10-1994

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WATER RESOURCES RESEARCH, VOL. 30, NO. 10, PAGES 2807–2811, OCTOBER 1994

The pricing of water in a university town: An economic analysis of draining a cash cow

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Abstract. This paper analyzes some economic issues involved with the common practice of using metered water rate revenue to fund debt retirement associated with the provision of municipal water and wastewater services. We conclude that rather than simply raising the metered rate, city officials should seriously consider increasing the tax rate levied under the local property tax. There is an important trade-off in the choice of a price policy. An increased property tax rate can result in tax savings to some home owners, which lowers their net expenditure for water. However, a corresponding decrease in the metered rate may increase water consumption, which in turn raises operating cost. In order to do what is best for home owners, it might make sense to give other customers (e.g., a university) an easy ride, even if the latter, because of its low (inelastic) price elasticity of demand for water, is viewed by the municipality as a cash cow.

1. Introduction

In November 1992, residents of Houghton, Michigan, received the following letter from their city government:

> Dear Water/Sewer Customer:
>
> As you are aware, the Portage Lake Water and Sewage Authority is currently constructing a new 20 million dollar sewage treatment plant. . . . We have been recently notified by the Authority that commencing next year, our monthly sewage treatment charge will increase from its current $24,000 per month to approximately $80,000 per month. This increase is for Bond Debt Retirement only and does not include any other maintenance or operational costs.
>
> Therefore, effective December 1992 your monthly water/sewage rate will increase by fifty percent. Once the impact of this increase is measured on Fund Revenues, a further rate adjustment in the magnitude of approximately 10 to 15% will be forthcoming in June of 1993.

Prior to December 1992, customers were charged uniform monthly metered rates of $0.75 per hundred cubic feet and $1.79 per hundred cubic feet for water and wastewater (sewage), respectively. After December 1992 the wastewater rate rose to $3.06 per hundred cubic feet. Thus while the combined water-wastewater rate rose 50%, the increase in the wastewater rate was 71%.

The new wastewater treatment plant is also used by the city of Hancock. Cost sharing of the debt between the two cities is based on historical usage of water. Like Houghton, Hancock has announced a metered rate increase to cover its share of debt retirement.

A metered rate is a user fee resulting in a positive price for incremental water use. A metered rate allows for a number of possible price structures, such as uniform rates, which may vary from peak to off-peak periods; block rates, which result in a rate change for water used beyond a certain amount; and step rates, which result in a different rate on all water used during a billing period once usage exceeds a given amount [e.g., *Young et al.*, 1983; *Lyman*, 1992].

In contrast, a flat rate, or lump sum charge, results in a zero price for incremental water use. The frequently cited study by *Hanke* [1970] found that substituting a metered rate for a flat rate caused the volume of water consumed to decline. Subsequent studies have also found that the quantity of water demanded declined as its price rose [e.g., *Hogarty and MacKay*, 1975; *Danielson*, 1979; *Carver and Boland*, 1980; *Howe*, 1982; *Hanke and de Mare*, 1982; *Young et al.*, 1983; *Lyman*, 1992].

The purpose of this paper is to analyze some economic issues involved with the policy of raising the metered water rate to obtain additional revenue to fund debt retirement. In particular, we address the following question: Rather than raising the metered rate, should a city choose to raise the tax rate levied under its local property tax? In addressing this question, two points are stressed. First, an increase in the metered rate raises revenue and decreases consumption and hence the variable (operating) cost associated with the provision of water. Second, raising property taxes to fund debt retirement allows home owners who utilize tax deductions or credits to shift some of the burden to other taxpayers. The accounting stance adopted here is purely local, and the tax shift to other areas is therefore ignored. As we will demonstrate, the optimum mix of metered revenue and property tax revenue depends on various parameters faced by decision makers.

2. Tax Setting

Unlike payments arising from a combined metered water-wastewater rate, property taxes are deductible under the federal income tax. In effect, this tax preference subsidizes the consumption of local public services for individuals who itemize on their federal income tax form.

Generally, if r is the proportional tax rate applied to residential real estate with an assessed value (the tax base) of V, property taxes paid, T, equal rV. Let t represent the percentage of a $1 increase in T offset by the federal

Paper number 94WR01384.
0043-1397/94/94WR-01384$05.00

deduction for itemizing federal taxpayers. Thus the deduction of T lowers the effective "price" of local government services from T to $(1 - t)T$. Since we focus on the provision of water and wastewater services, henceforth we assume that property taxes, T, are earmarked for the water-wastewater utility.

