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EQUITY AND EFFICIENCY IN PRICING LOCAL PUBLIC SERVICES:

THE CASE OF WASTEWATER

by

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Pricing decisions for local wastewater services can play a crucial role in the attainment of efficiency with equity. Normative judgments about equitable service should include concepts of ability-to-pay across users of the service, and concepts of spatial equity. The determination of a price for wastewater service, using the objectives of efficiency, equity, and simplicity, may better suit the goals and policies of local officials than the traditional determination of price through the cost-of-service method.

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Much has been written in the economic literature about pricing local public services. If a public service is defined as a public enterprise, or public utility, the management is often charged by statute to operate the enterprise in an economically efficient manner and to provide equitable service to all users. Locally provided wastewater service is an example of such a public enterprise.[1] Given the range of constraints imposed on local officials by state and federal guidelines, standards, local institutional structures, one of the most effective tools for shaping local public enterprise policy and achieving efficient and equitable service can be the tool of price making for the local public service.

The subject of this paper is an examination of pricing decisions for local wastewater systems. The two primary objectives of pricing decisions are efficiency and equity. Concurrent with these objectives, moreover, are the more publicly recognized qualifications that the rate structure should be acceptable to the public and easily understood, financially sound, and administratively feasible. We shall focus our attention on a model of pricing which incorporates these criteria into the rationale of adminstered pricing for local wastewater systems, abstracting from the recognized peak loading problems.

The design of a conceptual model which integrates efficiency and equity criteria into a pricing decision is contingent on an acceptable definition of equity. The traditional viewpoint of water and wastewater managers is that equitable service is provided when each user pays the full cost of service (to the user). This bias toward full cost of service criteria in ratemaking design stems from the view that cost is a criterion of both efficiency and equity [Greene, p. 32]. The recommendations of the professional societies, from whose ranks come the managers of wastewater systems, state that a rate structure is efficient and equitable if service is provided at least cost and if each user pays in approximate proportion to the cost of providing service to each user [Joint Committee Report, p. 7].

If it is assumed that a measure of marginal cost is a good proxy for marginal benefit, this approach conforms closely with the "benefit approach" in the theory of public finance [Musgrave, pp. 61-89; Gillespie, pp. 130-131]. This approach to public prices can be criticized on philosophical grounds,[2] but is subject to more precise criticism with the realization of the practical difficulties of allocating joint fixed and variable costs to users. Joint costs are a distinguishing characteristic of water and wastewater systems.

Rather than defining equity in terms of cost or marginal willingness-to-pay, thus constraining the definition of equity to the implausible condition of independent utilities among users, we can define equity in terms of ability-to-pay, which broadens the concept of equity to interdependencies among users. The ability-to-pay criterion invokes a concept of relative social welfare among wastewater service users [Behrens and Smolensky, p. 11].

The model presented here has its genesis in the work of Feldstein [1971, 1972], and is designed to show the derivation of an optimal price (in terms of efficiency <u>and</u> equity) for a public service when the public enterprise must cover total costs, but may operate at a scale where marginal cost is below average cost. The Feldstein model conforms to our definition of equity as ability-to-pay. The optimal price as determined by the model conforms to the objectives of efficiency, equity, and simplicity.

The practicality of this pricing model is apparent from the view of the applied theorist, however, different interpretations of several variables will be necessary for real world refinements. We shall leave the structure of the model intact, conforming where possible to the same parameter symbols of Feldstein. Our interest is in showing how a slightly different interpretation of the variables can render the pricing model of more interest and value to local decision makers, without changing the structure of the model.

In considering here only the application of pricing for household users of sewerage service, it is desirable to restrict the pricing analysis to considerations of a two-part tariff[3]; a constant marginal price per unit purchased and a fixed annual charge for the "right to purchase" at the marginal price. Both this marginal price and fixed charge are the same for all users. Marginal-cost pricing in a two-part tariff is subject to the criticism of the distortionary effects of a regressive head tax. What is needed is a pricing rule that balances efficiency and equity so that welfare losses will be minimized.

