ANALYSIS OF PUBLIC SUBSIDY TO RURAL COMMUNITY WATER SYSTEMS

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Introduction

The consolidated Farm and Rural Development Act[1] authorizes the Farmers Home Administration (FmHA) to provide grants and long-term, low interest loans for the installation, repair, improvement, or expansion of rural water facilities. The FmHA provides grant and loan funding for up to 75 percent of an eligible project's cost. Other federal agencies providing loans are Housing and Urban Development (HUD) and the Economic Development Administration (EDA). Other federal agencies providing grants are HUD, EDA, Environmental Protection Agency (EPA), Department of Defense (DOD), and the Ozark Regional Commission (ORC). State loan and grant programs are also available in Oklahoma (see Oklahoma Water Resources Board [25]).

Federal grants and loans have been substantial. The cumulative amounts provided by the FmHA nationally through September 1986 amounted to $2,896 million for 13,327 applications in grants and $9,132 million for 27,957 applications in subsidized loans (see FmHA [10]). A 1978 national survey (see Francis, et al. [14]) showed that FmHA accounted for 93 percent of total government agency loans and 50 percent of total government agency grants. The Oklahoma office of FmHA provided $271.1 million for 1,345 loan applications and $74.9 million for 514 grant applications from 1963-1986 in current dollars.[2]

The FmHA defines a rural water system as one that supplies water to a population of 10,000 persons or less (see Lawrence [22, p. 8]). In 1982 such systems accounted for more than 95 percent of the nation's

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[1]PL 92-419, 30 Aug. 1972, United States Statutes at Large 86, pp. 657-677.

[2]This information was obtained from documents of the FmHA state office.

water systems, but supplied water to less than 25 percent of the population (see Stevie and Clark [27]). In 1984-1985 the Oklahoma Rural Water Association (ORWA) had about 460 systems as members.

The median family income of the persons residing in an area served by a rural water system is used by the FmHA in determining the amount of grant funds made available and the interest rate charged on loans. A poverty line interest rate of 5 percent is used if median income for the system is less than the poverty level of income (see U.S. Department of Commerce [30]). An intermediate rate is used if median family income is greater than the poverty level income but not more than 85 percent of the nonmetropolitan median household income of the state. The market rate is applied to all loans that do not qualify for poverty line rate or intermediate rate.

Once a rural water system has been formed and has received grants and subsidized loans, it is operated like a not-for-profit public utility and generally does not exclude additional connections. Such utilities are in the public's best interest, because the economic structure of rural water systems is characterized as a natural monopoly where the minimum average cost of production occurs at a rate of output more than sufficient to supply the entire market at a price covering full costs.

Households within a rural water system are heterogeneous in income level, occupation of household head, settlement motivation, type of residence, and other characteristics. A random survey of ORWA members (see Dellenbarger [7]) showed that 36 percent of the households had annual incomes less than $15,000, but 11 percent had incomes over $50,000. Median household income was $22,500, only slightly lower than the 1983 median household income for Oklahoma of $24,250. In the same survey, farmers and farm laborers accounted for 11.5 percent of total connections. About 44 percent of the customers lived within the boundaries of the system because of a preference for rural living.

The above data indicate a substantial public interest in rural water systems, with the major benefactors being those households living in rural places. Because grants and subsidized loans are provided by federal and state agencies, the nation and the state also have an interest in whether such funding is used to meet social goals. A question from the public perspective may be whether all rural water system households need to be subsidized, as many such households have incomes close to or higher than the taxpayers providing such subsidies. About half of the rural water system households were motivated in location choice by a preference for rural living. This motivation could be due to locational benefits such as low rent, low land prices, and/or high psychic satisfaction from rural environments that outweigh locational costs such as increased commuting, increased probability of traffic accidents, higher fire insurance rates, etc. Another question may be whether the provision of public subsidies to households expressing a preference for rural living because of locational benefits is efficient, resulting in improved social welfare.

This paper analyzes the distribution of benefits of rural water system public subsidy programs and shows how water pricing strategies can be improved to simultaneously meet specified financial, economic, and social criteria. Financial criteria emphasize revenue requirements or cost recovery. Economic criteria emphasize economic efficiency of resource use. The social criteria include objectives concerning distribution of subsidy benefits. To estimate the distribution of water subsidy benefits, an estimate of rural community water demand is made.

Rural Community Water Demand

A large body of literature on water demand has developed over the last two decades. Major issues still remain, however, with respect to specification of the price variable and to the appropriate estimation technique. A further issue for rural water systems is locational preference. The demand for rural water also may reflect the demand for rural living.

The major problem in modelling water demand is that consumers do not face a single price but a multipart price schedule set by natural monopolistic water systems. Houthakker discusses economic implications of the presence of a price schedule, focusing on which price, marginal or average, should be included in the demand function. Marginal price usually has been the focus (e.g., Howe and Linaweaver [18]). The view argues that consumers respond to the price represented by the marginal step on the rate structure at which the consumer is observed.

