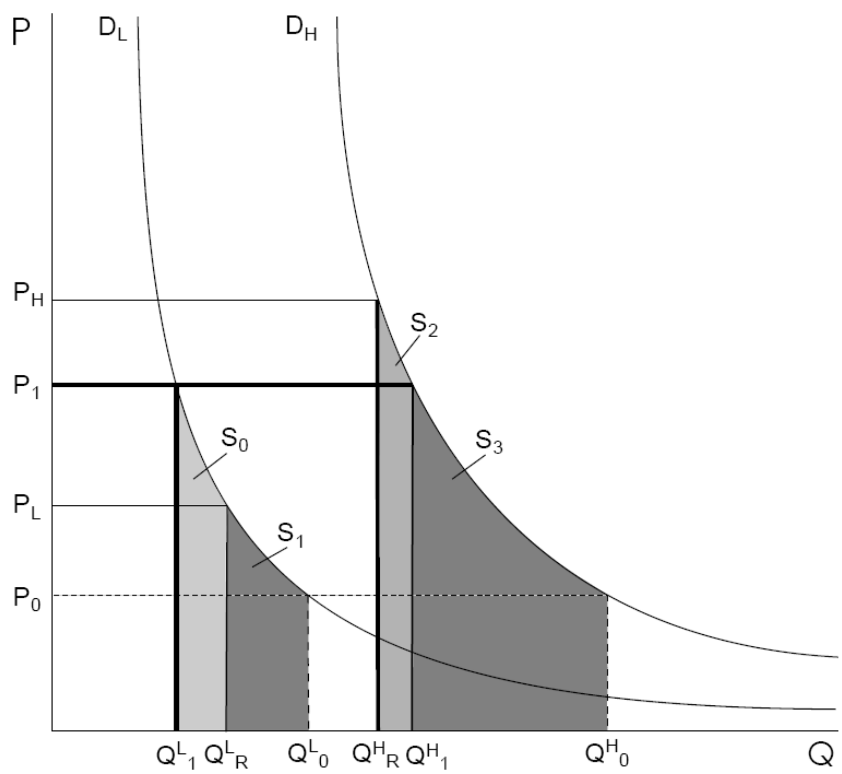

Figure 2: Welfare Gains from Trade (Two Counties)

The demand curves D_L and D_H represent one county with relatively low demand for water and one with relatively higher demand for water. P_0 is the observed price of water. The quantities Q_0^L and Q_0^H are what the hypothetical demand for water would have been at price P_0 absent restrictions.

Prices P_H and P_L are where the quantity of water actually demanded equals the amount consumed under the restrictions at Q_R^L and Q_R^H. The value at P_1 is the equilibrium price between these counties so that $Q_R^L + Q_R^H = Q_1^L + Q_1^H$ where Q_1^L and Q_1^H are the quantities demanded at P_1 for the low and high demanding counties respectively.

The overall welfare loss for the low-demanding county is equal to $S_0 + S_1$. Similarly, the loss for the high-demanding county is $S_2 + S_3$. The potential gain from trade of the low-demanding county selling water to the higher-demanding county is the value of S_0. Likewise, the high-demanding county can gain value shown by S_2 by purchasing water at a quantity equal to $Q_1^H - Q_R^H$.

The calculation of these potential gains from trade is the object of this thesis. I use differences in water consumption across the counties in South Carolina as my measure of consumer heterogeneity. Note that given the functional form selected (constant elasticity) and the constant reduction in water usage, in order for there to be gains from trade between heterogeneous consumers; they must have different price elasticities.

My first step is to specify the demand function for each county. I use a standard functional form with constant elasticity where quantity demanded is a function of price, income, and price and income elasticity of demand as in Equation 1.

$$Q = AP^{E_d} M^{E_i} \qquad (1)$$

Here *Q* is the quantity of water demanded, *A* is a constant, *P* is the price of water, E_d is the price elasticity of water, *M* is the average income for the county, and *Ei* is the income elasticity of demand for water.

