

# **COSTING PRINCIPLES IN THE TELECOMMUNICATIONS INDUSTRY**

**By**

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**(Revised)**

\* Florida Public Utilities Professor, and Research Fellow, respectively. Public Utility Research Center, University of Florida. This report presents an overview of issues raised in the PURC/FPSC Telecommunications Costing and Pricing Project. This presents costing principles, not detailed procedures for linking accounting data to particular services or families of services. The purpose of the overall project is to provide technical education and FPSC staff development opportunities, not to develop or certify a particular costing methodology. However, we hope that this report and associated PURC Workshops provide background information which facilitates staff investigations. The views presented here do not necessarily represent those of sponsoring organizations.

## I. Introduction

Why in this era of selective deregulation in telecommunications markets do we seem to have more lengthy and complex regulatory proceedings than ever before?

It is commonplace today in the telecommunications industry to hear of a seeming paradox. In the transition to competition and selective deregulation in this industry, we appear to have more complicated regulatory proceedings than ever before. A moment's reflection reveals why this premise might be true. In moving toward a competitive telecommunications industry, both potential entrants and incumbents want to be sure that regulatory rules do not put them at a competitive disadvantage. Similarly, customers have new options (and risks), so they, too, have a greater stake in the design of rules--compared to the pre-divestiture era. Thus, we have more parties interested in the outcomes of regulatory proceedings. The regulatory process becomes clogged with intervenors: the hearing room becomes the place where market advantage can be won or lost.<sup>1</sup> In some sense, if a potential entrant can be beat in the hearing room by being denied access to essential facilities, there is no need to beat them in the marketplace.<sup>2</sup> Similarly, if the incumbent is handicapped with burdensome rules and regulations, it may be unable to compete for some businesses which economically, it would be most efficient to serve. And, in fact, it may be easier for interested parties to "win" in the hearing room than in the marketplace.

One of the more controversial and complex regulatory issues today is the ongoing debate over costing principles and methodologies, since these might dictate the outcome of regulatory investigations. Indeed, the evolution of the

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<sup>1</sup> In some sense this is not unlike the problem of deciding what toppings to have on a pizza. The difficulty of deciding what to have on the pizza increases exponentially with the number of individuals sharing it.

<sup>2</sup> In fact, the increasing number of attorneys, economists and engineers appearing in regulatory proceedings could well be interpreted as rent-seeking behavior, in which interested parties battle over the slices of a fixed pie -- a zero or negative sum game. What is unclear is whether the quality of the regulatory outcomes is improved (or the size of the pie increased!) as a result of the abundance of technical experts appearing in support of a given cause. Posner (1975), Wenders (1987), McChesney (1987).

role of costing in telecommunications is an interesting and tortured one. According to Thomas McCraw (1984), Alfred Kahn, when he headed up the New York Public Service Commission, was one of the first regulators to require that telephone companies submit cost data in support of their rate design requests. At the time, New York Telephone had virtually no personnel dedicated to developing costs for service offerings. Today, the costing organizations in each of the seven Bell Operating Companies are large entities with many employees; in addition, numerous professionals work on issues involving jurisdictional separations.

That costs should serve an instrumental role in regulatory proceedings today is to be expected. But there are many pitfalls in both the development and meaningful interpretation of cost data. Indeed, as we shall discuss below, some costing methodologies are grounded in sound economic theory and decision science, while others represent little more than arbitrary manipulation of data designed to rationalize some predetermined outcome.<sup>3</sup> Yet the costing issue itself has proved somewhat intractable in the academic literature, so it is little wonder that confusion abounds in the hearing room with expert witness poised against expert witness and vested interest against vested interest. Indeed, as Professor John Wenders has pointed out, the costing docket at the FCC went on for some 30 years--absent resolution as to the appropriate methodology.<sup>4</sup> (Note that in a similar vein, it took the FCC some 15 years to rule whether AT&T's Tel-Pac tariffs were legal).<sup>5</sup>

The purpose of this paper is to discuss a set of costing principles that should prove of value to regulatory commissions and telecommunications companies as they sort through the various rate design and costing issues that competition and the Information Age will lay at their doorstep. This overview does not provide a comprehensive treatment of costing methodologies, but sketches out some of the key issues and principles. Future working papers will address specific

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<sup>3</sup> Kahn (1984).

<sup>4</sup> Wenders (1987).

<sup>5</sup> Brock (1981).

costing methodologies and attendant issues they raise.

The format of this paper is as follows. Section II is a brief overview of regulatory interest in costing principles. This section provides perspectives needed for the more technical material contained in later sections. Section III is a discussion of the rationale for the so-called *marginal cost* or *incremental cost standard*. This standard is the benchmark criterion for economic efficiency and will serve as a frame of reference for subsequent discussion. A digression on cross-subsidization is included in this section to highlight the role that marginal cost plays in protecting against cross-subsidization. A discussion of the economic distortions resulting from the use of inappropriate cost allocation mechanisms is contained in Section IV. Section V summarizes the key conclusions and provides a preview of future working papers. Appendix A contains selected excerpts and passages regarding the use of cost allocations in regulatory proceedings. Appendix B presents a simple matrix cost model as an example of how a costing methodology might be developed to address various rate design issues (including predation and undue discrimination), to evaluate investment and assumptions about capacity lives (especially for new technology adoption), and to establish policies toward entry.

## **II. Regulatory Interest in Costing Principles**

### **Why Should Regulators Be Interested In Costing Principles?**

The answer to this question is complex and multi-dimensional. If we were to list the reasons that regulators may be interested in costing principles, we might come up with something like the following list:

1. Achievement of Economic Efficiency, including cost minimization and the appropriate output mix.
2. Concern For Fairness/Income Distribution
3. Assurance of Opportunity to Obtain Revenue Requirements needed for Financial Viability
4. Fairness in the Apportionment of Total Costs
5. Avoidance of Strategic Behavior

We briefly discuss each of these in turn, digressing where necessary to address the operative interrelationships.

## 1. Achievement of Economic Efficiency

**THE BENCHMARK CRITERION FOR ECONOMIC EFFICIENCY IS THAT OF A COMPETITIVE MARKETPLACE IN WHICH PRICES ARE DRIVEN TO THE VICINITY OF MARGINAL OR INCREMENTAL COST AND EXCESS PROFITS ARE ZERO.**

To this point in our discussion, we have used the term "cost" rather loosely, without defining precisely what it is we mean by this term. When the economist uses the term cost, he or she generally means some measure of *marginal* or *incremental* cost. That is, from an efficiency perspective, prices should be set in such a way as to reflect the true resource costs borne by society in producing the marginal or incremental unit of the good or service. A price set higher than marginal cost will preclude some market transactions that could have made both the firm and the consumer "better-off." A price set lower than marginal cost will induce overconsumption--some agents will purchase the service when their valuation of the service is less than the resource cost borne by society in producing it. Both of these situations are sub-optimal. Hence, from an efficiency perspective, so-called first-best resource allocation is obtained when prices are set equal to incremental cost, assuming there are no market failures (like external effects) or market imperfections (like inadequate information for consumers).<sup>6</sup>

## 2. Concern For Fairness/Income Distribution

**THE REGULATOR, IN HIS/HER CAPACITY AS A "SOCIAL PLANNER" MAINTAINS A DE FACTO TAXING AUTHORITY IN SETTING RATES FOR SERVICES CONSUMED BY THE VAST MAJORITY OF THE POPULATION. OF CRITICAL CONCERN IN THIS CAPACITY ARE THE FAIRNESS AND INCOME DISTRIBUTIONAL IMPACTS ASSOCIATED WITH THE CHOICE OF PRICE STRUCTURES FOR CUSTOMER CLASSES AND PRODUCT LINES.**

Within the scope of the regulators' authority is the power to establish

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<sup>6</sup> Greer (1987) categorizes the problems justifying government intervention as involving market imperfections, market failures, dynamic incapacities, and ethical concerns. Imperfections are reflected in market power or information inadequacies: the conditions under which buyers and sellers come together deviate from competitive assumptions. Failures refer to externalities, public goods, and common property resource problems (eg. radio spectrum)--all of which characterize some telecommunications markets. Dynamic incapacities relate to the inability of institutional arrangements to adjust to new situations without causing undue hardship--microeconomic transition costs or macroeconomic instabilities. Finally, ethical concerns often motivate public policy: with the goal being fair (or less unequal) income distribution, the production of merit goods (such as education), and the achievement of other social goals.

public policy in a manner than best serves the *public interest*.<sup>7</sup> For example, regulators may decide on the basis of fairness and the collective social good that certain services, e.g. basic local service, should be priced in such a manner so as to ensure that every individual who desires such service shall not be denied access because of inability to pay. Mitchell and Vogelsang (1990) label this dimension of fairness the *economic right* to a commodity (such as universal telephone service). The particular service needs to be well defined and the sources of finance need to be identified if such an objective is to be met.

Another component of fairness is *status quo fairness*--or a non-loser criterion. No stakeholder is to be adversely affected in any way if such a concept of fairness is to be implemented. Of course, such an objective could be extremely costly in terms of lost opportunities and reduced productivity growth. However, the idea of a "safety net" is relevant in some situations.

Mitchell and Vogelsang also identify *cost causality* as a component of fairness. From this perspective, those who cause costs to be incurred ought to bear the burden of paying those costs. Regulators may selectively choose to set certain prices below the cost of the service. This does not imply that the regulator's knowledge of the true cost is inessential. Indeed, no "social planner" can perform his duties effectively without full knowledge of the costs and benefits of his/her respective actions. The key point is that knowledge of respective service costs is important, if only to know what it is that rates are departing from.

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<sup>7</sup> Agreement of just what is in the public interest may be more apparent than real, particularly with regard to the ability of politicians to balance different objectives--such as fairness and efficiency. Our awareness of government shortcomings has increased over time. These limitations include government imperfections, failures, dynamic problems (myopia and delay), and inconsistencies in the application of ethical criteria. Imperfections refer to government as a monopoly, the existence of voter apathy, and persistent lack of information needed by officials. These problems, identified by Greer (1987), parallel imperfections observed in markets. Government failures arise when benefit-cost analysis is misapplied--primarily due to special interest effects, externalities, bundling of policies, and a tendency to impose uniform treatment despite diverse situations. Myopia and delay stem from intertemporal inconsistencies, when costs and benefits of policies differ in the long and the short run. Some analysts find that policy cycles follow the election returns: when in doubt, avoid inaction. Finally, the stated goal of fairness is often used to justify regulation, although the actual incidence of the benefits and costs generally differs from popular understanding. The two alternative institutional structures for seeing that consumers' needs are met via least-cost suppliers (and that new goods and production processes are introduced) involve markets or governments: we either use markets to allocate resources or government agencies to allocate markets. Each institutional arrangement has strengths and limitations. The selection of the appropriate institutional structure involves a realistic comparison of performance with market incentives and with regulation.