Taylor observes that marginal price alone does not represent the effects of the rate structure on consumer response. Rather, a single marginal price governs consumer behavior while the consumer is in that block, but it does not explain why consumption occurs in that block as opposed to some other block. Taylor argues that both block marginal and average price are the correct specifications of consumer behavior for multipart rate schedules.

Nordin modifies Taylor's demand analysis and demonstrates that the theoretically correct specification under block rates is to include, in addition to marginal price, a variable equivalent to a lump sum payment the consumer must make before buying as many units as he or she wants at the marginal price. This lump sum payment represents the difference between what a consumer actually pays and what would have been paid if all units were purchased at the marginal price. This payment is known as the difference variable or the rate structure premium.

Other studies use average price for residential water demand under block rate schedules (see Gottlieb [15], Wong [31], Young [32], Foster and Beatie [12], and Cochran and Cotton [6]). Specifically, Foster and Beatie [11, 13] advocate the use of average price as a proper specification of demand. They question the perfect knowledge postulate implicit in the marginal price model; that is, the likelihood that consumers are aware of the detailed block pricing rate structure. Thus, they believe that consumers may not respond to marginal price or the change in lump sum payment, but are more likely to respond to their total water expenditure. Consumers thus perceive average price as a proxy for the unknown marginal block price. Foster and Beatie concede, however, that the price to which consumers actually respond is an empirical question. Their empirical study shows that parameter estimates from the Nordin specification are not significantly different from an average price specification (see Foster and Beatie [13]).

Opaluch develops statistical tests to determine whether consumers respond to average price or to marginal price plus a difference variable. Using these tests, it was determined that rural Oklahoma households respond to average price (essentially monthly water bill) rather than marginal price (see Kang 20]).

Using ordinary least squares (OLS) entails problems in the presence of block rate schedules because of:

1. the nonlinear nature of the pricing structure, where price depends on discontinuous quantities consumed;
2. the measurement error in water consumption near the boundary of the discrete rate schedule that assigns wrong marginal price and thus introduces errors in the price variables; and

3. the quantity dependent price and thus simultaneity bias (see Chicoine, Deller, and Ramamurthy [5]).

Nonlinearity in quantities consumed may cause biased estimates of the demand parameters; measurement errors may result in both biased and inconsistent estimates; and simultaneity may give both biased and inconsistent estimates.

For the first problem, there is little theoretical knowledge (see Chicoine, Deller, and Ramamurthy [5]). Kelejian theoretically demonstrates that two stage least squares can be used to estimate the parameters of a nonlinear model. Terza and Welch propose a two stage probit approach that is applicable only for increasing block rate schedules. For the second problem, an instrumental variable approach has been applied in several studies (see Billings [3], Henson [16], Jones and Morris [19], Deller, Chicoine, and Ramamurthy [5]). For the third problem, simultaneous equation models have been applied by Adams, Stevens, and Wills [1], Agthe, Billings, Dobra, and Raffiee [2], and Chicoine, Deller, and Ramamurthy [5]. Most empirical studies indicate that alternative estimation techniques (instrumental variable approach and simultaneous equation models) do not differ significantly from OLS results (see Jones and Morris [19], Adams, Stevens, and Wills [1], Chicoine, Deller, and Ramamurthy [5], Deller, Chicoine, and Ramamurthy [9], and Chicoine and Ramamurthy [4]). The Kang estimation used OLS.

Another issue arises over concern with the interrelationships between rural residence and rural water demand. Rural water districts (systems) have enhanced the location alternatives available to households. Cost reducing technologies (i.e., PVC pipe and rapid trenching equipment) and methods for organizing rural water-consuming households fostered by formation of the FmHA rural water districts greatly have reduced the cost and increased the convenience of supplying water to rural residences. Households now may select more easily a rural residence location because of lower cost of living or higher psychic values from a perceived improved environment. Households in rural areas, however, also may incur locational costs such as increased commuting, higher insurance costs, unpaved access roads, lower police and fire protection, and high water connection cost. Given a choice, rational households choose a rural location if the perceived benefits exceed the costs. An annual average growth of 8 percent in the number of rural water district household connections in Oklahoma gives evidence of a strong preference for a rural environment.

This preference for rural residence, however, is an effect on aggregate rural water demand, shifting the demand for rural community water to the right as the number and size of organized rural water systems increase. Without this increase in aggregate rural community water demand, social welfare presumably would be less, but public subsidy also would be less. Whether these externality benefits exist from organized rural water systems could be tested further by comparing increased land rents against costs of rural water system connections. If the land rents increased more than the costs of supplying rural water, then presumably those households preferring a rural residence location would be willing to pay more than the supply cost. In fact, those preferring a rural residence may be willing to pay full costs of supplying rural water, thus eliminating a need for public subsidy.