It is the nature of statements about equity that they are necessarily normative judgements. This model of pricing recognizes the normative nature of equity judgments, but allows the practitioner to specify this judgment explicitly. In order to make equity judgments, we need to know something about the distribution of household welfare.[5] Feldstein contends that this distribution can be represented by the relative density function of household income, f(y).

As the first point of departure from the Feldstein model, two additional comments are necessary here. First, the measurement of household income, a common measure of ability-to-pay, is subject to deficiencies. Reported annual household income is closer to a measure of transitory income than permanent income, the latter being a better measure of relative well-being among households [Reid, DeLeeuw, Carline]. For our purposes, a measure of ability-to-pay for a service such as wastewater collection and treatment, which is a household utility augmenting service, is annual cash expenditure on housing. This measure better reflects a household's economic position, and does not vary as much as transitory income.[6] The distribution of this measure can be represented by the relative density function f(h).

Second, when urban planners and local officials speak of equity in the provision of public services, they are concerned with spatial equity as well as equity across income groups. The concern for spatial equity arises with the recognition of the problems of urban sprawl, and the high cost of public services to low density areas. To incorporate a measure of spatial equity into the pricing model, we shall specify the relative density function f(h) as the marginal density function f(h;d), conditional upon the population density, d.

Now, in making the transformation from annual expenditure for housing to household social utility, there must be a specified housing expenditure-utility relationship. It can be postulated that household social utility is an increasing function of housing expenditure. The marginal social utility of a dollar of housing expenditure will be denoted as u'(h). It can be assumed that u'(h) is invariate with the marginal price and annual fixed charge, although this assumption is not necessary.

An intuitively natural formulation of the relationship between u'(h) and h is a constant negative elasticity between the two. The greater this elasticity, the greater the relative weight to be given to the relevant consumer surplus of low housing expenditure households, given the population density. A range of values for this elasticity can be thought of as policy parameters to test the sensitivity of the pricing results to equity judgments.

The total quantity purchased, Q, of the public service (measured in volume) when the marginal price is π and the population density is given is:

$$Q_d = N \int_0^\infty f(h;d)\, q\, (\pi,h)\, dh; \qquad (1)$$

where N is the number of households served, and $q(\pi,h)$ is the quantity consumed by a household with housing expenditure h when the price is π. The total cost of supplying Q is C(Q). It should be noted here that the total cost function is not a function of the quantity of wastewater treated alone, but is also a function of the areal extent of the collection network. Network costs can be expressed in terms of area, and population density. If there is a unique relationship between Q and d, the total cost function can be expressed as C(Q(d)): We shall retain the basic form C(Q), and recall latter the implications of the composite function.

The annual fixed charge to each household is:

$$A = \frac{1}{N}[C(Q) - \pi Q] \tag{2}$$

The consumer surplus of a household with housing expenditure h subject to price price π is $S(\pi,h)$. The net consumer surplus is:

$$S(\pi,h) - A = S(\pi,h) - \frac{1}{N}[C(Q) - \pi Q]$$

The net consumer surplus is measured in dollars. For aggregation over consumers it must be weighted by the relative social marginal utility of housing expenditure to households $u'(h)$. The aggregate consumer surplus is:

$$V = N\int_0^\infty f(h;d) \quad u'(h) \quad \{S(\pi,h) - \frac{1}{N}[C(Q) \quad - \pi Q]\}dh \tag{3}$$

The problem then is to maximize V subject to the constraint that the fixed charge A will be non-negative. We can maximize V directly, ignoring the constraint, and make adjustments in price later if the constraint is violated. The first order condition for a maximum of V with respect to π is:

$$N\int_0^\infty f(h;d) \quad u'(h)[\frac{\partial S(\pi,h)}{\partial \pi}]dh \quad = \quad [(\frac{\partial C}{\partial Q} - \pi)\frac{\partial Q}{\partial \pi} - Q]\int_0^\infty f(h;d)\ u'(h)\ dh \tag{4}$$

This result is subject to adjustment where the income effect on demand operating through housing expenditure, has a decided magnitude [Feldstein, 1972, p. 177].

