Cross-Subsidies That Minimize Electricity Consumption Distortions

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Abstract

Often times electricity charges are based solely on a per kilowatt-hour (kWh) basis, ignoring the fact that much of the cost associated with electricity service is fixed. From this basis, cross-subsidies have been implemented to achieve various social objectives such as affordable rates for the economically disadvantaged or extension of service to previously unserved areas. However, it is well known that regardless of whether rates have embedded cross-subsidies, this "average cost pricing" of power is not economically efficient.

This paper proposes a method of cross-subsidies that uses as its basis optimal multi-part pricing that accounts for the fixed nature of costs associated with electricity provision. The method of cross-subsidy is straightforward and relies on well-understood results from welfare economics that advocates lump-sum transfers over per-unit transfers. In the case of electricity rates, lump-sum transfers through the fixed charge portion of the multi-part tariff are used to implement cross-subsidies across customer classes without distorting consumption decisions and are efficiency enhancing.

While the result is relatively straightforward, implementation of such a scheme will require deeper consideration including demand estimation, cost-of-service studies and cost reflectivity, choice of regulatory mechanisms, the avoidance of uneconomic bypass, and the appropriateness of such a scheme to different customer base and industry structures.

Introduction

The cost structure of electricity service is unlike cost structures for most goods and services. The infrastructure necessary for providing power to customers suggests that the majority of the costs are fixed: generation plant, transmission and distribution facilities, and operating and maintenance costs that are not associated with the output. The only variable costs are associated with fuel and variable operation and maintenance costs associated with electricity output.

In spite of the underlying cost structure, electricity charges have traditionally been based on either an average price per kilowatt-hour (kWh) basis, or with the use of multi-part prices with a fixed demand charge per billing period, plus a price per kWh. While multi-part prices can, in theory, lead to an optimal pricing mechanism, the multi-part pricing mechanisms that are often used do match optimal multi-part prices in that the fixed demand charge does not cover the full fixed cost of serving customers, hence the remainder of fixed costs must covered through the per kWh charge. In either case, this leads to economically inefficient outcomes.[1]

In addition to the persistence of inefficient pricing mechanisms, the electricity sector, especially in developing countries, is facing increasing pressure to carry out policies that will achieve social and economic development objectives while being financially self-sufficient. Previously, such policies to carry out these objectives were done through government subsidies, but with industry restructuring and

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[1] For a discussion of multi-part prices for utilities, see Wilson (1995).

increasingly tight government budgets, this is no longer the case.[2] Some of these objectives include affordable rates for the economically disadvantaged, electrification programs in rural and impoverished urban areas, and country-specific ideas about fairness and equality. Moreover, as countries undertake electricity sector restructuring they are looking to “rebalance” the tariff and rate structure so as to ensure the prices paid by consumers are based on cost-causality or be cost-reflective of the service being provided. And, in rebalancing tariffs, there is a widespread belief that the economically disadvantaged will ultimately see their rates increase due to the elimination of subsidies that have been in place, which seems to run counter to the social objectives policymakers hope to achieve.

Consequently, there seems to be several sector objectives that are in conflict with one another. The objectives of financial independence from the government financing along with more efficient rate structures and rate rebalancing seems to conflict directly with the many stated social objectives.

This need not be the case. This paper proposes a method of cross-subsidies that uses as its basis optimal multi-part pricing that accounts directly for the fixed costs associated with electricity provision. The cross-subsidy between customer classes is straightforward and relies on well-known and understood results from welfare economics and the theory of optimal taxation that advocates lump-sum transfers through the fixed charge portion of the multi-part tariff. This lump sum transfer of monies is independent of per kWh charges, and therefore, the quantity consumed, so that the cross-subsidy between customer classes does not distort the consumption decisions of customers and is efficiency enhancing.[3]

In spite of the relative simplicity of the result and its intuitive appeal, implementation of such a cross-subsidy scheme does have potential problems. For example, a rigorous cost of service study is necessary to determine the cost reflective baseline tariffs from which the cross-subsidies will be determined. Additionally, the choice of regulatory mechanism and industry structure for the utility(ies) can have an impact upon the relative ease with which implementation can take place. And finally, this method of cross-subsidy does not present a solution to the problem of uneconomic bypass of the system by large users.

