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AN ANALYSIS OF FULLY DISTRIBUTED COST PRICING IN REGULATED INDUSTRIES*

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ABSTRACT

This paper examines the economic consequences of allocating common costs by (1) gross revenues, (2) directly attributable costs, and (3) relative output levels (such as ton-miles) to determine fully distributed cost prices for regulated firms. The analysis characterizes FDC tariffs, examining the nature of the economic inefficiency associated with the rules, and explains how opportunities for entry by unregulated firms might change if Ramsey optimal pricing were used instead of FDC pricing.

1. INTRODUCTION

In determining prices for the outputs of multiproduct firms, regulators have long been confronted with a number of difficult issues. Among other things one often finds the existence of economies of scale and costs which are shared in the production of two or more services. Economies of scale imply that marginal cost pricing, absent subsidy to the firm or multipart tariffs, will not allow the firm to break even. Further, shared costs cannot be unambiguously identified with individual products, so that any rule selected to associated shared costs with individual services will be arbitrary.[1]

In practice, regulatory authorities such as the Interstate Commerce Commission and the Federal Communications Commission historically have determined tariffs based on so-called Fully Distributed (or Allocated) Costs, which we will refer to as FDC pricing.[2] Under this method, regulators do (somehow) allocate shared production costs to individual services. Each service is then required to generate revenues which will cover all of the costs associated with that service. Although it is often argued that there is no economic foundation for FDC pricing, this practice obviously does have economic consequences.

It is our purpose to examine three well specified FDC rules, each having been used in regulatory proceedings, to address the following questions. What are the comparative characteristics of the price vectors that satisfy each rule? How do these price vectors compare with a Ramsey optimum? Do FDC rules lead to a systematic bias against the production levels of certain outputs? How is the set of FDC tariffs changed as larger profits are allowed? And finally, how might opportunities for entry by unregulated firms be affected by whether tariffs are determined by Ramsey rules or by FDC rules?

2. FDC PRICING PRACTICES

When regulatory commissions or regulated firms address the problem of rate structure, they do not usually do so by gathering the kind of long run marginal cost and demand data that economists would require in a determination of efficient prices. Instead, they often decide what portion of the firm's total costs must be covered by the revenues generated by each service. To start with, each service is typically assigned those costs which can unambiguously be attributed to that service. For example, the costs of railroad passenger cars would be assigned to passenger service.

In addition to costs which are directly attributable, a service may also be assigned a portion of those costs which cannot be clearly associated with any one service. Some administrative costs are shared by several services. Railroad track is used in the transport of many kinds of freight. Electric generators serve both business and residential users. As these examples suggest, shared costs may comprise a large portion of total costs. Thus, the method of allocating shared costs may significantly influence the rate which may be required for any particular service.

Verbal statements of allocation rules are often imprecise. For example, discussions of possible rules have sometimes included allocations based on such vague notions as "subjective social evaluation" and "value of service."[3] Even where rules have been more concretely defined, detailed variations in basic FDC methods can lead to a large number of candidates.[4]

In this paper we will examine three rather simple types of FDC rules that have received some attention in the literature and in regulatory proceedings. The first of these, as described by Alfred Kahn, is the distribution of shared costs "on the basis of some common basis of utilization, such as minutes, circuit miles, message-minute-miles, gross ton-miles, MCF [thousands of cubic feet (of gas)], or kwh [kilowatt-hours] employed or consumed."[5] Friedlaender has noted that in freight transportation, "the most usual means of prorating is on the basis of ton-miles."[6] Under this FDC approach, which we call the relative output method, shared costs are allocated in proportion to the number of units of output of each service.

A second approach sometimes used is the allocation of shared costs in proportion to the costs that can be directly attributed to the various services. We call this the attributable cost method. Kahn notes that this method has also been used to some extent in the transportation industry, and that this approach to accounting also has been used by many unregulated firms in their allocation of overhead costs.[7] (For our purposes, overhead costs are shared costs, since they are typically incurred in the production of all of the services provided by the firm.)

A third scheme requires allocation of shared costs in proportion to the gross revenues generated by each service. This gross revenue approach, is sometimes referred to as the "relative dollar value" method. As Friedlaender notes, "The ICC allocates overhead costs between freight and passenger services on the basis of revenues derived from each source."[8]

These three schemes obviously do not exhaust the list of candidates. Still, much can be learned about the nature of FDC pricing without an exhaustive list. For example, Bonbright has described an alternative in which "each class of service might be assigned a portion of the total cost equal, say, to 125 percent of its incremental cost."[9] We will show how this is closely related to the gross revenue and attributable cost methods.