Finally *fairness in process and opportunity* is another dimension warranting attention. Open hearings and the elimination of uneconomic entry barriers both are based on the principle that competition serves us well: in the marketplace of ideas and for most goods and services. That these four conceptions of fairness may conflict with one another at times is not surprising. We are continually balancing outcomes on the basis of how we value the various aspects of those outcomes. The key is to make those trade-offs explicit, so we understand what we are giving up when we choose one outcome over another.

### **3. Assurance of Opportunity to Obtain Revenue Requirements**

THE TASK OF SETTING REVENUE REQUIREMENTS CLOSELY PARALLELS THAT OF RATE DESIGN--WITH ONE KEY DIFFERENCE. ALLOWED RETURNS AND LEGITIMATE OPERATING COSTS ESTABLISH THE LEVEL OF REVENUE REQUIREMENTS WHILE RATE DESIGN IS CONCERNED WITH THE ACHIEVEMENT OF EFFICIENCY, WITH HOW THE CASH FLOWS ARE TO BE OBTAINED, AND WHICH CLASS OF CUSTOMERS BEARS THE GREATEST "BURDENS."

The regulator is first and foremost required to set the revenue requirements for the firm so as to ensure its ability to raise capital. That is, the regulator must ensure the viability of the enterprise itself. Historically, regulators and those they regulate have not always agreed on either the size of the capacity investment or how it should be financed. In general, competitive entry will tend to add an additional constraint to the process. Not only will competition serve to highlight departures from competitive market pricing in the past, it will also ensure that such departures not continue in the future.

The financial viability of firms is essential if continued investments needed to meet consumer demands are to be forthcoming. Both case law and common sense dictate that the providers of telecommunications services be given the opportunity to recover costs incurred to meet customer demands. Regulation does not "guarantee" investors a rate of return on their investment, but regulatory constraints should not preclude cost recovery of prudently incurred expenses.

There is another issue of potential importance, as telecommunications markets become increasingly competitive. This issue centers on the possible legal challenge to the regulator's discretion in setting both overall revenue requirements and rate levels necessary to generate these revenues. For example,

a regulator's decision to simultaneously allow competitive entry into a given market while constraining the regulated firm to rigid pricing and service obligations could be viewed as an unjust confiscation of property in violation of 14th amendment guarantees of equal protection.<sup>8</sup>

#### 4. Fairness In The Apportionment of Total Costs

THE RATE DESIGN FUNCTION DEPENDS CRITICALLY ON AN UNDERSTANDING OF THE UNDERLYING COST STRUCTURE FOR THE SERVICE IN QUESTION--AS EVERY DEPARTURE FROM INCREMENTAL COST RESULTS IN A LOSS IN ECONOMIC WELFARE RELATIVE TO A COMPETITIVE MARKETPLACE. FROM AN ECONOMIC EFFICIENCY PERSPECTIVE, UNALLOCABLE COSTS SHOULD BE BORNE BY SERVICES THAT WILL MINIMIZE THE DIVERGENCE OF DEMAND PATTERNS FROM THOSE THAT WOULD HAVE BEEN OBSERVED IN A COMPETITIVE MARKETPLACE.

As a general guideline, regulators may want to ensure that all services cover the cost to the firm of supplying them. Any rate that then covers the firm's cost of providing a service is understood to be *compensatory*. Of course, as we have discussed above, regulators may ultimately decide that fairness issues warrant a departure from such a standard--but without such cost information they could not know what they were departing from. This is a particularly important consideration under rate of return regulation, where the cost not paid by one class of customers must be passed on to some other class of customers.

Note that although consumption pattern distortions may be minimized if inelastic demanders are priced to recover large proportions of unallocable costs, those demanders may be precisely the ones regulators most want to protect. Inelastic demanders have few substitutes for the service in question. Yet, as Henderson and Burns (1989) stress in their recent NRRI report, value-based pricing may be appropriate in the presence of shared (unallocable) costs. Thus, the identification of "undue" price discrimination turns on alternatives available to "favored" customers in the long run. Henderson and Burns conclude that traditional (historical embedded) cost of service studies are inadequate to distinguish "due" from "undue" price discrimination (p. vii).

The advent of competition places an additional constraint on the regulator's

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<sup>8</sup> While the authors are not aware of any regulated firm taking such action to date, it has been a topic in the theoretical literature. See Weisman (1988, 89).

ability to establish rate levels for services. In a competitive marketplace, inefficient rate levels are synonymous with unsustainable rate levels, which generally means that the firm will fail to attain the particular revenue requirement either in aggregate, or for particular service classes. For example, prices above standalone costs will tend to induce self-provision of a service. Similarly, prices above costs of serving a coalition of customers (e.g., urban high volume customers) will be unsustainable in the long run, as new firms or groups of users enter the industry and provide service offerings. Such defections may be economic (if lower-cost suppliers are involved and the incumbent does not lose multiproduct economies) or uneconomic (as with "cream-skimming" induced by mandated rate-averaging for a regulated incumbent).

## 5. Avoidance of Strategic Behavior

**THERE IS AN INTERESTING EXPERIMENT THAT REGULATORS MAY WANT TO ATTEMPT. REQUIRE EACH PARTY TO A REGULATORY HEARING TO SUBMIT A PARTICULAR COST METHODOLOGY. ALL OF THE METHODOLOGIES WILL BE PLACED IN A HAT. EACH FIRM THAT WISHES TO DO BUSINESS IN THE TELECOMMUNICATIONS MARKET IN QUESTION MUST DRAW A COST METHODOLOGY FROM THE HAT AND UTILIZE IT IN DECISION-MAKING. WE MIGHT BE AMAZED AT JUST HOW SIMILAR THESE COST METHODOLOGIES ARE; AND PERHAPS MORE IMPORTANTLY, HOW CLOSELY THEY PARALLEL PRINCIPLES APPLICABLE TO A COMPETITIVE MARKETPLACE.**

This last issue deals with the manner in which both competitors and market incumbents can be expected to use costing principles that support and reinforce their own strategic best interests. For example, the market incumbent may be expected to propose a price floor equal to incremental cost. Existing competitors and potential entrants may object to such a standard for a number of reasons. First, they might argue that incremental costs are such that entrants would be closed out of the market if the incumbent had such pricing flexibility. Second, competitors may argue that since the incumbent is "guaranteed" capital recovery, the incumbent will over-invest in order to drive marginal cost down to artificially low levels and thus preclude competitors from the marketplace. This is one reason why potential competitors might argue for some type of fully allocated costing methodology for the incumbent--so as to preclude the type of behavior we have discussed here.

The incumbent could argue that its costs are what its costs are and that if it were over-investing, it is the regulator's responsibility to identify such

overinvestment and make disallowances accordingly. Hence, it is unreasonable for them to be precluded from making a sale that would have made some contribution to the recovery of fixed and overhead costs.<sup>9</sup> There is no straightforward solution to this conundrum. In fact, it will become increasingly more difficult to discern over-investment from stand-by capacity necessary to meet carrier of last resort obligations in the face of increasing competition.<sup>10</sup> It may be best to use some measure of long run incremental cost as the basis for a price floor and depart from that benchmark on a case-by-case basis, (Berg-Tschirhart (1988), pp. 453-456).

### Summary

The historical role of the regulator, at least in theory, was to serve as a substitute for the competitive marketplace, which could not be relied upon to produce acceptable performance under conditions of natural monopoly. To this end, regulators monitor the incumbent in ways that ensure acceptable performance--with this latter term defined in terms of the regulator's public policy goals. This task has now grown increasingly more complex at the state level due to technological advances, divestiture, FCC policies, and resultant competitive entry. The situation may now require the regulator to serve the role of the "central planner." However, playing the role of umpire and incumbent-handicapper is not an easy one: the length and complexity of regulatory proceedings illustrate this point.

Cost information will play an ever increasing role in regulators monitoring market activities in multiple dimensions--only a few of which we have discussed above. Determining how this information is utilized and establishing the standards which are preserved by it will nonetheless be somewhat subjective. It is our view that in deciding to pursue a certain policy objective, regulators should at least be apprised of the economic costs and benefits of doing so. This paper attempts to identify key principles and provide some broad guidelines to assist with this process.

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<sup>9</sup> This is essentially the argument that AT&T used in its tariff 12 and 15 proceedings with the FCC.

<sup>10</sup> Weisman (1989).

### **III. The Economic Standard: Marginal And Incremental Cost**

#### **Introduction**

The distinction between marginal and incremental cost is really one of degree. By marginal cost, we mean the change in the firm's total cost resulting from an infinitesimal change in output--generally one unit. With respect to some technologies, including those governing most regulated industries, it may not be meaningful to talk about adding one additional unit of output. In these circumstances, output (and capacity) tends to be added in indivisible quantities. Hence, when the additional output is more than one unit, we refer to the corresponding cost measure as average incremental cost, or simply incremental unit cost. By this we mean simply the change in the firm's total costs resulting from supplying the increment in output divided by the number of units that increment is capable of supplying. For example, an optical remote switching unit may be capable of switching 10,000 lines. In this circumstance, it makes little sense to refer to the marginal cost of a single additional access line. It makes more sense to look at the "lump" of investment in total, conditioned on the number of units capable of being supplied from this increment in investment. Hence, if this optical remote unit cost \$2 million, then the long run incremental unit cost per access line is on the order of \$200.

The incremental cost concept is essential for evaluating pricing decisions since it represents the resource cost borne by society in producing the next unit of output on the margin.

Economists generally support the use of incremental cost as a benchmark for pricing due to its efficiency properties. Consumers utilize prices as a guide to their purchasing decisions. A consumer who faces a price equal to \$6 will perform a type of cost-benefit analysis to determine whether to purchase the good. Suppose that the consumers valuation in terms of perceived benefits is equal to \$5. The consumer will not purchase the good under these conditions because her private cost-benefit analysis reveals the costs to exceed the benefits. Net utility would fall if the good were purchased. From a social perspective, it is not clear whether this decision not to purchase the good is

efficient (welfare-maximizing) unless we know that price was set equal to marginal cost.