The paper proceeds as follows. First, an overview of average cost pricing compared to multi-part pricing is provided showing the efficiency of multi-part pricing. Next, a short explanation of how the cost of service to different customer classes can differ is provided. Third, the cross-subsidy mechanism using lump-sum transfers through fixed charges is explained as well as the efficiency properties of this form of cross-subsidy. Following the explanation of the cross-subsidy is a discussion of implementation considerations and concluding remarks.

Average Cost Pricing vs. Multi-part Pricing

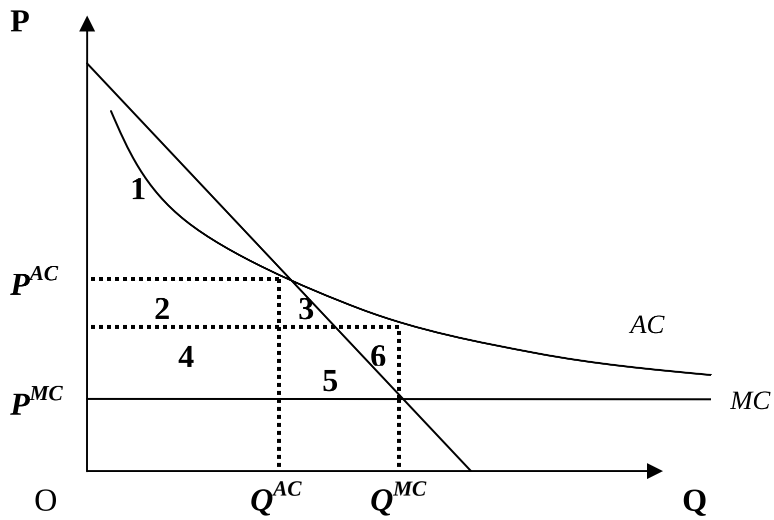
Consider a vertically integrated utility that serves a homogeneous population and must charge everybody the same price. This utility has an average cost (*AC*) and constant marginal cost (*MC*) as shown in Figure 1. Further, let us assume that the average cost, *AC*, also includes the regulated rate of return. Under traditional average cost pricing, with all costs recovered through the average per kWh charge, the price charged is $\boldsymbol{P^{AC}}$ and the quantity sold to customers is $\boldsymbol{Q^{AC}}$. The consumer surplus under this pricing methodology is represented by the area **1**, and the producer surplus is represented by the areas **2** + **4**, which is exactly the amount required by the utility to cover its fixed costs plus the rate of return on its assets at the quantity $\boldsymbol{Q^{AC}}$. The price, $\boldsymbol{P^{AC}}$, is above marginal cost and there is a deadweight loss associated with this pricing scheme represented by the areas **3** + **5**, hence showing the well-known result that the average cost pricing methodology is not economically efficient.[4]

Still, even if the utility were regulated to set price equal to marginal cost, $\boldsymbol{P^{MC}}$, resulting in a larger quantity sold to customers, $\boldsymbol{Q^{AC}}$, this still would not be an optimal outcome. Under this marginal cost pricing scheme, the utility is being regulated to a loss represented by the areas **4** + **5** + **6** which is the

[2] Very little literature exists in economics regarding the use of cross-subsidies in place of direct government subsidies. One paper by Laffont and N’Gbo (2000) examines cross-subsidies through an average cost pricing that may differ across customer classes to provide infrastructure extensions for under-served areas.
[3]According to Atkinson and Stiglitz (1980) lump-sum transfers are said to be non-distortionary since there is no substitution effect due to changing per unit charges. However, there is still an income effect in that fixed charges are akin to a decrease in available income to buy goods and services.
[4] For similar analyses of utility pricing, see Berg and Tschirhart (1988) or Viscusi, Vernon, and Harrington, Jr. (2000).

amount needed by the utility to cover its fixed costs plus the rate of return. But consumers are clearly better off in that the consumer surplus increases to the areas **1** + **2** + **3** + **4** + **5**.