Two models were specified for rural water demand in Oklahoma. Model 1 distinguishes demand by season, and Model 2 distinguishes demand by season, locational preference, and income level. The models are:

Model 1

$$Q_{it} = \beta_0 + \beta_1 AP_{it} + \beta_2 FAMS_i + \beta_3 YD_{it} + \beta_4 NRS_i + \beta_5 MILE_i + \beta_6 DM_t + \beta_7 APD_{it} + e_{it}$$

Model 2

$$Q_{it} = \beta_0 + \beta_1 AP_{it} + \beta_2 FAMS_i + \beta_3 YD_{it} + \beta_4 NRS_i + \beta_5 MILE_i + \beta_6 DM_t + \beta_7 INDP_i + \beta_8 INDM_i + \beta_9 LPD_i + \beta_{10} APD_{it} + \beta_{11} APYP_{it} + \beta_{12} APYM_{it} + \beta_{13} APL_{it} + e_{it}$$

where

Q_{it} = the quantity of water (1,000 gal.) consumed by household i in month t;

AP_{it} = average price ($) per 1,000 gallons of water for household i in month t;

$FAMS_i$ = number of persons in household i;

YD_{it} = monthly income ($1,000) of household i in month t and is equal to annual household income divided by 12 less Nordin's difference variable or rate premium in month t;

NRS_i = percentage (%) of water used outside the household residence from alternative sources for household i

$MILE_i$ = distance (miles) from residence to work place for household i;

DM_t = dummy variable for season where $DM_t = 1$ if (January-June, October-December) and $DM_t = 0$ if (July-September);

$INDP_i$ = dummy variable for family household income below poverty level where $INDP_i = 1$ if annual household income is less than or equal to $7,938 and $INDP_i = 0$ if other;

$INDM_i$ = dummy variable for family household income more than poverty level but less than median level where $INDM_i = 1$ if annual household income is greater than $7,938 but less than or equal to $25,701 and $INDM_i = 0$ if other;

LPD_i = dummy variable for locational preference where $LPD_i = 1$ if the residents express preference for a rural location and $LPD_i = 0$ otherwise;

APD_{it} = $AP_{it}*DM_t$ (average price and season interaction term);

$APYP_{it}$ = $AP_{it}*INDP_i$ (average price and low income interaction term):

$APYM_{it}$ = $AP_{it}*INDM_i$ (average price and median income interaction term); and

APL_{it} = $AP_{it}*LPD_i$ (average price and locational preference interaction term).

Average price (AP) per thousand gallons of water consumed per month is used as the price response variable based on results of the Opaluch test. This price specification limits the strict interpretation of marginal analysis when equating marginal price with marginal system cost. Because of the apparent response in household water demand to monthly water bill, however, the average price specification was maintained.

Family size (FAMS) is expected to influence positively monthly household water consumption, as is monthly household income (YD). The latter variable includes an adjustment for Nordin's difference variable or for the fact that households have less income available than would be the case if all water consumption were at the marginal price.

Model 2 further distinguishes three income categories including families below the poverty income level (INDP), families with household income above the poverty level but less than the median income (INDM), and families with household income above the median income. The influence of the latter category is contained in the intercept value. The expected relationship of $INDP_i$ and $INDM_i$ with Q_i is negative, indicating lower demand for lower income levels. Also, by including interaction terms with AP, the slope of the demand functions may vary by income category. The interaction terms (APYP and APYM) are expected to be positive, indicating that lower income families would be closer to basic (minimum) requirements for household water and thus less price elastic.

Rural households frequently have alternative sources of water that can be used for watering lawns and gardens and for some agricultural enterprises. To the extent households use these alternative sources, monthly consumption of water from the rural water system will be reduced. The relationship between rural water system demand and alternative source water demand is one of simultaneous interdependence, however, and depends upon the price (cost) of the alternative source as well as the rural water system price. Because information was not available on water consumption outside the residence and on cost of alternative sources of water, a variable defined as the percentage of water used outside the household residence from alternative sources (NRS) is used to approximate this relationship. The expected relationship between NRS_i and Q_i is negative.

Two location variables are included:

1. distance from rural residence to workplace (MILE); and
2. an expressed preference for rural living (LPD).

Distance from residence to work may indicate that longer commuting distances mean households spend fewer hours at home, thereby using less water for normal household functions and for activities outside the household such as gardening. There also may be a simultaneity effect with price of water--households may choose a place of residence further away from work only if cost of water is less. Because water expenditure is small relative to total household expenditure, the first interpretation is proposed. The sign of the coefficient is expected to be negative.

