Community Water System Regionalization and Stakeholder Implications: Estimating Effects to Consumers and Purveyors

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Abstract

The water resource literature documents the solution that community water system regionalization (CWSR) offers, based on economies of scale, to challenges small community water systems (CWSs) face born of financial distress. But in practice very few systems actually regionalize. Imposing a model based on economies of scale, this paper estimates stakeholder implications to consumers and water purveyors that could materialize if CWSR takes place. The analysis applies social welfare theory then, drawing upon the literature and with empirical analysis, estimates consumer surplus and CWS rents to ascertain consumer and purveyor effects. The paper applies the framework to four New Mexico communities and reports results based on expected outcomes within these areas. Results indicate that the magnitude of consumer effects (generally positive) and purveyor effects (also, generally positive) depend on the pricing scheme imposed post regionalization. The results will inform those interested practitioners in CWSR.

Keywords: social welfare theory, water demand, regionalization, local water management

JEL Codes: Q25, H70, R11

Community Water System Regionalization and Stakeholder Implications:

Estimating Effects to Consumers and Purveyors

Introduction

Small community water systems (CWSs) face the challenge to distribute large fixed costs across, by definition, a small rate base. At the same time small CWSs primarily operate in areas where economic conditions limit customers' ability-to-pay. Economic reflection on these two realities calls to mind the financial solvency of small CWSs. Distributing large fixed costs over a small rate base, where ability-to-pay such costs or the political will to collect them may be insufficient, means that pricing does not recover costs and system performance dwindles. These realities have led policy makers and researchers to investigate the role for community water system regionalization (CWSR) to mitigate water system problems that stem from large fixed costs, small rate bases and financial insolvency.

The United States has approximately 53 thousand community water systems, many of which are small CWSs, that the U.S. Environmental Protection Agency (EPA) regulates under the Safe Drinking Water Act (SDWA) (R. C. Raucher et al., 2007; US EPA, 1974).[1] EPA categorizes water systems into five categories based on number of customers served. Very large CWSs serve 50 thousand people or more, large systems serve 10 to 50 thousand, medium systems serve 3,300 to 10 thousand, small ones serve 500 to 3,300 and very small systems serve 500 people or less. Of the total CWSs that EPA regulates, nearly 90 percent are small to very small and nearly 30 thousand systems serve 500 people or less (R. C. Raucher et al., 2007; Shih, Harrington, Pizer, & Gillingham, 2006). Challenges that small CWSs face, therefore, extend across the United States.

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[1] A CWS provides service to at least 25 people or to 15 water connections.

Financial solvency challenges, and funding shortfalls, lead to failing and inadequate infrastructure. Poor and inadequate infrastructure jeopardizes system reliability and disrupts systems' goal of to provide safe and reliable drinking water (R. C. Raucher et al., 2007). Lee and Braden (2008) estimated that in the United States, and for very small to medium sized systems, CWSs need to invest 75 to 103 billion dollars within the next 20 years to maintain infrastructure reliability. Moreover the water resource literature explains how CWSR offers as a solution, based on economies of scale, to small CWS challenges (R. C. Raucher et al., 2007; Shih et al., 2006; Ottem, Jones, & Raucher, 2003; Graham, 1999; National Research Council, 1997). And yet in practice very few systems actually regionalize. Some argue that, among others factors, autonomy loss plays a leading role (National Research Council, 1997). This paper considers cost savings and efficiency gains but focuses beyond these to evaluate benefits to all stakeholders, including customers, from CWSR. Could it be the case that ratepayers are worse off under CWSR? Understanding consumer benefits will help CWS managers make better, more informed decisions when considering CWSR.

The literature that studies CWSR divides into two branches (R. C. Raucher et al., 2007). The large branch focuses on connection costs and physical limitations. The EPA found, for example, that as many as 50 percent of small CWS could reduce costs through CWSR (US EPA, 1993). Others found that for small-to-large mergers, system savings materialize approximately 35 percent of the time but that for small-to-small mergers the estimate range reduces to 10 to 20 percent (Castillo, Rubin, Keefe, & Raucher, 1997). Further, the urban and rural distinction in CWSs influences the size of expected savings due to availability of resources to fund the merge and due to system size (Ottem et al., 2003; Rubin, 2003). The smaller branch considers successful cases of regionalization. Graham (1999) explores key aspects of success in CWSR cases and finds that among several, considering customer benefits is not generally considered but is essential. Lee and Braden (2008) evaluated cases of CWSR in six states, finding that in some cases CWSs regionalized to achieve regulatory compliance with the SDWA.

Few studies estimate customer benefits from CWSR. Most studies focus on the impact to technical, managerial and financial capacity (TMF), which is essentially the capacity to generate increased revenue. Still others have recognized the gap in the water resource literature pertaining to stakeholder benefits (R. C. Raucher et al., 2007; R. C. Raucher, Harrod, & Hagenstad, 2004). Reese, Palmer, and Nelligan-Doran (2000) estimated benefits from CWSR in terms of source reliability improvement but not benefits to stakeholders directly. This paper begins to fill this void in the literature. It estimates benefits that customers could realize from CWSR in four New Mexico communities. It begins with background on CWSs and CWSR, and barriers that have prevented its implementation. Then the paper presents the theoretical framework to measure stakeholder effects followed by the empirical section that operationalizes the theory model. The results section shows anticipated outcomes when the model applies to four New Mexico communities. The results indicate that CWSR generates positive effects to consumers and purveyors but the magnitude of such impacts depends on the pricing structure imposed post regionalization. Lastly the paper summarizes and concludes.

Background and Discussion

The literature documents the potential cost savings from, and impediments to CWSR. Shih et al. (2006) found that nationwide, cost savings could reach 417 million to 794 million dollars from CWSR. But others found that loss of local control, self-governance and autonomy impede CWSR (National Research Council, 1997; Clark & Stevie, 1981a). Further, resistance to CWSR remains the norm despite the fact that CWSR would provide small CWSs' ability to achieve greater regulatory compliance with the SDWA, improve financial solvency and thus lead to greater system reliability. CWSR improves the efficiency and effectiveness of the delivered product by lowering production costs and increasing delivery reliability (R. C. Raucher et al., 2007, 2004). With documented potential for better CWS performance and yet limited implementation of CWSR, one might question why do we not see more of it. Could it be that CWSR negatively effects customers and thus be the source of resistance? The literature recognizes that CWSR will in fact not become widespread until “communities feel it is in their best interests” to implement such a policy (National Research Council, 2002). This underscores the relevance of this paper. By estimating CWSR effects to customers, it quantifies how customers ‘might feel’ about CWSR. This will allow policy makers to make more informed decisions regarding CWSR.