Each county must have an estimate of the price elasticity of demand. To accomplish this, I use the data provided by Agthe and Billings in their aforementioned 1987 study. After converting the income blocks to 2010 income levels, I estimate the following relationship between price elasticity (E_d) and income (*M*) and solve for two constants, X_1 and X_2:

$$E_d = X_1 * M + X_2 \qquad (2)$$

Applying this equation to the income level of each county in South Carolina allows me to calculate a separate price elasticity estimate for each county. As previously discussed, I note that the estimate income elasticity of demand for water means $E_i = .25$. Given the price of water and the income for each county in South Carolina, I then solve for the coefficient of the demand function on a per county basis.

I then find the inverse demand function *P*, as a function of quantity demanded (*Q*), a constant (*A*), income (*M*), price elasticity (E_d), and income elasticity (E_i) shown in Equation 3:

$$P = \left(\frac{Q}{A * M^{E_i}}\right)^{\frac{1}{E_d}} \qquad (3)$$

I will integrate this function to obtain the area under the demand curves for the current welfare loss calculation and future welfare recovery calculations. The indefinite form is shown in Equation 4.

$$\int \left(\frac{Q}{A*M^{E_i}}\right)^{\frac{1}{E_d}} dQ \;=\; \frac{E_d}{E_d+1} * A^{-\frac{1}{E_d}} * M^{\frac{-E_i}{E_d}} * Q^{1+\left(\frac{1}{E_d}\right)} \qquad (4)$$

By calculating the definite integral from Q_R to Q_0 (where Q_R is the reduced quantity due to restrictions and Q_0 is the original quantity consumed) I can obtain the entire shaded area in Figure 1. I then subtract the area S_1 to acquire the overall welfare loss (W_L) from the restrictions shown in Equation 5.

$$W_L \;=\; \int_{Q_R}^{Q_0} \left(\frac{Q}{A*M^{E_i}}\right)^{\frac{1}{E_d}} dQ - (Q_0 - Q_R) * P_0 \;=$$
$$\frac{E_d}{E_d+1} * A^{-\frac{1}{E_d}} * M^{\frac{-E_i}{E_d}} * \left[{Q_0}^{1+\left(\frac{1}{E_d}\right)} - {Q_R}^{1+\left(\frac{1}{E_d}\right)} \right] - (Q_0 - Q_R) * P_0 \qquad (5)$$

This calculation is then performed on each of the 46 counties in South Carolina to obtain the overall welfare loss that would be imposed by statewide restrictions. Now that I have obtained the overall welfare loss, I want to find what percentage of that can be recaptured by allowing trade between counties.

To accomplish this I first calculate the quantity used by the average household in each county under the restrictions, and also the quantity used for the entire county, Q_r. Using the inverse demand function (Equation 3), I solve for the equilibrium price P_r under restrictions based on income and elasticity.

The constraining assumption behind allowing trade is that the total quantity of water consumed after all trade is complete must be equal to the total quantity consumed under the restrictions. To ensure this, I calculate the quantity consumed after trade by each county, Q_C, shown by Equation 6.

$$Q_C = Pop/H_S\left(AP_1^{E_d}M^{E_i}\right) \quad (6)$$

In this equation, *Pop* is the county population and H_S is the household size in the county. *A* is the constant from the demand equation in Figure 3. *M* is income, E_d is price elasticity, and E_i is income elasticity. P_1 is a fixed statewide price for water. After calculating the quantity for each county, I iteratively adjust P_1 until the statewide quantity is equal to the quantity consumed under the restrictions. After obtaining P_1, I then calculate the welfare gains from trade, W_T, for each county by Equation 7.

$$W_T = \frac{E_d}{E_d + 1} * A^{-\frac{1}{E_d}} * M^{\frac{-E_i}{E_d}} * \left[Q_1^{\,1+\left(\frac{1}{E_d}\right)} - Q_R^{\,1+\left(\frac{1}{E_d}\right)}\right] + [Q_1 - Q_C]P_1 \quad (7)$$

With these welfare gains calculated, I then determine what percent of the overall welfare loss can be mitigated by allowing trade to occur by dividing W_T by W_L from Equation 6.

DATA SOURCES

In this study, I gathered data from a number of different sources. As mentioned previously, the estimates for price and income elasticity were gathered from the existing literature. The data for population and overall domestic water withdrawals was obtained from the United States Geological (USGS) survey online. (United States Geological Survey) This data was broken down by all 46 counties for the year 2005.