After substitution for $\frac{\partial S(\pi,h)}{\partial \pi}$ and Q, and rearranging, (4) can be written as:

$$\left[\frac{\pi - \frac{\partial C}{\partial Q}}{\pi}\right]\left(\frac{\partial Q}{\partial_\pi}\frac{\pi}{Q}\right) = \frac{\int_0^\infty f(h;d)u'(h)q(\pi,h)dh - \int_0^\infty f(h;d)q(\pi,h)dh\int_0^\infty f(h;d)u'(h)dh}{\int_0^\infty f(h;d)q(\pi,h)dh\int_0^\infty f(h;d)u'(h)dh} \qquad (5)$$

For interpretation of the ratio of integrals the reader may consult Feldstein [1972, p. 178]. The left side of (5) is the product of the excess of optional price over marginal cost, relative to that price, and the aggregate elasticity of demand at the optimal price. The interpretation of this result is as follows: charging more than marginal cost requires higher-housing expenditure households to pay a larger share of the fixed cost; the inefficiency loss due to net pricing at marginal cost is outweighed by gains in distributional equity.

So far this result is of little practical use. To make the price expression operational in the sense that judgments about pricing can be made for a real world wastewater service, we need to represent household demands that can be estimated with easily estimated parameters.

Household demand for wastewater services can be expressed in the functional form [Feldstein, 1972, p. 174; Howe and Linaweaver, p. 19]:

$$q = a\pi^\beta h^\alpha$$

Equation (5) now becomes:

$$\left(\frac{\pi - m}{\pi}\right)\beta = \frac{\int_0^\infty f(h;d)u'(h)h^\alpha dh}{\int_0^\infty f(h;d)u'(h)dh\ \int_0^\infty f(h;d)h^\alpha dh} - 1$$

The ratio of integrals is called the distributional parameter, D, [Feldstein, 1972, p. 179].

The expression m is the marginal cost of service. It should be noted that m, because of the total cost function expressed above, is a function of population density, d; i.e., m(d). This implies that the optimal price will be different for different areas of the service district, depending on the population density. Because low density areas can be serviced only at a higher marginal cost [Downing; Dajani and Gemmell], low density suburban areas at the metropolitan fringe will be charged at a higher marginal price.

An explicit formula for π is not yet available until the distribution parameter, D, has more explicit meaning. To do this we can specify $u'(h)$ and $f(h;d)$. The normative judgment for equity is embodied in the form $u'(h) = h^{-\eta}$, a constant elasticity marginal utility function. The form of $f(h;d)$ is unknown but can be determined from the data of the sewerage district being examined. For purposes of this paper, we can, like Feldstein, assume that $f(h;d)$ has a log-normal distribution. With these assumptions, the distributional parameter, D, now becomes $D = \exp[-\alpha\eta\sigma_h^2]$, and the optimal price is expressed as:

$$\pi_d = \frac{\beta}{[\beta + 1 - (1 + \frac{\sigma_h^2}{\mu h})^{-\alpha\eta}]} m(d) \qquad (6)$$

Equation (6) is the operational formula for pricing as derived by Feldstein.[7] The results here are merely illustrative in order to show that an operational formula for pricing decisions which include both efficiency and equity objectives, and maintain the criterion of simplicity, can be reduced to a function of the normative parameter η, and the estimable demand parameters β and α.