This section presents the intuition of CWSR, economies of scale. Then it reviews what CWSR means and the definition the paper use for the remainder of the exposition.

CWSs and Economies of Scale

The primary goal of a CWS is to provide safe and reliable water service at least cost (R. C. Raucher et al., 2007). Fixed costs, especially, characterize the motivation for CWSR. Building water infrastructure consumes many resources and leads to high cost. Infrastructure treats and delivers water with sufficient quality and reliability to satisfy customer demand. Given these roles that infrastructure plays, planners build it to create capacity that corresponds to pre-determined levels of customer demand and water quality. And both of these assumptions turn out to be important pieces of CWS management.

INSERT FIGURE 1 ABOUT HERE

Figure 1 shows three average cost curves for a representative CWS where average cost results form the division of total costs by total water delivered. Point **a** shows the minimum average cost for the curve labeled AC_1. Given a level of customers who demand Q_1, point **a** shows the production level that achieves the least per unit cost and P_1 is the price that recovers costs. The capacity and infrastructure associated with AC_1 are based on customer demand Q_1, and a fixed level of water quality which the figure does not represent. If demand increases to Q_2 and distribution capacity remains constant, per unit cost increases to point **b** and recovering costs requires the price P_2. If capacity is built based Q_1 but demand turns out to be less than Q_1, then costs fall as demand increases to Q_1 because of economies of scale. Per unit costs fall as production increases up to the point at which demand equals the level for which distribution or quality capacity was designed.

On the other hand if demand increases to Q_2 but capacity remains consistent with cost structure AC_1, diseconomies of scale means that unit cost increase to point **b**. But what if the CWS could somehow re-design its capacity to be consistent with a cost structure represented by curve AC_2? Then, due to economies of scale, unit cost decreases to point **c** and the price P_3 recovers costs. Carrying on the long run assumption of flexible capacity to meet demand, the dotted line represents the minimums of the average cost curves that would result. The long run average cost curve, LAC, shows that economies of scale exist for levels of demand less than Q_3 but that diseconomies exist for levels greater. This is the motivation for CWSR. CWSR will change a CWS's existing cost structure. CWSs can expand their capacity, take advantage of economies of scale, and thus distribute costs over a larger customer base through CWSR.

Community Water System Regionalization (CWSR)

Regional solutions to water management challenges include various alternatives, of which CWSR is one. Solutions divide into two types: structural and non-structural, and can be thought of as those that lead to CWS connections that are either physical or organizational (R. C. Raucher et al., 2004). In the vernacular of water resource management, non-structural solutions include mutual aid across CWSs, sharing agreements and contract services. Structural solutions include water purchase agreements, collaborative water resource development and consolidation (R. C. Raucher et al., 2007).[2] Consolidation leads to the greatest improvements in water supply reliability and quality compliance (R. C. Raucher et al., 2007). CWS consolidation occurs when two or more systems merge, to include tying together infrastructure from both systems, and form a new entity. In this paper, CWSR strictly means consolidation.

The feasibility for a community to adopt CWSR depends on the geographic location of CWSs therein. For example CWSR is not feasible for a CWS where the closest CWS neighbor is geographically far away. Previous research found that economies of scale exhaust as distance between merging partners increases (Castillo et al., 1997; Clark & Stevie, 1981a, 1981b). Therefore the paper models CWSR in communities where more than one CWS exists. If CWSR is geographically feasible the next issue becomes financial feasibility. The 1996 amendment to the SDWA made the Drinking Water State Revolving Fund available to water providers. Its purpose is for providers to upgrade system reliability, to include consolidation (Lee & Braden, 2008). Since the goal of this work is to estimate consumer and purveyor effects, the paper makes the assumption that geographic feasibility implies financial feasibility by way of loanable funds. To that end, the paper focuses on stakeholder effects on the margin and not connection costs.

[2] See Raucher et al. (2004) for in-depth discussion alternative regional solutions.

Water quality violations and service disruptions, which plague small CWSs, are effects of revenue shortfalls. Spreading treatment costs and supply acquisition costs over a small rate base means that systems operate with insufficient revenues and capacity, and thus challenges emerge. CWSR rectifies part of these challenges by expanding the rate base over which treatment and acquisition costs are spread. This improves CWSs' technical, managerial, and financial capacity (TMF). The paper makes the assumption that greater TMF results from greater net revenue. The SDWA calls for water systems to develop and or improve TMF because more TMF implies less water quality violations (R. C. Raucher et al., 2007; US EPA, 1993). The EPA has supported systems to build such capacity by investing millions of dollars (Jaffe, Braden, & Min-Yang, 2007), but CWSR is another way CWSs can build TMF and in turn provide high quality, reliable water service. Moreover, CWSR means better water resource management because management moves to the hydrologic basin level as opposed to the CWS level. Better resource management means less supply disruptions (R. C. Raucher et al., 2007). TMF, greater regulatory compliance, and improved system reliability put CWSs on a path to sustainability (R. C. Raucher et al., 2004; National Research Council, 1997). And CWSR promotes each of these.

Theoretical Framework

The paper considers how regionalization could affect water customers and water purveyors in a community that implements CWSR. It assumes purveyors provide water solely to customers whose water use is for domestic purposes. The impact magnitude that each group realizes depends, among other things but primarily on, the pre and post CWSR per unit water price. A market model of a CWS provides a framework to estimate effects to customers in terms of consumers' surplus (*CS*) and to purveyors in terms profit or rent (*R*). Figure 2 depicts the theoretical model on which the analysis relies. For both groups, the analysis measures effects at the level of the CWS then sums them to the community level. Comparing static outcomes at the level of the community before and after CWSR estimates effects to customers and purveyors. The mathematical model that follows considers an unspecified CWS, indexed with *i*, then will sum impacts across *m* CWSs within the community to ascertain community-wide effects.

INSERT FIGURE 2 ABOUT HERE

Within System Effects

CS measures the benefit to customers, denominated in dollars, from being able to consume water.[3] Figure 2 illustrates *CS* as the lightly shaded area labeled *Consumer Surplus*. Measuring *CS* requires a water demand function. Aggregate water demand for Q_i units of water within CWS *i*:

$$Q_i = D\left(P_i, Y_i, N_i, \mathbf{X}_i\right), \tag{1}$$

[3] *CS* is the difference between consumers' maximum willingness-to-pay for each unit of the good and the price where at the good is actually consumed (Layard & Walters, 1978). Marshallian consumers' surplus has long been used as a technique for evaluating welfare effects in utility regulation. See, e.g., Dimopoulos (1981) and Mitchell (1978). The approach has not been met without some criticism. For example Boardway (1974) notes that when evaluating a heterogeneous population complete welfare effects are not captured. However this critique can be overcome under two theoretical considerations. Willig (1979) points out that when income effects are relatively small, consumers' surplus acts as good measure of societal impact. Secondly, a theoretical condition for preferences (the demand function) can be constructed such that consumers' surplus acts as a good index of welfare change (Renzetti, 1992; Blackorby & Donaldson, 1985).

is a function of the per-unit water price, P_i, income, Y_i, the number of connections served, N_i, and a vector of socio-demographic characteristics, $\mathbf{X_i}$ in the community. Using equation (1), the analysis measures *CS* as:

$$CS_i = \int_{P_i}^{\bar{P}} D\left(P_i, Y_i, N_i, \mathbf{X_i}\right) dp, \tag{2}$$

where $\bar{P}$ is the choke price on the water demand curve. It is the price where customers demand no water, effectively "choking off" water demand.