The rules we will examine have been designed to work with data from a single technology. There are other schemes that base cost allocations for one technology on the costs which would be incurred using an alternative technology, including some of the allocation methods used historically by the Tennessee Valley Authority (river projects) and the Federal Power Commission (natural gas).[10] Because these involve comparative technologies, they are beyond the scope of this investigation.

Criticisms of FDC

Regulatory proceedings involving FDC pricing focused on a number of potential problems with the practice. Briefly, among the many criticisms of the practice are the following:

1. Fully distributed costs bear no direct relationship to marginal costs; hence, there is no basis in economic efficiency for FDC pricing.[11]

2. There exists no uniquely acceptable allocation rule. As Friedlaender notes, "Various means of prorating the common or joint costs can be used, but all of them have an arbitrary element and hence are dangerous to use in prescribing rates."[12]

3. On grounds of economic efficiency, it may sometimes be desirable to set a price for some service so that the revenues generated by a service do not cover its fully distributed costs.[13]

4. Because the determination of fully distributed costs is somewhat arbitrary, there is no economic basis for concluding that a service is being subsidized by other services if its revenues are less than its fully distributed costs.[14]

5. FDC pricing is anticompetitive since it prevents a supplier from offering a service at a proposed tariff less than an FDC price, particularly if the proposed tariff exceeds the marginal cost of providing the service.[15]

6. There is circular reasoning behind the FDC practice. Tariffs which are determined to be "appropriate" at a given time will depend on the existing levels of output or revenues, and these in turn depend on previous tariffs. Thus fully distributed costs may depend on the acceptance of a prior tariff structure.[16]

3. FDC PRICING USING FORECAST DATA

In examining tariff proposals, regulators are typically concerned with two major issues. First, will a proposed tariff generate an acceptable level of profits for the firm? Second, since there may be an infinite number of combinations of rate for individual services that will lead to any given profit level for a multiproduct firm, will the structure of a proposed tariff be acceptable?

Consider a firm that produces n services, $\{1,2,\ldots,n\}$, in quantities $\{x_1,x_2,\ldots,x_n\}$, and denote this vector of the levels of outputs by $\underset{\sim}{x}$. The regulator may regard some of the costs incurred by the firm as unambiguously and directly attributable to the provision of a particular service. We denote the costs directly attributable to the ith service by $C_i(x_i)$.

We assume that all of the shared costs incurred by the firm are fixed, represented by F, so that the total costs incurred are $C(\underset{\sim}{x})$, where

$$C(\underset{\sim}{x}) = F + \sum_{i=1}^{n} C_i(x_i) \qquad (1)$$

In writing (1), we are assuming that the firm acts to minimize the total cost of producing $\underset{\sim}{x}$. Of course, the total cost function also implicitly has factor prices among its arguments; we treat them as constant and suppress them in our notation.

We also assume that there exists an independent inverse demand schedule for each service, $P_i(x_i)$, so that the revenue for the ith service can be written as $R_i(x_i)$. Let the revenue contribution above attributable costs for the ith service be $Q_i(x_i)$, where

$$Q_i(x_i) = R_i(x_i) - C_i(x_i) \ , \ \forall i \tag{2}$$

In this analysis we restrict our attention to what we call the undominated region of an isoprofit contour.

Definition: An output vector $\underset{\sim}{x}$ lies on an undominated region of an isoprofit contour when $Q_i'(x_i) < 0$, $\forall i$. (The prime symbol (') denotes a derivative throughout this paper.)

An undominated region of an isoprofit contour is illustrated in Figure 1 along the arc DE. This region is of primary interest since it represents the set of prices for which there are no Pareto superior alternatives available to regulators. Any movement away from a point on the undominated region, such as point A, will require that either the profit level decline, or that the users of one of the services pay a higher price. In particular a point such as B is not undominated, since users of service 1 are better off at C, while no one else (users of service 2 and the firm itself) is worse off at C than at B.