Figure 1



However, with a multi-part tariff structure, there is a way to ensure that there is an efficient outcome in that price equals marginal costs and the utility can recover its fixed costs plus the rate of return. In charging $\boldsymbol{P^{MC}}$ per kWh, and taking the fixed cost corresponding to loss associated with marginal cost pricing, the areas **4** + **5** + **6**, and transferring part of the consumer surplus, represented by the sum of areas **1** through **5**, to producers that cover the fixed costs, then net surplus to consumers and producers is maximized. Not only is net surplus maximized, but consumer surplus is increased, relative to charging $\boldsymbol{P^{AC}}$, by area **3** + **5** without leaving the utility any worse off in terms of its surplus, relative to charging $\boldsymbol{P^{AC}}$, since fixed costs are covered.[5] To see this, note that fixed costs under the average cost pricing regime are equal to areas **2** + **4**, and under the marginal cost pricing regime to areas **4** + **5** + **6** and since fixed costs due not vary with output, these two areas are equivalent.

Cost of Service for Different Customer Classes

Unfortunately, utilities do not serve homogeneous populations at all. The customer population served by a utility is quite heterogeneous in terms of its use of electricity (how much and what for) and the ability to pay in many countries. It also seems to be the case that the cost of service to different customer classes is also different.

For example, consider fixed costs for a customer base with two types: residential and industrial. Industrial customers take power off of the system at higher voltages than residential customers. Therefore, the entire cost of low voltage distribution can be attributed to residential customers, while perhaps more of the high voltage transmission system cost is caused by the needs of Industrial customers. It also seems to be the case that Residential customer usage is more varied and contributes more to system peaks, so the utility must build more generation capacity so that it can meet the system peaks when they occur. So, while industrial customers likely are responsible for most of the base-load plant, it is residential customers that

[5] It is assumed here that there is no income effect due to the fixed charge. If there was an income effect, it would cause the entire demand to shift leftward (a decrease in demand) and the quantity consumed at the marginal cost price would be less than shown on the graph and the increase in consumer surplus would not be as great.

are responsible for the extra capacity needed to serve peak loads. Overall, it seems that while industrial customers are responsible for a larger portion of fixed costs than residential consumers, given the large quantity of consumption it is cheaper to serve industrial customers on an average cost basis than residential customers.

Here is where the problem begins. In many developing countries (and even more developed countries), residential customers likely have a lower ability to pay than large industrial customers. Because of this, many potential customers will not get served since they may not be able to afford service.

So, consider the demands for power for both residential and industrial customers in Figures 2 and 3 respectively. Note how the industrial demand is much larger and that average cost pricing is much closer to marginal cost pricing than for residential customers.

Figure 2

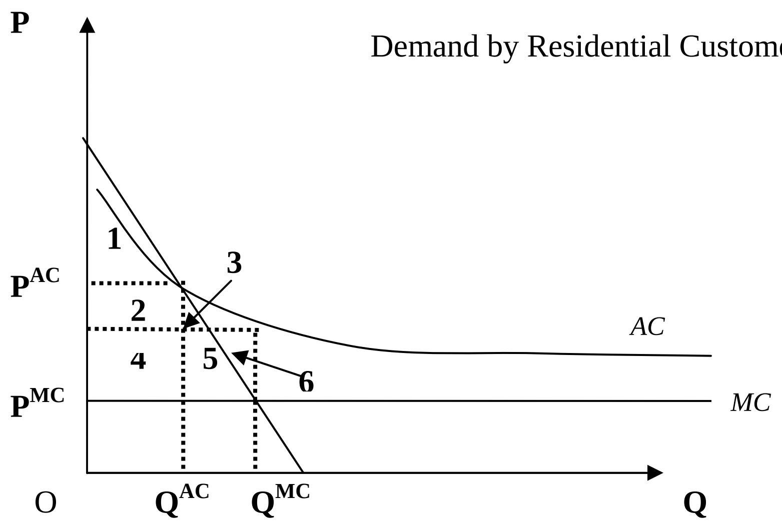
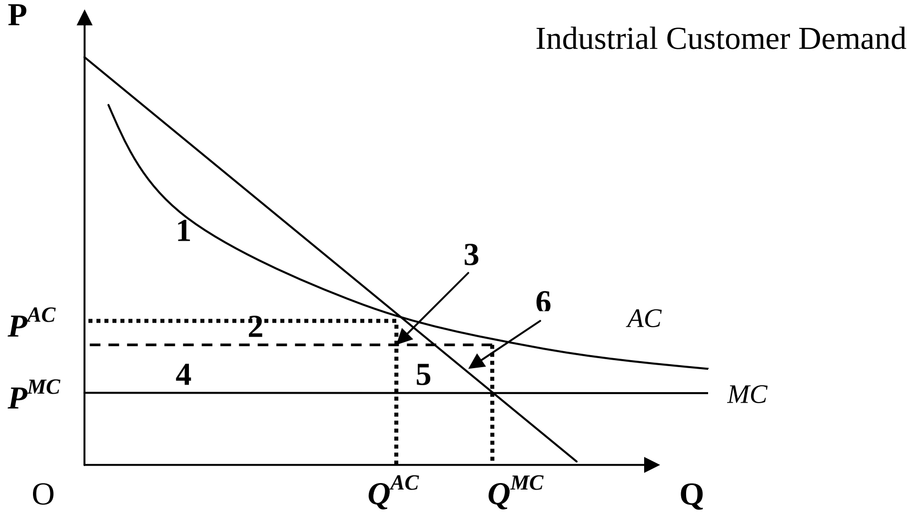


