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Rent dissipation through electricity prices of publicly owned utilities

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Abstract. A public-choice model is presented in order to explain the fact that publicly owned electricity utilities rarely price at marginal cost in practice. It is shown that if (i) government revenues are raised through proportional taxes, (ii) median income is less than mean income, and (iii) the share of a consumer's spending on electricity decreases with income, then the price resulting from a majority rule and universal voting is below marginal cost. The determination of a fixed subscription fee is also considered. Empirical evidence of our results is obtained from pricing and consumption data for Hydro-Québec.

Dissipation de la rente via la tarification des compagnies publiques d'électricité. Un modèle de choix public est développé dans le but d'expliquer le fait que les compagnies publiques d'électricité recourent rarement à une tarification au coût marginal. On montre que si (i) les revenus gouvernementaux sont prélevés à l'aide d'un impôt proportionnel sur le revenu, (ii) le revenu médian de la population est inférieur au revenu moyen et (iii) la part du revenu consacré à l'achat d'électricité décroît avec le revenu du consommateur, alors le prix de l'électricité issu d'un vote universel à la majorité est inférieur au coût marginal. La détermination d'une redevance fixe d'abonnement est également modélisée. Des données d'Hydro-Québec sur la tarification et la consommation s'avèrent conformes aux résultats du modèle.

I. INTRODUCTION

The most frequent normative prescription put forward by economists to ensure the efficient use of available resources is to price commodities at their marginal costs.[1] Only if price is equal to marginal cost will consumers receive the correct signal as

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1 For a derivation of this result in the context of public utilities, see Bos (1985).

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to the sacrifice that they impose on society when they choose to buy an additional unit of a good. In the case of electricity, Bernard and Chatel (1985) have estimated that the application of marginal cost pricing in the province of Quebec (Canada) instead of the actual prices, which are based approximately on average cost, would increase social welfare by $270 to $530 million per year, in constant 1980 Canadian dollars.[2]

If the benefits of marginal cost pricing of electricity seem so obvious to economists, it is rather surprising that actual electricity prices are so rarely related to marginal costs. The first and most obvious explanation that can be offered for this phenomenon is that economists have often neglected important transaction costs that would be incurred by a strict adherence to marginal cost pricing. These costs essentially come from the fact that electricity is not economically storable and its demand, as well as its supply, fluctuate randomly. As a result, marginal cost varies continuously in real time, and so should the price vary. Computation and transmission of this (spot) price and the need for the consumer to keep constantly informed and to react quickly to price changes could create a burden that well exceeds the benefits of increased allocative efficiency.

Recent technological advances, however, have reduced significantly such transaction costs, and pricing mechanisms that approximate marginal cost most of the time are now economically feasible. Doane and Spulber (1992) mention that there were five U.S. utilities in 1987 that offered experimental real-time prices on a voluntary basis; these spot prices are estimated and announced some time in advance, generally twenty-four hours. Less costly to implement are some quantity rationing programs, such as industrial interruptible/curtailable services or Hydro-Québec's residential dual energy programs. Such programs are designed to reduce the average gap between consumers' willingness to pay and marginal cost when there is excess demand, that is, at times when it is clear that the price is well below marginal cost. There appears to exist a certain tendency to adopt the prescription for marginal cost pricing, when technology permits it.

Yet most would agree that prices could be made immediately closer to marginal costs without incurring undue transaction costs. For instance, time-of-use pricing, implemented by Electricité de France[3] as early as the 1950s, is not yet widespread in North America. For privately owned utilities, Vogelsang (1990) mentions that this could be explained by rate-of-return regulation, since time-of-use pricing (often called peak-load pricing) reduces capital requirements. But he adds: 'On the other hand public enterprise in electricity and telephony on average seem to have avoided

2 In 1994 dollars, the range is between $525 and $1,030 million. Jenkins (1985) provides estimates for Canada as a whole and his evaluation of welfare loss through suboptimal electricity pricing ranges from $2,581 to $6,033 million. Although Bernard and Cairns (1987) argue that Jenkins's results probably represent an overestimate, it nevertheless seems clear that the welfare loss is significant.

3 The objective of the introduction of time-of-use pricing was specifically stated as closing the gap between price and marginal cost (see Boiteux 1957, 430). Of course, although the implementation of time-of-use pricing proves that such pricing is feasible, it cannot be inferred that it actually succeeded in approximating marginal cost pricing. After all, even if it has been managed by an economist, Electricité de France remains a public utility subject to political pressure.

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peak-load pricing even more than regulated utilities' (65). However, the author provides no explanation for the discrepancy.