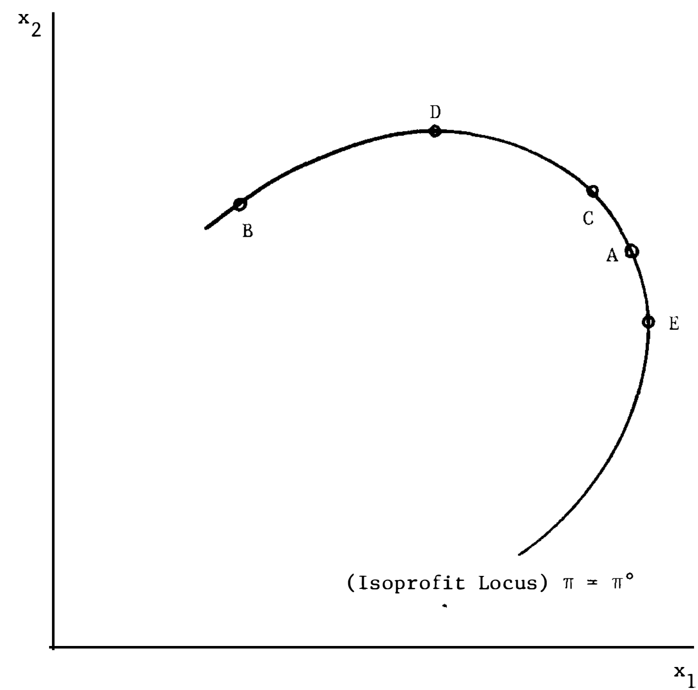

Figure 1: Undominated Output Vectors

Three Fully Distributed Cost Rules

The FDC pricing problem can be stated formally as follows. First, the common costs, F, must be allocated among the n services. To each service, say service i, a fraction, f_i, will be allocated. Since F must be fully distributed, we have

$$\sum_{i=1}^{n} f_i = 1. \tag{3}$$

Each service will be required to generate revenues, $R_i(x_i)$, sufficiently large to cover both the directly attributable costs and the allocated portion of the common costs. Thus, the FDC requirement can be stated

$$R_i(x_i) \geq f_i F + C_i(x_i) \ , \ \forall i. \tag{4}$$

Given any level of profits, $\Pi°$, a vector of tariffs will satisfy the FDC requirements if (4) is satisfied at the tariffs $(p_1,\ldots,p_n)$.

The specification of the fractions $(f_1,\ldots,f_n)$ is arbitrary. As we have suggested earlier, we focus on three such rules in this paper. First, if the f_i values are determined by gross revenues, then

$$f_i^g \stackrel{\Delta}{=} R_i(x_i)/\sum_{i=1}^{n} R_i(x_i) \ , \ \forall i. \tag{5}$$

If the allocations are based on directly attributable costs, then

$$f_i^a \stackrel{\Delta}{=} R_i(x_i)/\sum_{i=1}^{n} R_i(x_i) \ , \ \forall i. \tag{6}$$

And if common costs are distributed according to the relative levels of outputs, then

$$f_i^o \stackrel{\Delta}{=} x_i/\sum_{i=1}^{n} x_i \ , \ \forall i. \tag{7}$$

As noted earlier, use of the relative output rule requires that there exists some basic unit of measurement common to all services.

4. FDC TARIFFS WITH ZERO PROFITS

We now turn to the case in which FDC tariffs are determined for a firm that is just breaking even. This case is of interest for several reasons. First, FDC pricing rules prove to be most restrictive in the zero profit case, as we shall shortly see. Second, an examination of the zero profit case will permit us to compare FDC tariffs with Ramsey optimal tariffs. In addition, as Joskow (1974) has suggested, many of the rate hearings of this decade have been triggered by continuous, prolonged inflation, so that firms have struggled to avoid negative economic profits. Thus, at least in some cases, regulated firms may actually be operating so that near-zero economic profits are realized as regulators readjust rates.

We begin by noting that the FDC requirement of (4) can be rewritten as

$$Q(x_i) \geq f_i F \ , \ \forall i. \tag{8}$$

When Π^o is zero, then

$$\sum_{i=1}^{n} Q_i(x_i) = \sum_{i=1}^{n} f_i F = F. \tag{9}$$

Together, (8) and (9) imply that

$$Q_i(x_i) = f_i F \ , \ \forall i. \tag{10}$$

Thus, when profits are zero, FDC tariffs must satisfy

$$\frac{Q_i(x_i)}{Q_j(x_j)} = \frac{f_i}{f_j} \ , \ \forall i,j. \tag{11}$$

We now characterize the vector of tariffs that would satisfy FDC pricing rules at zero profits for each of the three allocation schemes, and summarize the results in rows one and two of Table 1. For convenience, we suppress reference to the arguments of R_i, p_i, Q_i, and C_i. First, for the allocation by relative output levels, from (7) and (11) it follows that at an FDC tariff

$$\frac{Q_i/x_i}{Q_j/x_j} = \frac{p_i - C_i/x_i}{p_j - C_j/x_j} = 1 \ , \ \forall i,j. \tag{12}$$

Thus, FDC tariffs determined by relative output levels will require that the difference between price and average attributable cost be equal for every service.