The income data was obtained from the South Carolina Budget and Control Board Statistical Abstract for 2005. (South Carolina Budget and Control Board) In addition, data on average household size was needed to convert the per capita income numbers to average household income. This was obtained from data gathered by the US Census Bureau. (United States Census Bureau) The average prices for residential water were obtained from various counties by contacting the water districts themselves for their data. Most of the water districts have lower water prices for individuals within city limits than those outside the city. They also charge different rates for different sizes of meter. However, over 90% of residents in the cities use 5/8" meters. Because of this, I take the in-city prices for 5/8" meters as the average rate.

After collecting around seventy data points for different districts between 2000 and 2010, the variations in prices proved to be small enough that I decided to use a single price ($3/1k gal.) for each district instead of estimating an average price based on the various water districts in each county.

RESULTS

After converting the data from the Agthe and Billings study to 2005 dollars, I obtained the following estimate of the elasticity of demand in Figure 3.

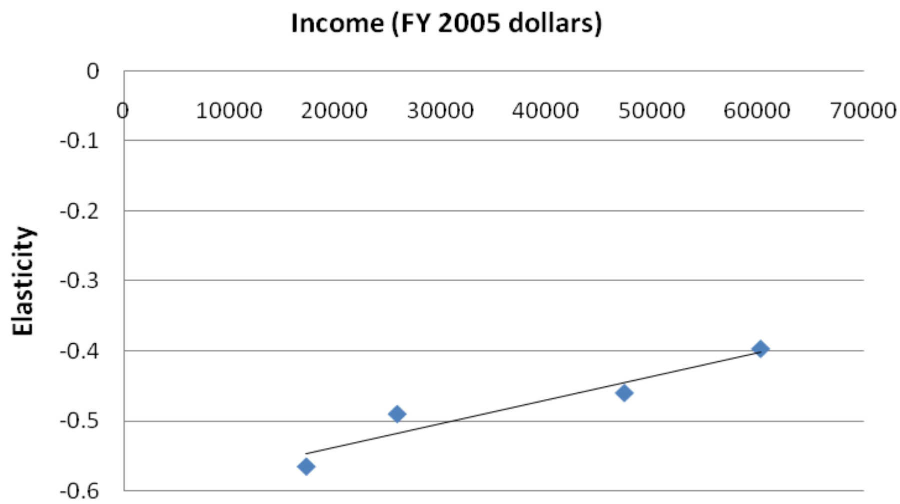

Figure 3: Estimate of Price Elasticity by Average County Income

The estimate for this relationship is shown below in Equation 8.

$$E_d = 3.72E - 6 * M - .605 \quad (8)$$

The following table contains the summary statistics from my dataset including the calculated price elasticity and household welfare loss (in dollars and percentage).

Table 1: Data Summary Statistics (Per Household)

Variable	Obs.	Mean	Std. Dev.	Min	Max
Average Income	46	64,725	10,246	48,310	98,663
County Water Use (Mgal/day)	46	9.25	9.65	1.01	40.74
Price Elasticity	46	-0.36	0.04	-0.43	-0.24
Shadow Price ($/Mgal)	46	8.14	1.13	6.94	13.39
Total Annual Expenditures ($)	46	281.03	10.30	259.52	301.18
Welfare Loss ($)	46	56	10	41	100
Welfare Loss (%)	46	19.9	3.6	15.8	36.5
Welfare Gains from Trade ($)	46	1.72	2.46	0.0013	15.62
Welfare Gains from Trade (%)	46	3.12	3.41	0.00	15.57

These statistics show that the water use for counties varied from 1 to 40 Mgal/day with an average of 9.25 Mgal/day. The calculated price elasticities of demand varied between -.24 and -.43 with the average at the midpoint of these at -.36. The calculated shadow prices (P_R in figure 1) varied between 7 and 13 dollars/1000 gallons. This was a very high increase from the observed rate of 3 dollars/1000 gallons.

The average welfare cost per household proved to be nearly $56 annually, which was almost 20% of their average water bill. The average individual in the county affected the most lost as much as 36.5% of their overall expenditures. The total average cost per household was around $281/month. For the entire state, this equates to an overall loss caused by restrictions of $102.4 million. By way of comparison, the aforementioned Grafton and Ward study found a $150 loss per household for a total of nearly 50% of the total water bill. (Grafton)

I calculate initially that allowing counties to trade would provide an overall recovery of the welfare losses equal to around 3%. This equates to the recovery of around $2 per household or approximately $2.27 million state-wide. Given the initial elasticity estimates, it does not appear that a significant amount of this loss can be recaptured by allowing individual counties to trade.