The effect of a behavioral variable on water consumption, like an expressed preference for rural living, is difficult to determine without knowing more about the specifics of behavior.[3] Those preferring rural living may represent a more conservative lifestyle with fewer water-using appliances (i.e., dishwashers) and less emphasis on water-using amenities (i.e., swimming pools). A preference for rural living thus would be related negatively to water consumption. If the preference for rural living is related more to a set of water-consuming activities, such as gardening, then the relationship could be positive. With more specific information on behavior, it would be possible to enter those variables directly to test their effect on water consumption. The current model tests only the broad response to a preference for rural living. Because the specific behavioral factors are not known, the expected sign is indeterminate. The interaction term of LPD with AP will determine if those with preference for rural living are more price responsive or less price responsive than those with no preference. One could argue that once the commitment and investment had been made for a rural location, marginal (or average) price is less important and results in a lower price elasticity. Under these conditions, the expected sign on the interaction term APL is positive.

The Bonferroni inequality test was used to define seasonality of water demand (see Dellenbarger, Kang, and Schreiner [8]). Peak season demand was determined as July through September, with off peak season as the remainder. A dummy variable (DM) was used in the regression models to define seasonality of water demand, with the off peak season taking the value of one and the peak season taking the value of zero. The expected relationship between Q_{it} and DM_t is negative, with off peak season water demand less than peak season water demand. An interaction term of water price and seasonality was included (APD_{it}) to allow for a different slope in the demand function and a different price elasticity of water demand by season. Because water demand is closer to basic requirements during the off peak season, the relationship between Q_{it} and APD_{it} is expected to be positive, thus reducing the price elasticity of demand during that season.

Data were obtained from a survey conducted in 1984 by the Department of Agricultural Economics at Oklahoma State University on Oklahoma rural water systems and households within the rural water systems (see Dellenbarger [7]). A random sample of 21 systems was

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[3] Gary D. Lynne helped the authors to understand better this behavioral response.

drawn, and 14 of the systems provided addresses of households in their system. A 10 percent random sample of households within each system was surveyed. Actual 1983 monthly water consumption and water billings data were obtained from water system records, and a mail questionnaire was sent to each household in the 10 percent sample to obtain data on family income, number of persons in household, alternative sources of water, and other household characteristics.

A total of 347 households responded after one follow-up letter for a 53 percent response rate. Of these, a total of 85 households provided 571 usable monthly observations representing 11 systems. Lack of information on household income and distance to place of work accounted for the 75 percent reduction in observations. Nonresponse bias for those systems not furnishing addresses, households not responding to the questionnaire, and households not responding to specific questions could not be tested. Comparisons for some variables, however, can be made between the sample of 347 households (see Dellenbarger [7]), the sample of 85 households (see Kang [20]), and the values from state census. For example, the mean monthly consumption of water per household from the sample of 347 is 7,140 gallons versus 7,394 gallons for Model 1 and 7,579 gallons for Model 2 that represents the sample of 85 households (Table 1). Median family income ranges from $20,001 to $25,000 in both samples; this compares with median income for the state of $24,250 which also would fall within the sample survey income range. Average number of persons per household is 2.8 for the sample of 347 households and 3.0 for the sample of 85 households. This compares with number of persons per household of 2.8 from census data (1980) for rural areas in Oklahoma. Based on these variables, it appears that the sample of 85 households is not biased in a significant manner from the sample of 347 households, and both samples are consistent with state data.

The two estimated water demand equations using OLS are shown in Table 1. In Model 1, the coefficients for all variables are of the expected sign and significant at the 5 percent probability level. Adjusted R^2 is 0.46. This equation gives seasonal water demands. A structural stability test for the equivalence of intercept and slope for the two seasons gives an F-statistic of 30.09 that is significant at the 5 percent probability level, indicating a difference in water demand between the two seasons.

In Model 2, coefficients of all variables except NRS are significant at the 5 percent probability level. The signs for similar variables in

Models 1 and 2 are the same, except NRS. The change in sign for NRS and its low level of significance are probably more indicative of the poor quality of measurement than of importance of the variable. The negative coefficients on the dummy income variables (INDP and INDM) indicate that lower income groups are structurally at lower water demand levels. The statistically significant negative coefficient on preference for rural living (LPD) indicates that such households have a behavioral response to consuming less water. The reasons for this behavioral response cannot be interpreted with the sample data.

All interaction terms with average price are positive, indicating that season, income, and preference for rural living have moderating effects on the highly significant direct negative effect of price on water demand. Adjusted $\bar{R}^2$ is 0.50. Model 2 gives seasonal water demands by household income level and locational preference. A structural stability test for the equivalence of intercept and slope across household groups gives an F-statistic of 2.04 that is significant at the 5 percent probability level, indicating differences between the household groups.

Elasticities are calculated for each season (Model 1) and for each household group (Model 2) at the mean monthly water consumption and mean price (Table 2). In general, low income groups are less price elastic than high income groups. This is consistent with low income groups being at water consumption levels closer to the basic requirement. Groups with preference for rural living are less price elastic than groups with no locational preference. Peak season water demand is more price elastic than off peak season. This is consistent with the off peak season having less discretionary water use and lower price elasticity. Weather factors such as rainfall and temperature may influence water demand--thus, the result for 1983 in Oklahoma may be different from that for other years.