The observation that publicly owned utilities do not price electricity at marginal cost is certainly consistent with the Canadian experience, as Cairns and Heyes (1993) show. In Canada, the bulk of electricity is produced and distributed by provincial crown corporations. Hydraulic sources generate most of the electricity in three of the provinces (Quebec, Manitoba, and British Columbia) and contribute a significant share in some of the other provinces. The fact that the first three utilities do not price electricity at marginal cost is rather puzzling, since they now operate under decreasing returns: 'the socially optimal price (equal to marginal social cost) is attainable and would provide a rent to the crown which could be used for many socially useful purposes, such as reducing the general level of taxation or building more hospitals or schools, among other things.'[4]

In this paper we present a public choice model that allows us to characterize the equilibrium price of a publicly owned utility, considering that this price results from a majority rule and a universal vote. The government is subject to a budget constraint and obtains its revenues from a proportional income tax and from the profit of its electric utility. Consumers/voters thus are faced with a trade-off between the electricity price and the general level of taxation. The model is built in such a way that marginal cost pricing maximizes a utilitarian welfare function regardless of the initial population income distribution, so that deviations from marginal cost pricing for redistributive purposes cannot be justified on utilitarian grounds.

Still, the political process generally leads to prices that differ from marginal costs. More precisely, it is shown that the equilibrium electricity price follows a generalized Ramsey rule that takes into account the fact that a change in the electricity price is necessarily accompanied by a change in the tax rate in order to meet the government budget constraint. According to this rule, if the population's median income is less than average income and if the electricity expenditure share in income decreases with respect to income, then the equilibrium price is below marginal cost. Furthermore, if a two-part tariff is used by the electric utility, some lower bound must be imposed on the fixed subscription charge because political pressure would exist to have this charge as low as possible, which could well result in a negative charge, that is, a subsidy or rebate.

In the next section, we describe the model in detail and present the derivation of the welfare-maximizing price and tax rate. In section III we then turn to the determination of the equilibrium price and tax rate under a majority rule and universal voting. Empirical evidence of our results is presented in section IV, using the case of the pricing policies of Hydro-Québec, one of the major Canadian public utilities. We offer conclusions in section V.

4 Cairns and Heyes (1993, 156). Cairns and Heyes take as their starting point the fact that 'Crown hydros are mandated to deliver power at cost, and this mandate has been interpreted to imply that profits are to be zero.' As a result, the optimal pricing policy would be to adopt the Ramsey rule, which they show is not followed by Hydro-Québec. They then raise another series of interesting questions by arguing that no existing economic theories can fully explain the actual pricing policies of Hydro-Québec.

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II. OPTIMAL PRICING AND TAXATION

1. Demand functions and notation

Consumers are assumed to have identical preferences over two goods: X, a private good produced on a competitive market and used as numeraire, and E, electricity, which is supplied by the government at a constant price p.[5] Consumers differ in their income, which is denoted by y. The latter follows the distribution function G defined over $[\underline{y}, \infty)$. It is also assumed that each consumer's indirect utility function, $V(p,y)$, takes the following Gorman form:[6]

$$V(p,y) = a(p) + b(p) \cdot y, \tag{1}$$

where $b(p) > 0$ and $a'(p)$, $b'(p) < 0$, $\forall\, p$. Since $V_2(p,y) = b(p)$, this indirect utility function implies that the marginal utility of money is constant with respect to income for all consumers. This property plays a crucial role in the ensuing development because it eliminates the need to use taxation or the price of electricity to redistribute income in order to equalize marginal utilities of money across consumers, as is generally the case when the objective is to maximize a utilitarian welfare function.[7] Allocative efficiency therefore will be the only goal of price- and tax-level determination. This property allows us to cast the social welfare function in terms of a representative consumer.

The electricity demand of a consumer with income y can be derived through Roy's identity:

$$\begin{aligned} E(p,y) &= -\frac{a'(p) + b'(p) \cdot y}{b(p)} \\ &= \alpha(p) + \beta(p) \cdot y, \end{aligned} \tag{2}$$

where $\alpha(p) \equiv -a'(p)/b(p)$ and $\beta(p) \equiv -b'(p)/b(p)$.

In order to facilitate the presentation and the interpretation of the optimality conditions derived below, additional notation related to the demand function is introduced. Price and income elasticities are denoted by $\epsilon_p(p,y)$ and $\epsilon_y(p,y)$, respectively. Let $\bar{y}$ be average income and t be the proportional tax rate, then $\bar{E} \equiv E(p,(1-t)\cdot\bar{y})$. In other words, $\bar{E}$ is the shortened form for the quantity demanded by an average income consumer at a price/tax-rate combination (p,t). Similarly, $\bar{\epsilon}_p \equiv \epsilon_p(p,(1-t)\cdot\bar{y})$ and $\bar{\epsilon}_y \equiv \epsilon_y(p,(1-t)\cdot\bar{y})$. The electricity expenditure share in gross income is also defined as

$$\omega(p,t,y) \equiv \frac{p \cdot E(p,(1-t)\cdot y)}{y}. \tag{3}$$

5 The case of a two-part tariff is considered in section III, below.

6 See Varian (1992, 153) or Deaton and Muelbauer (1980, 144). In general, the Gorman form allows for the function $a(p)$ to be consumer specific. Here, we assume that $a(p)$ is identical for every consumer. This ensures that the electricity expenditure share in income decreases with income.