Figure 3



If multi-part pricing were implemented for each of these customer classes, we would obtain the same results as the previous section. Each customer type would pay its respective fixed costs (**2** + **4**) as a fixed charge and be charged P^{MC} per kWh for consumption. Still, with this policy in place, some regulators and policy makers may worry that despite the efficiency of this pricing regime, some residential customers may no longer take service given the fixed charge, or that such a regime is seen as inequitable.[6]

The Cross-Subsidy

Given the increased consumer surplus for industrial customers, area **3** + **5** in Figure 3, that surplus can be transferred to the residential customers in the form of reduced fixed charges that could alleviate the concern that that some customers may be unable to afford service. Assuming no income effects from the fixed charge, industrial customers would be left no worse off than they were under cost-reflective average cost pricing, and residential customers would be better off in that they are paying reduced fixed charges and are buying power at marginal cost. A summary of the subsidy process is set out in the Table 1, and the welfare comparison to average cost pricing is presented in Table 2.

[6] This worry is based upon the income effect of the fixed charge for power in that residential customers may see the fixed charge as too high and not take electricity service.

Table 1

	Multi-Part Prices, No Cross Subsidy				Multi-Part Prices, Cross Subsidy		
Customer Class	Price and Quantity	Consumer Surplus	Fixed Charge		Price and Quantity	Consumer Surplus	Fixed Charge
Residential	P^{MC}, Q^{MC}	1+3+5	2+4		P^{MC}, Q^{MC}	1+3+5+(3 and 5 from Industrial)	2+4-(3 and 5 from industrial)
Industrial	P^{MC}, Q^{MC}	1+3+5	2+4		P^{MC}, Q^{MC}	1	2+3+4+5

Table 2

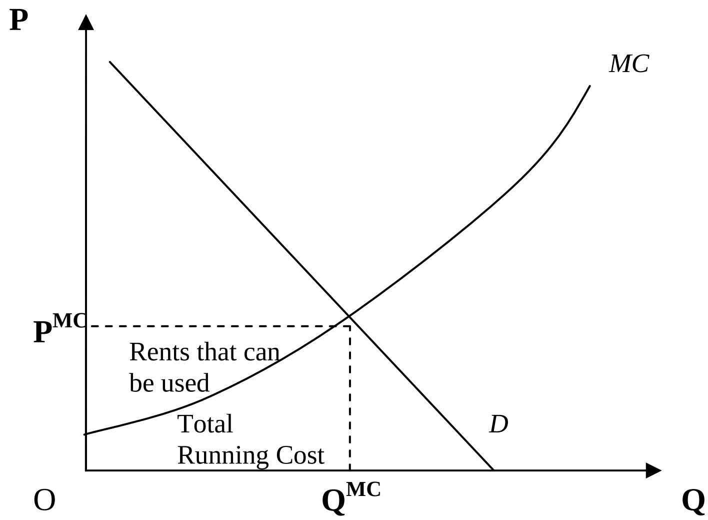
	Average Cost Pricing				Multi-Part Prices, Cross Subsidy		
Customer Class	Price and Quantity	Consumer Surplus	Producer Surplus		Price and Quantity	Consumer Surplus	Fixed Charge
Residential	P^{AC}, Q^{AC}	1	2+4 (3+5 is the deadweight loss)		P^{MC}, Q^{MC}	1+3+5+(3 and 5 from Industrial)	2+4-(3 and 5 from industrial)
Industrial	P^{AC}, Q^{AC}	1	2+4 (3+5 is the deadweight loss)		P^{MC}, Q^{MC}	1	2+3+4+5