The model measures purveyor effects with rents the system earns. Rents are the difference in the per unit price and average cost at a given level of production. Figure 2 illustrates these as the darker shaded area labeled *Rents.* The paper considers the CWS cost structure in the long run, to estimate *R*, when all costs are variable and incorporated into the production of Q_i. Following Shih et al. (2006), the average cost is:

$$AC_i = f\left(Q_i, \mathbf{Z_i}\right), \tag{3}$$

where $\mathbf{Z_i}$ is a vector of CWS specific characteristic such as water source and ownership type. Thus, rents to the i^{th} purveyor are given by:

$$R_i = \left(P_i - AC_i\right) Q_i. \tag{4}$$

Within Community Effects

The paper estimates CWSR effects at the level of the community for two primary reasons. CWSR is feasible within communities where more than one CWS exists. Customers and managers within a particular CWS may be either welcoming or reluctant to the idea of CWSR, depending on system characteristics wherein they are located and characteristics of potential CWSR partners. For example, a CWS that enjoys high system reliability could be hesitant to the idea of merging with a CWS that experiences frequent service disruptions. Similarly, hesitation could be born out of variations in water treatment quality or per-unit price across potential CWSR partners. Therefore, CWSR will likely produce “winners and losers” so the paper estimates impacts at the community level to see if losses can be offset by gains. Secondly, in earlier work on CWSR Clark and Stevie (1981a, 1981b) found that the largest cost savings will be for partner CWSs that are less than approximately nine miles apart. For these two reasons, variation in user impacts across CWSs and the Clark and Stevie distance restriction, the paper estimates effects at the community level.

Let *m* CWSs exist in community *k,* and assume that all CWSs within the community are partners in the CWSR. To find CWSR effects community wide sum across *m* CWSs to get:

$$CS_k^0 = \sum_i^m CS_i \tag{5}$$

and

$$R_k^0 = \sum_i^m R_i \,. \tag{6}$$

The superscript 0 denotes measurement prior to CWSR. Equations (5) and (6) measure how well off customers and purveyors are prior to adopting CWSR.

To find community effects, equations (5) and (6) need to be applied before and after CWSR so that the change can be identified. Recall from equations (2) and (4) the roll that P_i and AC_i play in *CS* and *R*. When CWSR occurs, the question becomes what P_k and AC_k will prevail after the merge? The answer to this question influences the extent of effects to both customers and purveyors. The paper now identifies its assumption for three pricing possibilities and average cost that it employs to estimate effects.

Prices and Costs

The paper calls the pricing alternatives it considers status quo pricing (*sq*), cost-recovery pricing (*cr*), and cost-plus pricing (*cp*). Under status quo pricing customers experience no change in the per-unit water price. The before-and-after CWSR price remains the same such that $P_k^{sq} = P_i$. This alternative means that prior customers of CWS_i may face a different price than prior customers of CWS_j where $j \neq i$ and yet receive water service from the same new system, CWS_k, where CWS_k results from the merger of CWS_i and CWS_j. This pricing alternative appears because of the potentiality that customers' primary resistance to CWSR may be due to fear of changing prices.

Cost-recovery is most similar to water management in practice today. This alternative sets $P_k^{cr} = AC_k$ for all customers in the new system. *A priori*, one would anticipate this alternative to generate the largest gain in *CS*. Passing all cost savings from CWSR through to customers is sure to make them better off, in the near term. In the long term customers may not be better off but this question is beyond this paper's intent.

Cost-plus pricing directly allows for rent generation in CWSR. Status quo pricing may allow for rents, depending on what AC_k turns out to be, but cost-plus pricing directly allows for rents since $P_k^{cp} > AC_k$. But what will the cost-plus mark up price be? The paper defines this alternative with a cost-price relationship, θ_i, for each CWS_i in community *k* according to the Lerner Index as:

$$\frac{\theta_i}{\eta} = \frac{P_i - AC_i}{P_i}, \tag{7}$$

where η is the price elasticity of water demand (Viscusi, Vernon, & Harrington, 2005). Then it applies the largest markup in community *k*, θ_j, where $\theta_j > \theta_i \ \forall \ j \neq i$ in:

$$P_k^{cp} = AC_k\left(\frac{\eta}{\eta - \theta_j}\right). \tag{8}$$

The socially optimal cost-plus mark up to apply would include the scarcity value of water or opportunity cost of foregone water use(Hansen, 2011), but that is beyond the scope of this analysis and is not included here.

Average cost in CWS_k depends on the characteristics of the systems that engage in CWSR. Similar to equation (3), average cost in CWS_k is given by:

$$AC_k = \left(Q_k, \mathbf{Z}_k\right), \tag{9}$$

where $Q_k = \sum_i^m Q_i$. The vector $\mathbf{Z}_k$ indicates the system characteristics that pertain to the new system after CWSR.

Net Effects

The paper identifies net effects within a community by comparing *CS* and *R* before and after the community chooses to implement CWSR. The customer and purveyor impacts after CWSR, denoted by the superscript 1, are:

$$CS_k^1 = \sum_i^m CS_i\left(P_k^l, Y_i, N_i, \mathbf{X}_i\right) \tag{10}$$

and

$$R_k^1 = \left(P_k^l - AC_k\right)Q_k, \tag{11}$$

where the superscript *l* on the price variable indexes the pricing alternatives *sq, cr,* and *cp*. Thus, to see the net impact of CWSR within community *k* and under three pricing alternatives, find the differences in equations (5) and (10) then in (6) and (11) as in:

$$\Delta CS_k = CS_k^1 - CS_k^0 \tag{12}$$

and

$$\Delta R_k = R_k^1 - R_k^0 . \tag{13}$$

Equations (12) and (13) are those that the analysis uses in the next section to estimate community impacts in four New Mexico communities. The paper now turns to the numerical methods that it uses to operationalize (12) and (13).