Every deviation of price from marginal cost results in a welfare loss to society--meaning that voluntary transactions that would have made both the firm and the consumer "better-off" are discouraged.

Suppose that marginal cost is actually \$4. In this case, pricing the good at \$6 causes a welfare loss. A transaction that would have made both the consumer *and* the firm better off was discouraged because price was set in excess of marginal cost. To put this another way, a market transaction for which the consumers valuation of the good exceeded society's cost of production was discouraged because price was set in excess of marginal cost. Of course, lowering the price to \$4 would reduce total consumer outlays on the good if the quantity demanded is relatively unresponsive to price (i.e., if demand is inelastic). A price reduction to \$4 for all units of output could jeopardize the producer's financial viability. The point here is that other rate designs, like multipart pricing (an access fee plus a per unit charge), could allow the marginal price to reflect marginal cost--while still enabling the supplier to cover costs (including a reasonable return on investment).

Thus, prices that are set equal to marginal cost send efficient signals to consumers in terms of their purchasing behavior. All voluntary market transactions or exchanges are by definition welfare-enhancing. Equivalently, there is no welfare-enhancing market exchange that failed to take place because of pricing anomalies. These results are perfectly symmetric when price is set below marginal cost. In this case, transactions are encouraged for which consumers valuation of the good fall short of society's cost to produce it. In a "first best" efficient world, such transactions should not take place. Alternatively, welfare could be improved if such transactions did not take place.

The welfare loss from prices being set greater than (less than) incremental cost is measured by the valuation of voluntary transactions that did not (did) take place, but otherwise would (would not) have occurred.

We illustrate these principles for  $P > MC$  with a simple diagram in Figure 1. Let "D" in the diagram represent a standard downward sloping demand curve. Quantity demand is greater at lower prices than at higher prices. Let "MC" represent marginal cost and  $P_0$  represent the initial price level. The triangular area marked with an "L" represents the welfare loss from price being set in excess of marginal cost.<sup>11</sup> Alternatively, this area represents the market valuation of those transactions that were discouraged because of inefficient pricing--sometimes referred to as *allocative inefficiency*.

[Figure 1 About Here]

Another source of inefficiency is known as technical (or production) inefficiency where society is not using the least cost method of production. This is illustrated in Figure 2.  $MC^R$  and  $MC^E$ ,  $PR$  and  $PE$  represent the regulated firm's and the entrant's marginal costs and prices respectively. When the regulated firm's price is pegged above marginal cost, perhaps in order to provide a contribution to covering some shared costs competitive entry may occur. Such entry is inefficient for the costs shown here, i.e. the shaded area in the diagram represents the excess resource costs borne by society in producing output  $Q^E$  with the relatively inefficient production process. Since consumers make consumption decisions on the basis of price signals (rather than cost signals), they are led to substitute the lower price (higher cost) service for the higher price (lower cost) product. Note that the socially efficient output level is  $Q^*$ .

Prices greater than incremental costs can induce uneconomic entry leading to production inefficiencies. However, entry can stimulate innovation by the incumbent. Furthermore, multiple centers of initiative can promote new service introduction.

The Bell operating companies have argued that when their rates for selected services are set far above underlying incremental costs, uneconomic bypass results as lower price (higher cost) services are substituted for higher price

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<sup>11</sup> Note, however, that these welfare losses--frequently referred to as the deadweight loss--is symmetric with respect to  $P > MC$  and  $P < MC$ .

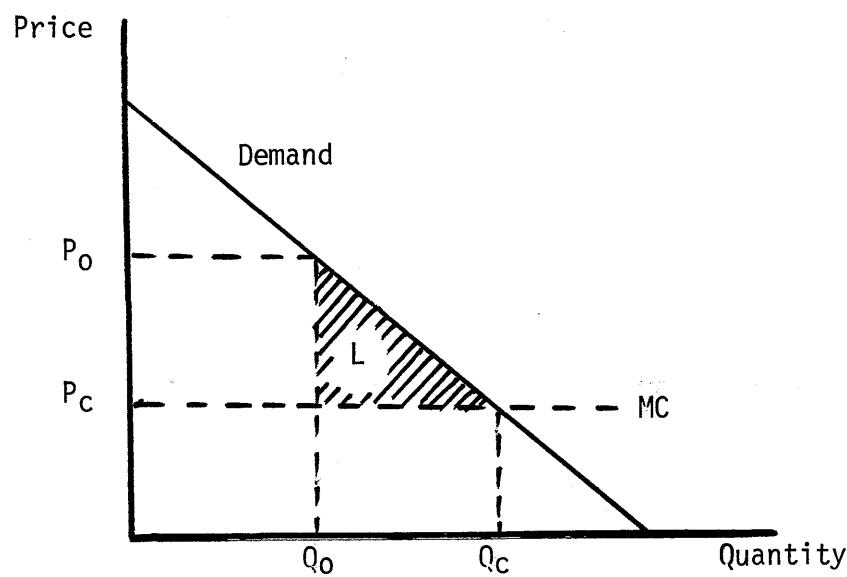


FIGURE 1  
Allocative Inefficiency

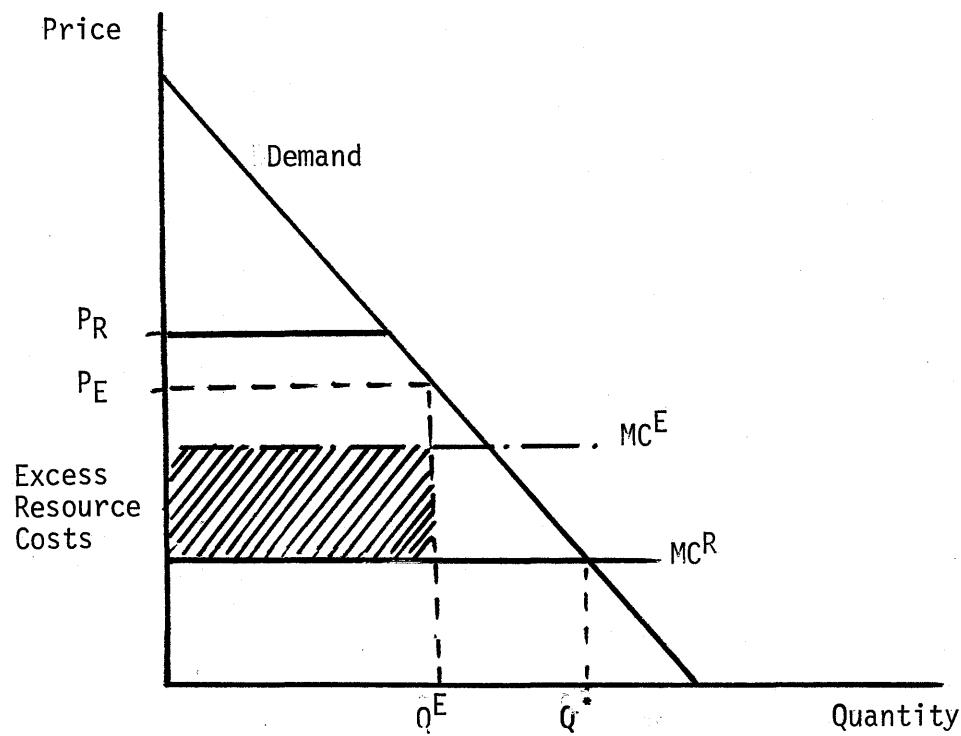


FIGURE 2  
Technical Inefficiency

(lower cost) services. This is an example of technical or production inefficiency. The foregoing analysis reveals the premise underlying the economist's support for marginal cost pricing: It sends the proper signals to consumers, yielding efficient resource utilization. Departures of price from marginal cost are revealed to encourage either under or over consumption relative to what is efficient from society's perspective. In addition,  $P > MC$  can induce higher cost entry which produces output displacing efficiently-produced output.

Of course, regulators may wish to encourage competitive pressures which stimulate cost-cutting activity by the incumbent (regulated) firm. Innovative efficiency may be enhanced by the existence of potential entrants who are not committed to old production technologies. Regulators will want to encourage technological change which leads to meeting new needs or serving old demands at lower incremental costs. A comprehensive examination of this issue is beyond the scope of this paper (see Berg-Tschirhart (1988), pp. 385-427 for a survey of the issues). Suffice it to note that regulatory policy may face a trade-off between technical efficiency (relative to today's technology and input prices) and innovative efficiency (discovering new services and introducing new production processes).

The principle of cost-causality is central to economic efficiency. In a first-best context, prices should generally reflect the resource costs that production of the good or service caused to be incurred in a forward-looking context: New Services do not cause "old" costs.

The incremental cost discussion is framed within the context of "cost-causality." Optimal resource allocation generally requires that buyers be responsible for the costs that they cause to be incurred. A moments reflection reveals that incremental cost is a cost measure that satisfies this criterion. Consider this issue now from the perspective of optimal resource allocation. If buyers of a new service are held responsible for a greater amount of costs than those which they cause, then underconsumption results, as buyers are signaled that the resource cost to society of their consumption is greater than it actually is.

Conversely, if buyers of a new service are held responsible for an amount of costs less than that which they cause to be incurred, buyers of other services produced by the firm must be subsidizing the production of the new service. In addition, over-consumption results as buyers of the new service are signaled that the resource cost of their purchases is less than that which it actually is. Consequently, prices set either above or below incremental cost induce market behavior that differs from when prices are set equal to incremental cost. This divergence represents a "welfare loss" to society in terms of either too few or too many voluntary market transactions. It is common to refer to the condition where price is equal to marginal cost as a "first best" condition--as these are the conditions that would generally prevail in competitive markets. Hence, from the standpoint of economic efficiency, the "cost-causality" principle is satisfied precisely when incremental cost is utilized as the relevant pricing benchmark.

Total service incremental cost is another useful concept, reflecting the additional costs associated with the production of a new product or service.

Cost causality can also be examined from the standpoint of an entire product line. If it costs \$100 to produce 100 units of the regulated service, and \$120 to produce those 100 units and 10 units of a an additional service, then the total service incremental cost is \$20, and the average service incremental cost is \$2. If the new service had a marginal cost of \$1 (that is, the cost of increasing output from 9 to 10 units), pricing the service at \$1 (and selling 10 units) would not be compensatory. Regulators would want to ensure that the new service recovered the total service incremental cost, \$20. This would be accomplished via multipart pricing, where the marginal price is \$1, but some fee or access charge allowed to cover the total service incremental costs of the product line. As Baumol (1983) notes, the regulatory objective is to avoid burdening the original customers with costs incurred to serve buyers of the new service.