We can perform the same operations on (6) and (11) to characterize the FDC tariffs for the allocation by attributable costs, and then use (5) and (11) to do the same for the allocation by gross revenues. It turns out that the zero profit FDC tariffs for these two allocation schemes are identical, with

$$p_i/(C_i/x_i) = p_j/(C_j/x_j) \ , \ \forall i,j. \tag{13}$$

In other words, for these two methods, a zero profit FDC tariff requires that the ratio of price to average attributable cost be equal for all services. Furthermore, these two methods are identical to the rule described by Bonbright under which each service would generate revenues equal to a given percentage markup on attributable costs.[17]

5. ZERO PROFIT FDC PRICING AND RAMSEY OPTIMALITY

As mentioned earlier, Zajac (1972) has shown that it may not be possible to reach a Ramsey optimum with an FDC pricing rule. In other words, at a Ramsey optimum, the revenues generated by the ith service need not always cover even all of the directly attributable costs. Without elaboration we note that this may occur particularly if a service exhibits decreasing marginal costs, or if there are strong demand complementarities among the products of the regulated firm. Thus, it is not surprising that under some circumstances all of the three FDC rules we have addressed will lead to economically inefficient pricing.

In this section we characterize the systematic nature of the inefficiency associated with these rules. In order to draw any such inferences, it will be necessary to relate the attributable costs used by the FDC rules to the marginal costs required to determine efficient prices. This we do with the standard definition of the elasticity of scale for product i

$$S_i = \frac{C_i}{x_i C_i'} \qquad (14)$$

Substitution of (14) into (12) and (13) yields the FDC pricing rules shown in row three of Table 1.

Recall that a Ramsey optimum (with independent demands) requires that[18]

$$Y_i \overset{\Delta}{=} \left(\frac{P_i - C_i'}{P_i}\right) \varepsilon_i = \left(\frac{P_j - C_j'}{P_j}\right) \varepsilon_j \overset{\Delta}{=} Y_j \; ; \forall i,j \, , \qquad (15)$$

where ε_i is the price elasticity of demand for service i, and Y_i is sometimes called a Ramsey number for market i. It is obvious that FDC prices will generally deviate from second best prices since FDC rules are based on attributable costs instead of marginal costs. As (14) shows, the distinction between average attributable cost and marginal cost disappears only when the scale eleasticity is unity.

To investigate the nature of the inefficiency for the attributable cost and gross revenue methods of FDC pricing, we can

TABLE 1

Efficiency Properties of Zero Profit FDC Tariffs

Allocation Rule	Relative Outputs	Attributable Costs	Gross Revenues
1) FDC Allocation: Set $\frac{R_i - C_i}{\sum_j (R_j - C_j)} = \frac{Q_i}{\sum_j Q_j}$	$f_i^o = \frac{x_i}{\sum_j x_j}$	$f_i^a = \frac{C_i}{\sum_j C_j}$	$f_i^g = \frac{R_i}{\sum_j R_j}$
2) FDC Pricing Rule	$\frac{p_i - C_i/x_i}{p_j - C_j/x_j} = 1; \forall i,j$	$\frac{p_i}{C_i/x_i} = \frac{p_j}{C_j/x_j}$; $\forall i,j$	
3) FDC Pricing Rule (with $S_i = C_i/C_i' x_i$)	$\frac{p_i - S_i C_i'}{p_j - S_j C_j'} = 1; \forall i,j$	$\frac{p_i}{p_j} = \frac{S_i C_i'}{S_j C_j'}$; $\forall i,j$	
4) Comparative Ramsey Numbers, Y_i, at FDC Tariffs (with unitary elasticity, $S_i = 1, \forall i$)	$\frac{Y_i}{Y_j} = \frac{\varepsilon_i / p_i}{\varepsilon_j / p_j} = \frac{R_j' - p_j}{R_i' - p_i}$	$\frac{Y_i}{Y_j} = \frac{\varepsilon_i}{\varepsilon_j}$	
5) Inefficient Output Bias, Assuming (1) FDC tariff is undominated (2) $\lvert\varepsilon_i\rvert$ is monotonically nonincreasing as output increases (3) $S_i = 1, \forall i$	If $R_j' - p_j < R_i' - p_i$, then efficiency could be improved, without affecting profits, by lowering p_i and raising p_j	If $\varepsilon_i < \varepsilon_j$, efficiency could be increased, without affecting profits, by lowering p_i and raising p_j.	

rewrite the FDC condition that $p_i/p_j = S_iC_i'/S_jC_j'$ in terms of Y_i and Y_j as follows (see the appendix).

$$Y_i = Y_j \frac{\varepsilon_i}{\varepsilon_j} - \varepsilon_i \frac{C_i'}{p_i}\left[1 - \frac{S_i}{S_j}\right] \tag{16}$$

The inefficiency of the FDC method is immediately observable, since Y_i will generally differ from Y_j. More specifically, for example, if at an FDC tariff service i has the more elastic demand and a scale elasticity no less than that of service j, then $Y_i < Y_j$. Note that if the absolute value of elasticity of demand is monotonically nonincreasing in each market as output increases, then a lower price in any market will make the corresponding Ramsey number less negative. Thus, a relative price change that would improve efficiency without affecting overall profits would be a reduction in p_i relative to p_j.