To illustrate the analysis necessary for the practical implementation of the Feldstein pricing formulation, we present some hypothetical (but realistic) parameter values applicable to wastewater service provided by the Madison Metropolitan Sewerage District. If the ratio of price to marginal cost $(\frac{\pi}{m})$ is written as a function of the elasticity of marginal utility of housing expenditure, η, we see how the markup of price over marginal cost varies with normative judgments about the value of the parameter η. Values of the demand parameters, β and α, and mean and variance of monthly housing expenditures for a combination of owners and renters are presented in Table 1.

TABLE 1

price elasticity	β*	-0.191
income (housing) elasticity	α*	0.3057
mean monthly expenditure	μ_h**	147.54
variance	σ_h^2**	1125.07

*Values are from a recomputation of Howe and Linaweaver data, using a weighted variable to correct for grouping heteroskedasticity.

**Estimates are from Block Statistics, Final Report, HC(3)270, Madison, Wisconsin Urbanized Area.

We can note that there is a practical limit to the $(\frac{\pi}{m})$ ratio. The lower limit is unity; pricing below marginal cost is clearly inefficient. The upper limit for $(\frac{\pi}{m})$ is that value where π equals average cost. Pricing above average cost is also ruled out on efficiency grounds. The range of value for the normative parameter, η, is from zero (implying that distributional equity is of no consequence, thus $\pi = m$) to the value of η determined where π equals average cost. It is therefore possible that average cost pricing will be the most desirable outcome if elasticities are sufficiently low, or if the relative variance is large. Table 2 shows the relationship between $(\frac{\pi}{m})$ and η, holding the values of α, β and relative variance constant at the values in Table 1.

TABLE 2

$(\frac{\pi}{m})$	η
1	0
1.02	.25
1.04	.50
1.06	.75
1.09	1.00
1.19	2.00
1.31	3.00

For the case of MMSD the ratio of price to marginal cost increases rather slowly as the value of the normative parameter η increases. Furthermore, the small relative variance has a greater absolute effect on $(\frac{\pi}{m})$ than the inelastic demand for wastewater services. Table 3 shows the marginal change in $(\frac{\pi}{m})$ due to unit changes in β and D, where

$$\frac{\partial(\frac{\pi}{m})}{\partial\beta} = \frac{-(D-1)}{[\beta-(D-1)]^2} > 0$$

and

$$\frac{\partial(\frac{\pi}{m})}{\partial D} = \frac{\beta}{[\beta-(D-1)]^2} < 0$$

TABLE 3

η	$\frac{\partial(\frac{\pi}{m})}{\partial\beta}$	$\frac{\partial(\frac{\pi}{m})}{\partial D}$
0	0.000	-5.236
.25	0.110	-5.453
.50	0.228	-5.683
.75	0.357	-5.927
1.00	0.495	-6.186
2.00	1.175	-7.400
3.00	2.123	-8.980

For the entire range of values for η, $\left|\frac{\partial(\frac{\pi}{m})}{\partial D}\right| > \left|\frac{\partial(\frac{\pi}{m})}{\partial \beta}\right|$ showing that the ratio of price to marginal cost is more sensitive to the relative variance of housing expenditure and its elasticity than to the price elasticity of demand for wastewater service.

If, however, the ratio of average cost to marginal cost is small, average cost pricing may then be desirable for efficiency and equity. The ratio of average cost to marginal cost is likely to vary considerably as the population density varies throughout the service area. Verification of the functional forms of the model is a goal of ongoing research by the authors.

The adjustments made in the interpretation of the variables of distribution, household utility, and spatial equity permit a more practical interpretation of pricing decisions for wastewater services. It is not advocated that this pricing solution is a once-and-for-all solution. Once the parameters have been estimated and evaluated it is still only possible to make value judgments about tradeoffs between efficiency and equity. These parameter values merely make tradeoff judgments more enlightened depending on the degree of faith one has in their accuracy.