7 Bos (1985) presents pricing rules when both efficiency and equity concerns are taken into account.

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From (2), we obtain that this share decreases with the income level:

$$\omega_y(p,t,y) = -\frac{p \cdot \alpha(p)}{y^2} < 0. \tag{4}$$

Finally, as for the demand functions, we use the shortened notation $\bar{\omega} \equiv \omega(p,t,\bar{y})$.

2. Government's (social planner) problem

The government's problem is to determine the price of electricity p and the tax rate t that maximize welfare. For that purpose, the same weight is assigned to each consumer in the social welfare function; that is, the social welfare function is taken to be utilitarian. The government is bound by the constitution to balance the budget, so that any profit from electricity production must be returned to the consumers in the form of a subsidy ($t < 0$) and any loss must be financed through taxation ($t > 0$).

Let $C(\cdot)$ represent the electricity cost function, assumed to be strictly quasi-convex, and $\pi(p,t)$ be the public utility profit when the electricity price is p and the tax rate is t; that is,

$$\pi(p,t) = p\int_{\underline{y}}^{\infty} E(p,y(1-t))dG - C\left(\int_{\underline{y}}^{\infty} E(p,y(1-t))dG\right). \tag{5}$$

Then, the government's problem can be written in the following way:

$$\max_{p,t} \int_{\underline{y}}^{\infty} V(p,y(1-t))dG \tag{6}$$

$$\text{s.t. } t \cdot \int_{\underline{y}}^{\infty} ydG = -\pi(p,t) \qquad (\mu), \tag{7}$$

where μ is the budget constraint Lagrange multiplier. Substitution of the Gorman indirect utility function (1) into (6) and of the demand (2) into (5) yields the following expressions:

$$\int_{\underline{y}}^{\infty} V(p,y(1-t))dG = a(p) + b(p) \cdot \bar{y} \cdot (1-t) \tag{8}$$

$$\pi(p,t) = p\bar{E} - C(\bar{E}). \tag{9}$$

Since government revenues can also be written as $t\bar{y}$, the maximization of the above social welfare function is equivalent to the maximization of the utility function of a consumer earning average income.

Let φ denote the Lagrangian function associated with problem (6). If we assume that an interior solution exists, the first order necessary conditions are

$$\varphi_p = -b \cdot \bar{E} + \mu \cdot \pi_p = 0 \tag{10}$$

$$\varphi_t = -b \cdot \bar{y} + \mu\bar{y} + \mu \cdot \pi_t = 0 \tag{11}$$

$$\varphi_\mu = t\bar{y} + \pi = 0, \tag{12}$$

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where the arguments of the functions are omitted for simplicity. It is straightforward to verify that a solution satisfying the above necessary conditions is the following:

$$p = C'(\bar{E}) \tag{13}$$

$$\mu = b(p) \tag{14}$$

$$t = \frac{C(\bar{E}) - p\bar{E}}{\bar{y}}. \tag{15}$$

This solution corresponds to the traditional prescription for optimal pricing, that is, pricing at marginal cost. The Lagrange multiplier for the government's budget constraint is set equal to the common marginal utility of money, an intuitive result given that every consumer receives the same weight in the social welfare function. Finally, (15) simply restates that the role of taxation is to cover revenue deficiency or to distribute rent, depending on returns to scale at the equilibrium.

Appendix A also shows that no feasible solution with $p \neq C'(\bar{E})$ can satisfy the necessary conditions. Marginal cost pricing is thus the only way to attain maximum welfare. Moreover, we assume that the average consumer's demand function crosses the marginal cost function from above once and only once, ensuring that there exists a price that equals marginal cost and that this price is the unique optimal solution.

Note that the optimality of marginal cost pricing is linked directly to our choice of utility and welfare functions: variable marginal utilities of money or unequal consumer weights in the welfare function would force the optimal price to differ from marginal cost. It could then be argued that marginal cost pricing is not observed in practice because such pricing would not be efficient.[8] We have specified our model precisely in order to avoid such questions. Our aim, rather, is to check whether marginal cost pricing is suitable to a majority of voters, considering, as most economists do, that it is optimal in a welfare maximizing sense.

III. PRICING WITH UNIVERSAL VOTING AND MAJORITY RULE

We turn to the case where the price of electricity and the tax rate are submitted to universal voting in a referendum and must be approved by a majority of voters to become effective. Of course, any price/tax-rate combination submitted to a vote must be constitutional, that is, must ensure a balanced government budget. The question then is what should the equilibrium price/tax-rate combination resulting from such a political process be?