Water Subsidy Distribution

A complementary survey of the same 11 systems used in the demand estimation was conducted in 1987 to collect data on subsidies received by the rural water systems in Oklahoma through the FmHA or other public agencies. Data on subsidies (grants and low interest loans) administered by the FmHA were collected from the permanent records of the district offices. Data on subsidies provided by other agencies were obtained from the individual rural water systems.

All the systems surveyed received low interest long-term loans, and all but four received grants. All the loans were supplied exclusively from FmHA. Nine systems received more than one loan from FmHA. Interest rates ranged from a low of 3.75 percent to a high of 5 percent per year. The subsidized rate is compared with the long-term U.S. Treasury bond rate at the time of each loan. The latter interest rate can be presumed closer to the social discount rate because it represents the opportunity cost of government funds used in providing public subsidies. Loans provided in the 1980s were subsidized more heavily than loans provided in the 1960s and the 1970s. Repayment period was 40 years for all loans.

The average amount of grant(s) per system was $100,248. The average amount of loan(s) per system for the 11 systems was $946,696 at current prices. The annualized cost of public subsidy is calculated in 1983 prices using the social discount rate identified above. The average annual subsidy provided the sample of rural water systems was $52,144, with the highest subsidy equal to $389,992 and the lowest subsidy equal to $464. The average subsidy per thousand gallons of water supplied by the sample of systems was $0.83, the highest subsidy equal to $1.66, and the lowest subsidy equal to $0.03.

Using the demand equations presented earlier and the average subsidy per thousand gallons of $0.83, the amount of subsidy paid to group i was derived by Kang as:

$$S_i = q_{i1} (p_{i1}-p_{i2}) + 0.5(q_{i2}-q_{i1}) (p_{i1}-p_{i2})$$

where

S_i = total amount of subsidy paid to a rural household belonging to group i;

q_{i1} = quantity of water demanded without subsidy for a rural household belonging to group i;

q_{i2} = quantity of water demanded with subsidy for a rural household belonging to group i;

p_{i1} = price of water per thousand gallons at consumption level q_{i1}; and

p_{i2} = price of water per thousand gallons with subsidy and results in consumption q_{i2}.

The subsidy distributions by rural household group are presented in Table 3. In off peak season, average monthly subsidy per household is \$4.23 and in peak season \$6.62, for an annual subsidy of \$57.93. Among the different household groups, poverty income households preferring rural living received the lowest monthly subsidy of \$2.64, and high income households with no locational preference received the highest monthly subsidy of \$10.76. Subsidy amounts were higher in peak season than in off peak season and were higher for households with no locational preference than for households with preference for rural living, except in the case of middle income groups. In general, public subsidies in absolute amount are greater to higher income groups and to groups with no locational preference.

Water Rate Schedules

The policy objective in providing public subsidy to rural water systems is to assist target groups (low income households and rural fixed location residents) by reducing water use cost. Thus, water rate schedules should incorporate strategies for improving efficiency of the subsidy program including the policy objective.

Water rate schedule determination in rural water systems is generally subject to three criteria: financial, economic, and social. Financial criteria emphasize cost recovery. Economic criteria emphasize economic efficiency in resource use, and social criteria emphasize allocation of water service benefits and costs. A fourth criteria of importance may be administrative cost if the social criteria includes costly implementation and monitoring procedures.

Consider a rural water system characterized with long-run marginal cost (LMC), long-run average cost (LAC), and aggregate water demand (D_A) in Figure 1(c). Suppose the water system serves two households with water demands D_L (low income) and D_H (high income) in Figure 1(a) and 1(b). For the moment, assume demand functions estimated from marginal price rather than average price (monthly water bill) as discussed earlier. Marginal cost pricing establishes water price P_m for the water system. Household L consumes q_1 and household H consumes q_2 at P_m, respectively. If pricing is other than P_m, there will be underuse or overuse of resources, and the economic efficiency criteria are not met. Each household faces the same marginal price (cost) for incremental capacity. Under economically efficient marginal cost pricing, however, total revenue does not cover total cost for the rural water system characterized by decreasing unit costs. The rural water system experiences negative cash flow equal to the area P_aJKP_m and does not meet the financial criteria.

Two approaches may be considered to meet revenue requirement for the financial criteria. The first approach is to make up all revenue loss through a public subsidy. In this case, the financial and economic criteria are met. The policy objective (social) criteria may not be met, because high income households with higher water consumption are subsidized more than low income households with lower water consumption and because public subsidy may come from taxpayers with incomes lower than the higher income households who are recipients of subsidized water.

The second approach is to use block rate schedules. This approach is used when public subsidy is not large enough to cover all revenue loss. The most common schedule is a decreasing block rate. The block rate may be set with marginal price discrimination or without marginal price discrimination. These two block rates are illustrated in Figure 2.