For the special case in which the scale elasticities are equal ($S_i = S_j$), and this is arguably a case of some interest,[19] then the FDC requirement (16) simplifies to

$$\frac{Y_i}{Y_j} = \frac{\varepsilon_i}{\varepsilon_j} \tag{17}$$

Thus, at an FDC tariff, the market with the more elastic demand (assume this is market i) will have the more negative Ramsey number. Again, a reduction in p_i relative to p_j would increase efficiency.[20] We can thus conclude that when $S_i \geq S_j$, both the gross revenue and attributable cost methods exhibit an inefficient bias against products with more elastic demands. A summary statement about the

bias for the case of equal (in particular, unity) scale elasticity in all markets is included in rows four and five of Table 1.

For the relative output method, the nature of the bias is a bit more complicated. We can rewrite the FDC condition that $p_i - S_iC_i' = p_j - S_jC_j'$ in terms of Y_i and Y_j as follows (see the appendix).

$$Y_i = Y_j\left(\frac{R_j' - p_j}{R_i' - p_i}\right) + \frac{\varepsilon_i}{p_i}\left[\left(\frac{C_i}{x_i} - C_i'\right) - \left(\frac{C_j}{x_j} - C_j'\right)\right] \tag{18}$$

At an FDC tariff, if the difference between price and marginal revenue is less in market i than in market j and if the difference between average attributable and marginal cost is no less in market i than in market j, then $Y_i < Y_j$. More efficient tariffs could be charged without affecting profits by lowering p_i relative to p_j.

For the special case in which all markets exhibit unitary scale elasticity, (18) becomes

$$\frac{Y_i}{Y_j} = \frac{R_j' - p_j}{R_i' - p_i} .$$

The nature of the bias for this case summarized in rows four and five of Table 1.

6. FDC PRICING WITH POSITIVE PROFITS

Suppose now that the firm is allowed to earn $\Pi^o > 0$. Then an FDC tariff vector must satisfy the following conditions:

$$R_i \geq f_i F + C_i \ , \ \forall i \qquad (19)$$

and

$$\sum_i R_i = F + \sum_i C_i + \Pi^o \qquad (20)$$

However, in contrast with the zero profit case, (19) and (20) imply that there may be an infinite number of tariff vectors that satisfy the FDC requirement when profits are positive. A simple example serves to illustrate this point. Consider a two product firm. The inverse demand schedules for services 1 and 2 are respectively:

$$p_1 = 50 - x_1$$

$$p_2 = 40 - 2x_2 \ .$$

Further, let the total cost function be

$$C = 500 + 2x_1 + x_2 \ .$$

In Fig. 2 we have plotted the undominated regions of the isoprofit curves for $\Pi = 0$, $\Pi = 100$, $\Pi = 200$, and $\Pi = 250$. The unconstrained profit maximum is at point D. K represents the first best solution, at which both prices equal marginal cost. The locus KD contains the price vectors at which the Ramsey numbers are equal in the two markets (see (15)). In particular, a Ramsey optimum occurs at point C, where