To answer this question, it is first shown, in subsection 1, that the equilibrium price/tax-rate combination maximizes the utility of a consumer with median income. The price/tax-rate combination favoured by the median income consumer is derived and interpreted in subsection 2. Finally, the equilibrium two-part tariff is analysed in subsection 3.

8 Of course, it would still have to be proved that the observed prices are effectively optimal.

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1. A median voter theorem

Since consumer preferences are defined over two variables, p and t, the single-peak property cannot be invoked directly to show that the result of the voting process maximizes the median income consumer utility. If we restrict decisions to (small) changes from a feasible price/tax-rate combination, however, the budget constraint effectively transforms the decision set to a one-dimensional choice on the price/tax-rate trade-off. This fact allows us to show that, in order for a price/tax-rate combination to be a local equilibrium, that is, a price/tax-rate combination from which no (small) change would be accepted by a majority, it must maximize the utility of the median voter.[9]

Consider a feasible price/tax-rate combination. If it corresponds to a local equilibrium, there exists no (small) change (dp, dt) in this combination that would be accepted by a majority. Now, a consumer earning income y would accept a change in the tax-price structure whenever his utility is increased by such a change; that is, whenever

$$dV = V_1(p,(1-t)\cdot y)\cdot dp - V_2(p,(1-t)\cdot y)\cdot y\cdot dt > 0. \tag{16}$$

From (1), this implies that

$$\{a' + b'\cdot(1-t)\cdot y\}dp - bydt > 0. \tag{17}$$

Assuming that electricity is a normal good ($b(p) > 0$) and dividing both sides of (17) by $b(p)$, we obtain from (2)

$$-E(p,(1-t)\cdot y)dp - ydt > 0. \tag{18}$$

If a price reduction along with a tax increase is proposed, so that $dp < 0$ and $dt > 0$, the consumer would accept such a proposal if

$$-\frac{dt}{dp} < \frac{E(p,(1-t)\cdot y)}{y}. \tag{19}$$

Multiplying both sides of (19) by p, we get

$$-\frac{dt}{dp/p} < \frac{p\cdot E(p,(1-t)\cdot y)}{y} \equiv \omega(p,t,y). \tag{20}$$

Since $\omega_y(p,t,y) < 0$, $\forall\ (p,t,y)$ (cf. equation (4)), if a consumer earning income $\tilde{y}$ accepts the price-decrease/tax-increase trade-off dt/dp, all consumers for which $y < \tilde{y}$ would also accept this trade-off. By a similar reasoning, if a consumer earning $\tilde{y}$ accepts a price-increase/tax-decrease trade-off, all consumers for which $y > \tilde{y}$ would approve the trade-off. We thus obtain the following lemma, which could be termed a 'median voter theorem.'

9 The arguments used in this section are partially based upon Roberts (1977) and Wright (1986).

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LEMMA 1. *The feasible price/tax-rate combination* (p,t) *is a local equilibrium if and only if there is no feasible (small) change to the combination that would increase median income consumer's utility.*

Proof. (*Necessity*) Let y^* represent median income and suppose a local equilibrium for which there exists a feasible price decrease (increase) that would increase median income consumer's utility. From (20),

$$-\frac{dt}{dp/p}\left\{\begin{matrix}<\\(>)\end{matrix}\right\}\omega(p,t,y^*). \tag{21}$$

Then all consumers for which $y \leqq y^*(y \geqq y^*)$ would vote in favour of the change, forming a majority. This contradicts the fact that the initial price/tax-rate combination was a local equilibrium.

(*Sufficiency*) Suppose a feasible pair (p,t) for which no feasible change can increase median income consumer's welfare. Then, from (20),

$$\frac{dt}{dp/p} = -\omega(p,t,y^*) \tag{22}$$

This means that for each consumer that would favour a feasible price increase $(y > y^*)$, there exists a consumer that would favour a price decrease $(y < y^*)$. No majority could then be formed for one proposition or the other and the pair (p,t) is thus a local equilibrium. QED

The upshot is that, under the budget constraint, a local equilibrium is found by maximizing the median income consumer utility. Such an equilibrium is derived in the next section.