It is further recognized that this particular pricing model assumes that the management of the public enterprise has full centralized authority to set prices for all users. This authority is not present for the example of MMSD, where user charges are levied on municipalities which in turn set prices to be levied on their own users. There is a distinct possibility that the municipal user charges could thwart the goals of efficiency and equity in pricing as sought by the public enterprise. This possibility suggests a closer look at the institutional constraints on such a centralized pricing policy, and the possibilities for institutional reform.

Given that equitable and efficient pricing for public services is a recognized goal of local givernments, and may also be an effective tool in combating urban sprawl, the method of pricing presented here represents a decided advantage over the traditional view of linking equity with the full cost of service.

FOOTNOTES

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1. In Wisconsin, metropolitan sewerage districts, utility districts, and town sanitary districts are special purpose units of governments operating under the authority and powers vested by the state. Although these entities are units of government, their single purpose nature makes them comparable to public enterprises.
2. The philosophical or political basis for argument on this point can be traced to the earliest writings of the classical economists. See, e.f., Myrdal, pp. 156-190.
3. Extensions of the model to include all sectors of the economy, and to considerations of the peak loading problem, would undoubtedly require relaxing this restriction.
4. This need not be so; the marginal price could vary with the amount purchased or with location.
5. There is a divergence of opinion here concerning the meaning of equity. Legal and institutional scholars contend that equity is a process toward equality rather than a state of the socio-economic structure of society. We can take the latter view only insofar that a given state of equity indicates the workings of the process toward equality.
6. For owner-occupied households the variation in transitory income can affect the variation in annual housing expenditure through the income tax structure where mortgage interest is deductible. It is here postulated that the variation in annual housing expenditure is less than the variation in transitory income because of the additional, relatively greater and more stable, elements which make up annual housing expenditure.

7. The reader should consult Feldstein, 1972, pp. 180-181, for details of the transformation from (5) to (6).

REFERENCES

Behrens, Jean and Smolensky, Eugene, "Alternative Definitions of Income Redistribution." Institute for Research on Poverty Discussion Paper No. 185-73, 1973.

Carliner, Geoffrey. "Income Elasticity of Housing Demand." Institute for Research on Poverty Discussion Paper No. 144-72, 1972.

Dajani, Jarir S. and Gemmell, Robert S. "Urban Wastewater Systems: Planning and Economic Analysis." Urban Systems Engineering Center, Northwestern University, TP-71-06-01, 1971.

De Leeuw, Frank. "The Demand for Housing: A Review of Cross Section Evidence." Rev. Economic & Statist. 53(1971): 1-10.

Downing, Paul B. The Economics of Urban Sewage Disposal, New York: Praeger, 1966.

Feldstein, Martin S. "Distributional Equity and the Optimal Structure of Public Prices." American Economic Review, 71(1973): 32-36.

Feldstein, Martin S. "Equity and Efficiency in Public Sector Pricing: The Optimal Two-Part Tariff." Quarterly Journal Economics, 84(1972): 175-187.

Financing and Changes for Wastewater Systems. A Joint Committee Report American Public Works Association, American Society of Civil Engineers, Water Pollution Control Federation, 1973.

Gillespie, W. Irwin "Effect of Public Expenditures on the Distribution of Income," in Essays in Fiscal Federalism, Musgrave (ed.) Washington D.C.: The Brooking Institution, 1965.

Greene,Robert Lee, Welfare Economics and Peak Load Pricing. Gainesville: University of Florida Press, 1970.

Howe, Charles W. and Linaweaver, F.P. "The Impact of Price on Residential Water Demand and Its Relation to System Design and Price Structure." Water Resources Research, 3(1967): 13-32

Musgrave, Richard A. The Theory of Public Finance, New York: McGraw-Hill, 1959.

Myrdal, Gunnar. The Political Element in the Development of Economic Theory, New York: Simon and Schuster, 1954.

Reid, Margaret. Housing and Income. Chicago: University of Chicago Press, 1962.

U.S. Bureau of the Census, Census of Housing: 1970, Block Statistics, Final Report HC(3)270, Madison, Wisconsin Urbanized Area.