In addition, many states, including Michigan, have a "circuit breaker" that provides a refund of state income taxes if residential property tax payments exceed a specified percentage of the taxpayer's income. A circuit breaker works like a tax deduction except that the net cost of a $1 increase in T is reduced by the credit rate c rather than the taxpayer's federal marginal income tax rate t. In other words, c represents the percentage of property tax offset by the property tax credit against the state's income tax. However, if the decrease in state income tax of c reduces the federal deduction by c, federal taxes would increase by ct, resulting in the taxpayer's losing the federal deduction. In this case, the net cost to the circuit-breaker-qualifying household of increasing T by $1 is $1 - t - c + ct = (1 - t)(1 - c)$. Therefore the appropriate method of financing the debt on the new wastewater treatment plant is of interest to those taxpayers who itemize and also to those for whom c is nonzero.

For Michigan taxpayers, c takes on values of 0%, 40%, or 100% (see *Fisher* [1993] for additional discussion on property tax credits). In 1990, 38% of Michigan residents filing federal income tax form 1040 claimed a property tax credit [*Michigan Department of Treasury*, 1992].

The circuit breaker and the deductibility of local property taxes result in a loss of revenue to federal and state treasuries. This lost revenue, commonly called a "tax expenditure" [*Hyman*, 1993, p. 501], represents an intergovernmental subsidy to residents of local communities which have a relatively heavy reliance on property taxes. Any such subsidy is likely to be offset by higher federal or state tax rates to compensate for the lost tax revenue. Thus the substitution of local property taxes for metered water rates has equity implications. It is likely to adversely affect individuals who do not itemize or use the circuit breaker and therefore might result in transfers from low-income individuals to high-income individuals. Such distributional considerations, while beyond the scope of this paper, raise questions as to the appropriateness of tax preferences as a means for providing subsidies.

Houghton city officials were asked why the city did not raise property taxes to meet the debt payments associated with the new wastewater treatment plant. Their immediate response was: "If we did that we would be giving a free ride to the largest single user of water in the city." This user is Michigan Technological University (MTU), which utilizes approximately 50% of the water distributed (see Table 1). The city of Houghton sends out approximately 1400 monthly water bills in addition to MTU's, of which approximately 1200 are to residential customers. Excluding MTU's approximately 7000 students, Houghton's population is approximately 7500 (1990 census).

Is it always in the interest of home owners to initiate a price policy which prevents a university or other large, tax-exempt users from taking a free or "easy" ride with respect to locally provided public services? An extreme example shows why the answer to this question is no. Suppose that all home owners of a community pay 0% of marginal property tax increases ($c = 1$). In this case, they could shift the entire debt burden to the state government by setting the metered rate equal to 0 and financing both debt and variable cost out of property taxes. All water customers would be free riders.

As demonstrated in the next section, city officials should recognize an important trade-off when choosing a price policy. Raising the property tax rate does result in tax savings to some home owners, which lowers their net expenditure on the public service. However, a corresponding decrease in the metered rate is likely to increase water consumption, which in turn raises variable cost.

3. Modeling

Suppose a city comprises two types of home owners: those for whom c or t (or both) > 0 and home owners for whom $c = t = 0$. We assume that the city government chooses the metered rate and property tax level so as to minimize total expenditure (EXPEND) on municipal water-wastewater services by both sets of home owners, subject to the constraint that the water-wastewater utility budget be balanced. City officials are viewed simply as agents elected by home owners (principals), and they serve the interests of home owners. We abstract from any analysis of the principal-agent problem the case in which agents pursue personal goals that conflict with principals' interests [*Pindyck and Rubinfeld*, 1992, p. 625].

While a municipality may face an upper limit on its property tax rate, we assume that this constraint is not binding and nothing restricts decision makers from using property tax revenue to fund debt retirement payments. For example, conditional grants from the federal or state government might be used to partially finance the construction of a new wastewater treatment plant. The donor might specify that user-based charges be levied to retire any debt associated with the construction. Such a mandate, however, need not imply that metered rates can serve as the only price instrument. One might reasonably argue that if property values and water usage are positively related, a property tax represents a user fee (the property tax as a user fee is discussed by *Rosen* [1992, p. 385]). In any event, our analysis demonstrates that preventing the use of property taxes as a price instrument might not be in the interest of local home owners.