2. Price under a majority rule and universal vote

Since the price and the tax rate that are to prevail under a majority rule and universal vote maximize the utility of the median income consumer, they solve the following problem:

$$\max_{p,t}\ a(p) + b(p)\cdot y^*\cdot(1-t) \tag{23}$$

$$\text{s.t.}\quad t\bar{y} = -\pi(p,t) \qquad (\lambda), \tag{24}$$

where y^* represents median income. Letting L be the Lagrangian function and assuming that an interior solution exists, the first-order necessary conditions are as follows:

$$L_p = -bE^* + \lambda\cdot\pi_p = 0 \tag{25}$$

$$L_t = -b\cdot y^* + \lambda\bar{y} + \lambda\cdot\pi_t = 0 \tag{26}$$

$$L_\lambda = t\bar{y} + \pi = 0. \tag{27}$$

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From (25) and (26), we obtain

$$E^* + \frac{y^*}{\bar{y}} \cdot \frac{1}{[(p - C')\beta - 1]}[(p - C')\bar{E}_p + \bar{E}] = 0, \tag{28}$$

where $E^* \equiv E(p, (1-t) \cdot y^*)$. Letting ω^* be the electricity expenditure share of the median income consumer, (28) can be rewritten as the following implicit price formula:

$$\frac{p - C'}{p} = \frac{(\omega^* - \bar{\omega})/\bar{\omega}}{[\bar{\epsilon}_p + \omega^* \cdot \bar{\epsilon}_y]} = \frac{(\omega^* - \bar{\omega})/\bar{\omega}}{\left[\bar{\epsilon}_p - \left(\frac{dt}{dp/p}\right) \cdot \bar{\epsilon}_y\right]}$$

$$= \frac{(\omega^* - \bar{\omega})/\bar{\omega}}{\left[\bar{\epsilon}_p + \left(\frac{d(\bar{y}(1-t))/\bar{y}}{dp/p}\right) \cdot \bar{\epsilon}_y\right]}, \tag{29}$$

where, in the denominator, ω^* is replaced by $-p\, dt/dp$ by virtue of lemma 1.

Before considering the interpretation of expression (29), we present conditions for which the equilibrium price is below marginal cost.

PROPOSITION 1. *If electricity is a normal good ($b(p) > 0$) and if median income is less than average income, then the equilibrium price, if it exists, is below marginal cost.*

Proof. We proceed by means of a geometrical proof using the fact, shown in appendix B, that the lower contour sets of the indirect utility function are strictly convex in the (p, t) plane.

Consider a pair (p, t) solving problem (23). Then, from lemma 1 and the fact that $\omega_y(p, t, y) < 0$, $\forall\, (p, t, y)$, we have

$$-\frac{dt}{dp/p} = \omega^* > \bar{\omega} \Rightarrow E^*/y^* > \bar{E}/\bar{y}. \tag{30}$$

Since E/y represents the marginal rate of substitution (MRS) of p for t when a consumer earns income y (cf. appendix B), (30) means that the average income consumer indifference curve that passes through the equilibrium (p, t) pair has a lower MRS than the median consumer indifference curve. This fact is illustrated in figure 1, where M represents an equilibrium price / tax rate.

Now, consider the welfare-maximizing solution where $p = C'$.[10] This solution cannot be to the left and below the median consumer indifference curve passing through M. If it were, it would mean that there exists a feasible solution that can increase the median consumer utility, which contradicts the fact that M is the equilibrium (p, t) pair. Nor can the solution be to the right and above the average

10 By assuming that the average income demand function crosses the marginal cost function from above once and only once, we have ensured that this solution exists and is unique.

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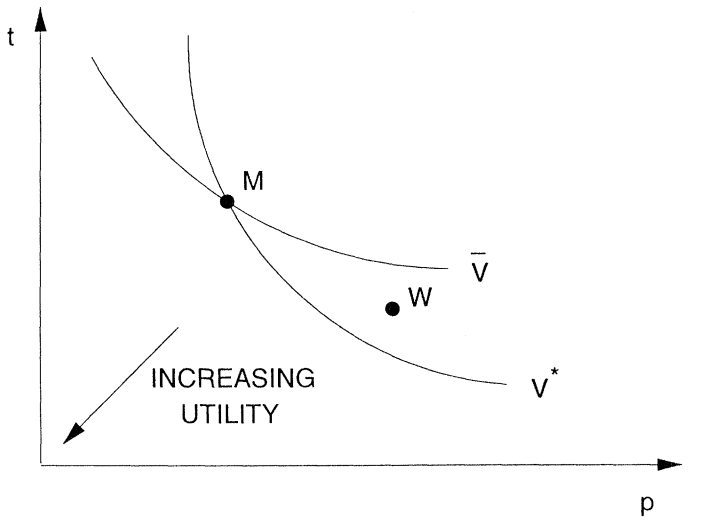


FIGURE 1 Pricing below marginal cost

income consumer's indifference curve passing through M. If it were, the equilibrium M would be a feasible solution that increases the average consumer utility, which contradicts the fact that the welfare-maximizing solution maximizes the average income consumer's utility. As a result, the welfare-maximizing solution pair is located to the right of M between the average and median consumer indifference curves passing through M (e.g., W in figure 1). But this means that the equilibrium price is lower than the welfare-maximizing price, which is equal to marginal cost. QED