Suppose D_A is aggregate water demand for a two household rural water system characterized with long-run average cost (LAC) and long-run marginal cost (LMC) in Figure 2(b). In Figure 2(a), D_L is water demand for the low income household, and D_H is water demand for the high income household. Suppose the system sets a water rate schedule abcf so that the two households face the same marginal price (cost) MC_0 and the initial block rate is designed to meet revenue shortage at marginal cost pricing. At marginal cost price P_H, the low income household demands q_L, and the high income household demands q_H. This rate schedule is efficient, because each household pays the same marginal price and is equal to the marginal cost. It meets revenue requirements by taking more consumer surplus through the higher initial block rate. The low income household pays higher average price, however, which is not consistent with the public subsidy policy objective of reducing water use cost for low income households.

Next consider the rate schedule adef which is a schedule frequently used by rural water systems (see Dellenbarger [7]). The financial objective is to encourage water consumption because of decreasing unit costs but to capture sufficient consumers surplus to equate total revenue with total cost. With this discriminatory marginal rate schedule, water demand for the low income household is q_L' and water demand for the high income household is q_H. Water system demand is $q_L' + q_H$ and system marginal cost is MC_1. Under this rate schedule, the low income household pays the higher marginal price (PL), and the high income household pays a marginal price (PH) lower than the system marginal cost MC_1. With this rate schedule, marginal benefits in the aggregate are greater than marginal costs. There is a loss of aggregate benefits equal to the shaded area in Figure 2(b). Discriminatory marginal rate schedules are not consistent with marginal cost pricing because each household group pays a different marginal price. It is also not consistent with objectives for public subsidy, as low income households pay an even higher average price than under nondiscriminatory marginal rate schedules.

The fact that water demand as presented previously is estimated from average price rather than marginal price does not change the equilibrium results of Figure 1. To obtain the equilibrium results, however, a rate schedule would have to be constructed for each of the two households to give an average price of P_H. At that average price, household L consumes q_1, household H consumes q_2, and aggregate demand is $q_1 + q_2$. If public subsidy is used to meet the revenue loss when all water is priced at P_H, then the average price to both households is also P_H--the equilibrium results of Figure 1 are attained. This also means the financial and economic criteria are met, but the social criteria are not. As shown in Table 3, the difference in water consumption between poverty income households and high income households with subsidy ranges from 2,677 to 6,643 gallons per month depending on season and locational preference. Clearly the high income households would benefit more than the low income households from the public subsidy. Furthermore, the public would be subsidizing high income households that perhaps are choosing rural locations because of preference for a rural environment.

A decreasing block rate schedule can reduce the amount of public subsidy needed to meet the financial criteria. A decreasing block rate structure with nondiscriminatory marginal price, however, gives a higher average price to low income households than to high income households, reduces the quantity of water demanded by low income households more than by high income households, and shifts public subsidy more toward the high income households. A decreasing block rate structure with discriminatory marginal price intensifies the results of the nondiscriminatory decreasing block rate structure. Thus, a common rate structure encountered in rural water systems increases average water price to low income households, thereby reducing their water consumption and shifting more of the public subsidy to high income households.

This result is not necessary. Because each individual household has its own separate water meter, water rate schedules can be constructed that target public subsidies more closely to low income and fixed location (i.e., farm family) households.

There are many such water rate schedules but they are all discriminatory--they charge low income and fixed location households less than high income and locational preference households. For economic efficiency, they should charge the same marginal price to all households in the system for the last unit of water consumed, and this price should reflect the marginal cost of supplying that unit.[4] One type of discriminatory rate schedule would be to charge low income households a lower rate for the initial block(s) of water consumed. This reduces average price of water, marginally increases their water consumption, and shifts the public subsidy back toward low income households. A second type of discriminatory rate schedule would be to provide low income and fixed location households an annual (quarterly or semiannual) rebate based not on amount of water consumed but on level of income and/or reason for residing in the system boundary (i.e., farm operator or farm laborer).

Conclusions and Policy Implications

This study has provided policy makers additional information on the distribution of public subsidy to rural water systems. Subsidy distribution is higher for high income groups and lower for low income groups. Furthermore, substantial public subsidy is paid to those households preferring rural living even though they could locate in an urban area. If the emphasis is to promote development of rural areas, policy makers may view this as a positive contribution.

Public subsidies to rural water systems do not appear to be well targeted. Subsidies have been granted to rural water systems and not to targeted groups within those systems. In general, all households within a rural system face the same rate structure. The subsidies,

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[4]This assumes equal marginal costs in delivering water to all rural households and businesses. This may not be the case if some households are in isolated areas of the system or if businesses require large volumes of water and unit costs decrease with increased volume.

therefore, have been used to lower overall water costs; the larger consumers of water benefit most from the subsidies.

Targeting of subsidies can be improved. Low income households can be assisted through reduced connection costs and/or a reduced initial block rate in monthly billings. The latter method, however, may encourage water consumption among low income groups beyond the point where their marginal benefits are equal to or greater than the costs of supplying the marginal units. An annual (semiannual) rebate based on a proportion of the costs in supplying basic household water requirements would reduce costs to low income households but would not encourage excess water consumption.