Our objective function accords well with the evidence that home owners are most likely to constitute the majority of voters in local elections [*Jackson*, 1974; *Piele and Hall*, 1973]. For non-residential property owners and residential landlords, water bills and property taxes are deductible

Table 1. University's Share of City of Houghton's Total Water Consumption, 1988–1992

Year	University's Share, %
1988	48.2
1989	46.4
1990	47.2
1991	46.6
1992	47.4

Source: City of Houghton.

business expenses. Alternatively, one might assume that choices should be viewed as optimum from the standpoint of the median voter, who is likely to be a tax itemizer [*Rosen*, 1992, p. 596]. Even in this case, it makes sense to view the government as attempting to minimize the tax burden of its spending policies to home owners [*Epple and Schipper*, 1981].

Since we assume an exogenous property tax base V, choosing the property tax rate r is equivalent to choosing the property tax level T. Thus city officials choose T and P so as to

$$\min \text{EXPEND} = [PQ_H(P) + T(1-t)(1-c)]\alpha + [PQ_H(P) + T](1-\alpha) \quad (1)$$

subject to

$$PQ(P) + T - \beta Q(P) - D = 0 \quad (2)$$

where

- P price per unit of water (uniform metered rate);
- $Q(P)$ total quantity of water consumed as a function of P $= Q_H(P) + Q_U(P)$ (H, household; U, university);
- T total property taxes ($= rV$);
- r proportional property tax rate ($0 \le r < 1$);
- V residential property tax base;
- β constant marginal cost (MC) of providing a unit of water ($\beta > 0$);
- D debt retirement payment;
- α proportion of home owners who itemize or use circuit breaker ($0 \le \alpha \le 1$);
- t marginal federal income tax rate ($0 \le t < 1$);
- c circuit breaker rate ($0 \le c \le 1$).

In treating α as exogenous, we ignore two possible cases that an increase in r can cause: (1) taxpayers who were previously ineligible for the credit or previously not federal tax itemizers become eligible or itemize with the new higher property tax rate and (2) taxpayers reach the maximum allowable credit (in Michigan the maximum credit is $1200).

Note that in equations (1) and (2), T is not an argument of the function $Q_H(\ )$ and hence $Q(\ )$. The sensitivity of Q_H to changes in property taxes might be near or equal to 0 when T is restricted to covering debt retirement, D. In this case, home owners might recognize that changing Q_H will not affect their property taxes (D is a fixed obligation independent of Q_H). However, when other factors are held constant, an increase in T reduces household disposable income, which may cause the demand for water to drop. On the other hand, if variable cost is covered by property taxes, one might discover Q_H to be sensitive to T owing to both an income and substitution effect [*Hogarty and MacKay*, 1975], assuming that home owners are informed as to what portion of variable cost is being covered by property taxes. In this analysis, we simplify matters by assuming that changes in T have no effect on Q_H.

The Lagrangian is

$$L = \text{EXPEND} + \tau[PQ(P) + T - \beta Q(P) - D] \quad (3)$$

where τ is the Lagrange multiplier. Letting L_i denote the partial derivative of L with respect to variable i, the Kuhn-Tucker minimum conditions are [*Chiang*, 1984, p. 722]

$$L_T = 1 - \alpha[t + c(1-t)] + \tau \ge 0 \quad (4)$$

$$L_P = Q_H(1+\Theta_H) + \tau[Q_H(1+\Theta_H) + Q_U(1+\Theta_U) - \beta(dQ/dP] \ge 0$$

$$L_P = dR_H/dP + \tau[dR_H/dP + dR_U/dP - d(\text{TVC})/dP] \ge 0 \quad (5)$$

$$L_\tau = PQ(P) + T - \beta Q(P) - D = 0 \quad (6)$$

$$TL_T = 0 \quad (7)$$

$$PL_P = 0 \quad (8)$$

where $\Theta_H = (dQ_H/dP)(P/Q_H)$ and $\Theta_U = (dQ_U/dP)(P/Q_U)$ are the household and university price elasticity of demand for water, respectively (Θ_H and $\Theta_U \le 0$).