Of course, the above situation is very simplistic--with no cost complementarities between the new service and the old one. That is, production costs of the old service are unaffected by the addition of a new service and by

new service output changes. If the production costs of the new service are lower when it is produced in conjunction with the first service (due to, say a shared input) than when it is produced separately, then fairness might dictate that consumers of the new service make some contribution to covering the costs of that shared input. However, efficiency does not require such a transfer (or cost allocation of "old" costs). Furthermore, an inefficient production configuration could be induced by too high a tax or contribution.

Another complication is the possibility that the new service is a substitute for or a complement of the initial service. If the new service is a substitute for the regulated service, a net-incremental revenue test is needed to assure that lost revenues (and avoided costs) associated with old service output reductions are taken into account. In addition, when many services and customer groups are involved, the test must be extended to combinations of services, (Baumol, 1983, p. 187). While these cost and demand interdependencies complicate regulatory analysis, the principles are straight-forward. Fully distributed cost concepts do not provide a good indication of whether burdens are being imposed on customers of the initial service when new services are introduced.

#### A. SHORT RUN AND LONG RUN INCREMENTAL COST

To this point in our discussion, we have used the term incremental cost as if the term were well-defined. In reality, the marginal cost concept has generated significant debate--not only in the hearing room, but in the academic literature as well.<sup>12</sup> In a very real sense, the debate continues to this day. While we will certainly not resolve all of these difficulties here, we should be able to at least shed some light on some areas of broad agreement and where there is still disagreement.

A major source of debate and confusion with the marginal cost concept is the distinction between short run and long run incremental cost, and which one represents the appropriate measure for economic efficiency. By long run incremental cost, we shall mean the change in the firm's total costs resulting

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<sup>12</sup> See Taylor (1990), Boiteux (1960), and Kahn (1988).

from a one unit change in output, when all inputs are perfectly divisible and optimally employed. By short run incremental cost, we shall mean the change in the firms total costs resulting from a one unit change in output, when the firm cannot vary all its inputs.<sup>13</sup>

Short run incremental cost has taken on one meaning in the hearing room and yet quite another in the academic literature. In the academic literature, the term short run incremental cost refers to the incremental change in the firms total costs when there is a change in output, but some of the input quantities cannot be varied.<sup>14</sup> Conversely, in regulatory hearings, the term short run incremental cost is generally taken to mean the change in total costs when there is excess capacity for production.<sup>15</sup> In the former case, short run incremental cost exceeds long run incremental cost over particular ranges of output. Whereas, with excess capacity, long run incremental cost exceeds short run marginal cost.

For the moment, let us work with the regulatory definition of short run incremental cost. To clarify some of these theoretical constructs while at the same time recognizing some practical considerations, we consider a stylized example drawn from the telecommunications industry. Suppose that there are only 3 inputs required to supply one unit of basic residential telephone service (1FR): Switching, Feeder Plant and Distribution Plant. Each 1FR requires two units of switching, and one unit each of feeder and distribution plant. Suppose that the input costs are as follows: switching is \$3 per unit, distribution is \$4 per unit and feeder is \$2 per unit. Long run incremental cost is thus \$12.

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<sup>13</sup> The operative principle is summed up quite nicely by William Vickrey (1985): "the marginal cost that is relevant to a pricing decision is a marginal cost of the output that will be affected by the pricing decision over the period for which that decision is to be considered not subject to possible revision. To attempt to import into a pricing decision considerations of fixed costs that will not be affected even indirectly by that decision is to chase a very wild goose indeed," [pp. 1333-1334].

<sup>14</sup> This is essentially a manifestation of the Le Chatelier principle of microeconomic theory. The response of the system to an exogenous shock will be greater, the fewer the constraints that are operative. Hence, when all of the firms input quantities are able to be changed, the change in the firms total costs when producing an extra unit of output will always be less than or equal to the change in the firms total costs when some of the inputs are constrained to operate at designated levels.

<sup>15</sup> Baumol and Walton (1973).

Suppose now that switching capacity is perfectly divisible, and there is excess capacity for both distribution and feeder plant. Short run incremental cost is thus \$6. Let us assume that there are 6 prospective subscribers of 1FR service with respective valuations of \$35, \$16, \$10, \$8, \$7 and \$3. In scenario I, suppose that the 1FR price is initially set equal to long run incremental cost. In this case, consumers 1 and 2 subscribe, but consumers 3-6 do not. Total revenues are \$24. In scenario II, suppose that the 1FR price is set equal to short run incremental cost. In this case, all consumers subscribe, with the exception of consumer 6. Total revenues are thus equal to \$30.

The question is whether or not "first-best" efficiency is obtained with prices set equal to long run marginal cost or short run marginal cost? Alternatively, is there any economic efficiency justification for denying 1FR service to consumers 3-5? Let us examine both sides of the issue.

### **Long Run Incremental Cost**

Long run incremental cost is the resource cost incurred by the firm in supplying an additional unit of the commodity when all inputs are perfectly divisible and optimally employed.

Those who support the use of long run marginal cost as a benchmark do so on the grounds that efficiency is attained when prices reflect the corresponding resource cost to society for supplying the next unit of output.<sup>16</sup> For such analysts, the fact that the firm may be operating with excess capacity in some of its inputs (i.e. those input costs are sunk) is no reason to signal consumers that the resource cost is less than long run incremental cost. In fact, to do so would be to send the improper signals to consumers as they make long run investment decisions in durable goods on the basis of prices that are artificially low.<sup>17</sup>

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<sup>16</sup> See Turvey (1969) and Boiteux (1960).

<sup>17</sup> Op. Cit.

The long run/short run distinction may not be the most instructive for understanding the operative subtleties here. *Full adaptation* versus *partial adaptation*, may more meaningfully convey what is really going on. Full adaptation refers to an environment in which the firm is producing *de novo* with no sunk inputs.<sup>18</sup> This concept parallels the long run incremental cost measure but is not inherently time related. Partial adaptation recognizes that the firm may have sunk inputs and face other constraints (eg. fixed plant size) that require it to produce output with a process that it would not otherwise have chosen if it had the ability to adapt perfectly to existing market conditions. A partial adaptation mode entails both production constraints (i.e. inability to use least-cost production techniques) and "free inputs" on the margin (i.e. sunk costs not included in incremental cost). Recognition of partial adaptation may generate incremental cost measures that are greater than or less than full adaptation incremental cost estimates.

It is argued further that when prices are set equal to short run incremental cost, they can be characterized by a degree of volatility that poses institutional difficulties for both consumers and producers alike. On these grounds, it may be prudent to set prices on the basis of long run marginal cost.

However, Edward Park (1989) finds that variable prices (reflecting short run conditions) can offer substantial efficiency gains for some situations involving lumpy telecommunications investments. The revenue requirement constraint results in the efficiency gains being passed on to consumers.

With respect to our 1FR example above, advocates of long run incremental cost would presumably argue that price should never be set below \$12. Hence, according to this standard, only consumers 1 and 2 should be supplied with service. For capacity planning purposes, expected future consumption depends on the forecasted price--and a price that only reflected short run incremental costs could induce excessive investment in capacity to meet the quantity demanded. However, once the lumpy investment is made, those sunk costs can be ignored for

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<sup>18</sup> While we generally acknowledge that in the long run there are no fixed costs, this run maybe so long as to be of nor practical relevance. For example, with fiber optics, once the firm buries the cable, those costs are essentially sunk for the foreseeable horizon. In this case costs are fixed even in the long run--the planning horizon for the firm--and incremental cost estimates would acknowledge them as such.

purposes of signalling additional consumption at that time. As noted above, allowing variability in prices, reflecting short run considerations, can enhance efficiency.

### Short Run Incremental Cost

Short run incremental cost represents the resource costs borne by the firm in supplying an additional unit of output when using the existing technology and taking into account that some input costs are sunk and thus not avoidable with respect to providing the next unit of output on the margin.

Those who support the use of short run incremental costs do so on the basis of demand uncertainty and efficiency. Alfred Kahn, Lester Taylor and others emphasize the uncertainty of demand forecasts associated with long run capital investments in the telecommunications industry.<sup>19</sup> Hence, at any given point in time, capacity may be over or under its optimum given prevailing demand conditions. Consequently, from this perspective, prices should rise and fall to ration demand to existing capacity at any given point in time.<sup>20</sup> To insist upon the use of long run marginal cost under conditions of excess capacity is to blur the distinction between sunk and avoidable costs with corresponding losses to economic efficiency.

To deny IFR service to consumers 3-5 is equivalent to assuming that the feeder and distribution plant costs necessary to provide them IFR service could be avoided if they did not subscribe. Clearly, this is not the case here since these costs are already sunk. Hence, if in a "first-best" world prices are to signal the resource costs to society of supplying the marginal unit of output, then feeder and distribution costs should not be included in this particular cost calculation.

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<sup>19</sup> Kahn op. cit., Taylor (1990) and Andersson and Bohman (1985)

<sup>20</sup> See Hotelling (1938) on the rationing role of prices. Park (1989) provides simulation results supporting the use of variable (short run cost-based) pricing: "The largest welfare gains under either optimal constant or optimal variable prices occur when the initial capacity is about the same as the initial demand, and the lump size is large. Then charging a high price can produce large welfare gains by postponing the time when an additional lump of capacity must be installed." (Park, 1989, p. ix.)

Space limitations preclude our resolving all of these issues. Indeed, this debate has continued for well over a century and we are not likely to resolve it here. We confine our attention to a few observations.

First, it is important that we understand the rationale for the choice of either short run or long run incremental cost. For instance, we may reach agreement that short run incremental cost is the proper benchmark for economic efficiency and yet simultaneously recognize that the volatility in the price path that results is unacceptable for practical or institutional reasons. In other words, it is important first to reach agreement on what measure sends the correct signal, and then depart from that measure as dictated by the needs of practical and consistent regulatory policy dictate.