Empirical Framework

Water Demand

Estimating *CS* requires a water demand function. This analysis uses data that the New Mexico Public Regulation Commission (NMPRC) provided, and it estimates a water demand curve. The section that follows describes the data and then discusses the empirical estimates of water demand that the paper produces.

The NMPRC currently regulates 36 privately run, investor-owned CWSs in New Mexico.[4] To ensure that CWSs offer fair and reasonable water rates to consumers, the NMPRC collects annual revenue and consumption data from each system. The NMPRC makes these data available to researchers upon request. This analysis uses data that reflects 33 CWSs under NMPRC regulation, which is the number NMPRC regulated at the time of the request. The data span 13 years from 1992 to 2005. However, the panel data is not balanced since data for each CWS is not available in every year of the time frame. By CWSs, the NMPRC data show the annual number of customers, the total gallons sold, and gross revenues. From these data, the analysis generates price and quantity variables. Table 1 shows the data's descriptive statistics.

INSERT TABLE 1 ABOUT HERE

[4] See, e.g., www.nmprc.state.nm.us/regent.htm for all utilities that NMPRC regulates. Last accessed 24 August 2011.

The price variable is the quotient, or average revenue, that results from the division of gross revenues by total gallon sales. The study uses average price since earlier findings suggest that consumers react more to average than marginal prices (Nieswiadomy, 1992). Quantity derives from total gallon sales reported in the data. The connection variable reports the total number of connections that each CWS serves and is not disaggregated into user types. Assume that each connection represents 2.6 people, which is the average household size the U.S. Census Bureau reports for NM, to convert connections to people served.[5] The conversion implies that the average CWS that NMPRC regulates fits into the small EPA system size category. Further, the data show that approximately 45 percent of the observations come from very small systems, 33 percent are from small systems, 15 percent from medium and six percent from large systems. The table presents variables for income and age to proxy for the socio-demographic characteristics of each community served by a CWS. These data come from the U.S. Census in the year 2000. The analysis converts monetary variables to constant, 1995 dollars using the Consumer Price Index provided from the Bureau of Labor Statistics.[6]

The analysis uses the data described in Table 1, and STATA 11, to estimate equation (1). It begins by estimating a pooled Ordinary Least Squares (OLS) model where quantity is the dependent variable, in gallons, and price is per gallon. The data are cross sectional and a Breusch-Pagan test finds that heteroscedasticity is a problem. To correct for it, the analysis re-estimates the model with a log-log specification but heteroscedasticity remains. The OLS model in Table 2 shows the log-log model, it uses heteroscedasticity consistent standard errors.

INSERT TABLE 2 ABOUT HERE

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[5] See, e.g., http://factfinder.census.gov/. Last accessed 25 August 2011.
[6] Consumer Price Index (CPI) available at www.bls.gov/cpi/ last accessed 25 August 2011.

The data originate from 33 CWSs over 13 years so the next step is to test for CWS specific effects. The FE model in the table presents the fixed effects estimation results. This model estimates that 77 percent of the variation in the dependent variable is due to CWS-level effects. Then the analysis uses a Hausman test to evaluate the correct model specification for CWS-level effects, fixed or random. The RE results in the table show the model for random effects. The Hausman test indicates that the RE specification is correct. Following the FE and RE models, however, further analysis finds that heteroscedasticity and autocorrelation remain.[7] The table presents the Generalized Least Squares (GLS) model that corrects for panel-level heteroscedasticity and autocorrelation. Within each panel, it uses heteroscedasticity consistent standard errors and an AR1 process. A further Hausman test finds that the GLS model is a better estimator than the RE model and thus the GLS model is the one the following analysis uses.

The log-log estimation in the GLS model means that the coefficients are elasticities. The price elasticity (-0.538) shows that water demand in the representative CWS is price-inelastic. It shows that, over the relevant range of prices, customers within the representative system are somewhat unresponsive to changes in price. A ten percent increase in price would lead to a 5.4 percent reduction in water demand. This is consistent with the median elasticity that Espy, Espy and Shaw (1997) report (-0.51) and with those summarized in Brookshire, Burness, Chermak and Krause (2002). The connection elasticity means that a 10 percent increase in connections leads to an equivalent increase in demand. The positive income elasticity shows that water is a normal good. As people's income rises, so too does their demand for water. The age elasticity, consistent with Krause, Chermak and Brookshire (2003), shows that older people use less water.

[7] The test in STATA for heteroscedasticity after a fixed effect model uses a Breusch and Pagan Lagrange multiplier test (Baum, 2006a). After a random effects model the test is a modified Wald-test (Baum, 2006b). The test in STATA for autocorrelation in panel data uses the Wooldridge-test (Drukker, 2003).

A ten percent increase in the median age of people in the community leads to a reduction in water demand of almost 12 percent.

Average Cost Function

The stylized model in Figure 2 illustrates, and equations (3) and (9) demonstrate, that to estimate *CS* and *R* requires an empirical average cost function. Data that empirical analysis entails to produce such estimation are proprietary and difficult to readily obtain at the CWS level. But Shih et al. (2006) estimated CWS economies of scale using survey data that the EPA collects every five years. Table 3 presents the model that Shih et al. estimated. It is the model this analysis uses to operationalize equations (3) and (9).

INSERT TABLE 3 ABOUT HERE

The EPA conducts the Community Water System Survey where it randomly identifies which CWSs in the U.S. it requires to report pertinent data for use in setting regulation policy. Shih et al. use data from the 1995 and 2000 surveys, and follow a simplified method based on one set out in Christensen and Green (1976), to estimate economies of scale for CWSs. Their paper estimates several models, but the one this paper uses (Table 3) has 565 observations from the 1995 survey. The approach they follow assumes that decision makers within CWSs operate the system at the point of technical efficiency. That is to say that water system production is on the production possibilities frontier so that no further output can be produced for a given level of inputs (Shih et al., 2006).

The dependent variable for the model Table 3 presents is the natural log of annual unit cost where unit cost is in 1995 dollars per one thousand gallons. Annual production of finished water, *W*, is in million gallons. The next three variables are dummy variables to control for system specific characteristics such as surface water or groundwater, purchased water, and public or private ownership. The Shih et al. paper nets out any taxes that private CWSs pay so that the ownership comparison is in like terms. Their model shows that for an increase in production of finished water of 10 percent unit cost falls by 1.6 percent (log-log specification means the interpretation is as an elasticity). Surface water systems' costs are 17 percent greater than systems that use groundwater. Systems that purchase water have unit costs 52 percent greater than those that do not purchase water. And, public systems' unit cost is 12 percent less than privately owned systems.