We assume a production process with constant marginal cost [MC $= d(\text{TVC})/dQ = \beta$]. Thus average variable cost, $\beta Q/Q$, equals β. Hereinafter, total variable cost, βQ, and average total cost, $(\beta Q + D)/Q$, will be denoted by TVC and ATC, respectively. Notice that for all $Q > 0$, ATC $> \beta$. Letting $R_i = PQ_i$ for $i = [H, U]$, the term $Q_i(1 + \Theta_i)$ in (5) is simply dR_i/dP. Finally, $d(\text{TVC})/dP = \beta(dQ/dP) \le 0$.

The above model represents the short run. The debt retirement payment, D, represents a fixed cost associated with an existing plant. We assume that any increase in wastewater caused by a change in price policy can be treated through the design capacity of the existing plant.

If the optimum value for the property tax level, T^*, is >0, then (4) and (7) imply

$$\tau = \alpha[t + c(1-t)] - 1 \quad (9)$$

where the bracketed term, representing tax savings to home owners on each additional dollar of property taxes, is ≤ 1, as $c \le 1$.

In order to interpret conditions (4)–(8) as well as to illustrate a possible trade-off between tax savings and variable cost, four cases are discussed.

Case 1. Suppose $dQ/dP < 0$ and no home owner itemizes or takes the property tax credit ($\alpha = 0$). With $\alpha = 0$, (9) results in $\tau = -1$. Substituting this result into (5) yields $-Q_U(1 + \Theta_U) + \beta(dQ/dP) \ge 0$, which can be satisfied by an equality if (an unlikely event) the price elasticity of demand for the university is elastic ($\Theta_U < -1$). P would be increased until $d(\text{TVC})/dP = dR_U/dP$. The reduction in total variable cost, the marginal benefit to home owners of raising P, is equated to the city's decline in revenue from the university, the marginal cost to home owners of raising P.

For inelastic ($\Theta_U > -1$) or unitary ($\Theta_U = -1$) price elasticity, with $T > 0$, (5) fails to satisfy the necessary condition for a constrained minimum. Thus, T^* is set equal to 0 and the balanced budget constraint (equation (6)) requires that the optimum metered price, P^*, satisfy $(P - \beta)/P = D/(PQ)$. In other words, $P^* =$ ATC $> \beta$.

Case 2. Suppose $Q_U = \Theta_H = 0$ and $0 < \alpha \le 1$. With no university, $Q_H = Q$. Substituting (9) into (5) yields the condition $1 > 0$, implying that $P^* = 0$. T is the only instrument used to finance total variable cost and debt retirement.

This case serves to highlight the trade-off (or lack thereof) mentioned above. Since household (total) consumption of

Table 2. Short-Run and Long-Run Implications of the Property Tax Instrument

Short Run ($D > 0$)		Long Run ($D = 0$)	
1. $T = 0$	2. $T > 0$	3. $T = 0$	4. $T > 0$
$P > \mathrm{MC}$	$P > \mathrm{MC}$, $T < D$ (outcome 1) $P = \mathrm{MC}$, $T = D$ (outcome 2) $0 < P < \mathrm{MC}$, $T > D$ (outcome 3)	$P = \mathrm{MC}$	$0 < P < \mathrm{MC}$

From case 4, interior solutions for T and P are consistent with parameter values: $0 < \alpha \leq 1$, $\Theta_H > -1$, and $\Theta_U > -1$.

mentioned above. Since household (total) consumption of water is perfectly price inelastic, $\Theta_H = 0$, reducing P to 0 does not cause an increase in total variable cost, βQ_H. P^* is set equal to 0 to capture the full tax advantages associated with property tax financing. This result holds regardless of the value for α. With $d(\mathrm{TVC})/dP = 0$, home owners for whom $t = c = 0$ are indifferent to the value of P.

Case 3. Suppose $Q_U = 0$, $\Theta_H < 0$, and $0 < \alpha \leq 1$. Substituting (9) into (5) yields

$$\alpha[t + c(1 - t)][dR_H/dP] \geq -\{1 - \alpha[t + c(1 - t)]\} \cdot [d(\mathrm{TVC})/dP]. \quad (10)$$

Since $d(\mathrm{TVC})/dP < 0$, satisfying (10) by an equality requires that $dR_H/dP > 0$, which is the case when the household price elasticity is inelastic ($\Theta_H > -1$). Inelastic demand is consistent with empirical estimates of Θ_H [e.g., *Danielson*, 1979; *Carver and Boland*, 1980; *Young et al.*, 1983; *Lyman*, 1992]. Satisfying (10) by an equality means that P^* is also >0.