Second, there is a critical interplay between the choice of marginal cost measure and the operative form of regulation. Should regulators allow the firm to price on the basis of short run incremental cost, there remains the question of who pays for the feeder and distribution costs that, while not part of marginal costs in a forward looking sense, remain part of the firms revenue requirement which must be paid by the subscribers in the aggregate. This may be where the *stand-alone cost* concept bears some fruit. For example, while regulators may be sympathetic to allowing the firm to price down to short run incremental cost, that same regulator may be concerned that some other ratepayer, or class of ratepayers, must foot the bill for the difference between short run incremental cost and the average revenue requirement for that particular service. Hence, regulators may want to proceed to establish bounds that would serve both economic efficiency and fairness ends. This would involve granting the firm flexibility to price down to short run incremental cost, yet impose the requirement that no class of consumers pay more than the stand-alone costs associated with providing them service.<sup>21</sup> Multipart pricing is useful in such situations.

Third, which shall be discussed in greater detail below, it is important to understand the strategic dimensions associated with unlimited pricing

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<sup>21</sup> See Kahn (1988) and Zajac (1978).

flexibility. Indeed, the combination of pure rate of return regulation and pricing flexibility down to short run incremental costs may generate some rather perverse investment behavior that serves neither fairness nor economic efficiency ends. Efficient potential entrants with lower long run incremental costs for a new service could be prevented from entering the market if the incumbent were allowed to price a substitute service at short run marginal cost. This may dictate the need for some combination of *price caps* on existing services, and *price floors* on new services. In the process, regulators could explicitly rank services on the basis of fairness and distributional concerns.

Fourth, we note that it is the comparison of long run incremental costs across firms that establishes efficiency superiority. A comparison of short run incremental cost measures conveys no informational value regarding the relative long run efficiency of the firm. This issue concerns proper comparisions of technical inefficiency in production. (See Figure 2 above and supporting analysis.)

Finally, the operative competitive dimensions must be taken into account. While regulators must be concerned that the regulated firm not be granted flexibility that impedes otherwise socially beneficial competition, it must also act to ensure that competitors not use the regulatory process to secure strategic advantage they could not otherwise secure in the marketplace. In other words, competitors must not be allowed to arbitrage the regulatory process to obtain private benefits which are exceeded by resultant social costs.

#### **B. SOME OBJECTIONS TO THE USE OF INCREMENTAL COST PRICING.**

Having discussed at some length the efficiency properties of the incremental cost benchmark, it is incumbent upon us to review some of the objections to this standard that have been advanced.

Regulatory consent to allow the regulated firm to price down to short run incremental cost may entail a transfer: a shift of revenue requirements to another class of ratepayers. How might this situation be addressed?

The short run incremental cost standard for pricing flexibility raises some fairness and income distributional concerns. Specifically, we mentioned above that regulators may well recognize the efficiency properties of short run incremental cost, yet also realize that average revenue requirements must be paid by someone in order to keep the firm viable. How are these issues resolved? We believe that there are some *efficiency gains from self-selection* in this particular case. Specifically, the regulator can provide the firm with the choice of pricing down to short run incremental cost, without guaranteeing that average revenue requirement burden will shift in total to some other class of ratepayers. Mechanically, this can be handled by capping the rates on some services, while simultaneously permitting the firm to choose its desirable course of action. For example, pricing down to short run incremental cost may result in under-recovery of the revenue requirement which, given caps on the prices of other services would have to be recovered from shareowners. This is precisely what would happen in an unregulated market and we believe it preserves some desirable efficiency properties here as well.<sup>22</sup>

It is highly improbable that one costing methodology will provide the regulator with all of the cost information she deems necessary to effectively monitor the firm. Other than data collection costs, there is no welfare loss in maintaining a number of different cost systems--such as incremental and accounting costs--as long as it is realized that the outputs of these systems are not in any sense interchangeable.

The incremental cost approach will generally fail what we might call the "adding-up" property. (We discuss this further in the next section) It will be difficult under standard approaches to work back from incremental cost and account for all of the costs incurred by the firm. However, this would not appear to be an insurmountable problem. It may simply require that the firm track its costs in a manner that allows regulators to add-up to totals without having such totals directly affect pricing decisions. In this regard, it is important that we recognize that one costing system or method is unlikely to

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<sup>22</sup> Note the parallels here with Baumol's (1983) theory of "quasi-permanence of rate reductions" as a solution to predatory pricing concerns.

provide regulators with all of the information they need to prudently regulate and monitor the firm. The problem historically has not been the existence of numerous costing methodologies, but the recognition that these diverse methodologies are not interchangeable. That is, cost accounting reports that track the expense of a given product line may be quite beneficial for regulators in understanding the level (and mix) of expenditures. The accounts that such expenditures are placed in can provide some information regarding directly attributable costs. It would be a mistake, however, to presume that this same costing methodology has a role to play in efficient rate design, particularly if arbitrary cost allocation procedures are involved.

A competitor who claims that a long run incremental cost standard will preclude his survival in the marketplace is a competitor who acknowledges his relative inefficiency in production.

Objections to the long run incremental cost measure will be lodged by competitors who will claim that such a standard is anti-competitive. The history of the railroad industry, particularly in the face of competition from trucking, is filled with attempts by competing entities to saddle each other with burdensome cost standards for rate design.<sup>23</sup> The same behavior has posed and will continue to pose a dilemma for regulators in the telecommunications industry. Several observations are in order.

We noted above that a comparison of short run incremental cost measures is of no informational value in assessing relative efficiency across firms. It is necessary to analyze long run incremental cost measures for this purpose. Hence, as a benchmark, regulators may want to adopt a standard of long run incremental cost and require the regulated firm to show cause why deviations may be socially beneficial. If regulators believe that a short run incremental cost standard will serve to impede otherwise socially beneficial competition, then this approach may be warranted. In the longer run, if such competition is not welfare-enhancing then the marketplace will sort this out accordingly. Moreover, we point out once again that no party should be allowed to secure in the hearing

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<sup>23</sup> Baumol and Walton (1973), Baumol et al. (1962) and Kahn (1988).

room what they are unable to secure in the marketplace. Arguments that the regulated firm should be subject to a strict fully distributed cost standard are totally without merit. There is no efficiency or equity end served by such a standard, and the welfare losses are likely to be extreme. In addition, claims by competitors that costs are being off-loaded to other, perhaps less competitive services is a frequent refrain. There is no question that under rate of return regulation, the firm may have selective incentives to engage in such behavior.<sup>24</sup> Nonetheless, such incentives are largely muted by adopting appropriate rate caps on other services or groups of services. This procedure will largely eliminate any incentive for the regulated firm to engage in such behavior, as there is no longer any return from shifting costs to services whose rates cannot be altered to recover them.

Acurate measurement of incremental cost is a complex and intricate task. Nonetheless, the majority of the welfare gains can be achieved in their being approximately correct. The economic principle is clear. Devote resources to improving the accuracy of the incremental cost estimates until the marginal welfare gains from improvement in accuracy are just equal to the marginal cost of increased accuracy. Obtaining precise calculations of fully distributed costs is of little help to regulators who seek efficient prices.

Actual measurement of marginal cost is complex and has been the subject of considerable academic debate and regulatory discussion. We note only that what is difficult is getting the measure 90 to 100 percent correct. An 85 to 90 percent correct measure is probably attainable for most telecommunications services, and the incremental efficiency gains from the extra 10 to 15 percent accuracy improvement is likely to be sacrificed in the form of rent-seeking within the context of academic and technical debates. It is not difficult to be approximately right: we believe this to be the appropriate target. It is also not difficult to obtain precise calculations of wrong numbers. Such calculations (as with embedded cost studies) may help regulators evaluate developments retrospectively, and they may be necessary to obtain overall revenue

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<sup>24</sup> This would require, however, that the firm somehow were able to recover costs in one category that could not be recovered in another, that the requisite financial incentives for such cost shifting exist, and that regulatory monitoring capabilities are inadequate to identify cost-shifting behavior (Rozek, 1984; Grace, 1986).

requirements. However, fully distributed cost studies based on historical costs provide no guidance for efficient pricing.

### **Protecting Against Cross-Subsidization: A Digression**

The issue of cross-subsidization is concerned with whether one or more products introduces a problem with unrecovered costs that must be borne by other services through prices higher than would otherwise be necessary.

One of the primary concerns that has been voiced regarding competitive and monopoly services is that of protection from cross-subsidization. That is, regulators want to ensure that the regulated firm does not cross-subsidize its competitive ventures with revenues generated from monopoly ratepayers (i.e. 1FR customers). In general, a cross-subsidy exists when the revenues from one service are used to price another service below its corresponding incremental costs. A simple example will clarify the concept. Suppose that a firm makes an investment that enable the sale of new products A and B. There is an overhead investment of \$50 to introduce this new product line. Suppose the incremental cost of product A and B are \$22 and \$28, for their respective output levels. Furthermore, let their corresponding stand-alone costs at those output levels be \$62 and \$60, respectively. In order to ensure that no cross-subsidies are flowing, either between products in a given product family or across product families, it is necessary that (1) the price of each product cover its corresponding incremental cost, (2) that the revenues from the sale of A and B together cover those incremental costs and the initial outlay of \$50 (here total product line incremental costs is \$100), and (3) that no product price exceeds its stand-alone cost. Note that condition (3) is a sufficient but not necessary condition for the absence of cross-subsidization. If these conditions are satisfied for every permutation of products across the array of product families, then there is no flow of cross-subsidies.

### **C. PROBLEMS WITH SHARED INPUTS AND THE MULTI-PRODUCT FIRM**

When evaluating the introduction of new product lines by regulated firms,

regulators must consider at least three issues: (1) potential for cross-subsidization; (2) effects on other firms; and (3) the extent of economies associated with the new product.

The first issue, cross subsidization, can stem from inappropriate allocations of fixed or variable costs or from inefficient investments in shared facilities. Also, transfer pricing which increases the reported costs of the regulated firm might be used to shift profits from the regulated firm to an unregulated subsidiary. This possibility raises a dilemma, since when regulators mandate complete separation among business units, the firm may not achieve economies of scope. Consumers end up paying higher prices.

The second issue, the impact on other firms, raises similar regulatory trade-offs. If high cost suppliers are driven from the market due to entry by a natural multiproduct monopoly, resource allocation is improved. However, these suppliers may claim predatory pricing if the output is produced by an unregulated subsidiary or by the regulated firm. Producers of substitute products could argue that revenues from the utility's captive consumer groups (or regulated products) cover costs associated with products subject to competition. However, one must be careful not to accept fully-distributed costs as indicators of subsidization.