Shown in Table 2 are the top and bottom five counties in terms of overall water usage per household. The usage amounts are listed in thousands of gallons and span from a high of

100,400 gallons for Berkeley and Jasper Counties to a low of 86,500 gallons in Horry County. The restricted usage is estimated at 70% of the unrestricted usage.

Table 2: Top and Bottom Five Counties in Average Household Usage

County	Annual Usage (1000s Gal)	Restricted Annual Usage (1000s Gal)
Berkeley	100.4	70.3
Jasper	100.4	70.3
Dorchester	99.3	69.5
Dillon	99.0	69.3
Williamsburg	98.2	68.7
Union	88.9	62.3
Charleston	88.3	61.8
Oconee	87.6	61.3
McCormick	87.2	61.0
Horry	86.5	60.6

In Table 3, I show the top and bottom counties in average household usage after trade occurs. The greatest change occurs as Beaufort county moves from one of the lowest usage counties into the very top spot.

Table 3: Top and Bottom Five Counties in Usage after Trade

County	Usage after trade (1000s Gal)
Beaufort	71.3
Berkeley	71.0
Dorchester	69.4
York	69.1
Jasper	68.5
Allendale	59.6
Abbeville	59.6
Union	59.4
Horry	58.7
McCormick	55.8

Table 4 more explicitly shows the changes in terms of overall usage. As mentioned, Beaufort experiences an 11.2% increase in the overall amount of water usage and Charleston and Lexington both increase by over 3%. The lower-demanding counties of McCormick and Allendale both use more than 8% less water than before allowing trades.

Table 4: Top and Bottom Five Counties in Usage Percentage Change

County	Household Change (1000s Gal)	Percentage Change
Beaufort	7.16	11.2%
Charleston	2.74	4.4%
Lexington	2.41	3.7%
York	1.88	2.8%
Greenville	1.71	2.7%
Bamberg	-4.53	-6.8%
Marlboro	-4.53	-6.8%
Barnwell	-4.73	-7.2%
McCormick	-5.27	-8.6%
Allendale	-5.68	-8.7%

We would expect that the counties that have the greatest welfare loss imposed on them by the restrictions (Table 5 below) would closely mirror those that purchase more water usage (shown in Table 4). This is borne out by the data as four of the heaviest affected counties are in the top five (Beaufort, Charleston, Lexington, and York) of those that attempt to trade to recover some of the restricted water usage.

Table 5: Top Ten Counties in Welfare Loss

County	Welfare Loss ($)	Percent Loss
Beaufort	100.33	36.5%
Lexington	70.29	25.1%
York	69.50	24.1%
Charleston	68.68	25.9%
Berkeley	67.70	22.5%
Georgetown	66.12	23.7%
Greenville	65.05	24.1%
Dorchester	63.82	21.4%
Florence	63.16	22.3%
Kershaw	62.92	22.3%

The top ten counties in Table 6 indicate those that stand to recover the greatest amount from trades. The gains from trade are measured in dollars per household and also as a percentage of the overall average household expenditures on water. This list is a combination of those counties that both buy and sell water. Interestingly, the only county on this list that is a net importer of water is Beaufort. All of the rest of the counties that have the highest amount of potential gains from trade are net exporters of water.

Table 6: Top Ten Counties in Mitigation

County	Gains from Trade ($)	Gains from Trade (%)	Welfare Loss ($)	Welfare Loss (%)
Beaufort	15.62	15.6%	100.33	36.5%
Allendale	4.94	11.2%	44.26	15.8%
McCormick	4.55	11.0%	41.45	16.8%
Barnwell	3.53	7.6%	46.62	16.6%
Williamsburg	3.25	6.5%	49.71	16.9%
Marlboro	3.24	6.8%	47.62	16.9%
Bamberg	3.18	6.8%	47.01	16.8%
Marion	3.11	6.3%	48.94	15.9%
Lee	3.06	6.1%	50.04	17.0%
Abbeville	2.64	5.7%	46.66	17.1%

One key question I must answer is how sensitive the model is to changes in the impacts assumed by the water restrictions. In Table 7, I show the changes in overall welfare loss and gains from trade by changing the quantity of water the reductions conserve. I test the impacts on the model of reductions ranging from 20%-40%. The change in overall welfare loss per household fluctuates from around $21 (7% of the total expenditure on water) to the high point of almost $123 (nearly 44% of total expenditures). Note that the upper estimates of the welfare loss are very close to the impacts found in the Grafton and Ward study.