Recall that the term $[t + c(1 - t)]$ represents the tax savings to home owners on each dollar raised through the property tax. Thus the left-hand side of (10), $\alpha[t + c(1 - t)][dR_H/dP]$, is the marginal cost to home owners of increasing P; it represents the lost tax savings resulting from not raising an additional dollar of revenue through the property tax. As one would expect, as α, t, or c rises, the marginal cost to home owners of increasing P also rises. The right-hand side of (10), $-\{1 - \alpha[t + c(1 - t)]\}[d(\mathrm{TVC})/dP]$, is the marginal benefit to home owners of increasing P; it represents the reduction in total variable cost which could have been covered from property taxes. Clearly, minimizing EXPEND requires that the trade-off between tax savings and variable cost be taken into account.

Case 4. With $Q_U > 0$, $dQ/dP < 0$, and $0 < \alpha \leq 1$, substituting (9) into (5) yields

$$\alpha[t + c(1 - t)][dR_H/dP] \geq \{1 - \alpha[t + c(1 - t)]\}[dR_U/dP - d(\mathrm{TVC})/dP]. \quad (11)$$

The sign of the term dR_U/dP is dependent upon the magnitude of Θ_U. If the university's demand for water is inelastic ($\Theta_U > -1$), the right-hand term dR_U/dP is a component of the marginal benefit to home owners of increasing P. It captures the increased revenue collected from the university rather than through the property tax. As long as the university has an inelastic demand for water, $dR_U/dP > 0$, city officials view it as a nonvoting cash cow. The more inelastic Θ_U, the more "liquid" the cash cow.

In conversation with the director of facilities management at MTU, we were informed that "MTU would most likely not attempt to cut back on water consumption, given the recently announced rate increase; decreasing consumption would only result in a higher metered rate." Therefore it appears that MTU is not prepared to initiate any conservation policies. This suggests that the university's price elasticity of demand, Θ_U, might be near 0 over the relevant price range. Thus (11) might be satisfied by an equality, in which case minimizing EXPEND requires that both T and P be greater than 0 and the optimum metered rate be less than the average total cost. The university would be an easy rider, since it would pay a smaller portion of the debt retirement than its portion of total water consumption. An important message is that no matter how liquid the cash cow is, city officials should not ignore the tax advantages available to home owners through revenue mechanisms other than metered rates.

4. Short- and Long-Run Implications

Suppose city officials ignore tax preferences associated with property tax financing ($T = 0$). In the short run, with a balanced budget, the metered rate (P) equals the average total cost (ATC) but exceeds marginal cost (MC). However, in the long run ($D = 0$), $P = \mathrm{MC}$, resulting in an efficient level of water consumption. These results are summarized in columns 1 and 3 of Table 2.

With $T > 0$, in the short run, the balanced budget constraint requires that T be either less than, equal to, or greater than D. In column 2 of Table 2, these three outcomes are labeled 1, 2, and 3, respectively. However, in the long run, P is less than MC, causing the consumption of water to exceed the efficient level. The overconsumption of water occurs because someone else is subsidizing local consumption.

Thus another important message is that introducing the property tax instrument into the water pricing policy initiates the long-run problem of inefficient use of society's resources.

5. Concluding Remarks

This paper demonstrates that depending on values for demand, cost, and tax parameters, the common practice of average total cost pricing might be inferior to price policies which involve financing some or all debt retirement and possibly even some of the variable cost through property taxes. In order to do what is best for some customers (home owners), it might make sense to give other customers (e.g., a university) an easy ride, even if the latter is viewed by the municipality as a cash cow.

From the perspective of home owners, the appropriate price policy requires that city officials (1) be aware of the possible trade-off between tax advantages, variable cost, and revenue obtained from large, tax exempt users of water and (2) obtain reliable estimates of relevant parameters.

Our analysis has focused on the short-run interest of home owners within a given community. We have drawn attention to the fact that taking advantage of the tax code's favorable treatment of property tax financing results in a long-run inefficient allocation of resources and raises issues related to the distribution of income within and across communities.

Acknowledgments. The cooperation of the city of Houghton and the comments of Jim Gale, Neil Hutzler, Terry Monson, and two anonymous reviewers are gratefully acknowledged.

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(Received January 24, 1994; revised April 7, 1994; accepted May 13, 1994.)