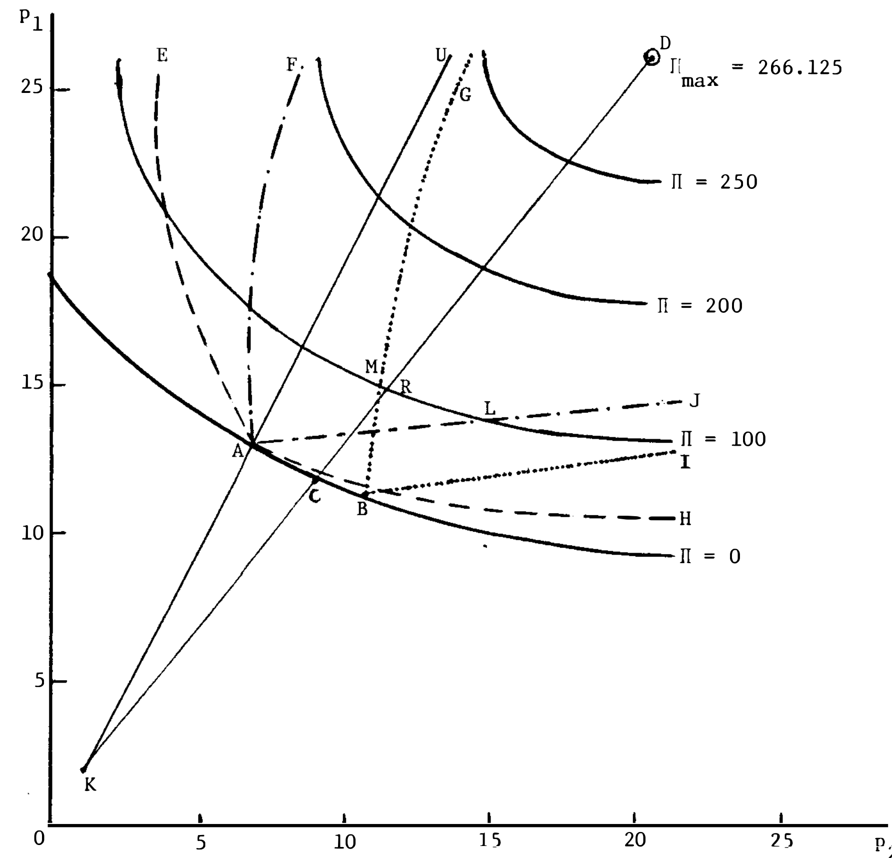

FIGURE 2. FDC PRICING EXAMPLE

profits are zero. In addition, the zero profit FDC tariff for the relative output method (see (12)) is at B. Finally, the zero profit FDC tariffs for the gross revenue and attributable cost methods coincide at point A (see (13)).

Note what happens to the various sets of FDC tariffs when positive profits are allowed. Any tariff vector to the "northeast" of the boundary EAH will satisfy (19) for the method of allocation by gross revenues. Any vector to the northeast of FAJ will satisfy (19) for the attributable cost method. Any vector to the northeast of GBI will satisfy (19) for the relative output method.

Several additional observations can be made. If we restrict our attention to the zero profit case, the example shows that alternative FDC methods can lead to different directions of bias in the tariff vectors, relative to a Ramsey optimum. Note that A and B lie on opposite sides of C in the example.

The example also shows that the FDC tariff vectors that satisfy the methods of allocation by gross revenues and attributable costs need not be identical with positive profits, even though they are identical in the zero profit case. It also shows that for some profit levels it may be possible to satisfy all three FDC rules simultaneously, as the segment $\overline{ML}$ does for $\Pi = 100$. Note also that when $\Pi = 100$, the most efficient price vector occurs at point R, since the Ramsey numbers are equal. Thus, in this example, the most efficient price vector at $\Pi = 100$ also satisfies all three FDC requirements, in contrast to the case with $\Pi = 0$, where none of the three FDC methods permitted an efficient tariff.

In summary, with positive profits a new type of arbitrary decision must be made, even after the choice of the FDC rule is specified, since many tariffs may satisfy the FDC requirements. One could impose more restrictive rules. For example, one could require that the percentage markup of price over average attributable cost be the same in all markets, as the method discussed by Bonbright would suggest. (In our example, this would correspond to a requirement that the tariff vector lie on the segment AU.) However, under any of the less restrictive allocation methods we have addressed in this paper, the choice of tariffs will remain ambiguous when positive profits are realized.

7. FDC PRICING AND ENTRY

Before closing, we briefly address some of the implications of FDC rules for competitive opportunities in markets for unregulated substitutes. Consider what may happen if an unregulated entrant provides a service that is a close, though imperfect substitute for the ith service offered by a multiproduct regulated firm that retains a monopoly in its other markets. Let p_i represent the tariff charged by the multiproduct firm for service i. In particular we ask whether a Ramsey optimal p_i is likely to be higher than or lower than a p_i determined by FDC rules.

First, we must be specific about the notion of Ramsey optimality where there are unregulated entrants. In particular we employ the notion of "partially regulated second best" (PRSB) pricing developed by Braeutigam (1979). The phrase "partially regulated" refers to a form of regulation in which the prices charged by the multiproduct firm can be regulated, but the prices charged by the competitive entrants are not regulated. Thus, PRSB prices are those charged by the multiproduct firm that maximize consumer and producer surplus generated by both the regulated and unregulated markets, subject to a minimum profit constraint (usually a zero profit condition) on the regulated firm. The minimum profit constraint is required to keep the regulated firm from earning the negative profits that would be incurred at marginal cost pricing because there are economies of scale. If the n products of the regulated firm have demands independent of one another, then PRSB prices must satisfy (15), so that the Ramsey numbers are equal in all markets served by the multiproduct firm. It is important to note that the PRSB rules are based on the demands facing the unregulated firm rather than on some undefined notion of a market demand.

How do these Ramsey optimal (PRSB) prices compare with FDC prices? To begin with, we observe that if positive profits are allowed, the answer is not at all obvious. In section six we showed that FDC pricing rules may generate a wide range of acceptable tariffs, and it will not generally be possible to state whether the allowed tariff for service i, the one where entry has occurred, will be higher or lower than the Ramsey optimal tariff at $\Pi^o > 0$.[21]

Now let us restrict ourselves to the zero profit case, for that is the usual constraint for which Ramsey optimal tariffs are defined. Following the development of section five, we retain the

assumption that the absolute value of elasticity of demand is monotonically nonincreasing as output increases in each market.