Table 7: Sensitivity Analysis of Changes in Reduction Percentage

Reduction (%)	Welfare Loss ($)	Welfare Loss (%)	Gains from Trade ($)	Gains from Trade (%)
20	20.82	7.41	0.52	2.53
25	35.43	12.62	0.98	2.80
30*	55.95	19.93	1.72	3.12
35	84.21	29.99	2.90	3.49
40	122.78	43.73	4.78	3.94

* Denotes initial value used.

The second key sensitivity analysis I perform relates to the variance among the elasticities. As the variance among price elasticities increases, so do the potential gains from trade. Therefore, I evaluate the model using equations that cause both more and less dispersion among the price elasticity estimates. The results are shown below in Table 8. The coefficient and constant values refer to the numerical values in Equation 8.

Table 8: Sensitivity Analysis of Elasticity Changes

Coefficient	Constant	Elasticity Min	Elasticity Max	Gains from Trade ($)	Gains from Trade (%)
1.69E-06	-.0403	-0.24	-0.32	0.77	1.05
3.72E-06*	-.0605	-0.24	-0.43	1.72	3.12
8.18E-06	-1.03	-0.22	-0.63	3.09	7.61
1.12E-05	-1.21	-0.11	-0.67	13.54	17.19

* Denotes initial values used.

The original model is shown in the second line with elasticities varying between -.24 and -.43. This resulted in gains from trade for each household of around 3.12% of the welfare loss. Decreasing the distribution of the elasticities to vary between -.24 and -.32 lowers the gains from trade to only 1.05% of the overall welfare loss. More interestingly, if we increase the spread to vary between -.22 and -.63 the gains from trade increase to 7.62% of the welfare loss. The largest differences in the elasticity equation I test results in the county elasticities varying between -.11 and -.67. This results in gains from trade of $13.54 per household at a recovery rate of over 17%. As expected this increasing variation of elasticities results in much greater gains from trade among counties.

I took Aiken County (as the largest county that realized no gains from trade) and evaluated the top and bottom 10% of income. The bottom 10% of households had income below $10,000 annually and the top 10% had incomes above $128,000. Using these to estimate price elasticity provides a low value of -.13 and a high value of -.57. This is reasonably in-line with the final estimate of gains from trade in Table 7 above with the values -.11 and -.67.

ANALYSIS

It is certainly the case that governments interfere with water markets at times with different purposes than maximizing overall wealth. I acknowledge this but proposing a solution to that issue is beyond the scope of this work. I will constrain my analysis to attempt to maximize overall welfare.

Based on the low amount of welfare recovery possible in my model, it appears that allowing counties to trade water does not allow enough of the welfare costs to be recaptured to be worthwhile. It is likely the costs to set up an infrastructure to allow inter-county trading would be fairly low but probably not low enough to justify a mere 3% recovery. However, if we accept the elasticity estimates from subsequent tests in the sensitivity analysis, there appear to be enough gains from trade to pursue inter-county trading.

In either case, we know that individual consumers will have greater variations in their demand for water than the counties as a whole. Thus, if we allow trading among individuals, a greater amount of surplus would be recoverable than just by counties trading. One would expect an efficient market to recapture additional surplus if the rights to water are well-defined, enforceable, and transferable.

There are many cases of well-defined water rights including volumes of water, specific share of a water body, or the availability of a given quantity at a given location (potentially non-consumable). As Anderson and Hill discussed in their study on water rights in the American West, enforcement activities and laws were established as the benefits of defining and enforcing water rights increased. (Anderson) The primary challenge to establishing an efficient market for water seems to be transferability. Two key factors seem to be a part of this challenge – that of obtaining information about supply and demand for water and establishing methods of physically transferring it.