Of course, it is not clear from such a simple graphical analysis whether the surplus transferred from industrial to residential customers is enough to cover the entire residential fixed cost. However, if there is some sort of income effect for residential consumers, this cross-subsidy does reverse some of the income effect.

Additional Sources for Implementing These Cross-Subsidies

In the above analysis, a constant marginal cost has been assumed. However, in real power system operation, the marginal cost is constantly changing due to changing load levels, generator maintenance schedules, and so forth. And even if the load were constant, it is unlikely that the marginal running cost for all of the generating units is the same. Therefore, the marginal cost curve for generation is upward sloping as depicted in Figure 4. If customers are paying marginal cost for power, then the revenue generated from power sales, $\mathbf{P^{MC}}$ x $\mathbf{Q^{MC}}$, is greater than the total running cost of providing that power as shown in Figure 4. The total cost of generating power is the area below the marginal cost curve, and the revenue is the rectangle bordered below and to the left by the axes, and above and to the right by dashed lines. The extra "rents" could then be used to offset other fixed costs since the allowed or target rate of return is already included in fixed costs.

Figure 4



Implementation Considerations

While this method of cross-subsidy is relatively easy to implement in the abstract, there are some very serious implementation issues that must be considered before moving forward. Among these are estimates of demand, cost-of-service studies and ideas of cost reflectivity, choice of regulatory mechanisms, and avoiding uneconomic bypass by large or wealthy customers, and effectiveness under different configurations of the customer base.

Estimates of Demand

In order to implement the cross-subsidy mechanism proposed here, it is almost essential to have reliable estimates of demand by customer class. Estimating demand is not only an engineering exercise to estimate future infrastructure needs, but is also an economic exercise to estimate the demand as a function of price, income, and other factors by customer class. However, estimating demands as a function of price and other factors is a data intensive exercise, and in some cases, the necessary data may not be available. Good estimates of demand will allow regulators to implement the proposed cross-subsidies so as to ensure that no one customer class is made worse off relative to a cost-reflective average cost pricing scheme. However, if good data is not available to estimate demand, then cross-subsidies could be implemented, but great care must be taken to not encourage some customer classes to engage in uneconomic bypass.

Cost-of-Service Studies and Cost Reflectivity

Underlying the analysis conducted above is the idea that rigorous cost-of-service studies have been done and that they have been used to implement a cost-reflective rate design. In many countries, either cost-of-service studies have not been done, or done long before the advent of reforms. Also, many countries do not implement what are believed to be cost-reflective tariffs as yet. The direction of the cross-subsidies through rates can range from large and wealthy customers subsidizing poor and rural customers to the smallest and poorest customers subsidizing the large users. However, regardless of the situation, the idea of cross-subsidy presented here bases the cross-subsidy on rates that are cost-reflective, which requires appropriately detailed cost-of-service studies.[7]

Choice of Regulatory Mechanism

The assumption in the analysis that average costs also included the "allowed target rate of return" was not meant to prejudge the type of regulatory mechanism. Given that the fixed charges are meant to cover the fixed costs of the utility, it would seem logical that a revenue cap regime would be the most fitting regulatory mechanism to employ.[8] At the time of a so-called "rate review", the regulator can determine how much capital is tied up in the fixed costs of providing electricity, determine a target rate of return, and therefore determine the required revenue to be collected. There would still be some opportunity for the utility to reduce fixed costs where possible to increase profits, and the utility would face little, if any, risk in covering its fixed costs and return since cost recovery is independent of the quantity of power it sells.