First, for the gross revenue and attributable cost methods, we recall that $p_i/S_iC_i' = p_j/S_jC_j'$ at an FDC tariff. Suppose that the effect of entry by unregulated competitors into market i to make the regulated firm's demand for i more elastic than its demand for j, at any FDC tariff. In addition, if $S_i \geq S_j$, then (16) implies that $Y_i < Y_j$. Thus, at an FDC tariff, economic efficiency could be improved, without affecting profits, by lowering p_i relative to p_j, a movement that would diminish the opportunities for the unregulated competitors.

A similar remark can be made regarding the method of allocation by relative output levels. At an FDC tariff we recall that $p_i - S_iC_i' = p_j - S_jC_j'$. Suppose that the effect of entry is to make the difference between the marginal revenue and price in market i smaller then the difference in market j at an FDC tariff. Then if the difference between average attributable and marginal cost is no less in market i than in market j, then (18) implies that $Y_i < Y_j$ at an FDC tariff. Once again, economic efficiency could be improved without affecting profits, by lowering p_i relative to p_j.

8. CONCLUSION

Although it is often argued that FDC tariffs are not based on economic principles, they certainly do have economic consequences. This analysis of three well defined FDC rules has demonstrated several economic implications.

When positive profits are allowed, FDC requirements may be satisfied by a wide range of tariffs, some of which may be quite efficient, and others of which may be rather inefficient. FDC requirements are most restrictive when economic profits are zero. With zero profits, the FDC tariffs that satisfy the gross revenue and attributable cost methods of allocating common costs are identical.

None of these FDC rules will lead to Ramsey optimality in general, even when profits are zero. We have shown how the systematic nature of the inefficiency will depend on the elasticities of scale and demand. Stated imprecisely here, the basic nature of the bias for all three rules is this. At an FDC tariff the products with the most elastic demands and highest elasticities of scale will be priced higher relative to other products than they would be at a Ramsey optimum. This suggests that opportunities for unregulated entry into one of the markets served by a regulated firm might be encouraged more under zero profit FDC pricing than under a regime of Ramsey pricing if entry would leave the regulated firm with a highly elastic demand in the entered market.

Extensions of this line of research might take a number of directions. As we stated at the outset, there are many forms of FDC rules other than the three we have addressed, many of which are poorly defined, and some of which are quite complicated. Other work may focus on the existence of variable common costs, interdependent demands, costs common to proper subsets of services, and more complicated forms of regulation, including, for example, the combination of FDC pricing with rate of return regulation.

FOOTNOTES

1. The term "shared costs" will be used to include both "joint costs" (in which the ratio of the level of one output to another is fixed) and "common costs" (in which outputs can be produced in variable proportions).

2. The ICC confirmed the practice of FDC pricing in Docket 34013, 337 ICC 298, July 30, 1970; the FCC did so in Docket 18128/18684, 61 FCC 2d, November 26, 1976, p. 606.

3. See, for example, the rather extensive discussions in Bonbright (1961a) chapter 18, and Bowman, et al. (1976). The vagueness of "subjective social evaluation" is obvious; for more on "value of service," see Locklin (1972), pp. 157-162.

4. For example, as Bonbright (1961b) notes, in 1953 and 1957 the Illinois Commerce Commission refused to order the Commonwealth Edison Company of Chicago to make a fully distributed cost study in support of a proposed rate increase, because there were at least "twenty-nine rival formulas for the allocation of capacity costs alone -- formulas each of which had received some professional sponsorship." (See pages 306 and 307.)

5. See Kahn (1970), p. 151.

6. Friedlander (1969), p. 133.

7. Kahn (1970), p. 151. On p. 78, in commenting on this common practice, Kahn notes, "The assumption presumably is that the greater the quantity and the higher the cost of labor and materials used in fabricating a product, the greater also will be the quantity and value of equipment employed in its production, the draft on the time and attention of inspectors . . . ."

8. See Friedlaender (1969), p. 32. Also see Bowman (1976). The so-called "relative sales volume" method has been employed in the meat packing industry to allocate administrative costs to individual production plants. Under this scheme the administrative costs are assigned to individual plants according to prior dollar sales volumes.

9. Bonbright (1961b), p. 309.

10. For example, the Tennessee Valley Authority allocated the shared costs of river development projects among the various services (navigation, electric power, and flood control) in proportion to what "it would have cost to provide each of those services in the same quantity in single-purpose projects set up exclusively for them." See Kahn (1970) p. 151, and Federal Power Commission (1949). A similar method (the "relative cost method") was used by the FPC to allocate the joint costs incurred on leases producing both oil and gas. Again see Kahn (1970) p. 151, and Federal Power Commission (1965).