Empirical Equations for *CS* and *R*

In order to estimate impacts from CWSR, the analysis requires numerical specification of theory. The GLS model in Table 2 provides necessary information to specify equation (1) thus:

$$Q_i = c_1 P_i^{-0.54} \tag{14}$$

where $c_1 = e^{8.05} N_i^{1.03} Y_i^{0.42} A_i^{-1.16}$ and N_i is connections, Y_i is income and A_i is age. The Shih et al. cost model in Table 3 provides the parameters necessary to specify equation (3):

$$AC_i = c_2 \left(\frac{Q_i}{1{,}000{,}000} \right)^{-0.16} \tag{15}$$

where $c_2 = e^{8.34+0.17SUR+0.52PUR-0.12PUB}$. Using these two equations, the analysis estimates *CS* and *R* before and after CWSR.

To find the numerical specification for *CS*, take equation (14) and integrate it over changes in price to find:

$$CS_i = 2.17 c_1 P_i^{0.46} \Big|_{P_i}^{\bar{P}_i} \tag{16}$$

where P_i is the per unit water price within CWS_i prior to CWSR. Recall that the paper imposes three possible price alternatives after CWSR. To find *CS* after CWSR, the analysis substitutes

P_k^l in for P_i. Earlier the paper mentioned that $\overline{P}$ is the choke price, or maximum price consumers are theoretically willing to pay to consume the last unit of water. With a linear demand curve the choke price is finite however with the exponentially estimated form used here the number is infinite, and that is not theoretically consistent. To correct this the analysis computes a price for each CWS consistent with 13.2 gallons (50 liters), a recognized amount necessary for basic human existence, drinking, food preparation and sanitation (Gleick, 1998). This means that $\overline{P}_i$ represents the maximum price consumers in CWS_i would be willing to pay for water beyond this basic subsistence level, and the it means consumption meets basic needs.

The numerical specification for *R* derives from substituting equation (15) into equation (4) to find:

$$R_i = \left(P_i - c_2 \left(\frac{Q_i}{1{,}000{,}000} \right)^{-0.16} \right) Q_i \,. \tag{17}$$

Equation (17) shows the specification to estimate *R* before CWSR. To find it after CWSR, analogous to the after method to find *CS*, substitute P_k^l in for P_i. Further, substitute Q_k in for Q_i where $Q_k = \sum_i^m Q_i$.

Equations (16) and (17) are those that the next section uses to estimate consumer and purveyor impacts from CWSR.

Estimating CWSR Impacts in four New Mexico Communities

Drought in the summer of 2002 created stress on New Mexico (NM) CWSs that over ten percent of systems where not able to bear, and 70 CWSs shutdown. These systems lacked capacity and ability to collaborate with other systems and hence continue to provide water service. State government leaders investigated the crisis and found that “(a) chronic lack of planning, resulting in community water systems that were not robust enough to handle the stress of drought conditions" (NM State Engineer's Office, 2005). To solve the problem, leaders initiated the Area-Wide Collaborative Water Planning Project to increase collaboration between neighboring CWSs (Cervantes, 2005).

The project's goals were to increase collaboration to manage water resources, promote collaboration among stakeholders for infrastructure planning, and improve efficiency of CWS operation. The project planned for goals to be carried out with a series of nine steps that parallel non-structural and structural collaboration discussed earlier in the paper. In the project, collaboration increased with steps to the point of full consolidation. A few NM CWSs agreed to planning-documents, but consolidation remains unobserved. CWS managers are reluctant to participate due to autonomy loss and increased government involvement (Holmes, 2006), a situation found in earlier research (National Research Council, 1997; Clark & Stevie, 1981a).

This section estimates what NM policy makers could expect if CWS managers in four communities were to adopt CWSR. In these communities small CWSs exist alongside larger systems. By hypothetically imposing CWSR, the paper evaluates how CWSR could affect consumers and purveyors. Table 4 shows the communities (Hurley, Questa, Ruidoso and Los Lunas) and the CWSs within each community.

INSERT TABLE 4 ABOUT HERE

These communities provide representative examples of issues that influence CWSR outcomes, and they reflect the nature of outcomes to expect if NM policy makers adopt CWSR. The town of Hurley, for example, provides a case where the two CWSs are under different types of ownership and supply water from different types of sources. Further, the two CWSs are both in the very small EPA category where a merger would move the new system into the small category. Questa shows the case where a very small system merges with a small system and the new system remains in the small category. It further shows two CWSs that have different pricing structures. Cerro East charges a flat rate water price while Questa Water charges a per unit price. Ruidoso and Los Lunas each provide cases where very small and small systems merge with systems of medium size. Further, these two communities offer a case where three CWSs would be partners to the merge.

This paper's author compiled the data for Table 4 from three sources. The New Mexico Environment Department Construction Program Bureau surveys New Mexico CWSs and it reports findings in the Municipal Water and Wastewater User Charge Survey. The NMPRC collects data, as noted earlier, that provides information on individual CWSs. Finally, staff in the New Mexico Office of the State Engineer filled in missing information that was not available in the two previously listed sources. The prices that Table 4 shows are in constant 1995 dollars to maintain consistency with the empirical framework discussed in the previous section.

Using the prices that Table 4 displays, and the cost model from equation (15), the analysis finds that seven of ten systems earn positive rents. Both Hurley systems and the Cerro East system from Questa earn negative rents, or in other words operate at a financial loss. For the Hurley systems, the loss results since the unit cost is greater than the unit price. The estimated unit cost for the Hurley Water Supply System and North Hurley System is 3.3 and 4.3 dollars per one thousand gallons, respectively. The negative rent issue for Hurley systems poses a problem for the cost-plus pricing alternative since neither system charges a price mark-up. To correct for this in the results that follow, with respect to Hurley rents only, the cost-plus pricing results are identical to the cost recovery results since cost recovery is a price increase.

For the Cerro East System, the loss is due to flat rate pricing. Flat rate pricing prevents the analysis from determining water consumption using the demand curve in equation (14). In order to overcome this impediment the paper assumes that daily per capita consumption in this system is 500 gallons, which translates the unit price to 0.10 dollars per one thousand gallons, essentially a consumption level where price is not a determining factor. Under this assumption, the unit cost for water in the Cerro East System is 2.4 dollars per thousand gallons.

The paper now turns to Table 5, where it presents the results of CWSR estimated effects to consumers and purveyors in each community.

INSERT TABLE 5 ABOUT HERE

The results imply that the extent consumers experience effects depends on the pricing alternative. For example, under the status quo alternative customers realize no immediate effect. This is due to the fact that prices do not change under the status quo. Yet this makes possible a situation where one group of customers within the newly merged system face higher (lower) prices than other customers within the same system. Customers realize the largest, positive effect under the cost recovery alternative. This results since all of the efficiency gains from CWSR pass directly to consumers. Cost plus pricing shows that customers will experience benefits, albeit less than under cost recovery.