Customers would also be protected to some extent. Given that the required revenue is covered through fixed charges, consumers will not "overpay" for fixed assets as could happen with average cost pricing.[9] Moreover, as more customers were connected to the system, the fixed charge attributable to each would decrease, all else equal.

Avoiding Uneconomic Bypass

It is a well-known and understood problem that carrying cross-subsidies too far can lead large or wealthy customers to bypass the system and self-generate. This danger exists with the proposed cross-subsidy mechanism above, as well as any other cross-subsidy mechanism. The reason is that if the cross-subsidy through fixed charges leaves the large users worse off than under a cost-reflective average cost pricing regime, they may have an incentive to leave the system. A potentially interesting property of the cross-subsidy mechanism proposed here is that all of the subsidies are transmitted via the fixed charge. Therefore, given the fixed and variable component on rates, it will be easier to detect whether the cross-subsidy is reaching the point where some large users wish to leave the system and self-generate by comparing fixed costs of a new generating facility plus the marginal cost to the fixed charge plus the per kWh charge. As envisioned here with reliable estimates of demand, the cross-subsidy would not leave the large or wealthy users any worse off than under a cost-reflective average cost pricing regime, which should eliminate any incentives for bypass.

Different Customer Base Configurations

The analysis assumes that large and wealthy users of electricity account for the majority of the load being served and that they are the economic elites of the country. However, in many cases, large customers may not be that wealthy, and may be unable to absorb additional fixed charges to implement cross-subsidies to the extent that the political process may want. It may also be the case that much of the load is accounted for through smaller residential loads, though many of these customers may be wealthy. If this is the case, there must be some sort of mechanism to determine who will be providing the subsidy, based on income, and who will receive the subsidy, based on income. These can become highly charged

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[7] Even with the most rigorous of cost-of-service studies, there will still be disagreement over the assignment of common costs. In this case, whatever is decided to be the "split" of common costs between customer classes can be used as the baseline for the cross-subsidies.

[8] Revenue caps are becoming increasingly popular with regulators worldwide. Regulators in Scandinavia are using revenue caps for the wires part of the industry and in Florida, USA. The state regulator in Florida has approved a revenue cap mechanism for recovery of fixed costs including wires and generating plant.

[9] Customers could overpay for fixed assets if under average cost pricing, the amount of power consumed is in excess of the estimates of power consumed at the time of a rate review.

political issues, which may make it difficult to implement this kind of cross-subsidy scheme, which is no different than any other cross-subsidy scheme.

Different Industry Configurations

While the cross-subsidy mechanism proposed here assumes a vertically integrated, the mechanism can easily be applied to industry structures where there has been vertical unbundling of generation, transmission, and distribution as well as the introduction of competition in generation. The reason is that each part of the unbundled industry can be split into its component fixed and variable costs just as they would with a vertically integrated utility. Thus the final bill to customers would still include the fixed portion (including fixed costs from each of the three parts of the industry), plus the variable costs.

Concluding Remarks

This paper has proposed a cross-subsidy mechanism that uses optimal multi-part pricing as its basis. The proposed cross-subsidy does not distort consumption decisions in that the cross-subsidy is done through the fixed charge part of the multi-part price that does not depend on the quantity consumed. While this is a conceptually simple cross-subsidy mechanism, its implementation could be considerably more complicated. To implement the proposed cross-subsidy scheme as envisioned here, it is necessary to have reliable estimates of demand as a function of price, income and other factors. Moreover, it would require rigorous cost-of-service studies to determine the baseline cost-reflective tariff structure that is used to determine the amount of the cross-subsidy. There may also be political battles over the level of the cross-subsidy.

Still, despite the potential barriers to implementation, the proposed mechanism can, when combined with a revenue cap mechanism, offer utilities and consumers some benefits. Furthermore, this mechanism can be implemented whether the industry is vertically unbundled or vertically integrated. Finally, even if reliable estimates of demand and the cost of service cannot be obtained, it is still possible to determine a cross-subsidy that avoids uneconomic bypass.

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