11. See the "Proposed Findings of Fact and Conclusions of Bell System Respondents," FCC Docket 18128/18684, March 12, 1973, pp. 144-145.

12. See Friedlaender (1969), p. 133.

13. See Zajac (1972) for a rigorous example of this point. In less rigorous terms Locklin (1972) has made a similar point (see p. 168).

14. See the Bell System "Proposed Findings . . ." (footnote 11), pp. 158-159.

15. See the testimony of Dr. James Bonbright, FCC Docket 18128/18684, p. 10590 of the transcript.

16. There are a number of other problems with FDC pricing discussed elsewhere. For example, should the fully distributed costs of a service reflect the extent to which the historical total costs of the firm were affected by the presence of the service? Should current replacement costs be used instead of historical costs? These familiar questions transcend the issue of FDC pricing. For a good summary, see Kahn (1970), pp. 151-158.

17. See n. 9 above. Bonbright refers to a markup on incremental costs, which are usually defined for, say service 1, as $C(x_1,x_2,\ldots,x_n) - C(0,x_2,\ldots,x_n)$. Under the cost structure used in our work, incremental costs and attributable costs are clearly identical. Under a more complicated cost structure in which shared costs are not fixed, the concepts are not identical.

18. The rules for a Ramsey Optimum, as derived by Baumol and Bradford (1970), maximize the sum of consumer and producer surplus subject to a minimum profit constraint. At second best, the minimum profit constraint is equivalent to a nonnegativity constraint. However, one could in principle maximize the sum of the surpluses subject to any minimum profit level, $(\Pi \geq \Pi^o)$, and derive the necessary conditions of (15).

19. The ICC estimates rail costs using a functional form which characterizes marginal costs (or, so-called out-of-pocket, or average variable costs) as constant. Under the ICC procedure, shared costs are viewed, as fixed, and each service has constant average variable costs attributable to each service. For a critique of this practice, see Friedlaender (1969), especially pages 28 through 34, and Appendix A.

20. In particular, if $S_i = S_j = 1$, then the condition for an FDC tariff will be $p_i/C_i' = p_j/C_j'$ (i.e., that the price-marginal cost ratios are equal in each market). This is familiar within the general literature on second best. That condition does solve the problem of maximizing the sum of producer and consumer surplus given a maximum constraint on total costs. However, the FDC solution is not Ramsey Optimal when $\varepsilon_i \neq \varepsilon_j$, since the sum of the surpluses can be increased without affecting the level of profits.

21. As noted earlier, the Ramsey optimal tariff is usually determined given a minimum profit constraint of zero profits. However, one could satisfy (15) given a minimum profit constraint different from zero. Recall that the segment KD in Fig. 4 represents the locus of such tariffs in the example of section six.

APPENDIX

Derivation of (16).

From (13) and (14) we obtain

$$p_i/p_j = S_iC_i'/S_jC_j' \ .$$

Thus

$$\frac{p_i - C_i'}{p_i} = \frac{p_jS_iC_i'}{p_iS_jC_j'}\ \frac{\left(p_j - C_j'\right)}{p_j} - \frac{C_i'}{p_i} + \frac{S_iC_i'C_j'}{S_jC_j'p_i}$$

and

$$\left[\left(\frac{p_i - C_i'}{p_i}\right)\varepsilon_i\right]\varepsilon_j = \left[\left(\frac{p_j - C_j'}{p_j}\right)\varepsilon_j\right]\varepsilon_i - \frac{C_i'}{p_i}\left[1 - \frac{S_i}{S_j}\right]\varepsilon_i\varepsilon_j$$

which can be restated as (16) in the text.

Derivation of (18).

We rewrite (12) as

$$p_i - C_i' - \left(C_i/x_i - C_i'\right) = p_j - C_j' - \left(C_j/x_j - C_j'\right).$$

Thus,

$$\left[\left(\frac{p_i - C_i'}{p_i}\right)\varepsilon_i\right] = \left[\left(\frac{p_j - C_j'}{p_j}\right)\varepsilon_j\right]\frac{\varepsilon_i\ p_j}{p_i\ \varepsilon_j} + \frac{\varepsilon_i}{p_i}\left[\left(\frac{C_i}{x_i} - C_i'\right) - \left(\frac{C_j}{x_j} - C_j'\right)\right]$$

We arrive at (18) by using the fact that

$$\frac{p_j}{\varepsilon_j} = \frac{\partial p_j}{\partial x_j}\ \frac{x_j}{p_j} \cdot p_j = R_j' - p_j \ .$$

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