Analogous to consumer effects, purveyor effects depend on which pricing alternative follows CWSR. When status quo prices follow the results show that purveyor impacts vary. Recall that the Hurley systems both operated at a loss prior to CWSR. The status quo results show that Hurley would experience a 118 percent increase in rents. But in Ruidoso and Los Lunas rent modestly increases. The cost recovery alternative shows that Hurley would see a rent increase but the other communities would see rent decreases. This is because gains from CWSR pass directly to consumers leaving systems that were previously collecting rent now without it. The cost plus alternative shows significant potential for rent to increase in each community.

Table 5 shows that CWSR effects, in addition to variation with the post merger price, vary with system size. The purveyor effects show that when the merger results in a medium sized system the potential for increased *R*, and thus TMF (technical, managerial, and financial capacity), is greater than when the merger results in a small system. Hurley's potential for increased *R*, where the new system is a small one, is 118 percent while for Ruidoso and Los Lunas, where the new system is of medium size, the potential exceeds 200 percent. Questa's *R* potential, where the new system is small, is 458 percent but this spurious result is due to one of the merging systems' flat rate pricing prior to CWSR. These findings are consistent with Castillo et al. (1997) who found that cost savings materialized more often with small-to-larger mergers than small-to-small mergers. Further, the findings imply that the direction of customer impacts might be reverse of purveyor impacts. The largest gain in *CS* results in Hurley and Questa (24 and 20 percent, respectively) while smaller gains result in Ruidoso and Los Lunas (12 and 19 percent, respectively).

Perhaps herein lies at least a part of the reason why CWSR is not more pervasive in water utility management. Cases with the potential for the greatest improvement in TMF might also be those where the potential for positive customer effect may be the least, and thus the source of CWSR resistance. Examining customer effects by system sheds further light on how consumer impacts vary from mergers.

INSERT TABLE 6 ABOUT HERE

Table 6 shows how customer effects vary within the community. For example consider the hypothetically new CWS in Hurley that serves two groups of customers; one group from the former Hurley Water Supply System (HWSS) and one group from the former NHMDWCA. Customers from the former HWSS experience virtually no effect under either pricing alternative yet NHMDWCA customers realize a positive benefit. The monthly effect to customers of the latter group is 8 to 45 dollars of *CS*, depending on pricing alternatives. Further, even greater variation exists for customers of the new Questa CWS. CWSR negatively impacts former customers of CEMDWCA, -21 to -28 *CS* dollars per month, while it positively impacts former customers of QWS, 4 to 45 *CS* dollars per month. These two communities highlight the variation in customer effects that CWSR likely will produce. To a lesser extent, variation exists in customer impacts for Ruidoso and Los Lunas. Former customers of AVSD and HMEWC, both very small systems, realize roughly half the benefits that former customers of larger systems in Ruidoso and Los Lunas realize. One exception, however, is for the former customers of MWC where cost plus pricing negatively impacts them.

The results above show that CWSR, with respect to consumers, makes some groups strongly better off, some groups moderately better off and some groups worse off. Water policy makers who hold authority to implement CWSR should find this information engaging. To be sure, efficiency gains have been found in previous work (Raucher et al., 2007; Shih et al., 2006; US EPA, 1993) and the research here finds the same result. However, these results supply new information for policy makers when considering CWSR. First, CWSR primarily leads to positive customer effects. Some customer groups are more positively effected than others but for the most part customers are better off. Second, the distribution of customer effects is uneven. These two findings imply potential reasons why CWSR is not more widespread. A likely reason stems from customers' lack of knowledge on how much better off they would be under CWSR. Or, perhaps customers are concerned about the uneven distribution of effects. In either case, this means that for CWSR to be successful policy makers need to inform customers how CWSR will affect them, positive or negative, and for how long.

CWSR produces some unintended consequences too, like increased water demand. Under status quo pricing, the analysis predicts no change in water demand since prices remain unchanged. For cost recovery pricing water demand increases 2.7 times in Hurley, three times in Questa, five times in Los Lunas, and by roughly ten percent in Ruidoso. For the case of cost plus pricing water demand increases by 2.7 times in Hurley, 2.1 in Questa, 2.4 in Los Lunas, and by five percent in Ruidoso. This unintended consequence suggests that when policy makers consider how to implement CWSR, they need to also consider prices to reflect water scarcity.

Summary, Extensions and Conclusions

Researchers have found that community water system regionalization (CWSR) offers community water systems (CWSs) a solution to financial solvency challenges. By taking advantage of economies of scale CWSs can distribute fixed costs across a larger rate base, reduce unit costs and thereby reduce the per unit price needed to recover operating costs. But despite findings to create cost savings, CWSR is not widely practiced. Perhaps this is because of how little is known regarding how CWSR impacts stakeholders. This paper relies on social welfare theory (consumer surplus and rents) and empirical analysis to estimate how CWSR might affect two groups of stakeholders, water consumers and water purveyors. It applies the model in four New Mexico communities. By hypothetically imposing CWSR in these communities ten CWSs become four CWSs, one system per community. Doing so lets the paper estimate effects that policy makers should think about when considering plans to implement CWSR.

The paper finds that in the NM communities (Hurley, Questa, Ruidoso and Los Lunas) CWSR generally makes a positive impact to consumers and purveyors, but the magnitude of the effects depends on water prices before and after the merge. Customers who pay flat rate prices prior to CWSR loose some consumer surplus by merging into a new system where the pricing scheme is per unit. Customers who come from CWSs that prior to CWSR operated at a loss will also loose some consumer surplus. But the majority of customers in these communities will gain consumer surplus. Further, water purveyors who prior to CWSR operated at a financial loss will at least break even and at most generate greater revenue. Yet the effects to customers and purveyors that this paper finds depend on the pricing scheme chosen after CWSR.

The paper carried out the analysis in a static framework. Extending the framework to dynamic analysis would let this line of research investigate the extent of population and income growth on CWSR effects. Further, dynamic analysis would facilitate incorporating connection costs into the analysis and thus determine the time frame required for CWSR to be cost-effective.

The paper hypothetically implemented three pricing alternatives that it called status quo, cost-recover and cost-plus pricing. Status quo pricing held prices constant before and after CWSR. Consumers did not loose consumer surplus but purveyors gained rent. Cost-recovery, sometimes referred to as full-cost pricing, passed all the savings generated by CWSR to consumers. Consequently customers gained a lot of consumer surplus but purveyors did not gain any additional rent. Cost-plus pricing computed the largest cost-price mark up of CWSs within the community and maintained the same mark up level after CWSR. This alternative found that consumers did gain surplus but that purveyors also improved their rent position. The results of these three pricing alternatives lead to a primary conclusion with respect to CWSR. Water prices matter. And they matter a lot.