Since population income distributions are generally known to have their median below the average, the model predicts that publicly owned utilities would price electricity below marginal cost. The extent of the mark-down is determined by a modified Ramsey rule, which takes into account the fact that a price decrease is necessarily accompanied by a tax increase. Thus, the denominator of (29) shows that the mark-down is higher the lower is the impact of a 1 per cent price decrease on total consumption: besides the direct effect of increasing consumption by $\bar{\epsilon}_p$, a 1 per cent price decrease brings a ω^* per cent decrease in disposable income, thus indirectly decreasing consumption by $\omega^*\bar{\epsilon}_y$. The numerator shows that the difference between the price and the marginal cost will be proportional to the difference between the electricity expenditure shares of median and average income consumers. This result is to be expected, since this difference represents the gap that exists between the median income consumer's objective and the social welfare function:[11] the extent to which a median income consumer spends relatively more on electricity than an average income consumer measures the incentive to reduce

11 Recall that the social welfare function corresponds to the average consumer's utility function.

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the price of electricity. If median and average incomes were equal, no such incentive would exist and marginal cost pricing would prevail.

3. A two-part tariff

It is a common practice for public utilities to have tariffs that include a subscription fee. Such pricing structures attempt to recover fixed costs while minimizing the distortions created by the use of a price which differs from marginal cost. In this section, we analyse the effects of the political process on the determination of a subscription fee.

Let F be a fixed charge that the consumer has to pay to be able to consume electricity. We constrain this charge to be greater than δ. A negative value for $\delta(\delta < 0)$ would permit the redistribution of all or part of the rent in the form of a per capita subsidy, while $\delta \geqq 0$ would prohibit such negative taxation.[12] In practice, the subscription fee is usually justified by the need to recover consumer specific fixed distribution cost such as connection or meters, and δ is positive. In order to find the optimal price structure and tax rate (F, p, t), we thus have to solve the following problem:

$$\max_{F,p,t} \; a(p) + b(p) \cdot [y^* \cdot (1-t) - F] \tag{31}$$

$$\text{s.t.} \quad p[E(p, \bar{y}(1-t) - F)] + t\bar{y} + F = C(E(p, \bar{y}(1-t) - F)) \qquad (\zeta) \tag{32}$$

$$F \geqq \delta \qquad (\eta), \tag{33}$$

where the variables in parentheses are Lagrange multipliers.

Let Λ be the Lagrange function associated with this problem. The first-order conditions are

$$\Lambda_p = a' + b' \cdot [y^* \cdot (1-t) - F] + \zeta\{(p - C') \cdot [\alpha' + \beta' \cdot (\bar{y} \cdot (1-t) - F)] + \alpha + \beta \cdot (\bar{y} \cdot (1-t) - F)\} = 0 \tag{34}$$

$$\Lambda_t = -b \cdot y^* + \zeta\{-(p - C') \cdot \beta \cdot \bar{y} + \bar{y}\} = 0 \tag{35}$$

$$\Lambda_F = -b + \zeta\{-(p - C') \cdot \beta + 1\} + \eta = 0 \tag{36}$$

$$\Lambda_\eta = F - \delta \geqq 0 \qquad \Lambda_\eta \cdot \eta = 0 \qquad \eta \geqq 0. \tag{37}$$

Deriving the value of ζ from (35) and substituting it into (36), we obtain the fixed charge constraint multiplier:

$$\eta = b\left(1 - \frac{y^*}{\bar{y}}\right). \tag{38}$$

12 In this model, it is possible to interpret F as lump-sum taxation applied by government rather than the fixed subscription charge of the electric utility. It would then seem more plausible to allow negative values for F. However, lump-sum taxation is rarely observed in practice.

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If $y^* < \bar{y}$, then $\eta > 0$, implying that the fixed charge constraint is binding. Under majority voting, the fixed charge will thus be set as low as possible: since a fixed charge constitutes a regressive lump-sum tax, the median consumer is willing to tilt revenue collection towards the proportional tax as much as possible.[13] So, in order to have a feasible solution, a constraint has to be put on the value of F, as we have done here. Furthermore, we should observe that the fixed charge is as low as the constraint permits.

IV. EMPIRICAL EVIDENCE FROM QUEBEC

A two-stage nationalization in 1944 and 1962 led to the creation of Hydro-Québec, the government-owned utility that produces and distributes most of the electric power in Quebec.[14] It is one of the largest electric utilities in North America with assets of $52,182 million (Hydro-Québec 1995). In 1995, sales of 166 TWh generated income of $7,610 million. Hydro resources provided 94 per cent of the generation capacity of 36,590 MW. Hydro-Québec pays no water rentals, whereas private producers in Quebec do.