Multiproduct economies are generally the basis for entering new (unregulated) markets. Economic gains can arise from underlying technological factors or from demand interdependencies. Determining how to share the benefits of jointly used facilities requires that regulators have full information on demand and cost interdependencies. Often, the feasible sets of alternative price combinations (and associated "implied" cost allocations) will be quite large, so a wide range of alternative divisions of benefits is possible. This division between the firm and consumers and among consumer groups raises troublesome questions for regulators. However, reasonable bounds can be placed on the appropriate sharing mechanisms.

The arbitrary nature of fully distributed cost (FDC) pricing is well documented. Another appellation for most separations procedures is "fully

manipulable cost pricing," where a multiproduct firm is charged with allocating its total costs, including common costs, over its various products in an effort to ensure that revenue from the sale of each product covers its allocated cost (See Baumol, Koehn, and Willig, 1987). The same concept has been applied when a regulated firm diversifies into unregulated markets. Regulators usually require that the firm separate its regulated business from its unregulated business to ensure that no cross subsidies occur.

Besides leading to undesirable prices and cross subsidies, there is the danger that separations procedures may foster an unwarranted feeling of accomplishment among regulators. Sweeney (1982) is one economist who has explored problems with separations procedures. He finds that output-based allocation schemes can yield perverse results: we end up with prices such that one or more of them can be lowered to improve welfare without decreasing the monopolist's profit. In addition, we can have relatively high prices in unregulated markets. Sweeney explains these results by noting that because regulated products are permitted to return a "fair return" on shared input, output reductions in unregulated markets allow more of the common cost to be shifted to regulated markets. As a result, greater profits are earned under rate of return regulation.

These results may appeal to myopic regulators. The prices are high in the unregulated markets, thereby quelling fears of cross subsidies from the regulated markets. Also, competitors in the unregulated markets would be pleased, since the monopolist is apparently not relying on profits from the regulated markets to predatory price in their markets. However, far-sighted regulators who are concerned for consumers of the regulated service will help those consumers (and consumers of the unregulated service) by basing prices on incremental costs. In the long run, the monopolist's prices could be undercut in at least some of the unregulated markets, perhaps even driving the regulated firm out entirely. Economies of scale and scope may no longer be realized, leading to higher per unit costs for the regulated service. The advantages of natural monopoly production for multiple markets are then lost, and the regulator's optimism regarding FDC procedures proves short-lived.

#### **IV. Cost Allocations and the Regulatory Process.**

The primary function of costing in most enterprises is to ensure that all costs have been accounted for--the so-called "adding-up property." On this score, cost allocation systems perform admirably. Yet such cost allocation systems are incapable of addressing the matter of cost causality in any meaningful way, and thus satisfy few, if any, efficiency properties.

Cost allocations have a long and venerable history, not just in the telecommunications industry but in all regulated industries for that matter. But the use of cost allocation systems is not confined to industries subject to governmental oversight. Many businesses in competitive markets use cost allocations systems as well. Before delving into the underlying cause of the use of cost allocations, let us briefly describe what they are and how they work.

**The very process of allocating costs is inherently arbitrary.**

By a cost allocation system, we generically mean any costing methodology that apportions costs incurred by the firm to various activities and products such that: (1) all costs are accounted for; (2) costs are distributed across products and services with little or no regard for cost-causation and (3) the "adding-up property" is always satisfied. The critical point to be made here is that cost allocation systems are first and foremost an accounting tool, and as an accounting tool they may serve a perfectly useful and even socially beneficial function. It is when these systems are used for other purposes, such as to establish prices, that efficiency problems arise.

**Inappropriate cost allocations cause distortions in economic efficiency.**

Economists have long been opposed to cost allocation systems--largely because such systems do not distinguish between sunk and avoidable costs.<sup>25</sup> Consequently, inefficiency is perpetuated because prices based on fully allocated costs are incapable of signaling the true resource costs to society associated

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<sup>25</sup> See Weisman, 1991.

with the product or service in question. This is not to suggest that cost allocation systems have no redeeming qualities--in fact, they do, but economic efficiency is not one of them. Two examples may clarify these issues. The first is drawn from the airline industry and the second from telecommunications.

### **Example I: Stand-by-Air Fares**

One of the great victories of marginalist concepts in regulated industries was that of the Civil Aeronautics Board's (CAB) approval of discounted air fares for stand-by passengers. Let us analyze this issue, first using cost allocation theory and then marginalist theory. The divergence in the results should indicate the magnitude of the distortions introduced by the use of cost allocation systems.

Suppose that there are 6 categories of costs associated with an airline flight: (1) capital cost of the airline; (2) landing and take-off fees (3) maintenance; (4) labor and flight personnel; (5) food and beverages and (6) fuel. The capacity of the airliner is 200 seats. The total costs associated with each of the above 6 categories of costs is \$20,000. The fully allocated or fully distributed cost per seat on the plane is thus \$100.

The airliner is now 5 minutes away from take-off and there are 4 empty seats on the plane. Coincidentally, there are 4 would-be passengers at the gate. Suppose that these passengers, indexed 1 through 4, have a willingness to pay or valuation for this flight of \$80, \$60, \$55 and \$25. The question concerns whether economic efficiency would dictate that some or all of these would be passengers be allowed to board this plane at some price less than \$100?

The cost allocation system has already given us the \$100 as the benchmark level below which the airline will fail to recover the "costs" it has incurred. Why would we ever choose to allow passengers to board this flight at a price less than \$100? The answer to this question is that the \$100 figure reflects the average cost per seat the airline has incurred for this flight, but it does not reflect the costs the airline would avoid if those 4 seats remain unoccupied.

Of the six categories of costs we referenced above, it is necessary to distinguish between sunk and avoidable costs. None of the capital costs, flight personnel, maintenance or take-off and landing fees are avoidable costs 5 minutes before take-off. That is, the airline will incur those costs independently of whether it transports these 4 passengers. The only costs that are avoidable are an infinitesimally small part of the fuel costs, and meals. Let us suppose these costs sum to \$32 per passenger. Hence, from an economic efficiency perspective, it is optimal to allow passengers 1-3 to board the plane at a discounted fare. Passenger 4 must either walk or take the bus. The airline is better off in the sense that profits are higher if passengers 1-3 fly rather than not fly.

Note than in the above example, following the implicit advice of a cost allocation system would have made both the airline and its passengers worse-off. Such are the losses in economic welfare when prices fail to accurately signal true resource costs.

### **Example II: Additional Access Lines**

Some of the very same issues discussed in our first example with respect to stand-by airfares have arisen in the telecommunications industry as well. Consider the following debate concerning additional access lines, or so-called second lines. Some telephone companies have contended that the long run incremental cost of basic local service (LFR) is on the order of about \$25 per month. Nonetheless, telephone companies have begun to selectively market additional lines (that is second lines into a residence) at prices of between \$12 and \$14. The parallels with the discounted stand-by fares example above are immediate.

The telephone companies contend that in selected areas, excess capacity exists in feeder, distribution and switching. Hence, the true incremental costs of supplying the second line should not treat such costs as avoidable (just as the airline should not have treated the capital costs of the airline as being avoidable). By selling additional lines at prices that exceed the true incremental costs, yet discounted from the standard tariff rate, some contribution is made to the recovery of fixed and overhead costs. The telephone

company and its ratepayers are thus better off as a result of these actions. We return to this example in greater detail below with respect to our discussion of a matrix costing model.

To summarize, we return to the question posed at the beginning of this section: If cost allocation systems are so problematic, why do so many firms use them? We offer a few thoughts on this matter. First, the role of costing in most firms has traditionally been an accounting function, and the number one task of most accountants is to ensure that all costs are accounted for. On this score, cost allocation systems receive high marks. They do allow managers to track every dollar of costs and thus satisfy the so-called "adding-up" property. Second, when demand is tracking expectations and input prices are stable, and technologies are unchanged, there may be no deviation between what fully allocated costing systems might propose and what incremental cost systems propose for prices. It is precisely when competition makes inroads into a market, or when economic change occurs, that the recommendations from these two approaches differ, and then they differ in substantive and significant ways. For example, in the face of serious downturns in demand, either because of competition or some exogenous factor, output or revenue-based cost allocations systems can serve to exacerbate the problem of covering costs.

Finally, as we stated in the beginning of this section, the role of fully distributed costs has a long and venerable history in regulated industries. In the appendix we provide selected excerpts from regulatory proceedings, court hearings and academic writings on the (ir)relevance of fully distributed costs. However, dependence on costing formulae based on arbitrary allocations (by directly attributable costs, revenue, or relative output) can have severe negative consequences for the financial health of incumbent firms and for the welfare of customers (Sweeny, 1982; Baumol, Koehn, and Willig, 1987).

## V. Concluding Observations

In this survey of costing principles, we have attempted to provide the reader with an overview of the costing issues currently under debate in the

telecommunications industry. Since cost data generally serves as the foundation for rate design, we should fully anticipate that costing questions identical to the ones we have raised here, will surface in regulatory hearings across the country. Competition will serve to fuel what is already a highly litigious process--and the focus of much of this hearing room debate will center on the principles appropriate for cost measurement.

Some of the issues we have discussed, such as the efficiency properties of incremental vs. fully distributed costs, will be accepted without exception by most economists of academic repute. Other issues, such as the long run or short run marginal cost standard and sufficient costing information for protection from cross-subsidization are more elusive, and require more technical analysis than is presented here. These issues warrant thoughtful, independent study.

Finally, any study of costing issues recognizes at the outset that economic analysis often produces a grey answer when regulators desire something black or white. Such knife-edge precision is probably inappropriate for cost analysis when production technologies utilize shared inputs--as cost responsibility is difficult to assess. Fully distributed cost methods enjoy some support because of the false sense of security that comes from (misleadingly) placing costs in one bucket or another. In other words, we may not have all the costs in the right buckets, but at least we know where they are. The grey areas in cost recovery analysis--meaning recovery of costs that cannot be directly attributed--can be addressed through techniques of Ramsey, and multi-part pricing. In other words, it is essential for economic efficiency that the grey areas in cost analysis remain grey--in spite of the discomfort policy makers may feel with such an outcome. In our view, a move in the direction of fully distributed costing methods is a move away from economic efficiency.