Subdivisions in rural areas and nonfarm residences could be charged full costs of connection and full costs of water supply. This would allow households to enjoy net locational benefits from a rural residence without the additional benefits of a public subsidy. This also should bring more efficient location of rural residences.

water consumption and shifting more of the public subsidy to high income households.

This result is not necessary. Because each individual household has its own separate water meter, water rate schedules can be constructed that target public subsidies more closely to low income and fixed location (i.e., farm family) households.

There are many such water rate schedules but they are all discriminatory--they charge low income and fixed location households less than high income and locational preference households. For economic efficiency, they should charge the same marginal price to all households in the system for the last unit of water consumed, and this price should reflect the marginal cost of supplying that unit.[4] One type of discriminatory rate schedule would be to charge low income households a lower rate for the initial block(s) of water consumed. This reduces average price of water, marginally increases their water consumption, and shifts the public subsidy back toward low income households. A second type of discriminatory rate schedule would be to provide low income and fixed location households an annual (quarterly or semiannual) rebate based not on amount of water consumed but on level of income and/or reason for residing in the system boundary (i.e., farm operator or farm laborer).

Conclusions and Policy Implications

This study has provided policy makers additional information on the distribution of public subsidy to rural water systems. Subsidy distribution is higher for high income groups and lower for low income groups. Furthermore, substantial public subsidy is paid to those households preferring rural living even though they could locate in an urban area. If the emphasis is to promote development of rural areas, policy makers may view this as a positive contribution.

Public subsidies to rural water systems do not appear to be well targeted. Subsidies have been granted to rural water systems and not to targeted groups within those systems. In general, all households within a rural system face the same rate structure. The subsidies,

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[4]This assumes equal marginal costs in delivering water to all rural households and businesses. This may not be the case if some households are in isolated areas of the system or if businesses require large volumes of water and unit costs decrease with increased volume.

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Table 1
Estimated Water Demand for Rural Communities in Oklahoma, 1983[a]

	Model 1		Model 2	
Variable	Mean Value	Regression Coefficients, t Values, and Other Statistics	Mean Value	Regression Coefficients, t Values, and Other Statistics
Intercept		10.806 (8.83)		19.329 (8.25)
AP	3.36	-2.659 (-9.91)	3.34	-5.654 (-12.34)
FAMS	3	1.587 (8.90)	3	1.166 (5.83)
YD	2.14	1.468 (8.45)	2.18	1.852 (4.59)
NRS	26	-0.010 (-1.91)	27	0.003 (0.56)
MILE	7.5	-0.057 (-2.72)	7.8	-0.065 (-2.81)
DM_1		-7.545 (7.17)		-6.848 (-6.38)
APD		1.487 (4.99)		1.283 (4.23)
INDP				-6.864 (-3.03)
INDM				-5.843 (-3.28)
LPD				-4.892 (-4.02)
APYP				2.699 (6.42)
APYM				2.389 (5.72)
APL				1.356 (3.68)
n[b]		571		511
$\bar{R}^2$		0.46		0.50

[a] Mean of dependent variable $\bar{Q}$ was 7,394 gallons for Model 1 and 7,579 gallons for Model 2

[b] The difference in sample size is due to missing data on locational preference

Table 2
Price Elasticities of Water Demand by Season and Household Group for Rural Communities in Oklahoma, 1983

Group	Mean Quantity of Water (gal.)	Price Elasticity
Model 1		
Off Peak Season	5,587	-0.78
Peak Season	9,084	-0.91
Model 2		
Off Peak Season		
Prefer Rural Living		
Poverty Income	3,311	-0.26
Middle Income	5,311	-0.35
High Income	5,988	-1.87
No Locational Preference		
Poverty Income	5,142	-0.73
Middle Income	5,784	-1.25
High Income	8,938	-1.48
Peak Season		
Prefer Rural Living		
Poverty Income	7,145	-0.54
Middle Income	8,171	-0.72
High Income	11,066	-1.16
No Locational Preference		
Poverty Income	8,665	-0.82
Middle Income	8,343	-1.37
High Income	15,308	-0.88