There is no independent regulatory overview of Hydro-Québec. Rates are approved by the government after a public examination by a commission of the provincial legislature. Overall revenues have to be sufficient to meet operation expenses, taxes, capital depreciation, and net interest payments (Lois refondues du Québec, chap. H-5). Furthermore, no dividends are to be paid to the government if one of the following two financial criteria is not met: 100 per cent gross interest coverage and 25 per cent share of capital contributed by retained earnings. In such a framework, the average price of electricity follows the average historical cost, modified by the application of the two financial criteria. From year to year, the government is rather free to set the overall revenue requirements.

This regulatory framework and the access to hydro resources have made Hydro-Québec's rates among the lowest in the world. Rates of return on equity, however, have been dismal: from 1989 to 1995 the nominal rates of return ranged from 3.3 per cent to 8.4 per cent, rates that are roughly equal to treasury bill rates of return. The question then is why would residential electricity customers in Quebec, who are also voters, elect governments that approve both low electricity prices and high tax rates, with the resulting efficiency losses pointed out by economists?

Proposition 1 suggests that price below marginal cost would prevail under public ownership of an electric utility provided that electricity is a normal good, that median income is less than average income, and that electricity expenditure share

13 It is easy to show that if government revenue were raised exclusively through the fixed charge (t is constrained to be 0), the equilibrium electricity price would be set above marginal cost: the median income consumer, using less electricity than the average income consumer, clearly gains from a higher price, which raises government revenue from electricity and allows a lower lump-sum tax.

14 There are still a few municipal distributors. Also, some private companies, principally aluminum producers, generate power for their own use. ALCAN is the largest such private producer.

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TABLE 1
Average electricity consumption and bill by customer class (1989)

Income class ($)	Average annual consumption (kWh)	Average bill ($)	Customers (per cent)	Average bill/ middle income (per cent)
less than 10,000	12,406	623	11	–
10,000–14,999	13,707	692	10	5.54
15,000–19,999	15,265	758	9	4.33
20,000–24,999	15,650	778	10	3.46
25,000–29,999	16,624	838	10	3.05
30,000–34,999	17,783	883	10	2.72
35,000–39,999	18,359	912	8	2.43
40,000–49,999	19,225	960	12	2.13
50,000–59,999	20,915	1,017	8	1.85
60,000 and more	23,291	1,156	12	–

SOURCE: Hydro-Québec (1990)

decreases with income.[15] All these conditions would appear to be stylized facts of any electricity market. Nevertheless, we have to check whether they are actually observed for the particular case of Quebec.

First, Bernard, Lemieux, and Thivierge (1987) have estimated the income elasticity of Quebec electricity demand to be approximately 0.17, which is small but positive. Second, table 1 presents electricity expenditure by income class from a sample of 28,000 residential users surveyed by Hydro-Québec (1990). Median income of $30,000 can be read directly from this table, since the first five income classes account for 50 per cent of the sample. Average income is obtained by assigning the middle value to each income class and the arbitrary value of $65,000 to the upper open-ended class. This probably underestimates mean income and explains why average income so calculated, $32,225, seems closer to median income than one would expect. Nevertheless, the second condition of proposition 1 is met in our data set. Finally, it can be seen that the electricity expenditure share decreases with income, starting at 5.54 per cent of mid-point income for the $10,000–14,999 class, while ending at only 1.85 per cent for the $50,000–59,999 class.

A mark-down of the electricity price relative to marginal cost thus is consistent with the model's main prediction. The size of this mark-down can also be estimated through the modified Ramsey rule (29). From table 1, the estimates of the share of electricity expenditure in median and average income (ω^* and $\bar{\omega}$) are 2.79 per cent

15 Actually, the third condition is implied by the second when the utility function is assumed to have the Gorman form (see equation (4)). For this reason, this condition is not specified in the wording of proposition 1. We nevertheless mention it explicitly, because it plays an important role in the proof of the proposition. Furthermore, in practice, it could be the case that the second condition would be verified but the third would not; considering both of them thus allows for a more thorough empirical analysis of the assumptions made in the model.

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and 2.69 per cent, respectively.[16] Along with the income elasticity above, a price elasticity estimate of −0.59 is borrowed from Bernard, Lemieux, and Thivierge (1987). Substitution of these values in (29) yields a mark-down of 6.8 per cent. This amounts to $553 million, according to Hydro-Québec gross income in 1995 (see Hydro-Québec 1995). This relatively low mark-down can be traced to the small difference between the estimates of ω^* and $\bar{\omega}$ from our sample.

In practice, Hydro-Québec's residential tariffs have two components: a fixed charge and a two-part energy levy based on kWh consumption. It is the policy of Hydro-Québec to tie the fixed charge to narrowly identified metering costs (see Hydro-Québec 1992, 55). This policy is also in agreement with the conclusion obtained from the model for a two-part tariff: a lower bound has to be set on the fixed charge so as to limit redistribution through this channel.