There are models for easing these challenges in the forms of online markets that have appeared within the past decade. The difficulty of obtaining information is greatly reduced when motivated sellers and buyers are able to instantly access the details of water markets by simply visiting a website. One solution would consist of creating a website that facilitates trades of volumes of water, access rights to bodies of water, in-stream flows, etc. This market would function like a site similar to Craigslist or Zillow in that geography is a key factor in matching sellers and buyers. This also allows for the resolution of the issue of physical transfers (when necessary). Just as transit costs can be specified at a flat rate with UPS or FedEx, they can also be automatically added to trades. Alternately, this could create the possibility of a secondary market for entrepreneurs to step in and provide more efficient methods of transferring water.

In this market, industrial users likely want to trade at a much higher volume and might function separately from residential users. One option would be to allow local water companies to trade directly with industrial users. The keys here are that local water companies must have the ability to modify prices for their residential customers to allow for the efficient market price to be reached, regardless of the final use of water. In addition, individuals or entities owning water rights are easily able to redirect their resource back to a higher valued purpose.

This concept is similar to new systems springing up to create new market for power. In New South Wales, the government introduced a plan to pay resident up to $10,000 annually for selling power back into the grid from having solar panels installed. (Kraemer) This particular example may not prove to be economically efficient; however, there seems to be a large amount of potential cross-over between establishing better markets for these similar resources.

CONCLUSION

In this study, I have evaluated the net loss to welfare of water rationing for the state of South Carolina. In addition, I have calculated what proportion of that could be recovered by allowing counties to trade water. The welfare loss calculations of 20% indicate a fairly substantial loss to residents of South Carolina. This leads to the conclusion that there are undoubtedly opportunities for gains from trade.

By allowing for counties to trade water, I eliminate a number of potential barriers to setting up an infrastructure to allow for the trades to occur. However, with the similar calculated elasticities for the counties based on income, there is not enough variation to obtain large benefits from trade. This resulted in findings of only around 3% of the welfare losses being recoverable from trading.

By restricting trades to county-wide averages, we lose some of the benefit of gains from trade by averaging out the highest and lowest demanding individuals within those counties. These individuals represent the greatest potential source of benefit but are aggregated away by using the county-wide data. By allowing for the possibility of greater swings in price elasticity of demand I find that implementing cross-county trades may prove to be economically beneficial in some cases. In the second analysis I find that over 17% of the welfare losses could be recovered by trading.

It should also be recognized that I have taken into account only residential water usage. I readily acknowledge that in all likelihood greater potential exists for gains from trade by including industrial, commercial, and agricultural users in a similar evaluation. This would be a valuable study in the future and I hope that my analysis here might be able to form a basic model on which to build further studies.