Table 3

Water Cost Subsidy Distribution Among Rural Household Groups in Oklahoma

Household Group	Quantity With Subsidy (Gal./Month)	Price With Subsidy ($/1,000 Gal.)	Subsidy Per 1,000 Gal. ($)	Price Without Subsidy ($/1,000 Gal.)	Quantity Without Subsidy (Gal./Month)	Subsidy Distribution Per Household ($/Month)
Model 1 Demand						
Off Peak Season	5,587	3.71	0.83	4.54	4,612	4.23
Peak Season	9,084	3.16	0.83	3.99	6,874	6.62
Model 2 Demand						
Off Peak Season						
Prefer Rural Living						
Povery Income	3,311	2.88	0.83	3.71	3,049	2.64
Middle Income	5,311	3.10	0.83	3.93	4,790	4.19
High Income	5,988	3.59	0.83	4.42	4,034	4.16
No Location Preference						
Poverty Income	5,142	2.23	0.83	3.06	3,754	3.69
Middle Income	5,785	3.68	0.83	4.51	4,146	4.12
High Income	8,938	3.03	0.83	3.86	5,320	5.92
Peak Season						
Prefer Rural Living						
Poverty Income	7,145	2.53	0.83	3.36	5,814	5.38
Middle Income	8,171	3.13	0.83	3.96	6,589	6.13
High Income	11,066	3.02	0.83	3.85	7,515	7.71
No Location Preference						
Poverty Income	8,665	2.41	0.83	3.24	6,201	6.17
Middle Income	8,343	3.53	0.83	4.36	5,625	5.80
High Income	15,308	2.38	0.83	3.21	10,626	10.76

Figure 1
Efficient Water Pricing
with Full Subsidy for Revenue Loss

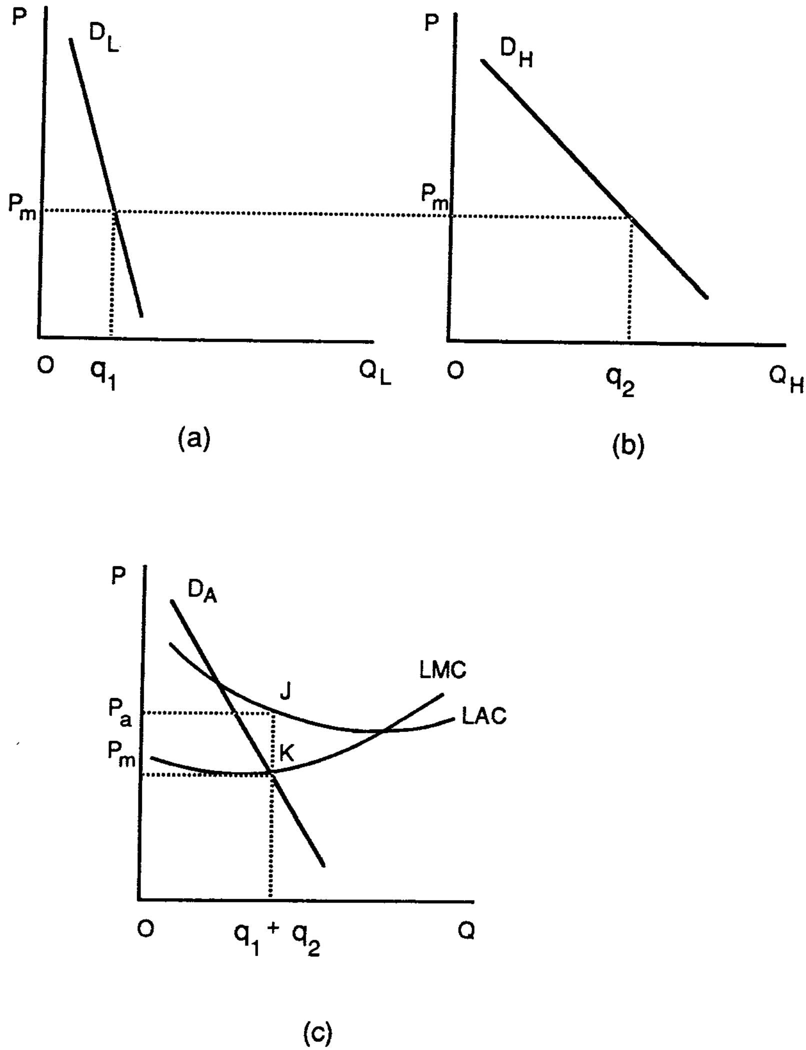
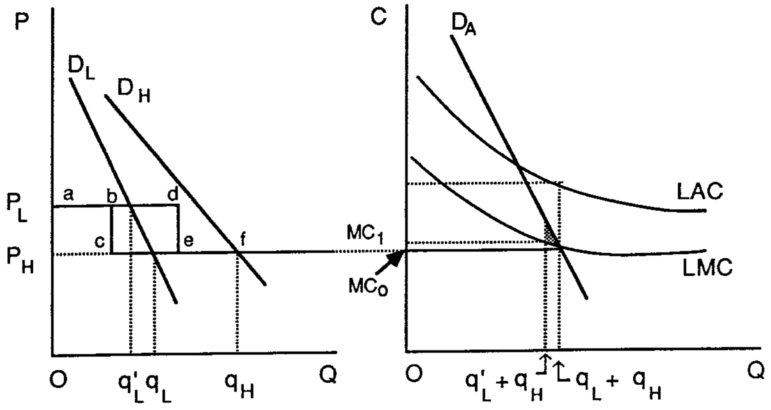


Figure 2
Block Rate Schedule
with Marginal Price Discrimination
and Without Marginal Price Discrimination



(a)

(b)