In summary, we note that the recent *Report of the Blue Ribbon Telecommunications Task Force to the Illinois Commerce Commission* includes many points which parallel those presented here. The Task Force recommends that the Commission be authorized to justify prices by a variety of standards, including new service prices that cover long run marginal cost (Monson, 1990, p. 33). As the Report states:

"... confronted with the need to set rates for services provided with common plant, regulators have traditionally justified prices on the basis of some allocation of common costs. Apparently, bowing to what they perceive as the demand of legislators, judges, and laymen to cost justify prices, regulators have pretended what must be done arbitrarily can be done in a principled fashion. They allocate common costs among services and among time periods. They pretend to estimate a separable cost for each service even though no such cost exists. Regulators have employed a variety of allocation methods. Some appeal to different notions of "fairness" more than others, but all rely on fictions. These fictions tend to obscure what regulators are really doing. Moreover, their use fosters the notion that "cross-subsidy" has the same unambiguous meaning in the presence of common costs that it does in their absence. It does not (except tautologically), and fostering the notion that it does makes for mischief."

The present study is consistent with the thrust of the Illinois Task Force Report, and with its emphasis on incremental costs as the basis for evaluating efficiency.

When conducting a costing study, it is better to have a rough approximation of the right number than a precise calculation of an irrelevant number. Estimates of incremental costs are the relevant starting points for efficient pricing in telecommunications.

## Appendix A

### Comments on Fully Allocated Costs

". . . not all costs can be identified causally with specific quantities of production. Much of the controversy over cost concepts stems from the false notion that all costs can be traced and attributed to specific blocks of output. Although many costs are traceable, there are also non-traceable costs which simply do not lend themselves to this method of identification."

"Some costs, called fixed costs, do not change in magnitude when the quantity of output for a given plant varies. Hence it is impossible to assign any specific portion of these costs to a particular unit of output. . . ."

". . . common and joint cost conditions are frequently encountered in the railroad industry as well as elsewhere. Whenever incremental costs are either joint or common costs, the resulting difficulties of allocation cannot be sidestepped. . . . The practical consequence is that incremental joint costs are not traceable to individual railroad services and can be allocated only arbitrarily. In contrast, those common costs which are incremental are traceable in principle. . . ."

"Arbitrary apportionments of non-traceable costs among particular kinds of outputs must be employed in the calculation of 'fully distributed costs'. . . . fully distributed costs have no true economic content because their derivation falsely assumes that all costs can be traced to particular kinds or quantities of output and can rationally enter directly into pricing decisions. The greater the degree of non-traceable costs, the more inappropriate is the use of fully distributed costs as a guide to minimum prices."

"The relevant incremental costs constitute all the cost information pertinent to the determination of floors in the pricing of particular railroad services. "Fully distributed" cost, measured by some kind of arbitrary statistical apportionment of the unallocable costs among the various units or

classes of traffic, is an economically invalid criterion for setting minimum rates, from both a managerial and regulatory stand-point. No particular category of traffic can be held economically responsible for any given share of the unallocable costs. Whether some particular rate is above or below some fully distributed cost is without real economic significance for minimum pricing."

"Thus, the fully distributed costs doctrine does not reflect valid principles of pricing. . ."

from: William J. Baumol, James C. Bonbright, Yale Brozen, Joel Dean, Ford K. Edwards, Calvin B. Hoover, Dudley F. Pegrum, Merrill J. Roberts, and Ernest W. Williams, "The Role of Cost in the Minimum Pricing of Railroad Services," JOURNAL OF BUSINESS, 1962, pp. 357-67.

"for maximum economic efficiency, rates should be related to costs, but not to an arbitrary allocation of costs. . . "Cost-oriented rates" in the true economic sense are related to the economist's concept of marginal cost--the increase in total expenses as a result of carrying additional ton-miles of traffic. In order to ensure efficiency, marginal, rather than average cost should be the principal regulatory criterion in application for rate reductions. . . where competition and new technology dictate rate reductions, competitive rates could be lowered to the level of marginal cost."

from: ANNUAL REPORT OF THE COUNCIL OF ECONOMIC ADVISORS, January 1966, p. 127.

"The role that average cost pricing plays in the policies of firms is a matter of considerable debate. This is sometimes called "full-cost pricing," the full cost per unit of output being calculated by adding to the directly ascertainable unit costs an arbitrary portion of the unallocated fixed and common costs. . . There are three difficulties with this method of pricing. First of all, it contradicts the principle of marginal cost pricing, in that the price of the last unit of output may actually be below the additional cost of producing it. Even though marginal cost may be difficult to ascertain, the use of average cost pricing necessarily results in pricing being different from marginal cost except at the point of competitive equilibrium, a situation that is not likely

to obtain at any particular time. . . In the second place, full cost pricing requires an arbitrary allocation of the costs which cannot be traced; this allocation cannot rest on the necessary relation between the costs involved and the resulting products. Third, if average total cost is used for pricing in multi-product firms, and if sales are not permitted at prices below full cost, variable cost pricing to utilize unused capacity is thereby prevented. . . Full-cost pricing for multi-product firms must be arbitrary because of non-traceable, and also fixed, costs. In addition, if the practice is followed according to the logic of it, the prices of various firms in competition with each other would have to be different because their costs and product mix will not be the same. . . It is impossible to calculate the precise total unit costs of output, even theoretically, in a multi-product firm. Fixed costs should not enter into the pricing calculation. Common costs cannot be allocated except on an arbitrary basis and therefore should be considered only with the multiple products, not with the individual ones."

from: Dudley F. Pegrum, PUBLIC REGULATION OF BUSINESS,  
1965, pp. 196-197.

"Quite simply, the basic defect of fully distributed costs as a basis for rate making is that they do not necessarily measure marginal cost responsibility in a causal sense. They do not measure by what amounts costs would be increased if additional quantities of any particular service were taken, or by what amount costs would be reduced if the service were correspondingly curtailed. They are average costs: the allocations among the various services are often made in part on the basis of the relative number of physical units of consumption or utilization by each, and the total allocated dollars are then divided by those physical units to get the unit costs. Also, being apportionments of historical costs, even when they do accurately reflect historical responsibility for the incurrence of these costs among the respective users, they do not provide a reliable measure of what will happen to costs in the future if particular portions of the business are expanded or dropped. Therefore, they do not tell whether a particular service is really profitable or unprofitable, in the sense that its continued provision at existing rates makes a net contribution to company revenues over and above the costs for which it is responsible, or whether, instead, it is a burden on the other subscribers."

"The basic defect of full cost distributions as the basis for pricing is, then, that they ignore the pervasive discrepancies between marginal and average cost. And. . . those discrepancies may require prices that take into account not just the costs but also the elasticities of demand of the various categories of service if the company is to recover its total costs. Whenever there is some separable portion of the demand sufficiently elastic that a rate below fully-distributed costs for it would add more to total revenue than to total costs, any insistence that each service or group of patrons pay their fully allocated costs would be self-defeating. It would force the firm to charge a price that would result in its turning away business that would have covered its marginal costs--in other words, would prevent it from obtaining from customers with an elastic demand the maximum possible contribution to overheads. Thus, under the guise of ensuring a fair distribution of common costs and preventing undue discrimination, it would be serving the interests neither of the patrons who would be prepared to take additional quantities if prices were closer to marginal costs, nor of the customers with the more inelastic demands."

from: Alfred E. Kahn, THE ECONOMICS OF REGULATION,  
(1970), Vol. I., pp. 150-55.

"To illustrate how (fully distributed cost and incremental cost) are calculated, assume a firm plans to construct a plant, and three possibilities are under consideration: (1) a plant that could produce A alone for \$7 million; (2) a plant that could produce B alone for \$8 million; and (3) a plant that could produce A and B at a total cost of \$12 million. Comparing plant (3) with plant (1) tells us that the incremental cost of producing B in addition to A is \$5 million; by comparing plant (3) with plant (2), we see that the incremental cost of producing A in addition to B is \$4 million. Because the two incremental cost figures total only \$9 million instead of \$12 million cost of turning out the two products together as in plant (3), the incremental cost figures leave \$3 million which is not directly attributable to either service. A fully distributed cost calculation would allocate the \$3 million of unattributable costs between A and B. The \$3 million could be allocated on the basis of any of a variety of accounting conventions. For example, it could be allocated in proportion to the incremental costs of A and B, making the fully distributed cost of A approximately \$5.3 million and the fully distributed cost of B approximately \$6.7

million. Another approach might be to allocate unattributable costs in proportion to the "relative usage" of the facilities by A and B, though some convention would then be needed to define "relative usage." In railroading, for example, it has been calculated on the basis of weight or volume or value of the different classes of traffic. Whichever allocating procedure is chosen, the choice will be an arbitrary one. . . ."

". . . a rate set on the basis of incremental cost would benefit not only the customers of B, the firm's competitive service, but also the customers of A, the firm's monopoly service. In an industry whose profits are limited by regulation, the production of any additional B whose incremental revenue exceeds its incremental cost must benefit the customers of A, because the net earnings of B can be used to reduce unattributable costs were allocated to B, making B's fully distributed cost approximately \$6.7 million. If potential customers of B were willing to pay no more than \$6.2 million for it, then no B would be sold. Users of A would then shoulder the entire \$3 million of unattributable costs alone and have to be supplied by the single purpose plant costing \$7 million. But, if B's price was set at the competitive rate of \$6.2 million, well above its incremental cost floor of \$5 million, B's net earnings would reduce the \$3 million of unattributable costs borne by A's customers by \$1.2 million. Clearly, the customers of A are better off if B is sold at a competitive price below its fully distributed cost floor. . . ."

"Advocates of incremental cost argue that such a cost standard would still provide a test for whether monopoly service A is subsidizing competitive service B and thereby permitting the firm to sell B at price that undercuts its competitors. They contend that A is "subsidizing" B only if A's customers would be better off if B were not produced. So long as B's incremental revenue exceeds its incremental cost, however, B will be making a net contribution to reducing the firm's unattributable costs. Thus, if the supply of B results in a reduction in the outlays required by A's customers, A cannot be said to be subsidizing B."

from: William J. Baumol and Alfred G. Walton, "Full Costing, Competition and Regulatory Practice," THE YALE LAW JOURNAL, March 1973, pp. 640-41.

"The alternative method of pricing based on fully distributed costs has no basis in economic principle, and we can only speculate upon the reasons for its persistence in public decision making in spite of its complete lack of foundation. Further, we have shown mathematically that in general, no method of determining fully distributed cost will always yield subsidy free prices, and may thus encourage wastefully duplicating competitive entry."

from: Gerald R. Faulhaber, "Cross Subsidization in Public Enterprise Pricing" in John T. Wenders, Editor, PRICING IN REGULATED INDUSTRIES: THEORY AND APPLICATION II, Denver, Colorado: Regulatory Matters Division, Mountain States Telephone and Telegraph Company, 1979, p. 113.