A dearth exists in the water resource literature regarding customer benefits that might result from CWSR. But a similar dearth exists regarding what water prices will prevail after

CWSR. This paper begins to fill the gap regarding customer benefits. The extent of stakeholder benefits heavily depends on prices. This finding suggests that water policy makers who consider CWSR should carefully evaluate the prices that will prevail after CWSR. Prices can be designed so that they do not negatively affect customers and still generate rent, which is to say technical, managerial and financial (TMF) capacity, for purveyors. The cost-recovery finding is perhaps most striking. If full-cost pricing follows CWSR and all costs, to include water scarcity costs, are not included, then CWSR creates two adverse consequences. It lowers prices to the point that demand increases and the financial position for CWSs does not improve. CWSR holds the potential to solve CWS challenges, and customers can be made better off because of it, but the appropriate administration of prices is paramount.

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Table 1

Descriptive statistics

Variable		Mean	Std. Dev.	Min	Max	Observations
Quantity	overall	154,176.8	335,471.6	515	1,573,818.0	372
(thousand	between		302,178.4	1,143.7	1,4386,874.0	33
gallons)	within		75,133.4	-318,550.5	724,962.5	11.3
Price*	overall	3.51	1.73	0.94	10.77	372
(per	between		1.60	1.40	6.80	33
thousand	within		0.73	1.19	7.49	11.3
gallons)						
Connections	overall	1,230.6	2,773.9	7.0	14,646.0	373
	between		2,459.9	10.1	12,647.6	33
	within		772.4	-3,100.5	8,258.6	11.3
Income*	overall	28,511.40	6,329.59	20,025.00	45,269.85	373
	between		6,047.74	20,025.00	45,269.85	33
	within		0	28,511.40	28,511.40	11.3
Age	overall	34.5	4.6	28.6	47.0	373
	between		4.6	28.6	47.0	33
	within		0	34.5	34.5	11.3

*Monetary units converted to constant 1995 dollars with the CPI.

Table 2

Models of CWS water demand by estimation type

Variable	OLS	FE	RE	GLS
Constant	6.12*	9.23*	6.64*	8.05*
	(0.672)	(0.384)	(1.660)	(0.710)
ln Price	-0.656*	-0.489*	-0.554*	-0.538*
	(0.033)	(0.050)	(0.042)	(0.026)
ln Connections	1.02*	0.908*	1*	1.03*
	(0.007)	(0.037)	(0.018)	(0.006)
ln Income	0.415*	omitted	0.487*	0.417*
	(0.064)		(0.187)	(0.070)
ln Age	-0.776*	omitted	-0.937*	-1.16*
	(0.115)		(0.309)	(0.111)
Observations	372	372	372	369
Adjusted R^2	0.984	0.615		
Wald χ^2			3,501	37,046
RMSE	0.236	0.169	0.171	

ln natural log operator
*Significant to 1% level
(Standard Error)

Table 3

Scale economies of total operating expense

Variable	Number (Standard Error)
Constant	8.34* (0.061)
ln *W* †	-0.16* (0.009)
Surface	0.17* (0.050)
Purchased	0.52* (0.053)
Public	-0.12* (0.041)
Adjusted R^2	0.46
Observations	565

* Significant to 1% level
† Log change in production
Reproduced from Table 3 in Shih et al., (2006)

Table 4

Four New Mexico communities to estimate CWSR effects

Community	Age	Income	CWS	Population/ Connections	Price*	Water Source	Owner Type
Hurley	39	24,251	Hurley Water Supply System	275 41	2.02	Ground	Private
			North Hurley MDWCA	365 127	2.90	Purchase	Public
Questa	38	20,750	Cerro East MDWCA	81 31	12.91**	Ground	Public
			Questa Water System	1,800 768	2.90	Ground	Public
Ruidoso	46	32,838	Alpine Village Sanitation District	195 78	3.07	Ground	Public
			Rancho Ruidoso Rainmaker	475 234	3.31	Ground	Private
			Village of Ruidoso	10,001 8,096	3.07	Ground	Public
Los Lunas	32	32,071	Hi Mesa Estates Water Corp	200 100	3.71	Ground	Private
			Los Lunas	11,536 3,846	3.71	Ground	Public
			Monterey Water Co	1,050 440	2.50	Ground	Private

*Constant 1995 dollars per 1,000 gal

**Flat rate price per month

Table 5

CWSR effects to consumers and purveyors by community

Community	Pricing Alternative					
	Status Quo		Cost Recovery		Cost Plus	
Consumer impacts						
	Δ *CS*	%	Δ *CS*	%	Δ *CS*	%
Hurley	-	-	69	24	12	4
Questa	-	-	408	20	28	1
Ruidoso	-	-	4,797	12	455	1
Los Lunas	-	-	3,963	19	337	2
Purveyor impacts						
	Δ *R*	%	Δ *R*	%	Δ *R*	%
Hurley	24	118	20	100	20	100
Questa	8	21	-36	-100	167	458
Ruidoso	37	3	-1,248	-100	2,542	203
Los Lunas	78	7	-1,062	-100	2,317	218

Δ *CS* and Δ *R* in thousands of dollars

% change in *CS* and *R*

Table 6

CWSR consumer effects by system and under two pricing alternatives:

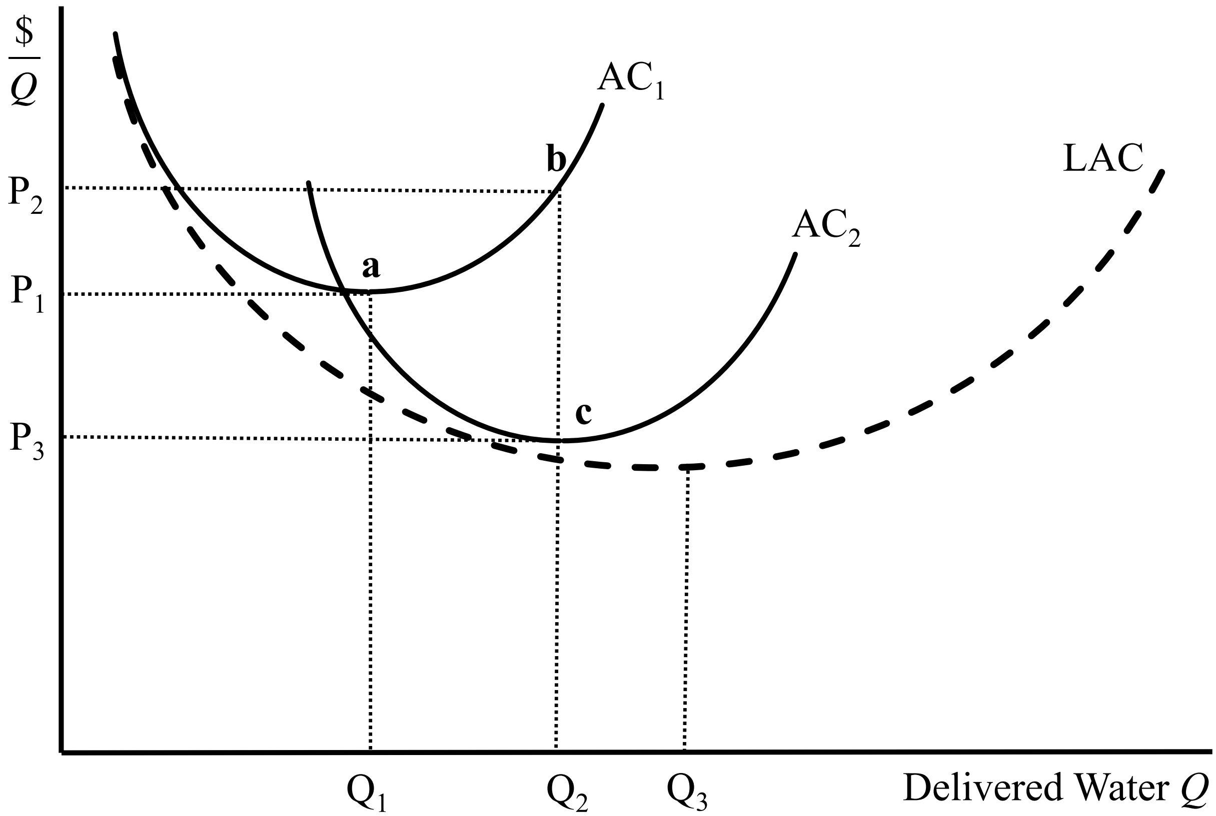
Δ *CS in dollars per connection per year*

Community	CWS	Cost Recovery	Cost Plus
Hurley	Hurley Water Supply System	7	7
	North Hurley MDWCA	538	90
Questa	Cerro East MDWCA	-256	-341
	Questa Water System	542	51
Ruidoso	Alpine Village Sanitation District	206	47
	Rancho Ruidoso Rainmaker	535	67
	Village of Ruidoso	575	54
Los Lunas	Hi Mesa Estates Water Corp	377	83
	Los Lunas	937	92
	Monterey Water Co	732	-59

Figure Captions

Figure 1. Average Cost Curves

Figure 2. Stylized CWS_i Market Model



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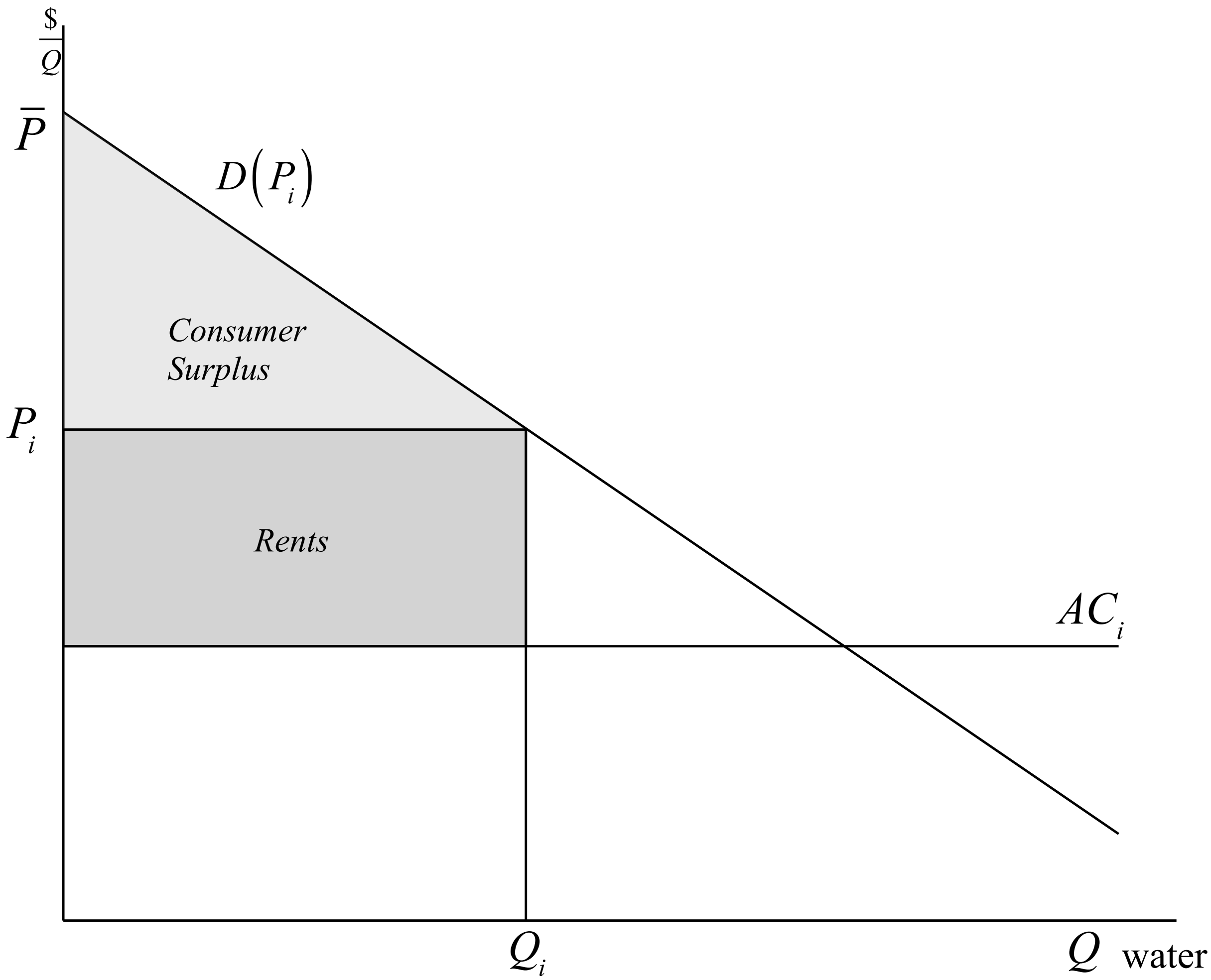

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$D(P_i)$
Consumer Surplus
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Rents
AC_i
Q_i
Q water