V. CONCLUSION

In Canada, government-owned electric utilities operate under a set of rules that have led to electricity prices based on average historical costs, which themselves are below the costs of new power facilities. This is particularly the case for provinces that rely principally on hydro resources. A number of studies have pointed out the large economic losses associated with the current institutional arrangements and have recommended that electricity prices be brought in line with marginal costs. Thus far, these studies and their recommendations have had little success, and their impact on pricing policies adopted by the provinces with respect to their electric utilities has been nil. The issue, then, is why electricity consumers, who are also voters, elect governments that, on the one hand, approve electricity prices below marginal cost and, on the other hand, apply high tax rates on income. In this paper, we have put together two strands of the economic literature, public choice and the theory of public utility pricing, in order to develop a simple model that explains why, under rather realistic conditions, the median voter would prefer a low electricity price and a high tax rate. A large sample drawn from a Hydro-Québec survey confirms that these conditions are satisfied in Quebec.

APPENDIX A: NECESSITY OF MARGINAL COST PRICING FOR PROBLEM (6) OPTIMALITY (PROFIT CONSTRAINT NOT BINDING)

In this appendix, we show that if the profit constraint in problem (6) is not binding, the optimal price is necessarily equal to marginal cost.

We proceed by proving that no price different from marginal cost can satisfy the necessary conditions (10)–(12). Suppose $p \neq C'$ solves equations (10)–(12). Then we obtain from (10) and (11):

$$(p - C') \cdot \frac{\bar{E}_p}{E} = \left(\frac{b}{\mu} - 1\right) \tag{A1}$$

16 ω^* is computed by using the average bill of the $25,000–$29,999 class.

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$$-(p - C') \cdot \beta = \left(\frac{b}{\mu} - 1\right). \tag{A2}$$

From the left-hand sides of (A1) and (A2), we thus have

$$\bar{E}_p + \beta \cdot E = 0. \tag{A3}$$

After simple algebraic manipulations, this equation can be written as

$$\bar{\epsilon}_p + \bar{\omega} \cdot \bar{\epsilon}_y = 0. \tag{A4}$$

The left-hand side of (A4) represents the compensated price elasticity, that is, the price elasticity of the Hicksian demand function. The necessary conditions would thus be satisfied at a point where the Hicksian demand is perfectly inelastic. This result is derived from the budget constraint, which forces the government to return or recover any additional revenue raised or lost by changing the electricity price: if the Hicksian demand is perfectly inelastic at a given price, no substitution effect is induced by a (small) change in price and the concomitant (revenue neutral) change in the tax rate exactly compensates for the income effect, thus leaving the consumer indifferent.

However, the case of a perfectly inelastic Hicksian demand is without interest and has been excluded by assumption of a strictly quasi-convex indirect utility function.[17] As a result, there exists no solution in which the price differs from marginal cost. Moreover, we assume that the average consumer demand function crosses the marginal cost function from above once and only once, ensuring that there exists a price that equals marginal cost and that this price is the unique optimal solution.

APPENDIX B: STRICT CONVEXITY OF THE INDIRECT UTILITY FUNCTION LOWER CONTOUR SETS IN THE (p, t) PLANE

In this appendix, we show that the lower contour sets of the indirect utility function (1) are strictly convex in the (p, t) plane.

By differentiating the indirect utility function, we have

$$dV = V_1(p, (1 - t) \cdot y) \cdot dp - V_2(p, (1 - t) \cdot y) \cdot y \cdot dt > 0. \tag{B1}$$

From (1) and (2), this implies

$$\text{MRS}_{pt} \equiv -dt/dp = \frac{E(p, y(1 - t))}{y}. \tag{B2}$$

We thus have

$$\frac{d\text{MRS}_{pt}}{dp} = \frac{1}{y} \cdot \left[E_p - \beta y \cdot \frac{dt}{dp}\right]. \tag{B3}$$

17 Since $V(p, y) = a(p) + b(p)y$, with $a'(p), b'(p) < 0$, $\forall\ p$, V is strictly decreasing in p and, therefore, strictly quasi-convex in p.

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Multiplying both sides of (B3) by py/E allows us to write

$$\frac{py}{E} \cdot \frac{d\text{MRS}_{pt}}{dp} = \epsilon_p + \omega \cdot \epsilon_y = \epsilon_p^c < 0, \tag{B4}$$

where the arguments of the functions are omitted and where ϵ_p^c represents the compensated price elasticity of demand. (B4) implies that the marginal rate of substitution is decreasing at all points on an indifference curve. The lower contour sets of the indirect utility function are thus strictly convex in the (p, t) plane.

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