"In an antitrust context, fully distributed cost is not an economically relevant definition of average total cost and must be rejected as determinative. First, FDC is a quite arbitrary allocation of costs among different classes of service. There are countless FDC methods, each allocating costs by a different mathematical formula. Despite telling criticism on economic grounds, FDC continues to be used for regulatory purposes, *Inter Alia*, because of its ease of application in dividing an authorized total revenue requirement among individual products or service--much as a pie is divided into slices. But FDC cannot purport to identify those costs which are CAUSED by a product or service, and this is fundamental to economic cost consideration.

FDC also fails as an economically relevant measure of cost for antitrust purposes because it relies on historical or embedded costs. For it is current and anticipated cost, rather than historical that is relevant to business decisions to enter markets and price products. The business manager makes a decision to enter a new market by comparing anticipated additional revenues (at a particular price) with anticipated additional costs. If the expected revenues cover ALL the costs caused by the new product, then a rational business manager has sound business reasons to enter the new market. The historical costs associated with the plant already in place are essentially irrelevant to this decision since those costs are "sunk" and unavoidable and are unaffected by the new production decision. This factor may be particularly significant in industries such as telecommunications which depend heavily on technological

innovation, and in which a firm's accounting, or sunk, costs may have little relation to current pricing decisions.

In particular, FDC fails as a relevant measure of costs in a competitive market. FDC is, at best, a rough indicator of an appropriate rate CEILING for regulatory purposes and should not be used as a measure of the minimum price permissible in a competitive market. The justifiable fear of monopoly, and the basis of sections of the Sherman Act, is that a firm enjoying monopoly power will not be constrained by market forces; it will raise prices and decrease output in such a manner that its own profit will be maximized but that consumers will be subject to higher prices and a less efficient allocation of resources than would be the case in a competitive market. A standard making predatory pricing illegal and subject to treble damages must be carefully structured to fit the needs of the Sherman Act and its encouragement of competition on the merits. When a price floor is set substantially ABOVE marginal or incremental cost a price "umbrella" is created which allows less efficient rivals to remain in the market sheltered from full price competition. A fully distributed price floor may thus misallocate resources and force consumers to pay more for less production than competition would dictate.

The economic literature that has considered the problem of predatory pricing has rejected almost entirely the notion that fully distributed costs are a relevant measure of average total cost (ATC). To the contrary, long run incremental cost has been approved as an economically relevant measure of ATC for one product produced by a multiproduct firm. Professor Baumol has stated in reply to the sloppy use of the term "average total cost:"

By average total cost, (one) surely does not mean fully allocated cost, which is a mare's nest of arbitrary calculations parading as substantive information. . . consequently, I assume that when (one) requires the price of a good in the long-run to exceed its "average total cost," (one) defines the latter to mean the average incremental cost of the product including any fixed cost outlays required by the item.

Professors Joskow and Klevorick agree with this critique of fully distributed cost as a measure of average total cost:

For a single product firm, average cost is easily defined.

In the more likely multiproduct context, we are using "average total cost" to signify the average incremental cost of the commodity of concern and not any arbitrary "fully allocated cost measure."

Since all costs are variable in the long run it is long-run incremental costs (including return on investment) which most closely measure anticipated average total cost.

It is not surprising that no court has ever adopted fully distributed cost as the appropriate cost standard in a predatory pricing case.

It is important to understand that the "average total cost," to which some courts and commentators refer, should not be equated with FDC; it is, when properly understood, best measured in the multiproduct context by AVERAGE LONG-RUN INCREMENTAL COST. Essentially, this is the case because LRIC, unlike FDC, only measures costs which are causally related to the service or product in question.

This is not an economist's quibble or a theoretical musing; it is a matter of principled analysis and practical reality in the market place. Pricing at or above long-run incremental cost in a competitive market is a rational and profitable business practice. Because there are legitimate, and in fact compelling, business reasons for pricing products at or above their long-run incremental cost predatory intent should not be presumed or inferred from such conduct.

As a footnote to the above, the court noted:

"Thus, various FDC methods will normally produce quite different calculations of the cost of a product or service. In one electric utility rate

case one witness testified to the existence of at least 29 different methods of apportioning costs among services. J. Bonbright, PRINCIPLES OF PUBLIC UTILITY RATES 351 (1961). The FCC itself has required AT&T to submit at least seven different FDC cost studies. In the instant case, cost studies using these seven different FDC methods were introduced at trial. Not surprisingly, each method yielded a significantly different cost profile."

from: Opinion of the United States Court of Appeals for the 7th Circuit, Case Nos. 80-2171 and 80-2288, pp. 61-78, footnotes and references omitted.

"Aside from the extraordinary delays that arose in judging the lawfulness of Telpak rates, and making decisions that survived court appeals, the salient aspect of this experience was that the FCC failed to determine whether cross-subsidization actually took place because the FDC criterion it used was patently inappropriate! Prices should be set on the basis of expected future costs and demand of a service, not on the basis of average historical costs generally used in FDC calculations. Moreover, the costs of a particular service offered with others are not accurately measured by an arbitrary allocation of common costs. Users of the firm's other services are better off if the service in question is offered, so long as it covers its own costs and contributes ANYTHING to covering common costs. Otherwise, these users would bear the full common cost burden. Imposing the FDC criterion as a price floor raises the danger of "umbrella" pricing, under which new entrants could undercut Bell's prices even though their costs would be higher than Bell's costs of offering the service in combination with its noncompetitive services."

from: Leland L. Johnson, COMPETITION AND CROSS-SUBSIDIZATION IN THE TELEPHONE INDUSTRY, RAND Corporation, Publication R/-2976-RC/NSF, December 1982, pp. 12-13.

## Appendix B

### A Simple Matrix Model of Cost Dynamics

In this section, we present a simple model of cost dynamics in building upon our earlier example of additional access lines (ADL's). We proceed as follows. Suppose that there are five inputs required for an ADL: (1) switching; (2) feeder plant; (3) distribution plant; (4) labor; and (5) power. The marketing manager for the telephone company is interested in an ADL promotion and inquires of the rates department as to the lowest price that he can charge for an ADL and yet still cover avoidable costs. The rates department replies that it depends on where the ADL's are sold. In area A, we have excess capacity in feeder and distribution. In Area B, we have excess capacity in switching only. In area C, we have excess capacity in distribution, but only labor is under long term contract. Consequently, the avoidable cost measure will vary across geographic area. We now develop a simple model to facilitate developing the requisite information.

#### A Formal Model

Denote each of the five inputs necessary for "producing" an ADL by  $x_1, x_2, x_3, x_4, x_5$ , where the subscript references the numbers assigned above to each of the inputs. We now introduce the concept of a utilization matrix. This matrix operates on the input vector with the effect of classifying a particular input as either a sunk cost in the provision of the ADL or an avoidable cost. Hence, the utilization matrix is comprised exclusively of 0's and 1's. A zero in a particular row or column indicates the input cost is sunk and thus not avoidable. Conversely, a one in a particular row or column corresponds to an input cost that is avoidable. We define the utilization matrix as follows:

### State of Nature

$$(1) \quad [U_{ij}] = \begin{bmatrix} 1 & 1 & 1 & 1 & 1 \\ 0 & 1 & 1 & 1 & 1 \\ \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot \\ 0 & 0 & 0 & 1 & 1 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix} \quad \begin{matrix} 1 \\ 2 \\ \cdot \\ \cdot \\ \cdot \\ 31 \\ 32 \end{matrix}$$

The reader will note that there are 5 inputs, each of which can be either sunk or avoidable. Hence there are  $2^5$  or 32 possible states of nature concerning an ADL avoidable cost. Hence, the utilization matrix has dimension 32 x 5.

We know define the technology vector and the input price vector. The technology vector represents the quantity of each of the 5 inputs necessary to produce exactly one ADL. Suppose that each ADL requires: 2 units of switching at \$3 per unit; 1 unit of feeder plant at \$3 per unit; 1 unit of distribution plant at \$4 per unit; 4 units of labor at \$3 per unit and 1 unit of power at \$1 per unit. The technology and price vectors are given respectively by

$$(2) \quad [T_{ij}] = \begin{bmatrix} X_1 \\ X_2 \\ X_3 \\ X_4 \\ X_5 \end{bmatrix} = \begin{bmatrix} 2 \\ 1 \\ 1 \\ 4 \\ 1 \end{bmatrix} \quad (3) \quad [P_{ij}] = \begin{bmatrix} P_1 \\ P_2 \\ P_3 \\ P_4 \\ P_5 \end{bmatrix} = \begin{bmatrix} 3 \\ 3 \\ 4 \\ 3 \\ 1 \end{bmatrix}$$

From these two vectors, we can create an expenditure as follows:

$$(4) \quad [E_{ij}] = \begin{bmatrix} P_1 X_1 \\ P_2 X_2 \\ P_3 X_3 \\ P_4 X_4 \\ P_5 X_5 \end{bmatrix} = \begin{bmatrix} 6 \\ 3 \\ 4 \\ 12 \\ 1 \end{bmatrix}$$

Premultiplication of the expenditure vector,  $[E_{ij}]$ , by the utilization matrix  $[U_{ij}]$ , yields a cost vector,  $[C_{ij}]$ , with dimension, 32 x 1

$$(5) \quad [C_{ij}] = \begin{bmatrix} C_1 \\ C_2 \\ \cdot \\ \cdot \\ C_{31} \\ C_{32} \end{bmatrix} - \begin{bmatrix} 26 \\ \cdot \\ \cdot \\ \cdot \\ \cdot \\ 0 \end{bmatrix}$$

Now, let us return to the marketing manager's request for avoidable cost measures for ADL, broken down into areas, A, B and C. The relevant rows of our utilization matrix are given by:

$$U^A = [1 \ 0 \ 0 \ 1 \ 1]$$

$$U^B = [0 \ 1 \ 1 \ 1 \ 1]$$

$$U^C = [1 \ 1 \ 0 \ 0 \ 1]$$

and costs given by  $C^A = \underline{16}$ ,  $C^B = \underline{17}$ ,  $C^C = \underline{10}$ . Note that in case C, the fact that labor is under long term contract means that labor costs are sunk and unavoidable in the short run.

This simple type of model can thus be used to estimate avoidable costs corresponding to different states of nature. Note further that this type of model is perfectly consistent with the theoretical discussion of costs in the text above.

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