APPENDIX

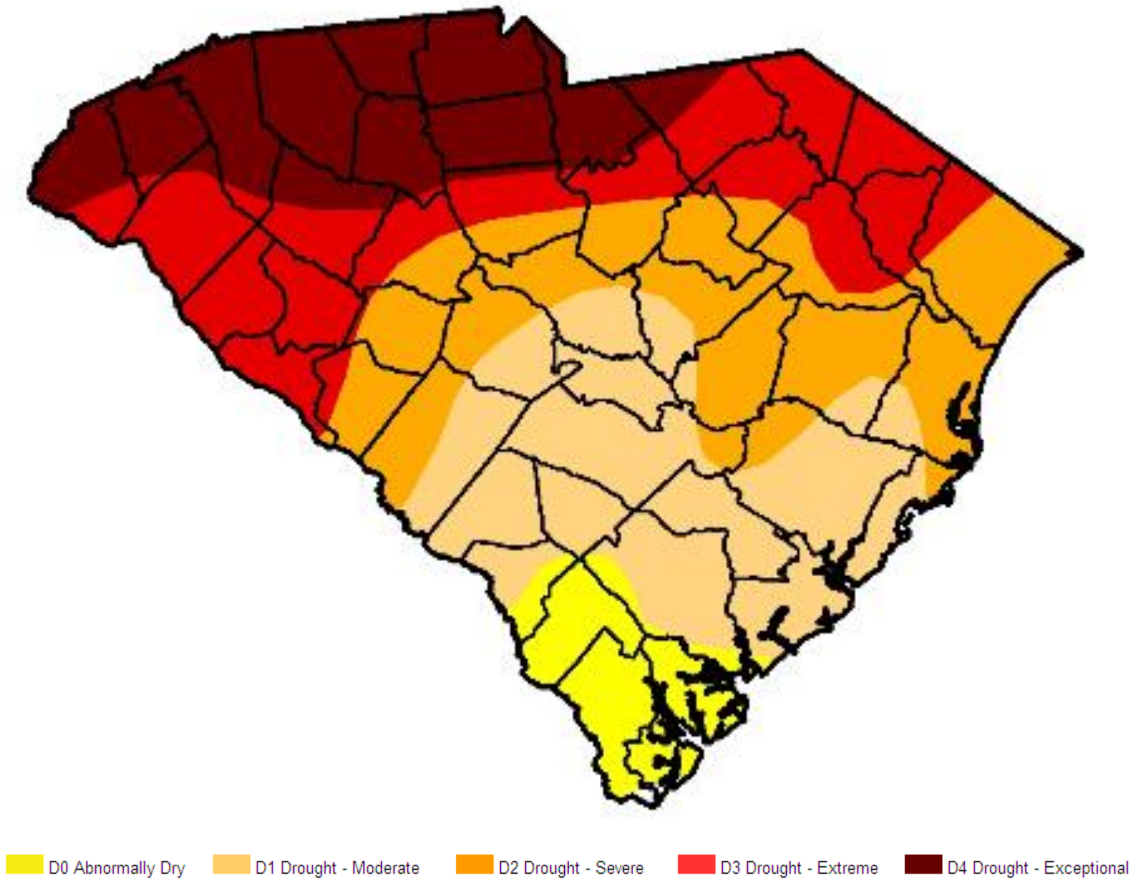

Figure 4: SC Drought Conditions on Jan. 29, 2008 (US Drought Monitor Archives)

Table 9: Key Statistics by County

County	Pop	HHold Size	Income	Water Usage
Abbeville	26.133	2.49	55,056	2.61
Aiken	150.181	2.54	72,182	15.01
Allendale	10.917	2.56	48,310	1.09
Anderson	175.514	2.48	66,881	17.55
Bamberg	15.880	2.55	53,522	1.59
Barnwell	23.345	2.57	52,451	2.33
Beaufort	137.849	2.51	98,663	13.78
Berkeley	151.673	2.75	74,360	15.17
Calhoun	15.100	2.54	72,210	1.51
Charleston	330.368	2.42	82,662	33.04
Cherokee	53.844	2.53	57,307	5.39
Chester	33.228	2.62	65,013	3.32
Chesterfield	43.435	2.54	56,606	4.34
Clarendon	33.363	2.62	55,717	3.34
Colleton	39.605	2.62	59,642	3.96
Darlington	67.346	2.57	66,165	6.73
Dillon	30.974	2.71	56,504	3.1
Dorchester	112.858	2.72	71,283	11.29
Edgefield	25.528	2.66	61,598	2.55
Fairfield	24.047	2.63	62,925	2.4
Florence	131.097	2.59	73,779	13.11
Georgetown	60.983	2.55	77,517	6.1
Greenville	407.383	2.47	78,445	40.74

Greenwood	67.979	2.49	63,423	6.79
Hampton	21.329	2.64	56,934	2.13
Horry	226.992	2.37	63,490	22.7
Jasper	21.398	2.75	65,164	2.14
Kershaw	56.486	2.58	73,775	5.65
Lancaster	63.113	2.56	60,314	6.32
Laurens	70.293	2.55	61,310	7.03
Lee	20.638	2.68	54,423	2.07
Lexington	235.272	2.56	80,832	23.53
McCormick	10.108	2.39	48,515	1.01
Marion	34.904	2.64	54,080	3.49
Marlboro	28.021	2.59	53,465	2.8
Newberry	37.250	2.50	59,753	3.73
Oconee	69.577	2.40	68,546	6.96
Orangeburg	92.167	2.58	61,925	9.21
Pickens	113.575	2.50	61,430	11.36
Richland	340.078	2.44	76,904	34.01
Saluda	18.895	2.65	68,018	1.89
Spartanburg	266.809	2.52	67,173	26.68
Sumter	105.517	2.68	67,113	10.55
Union	28.539	2.44	59,526	2.85
Williamsburg	35.395	2.69	53,813	3.54
York	190.097	2.63	78,648	19.01

* Pop is total Population in Thousands. HHold Size is the Average Household Size in the county. Income is the average household income. Water Usage is the overall county water usage measured in Mgal/year.

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