Strategic Cross-Subsidies and Vertical Integration in Opening Telecommunications Markets

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This paper analyzes the strategic role of cross-subsidies under vertical integration. We consider an incumbent firm which operates in a regulated market (switched telecommunications service) and a competitive market (unswitched service). Fitting cost data generated with an engineering cost proxy model to smooth functional forms, we first assess the extent of cross-subsidies due to allocation of common costs and managerial effort. We then focus on the cost incentives of the regulatory scheme in the regulated segment and identify situations where the incumbent may blockade entry in the competitive segment.

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I. Introduction

When competition is introduced in markets for services using an infrastructure, an important structural decision to be made concerns the vertical disintegration of the incumbent firm that provides both the infrastructure and the services. Preventing the owner of the infrastructure to compete in services, as Judge Greene decided in the AT&T case, may destroy potential economies of scope, create

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more transaction costs, but eliminate most incentives for favoritism because of the incumbent's internal use of the infrastructure.

In Europe the liberalization reforms have maintained the vertical integration of incumbent operators accompanied with a requirement of accounting separation between services and infrastructure activities. In the United States the FCC has issued a series of rulemakings, known as the Computer Inquiries, that have progressively weakened the separation requirements by moving from a regime of structural safeguards to various forms of accounting safeguards.[1] This paper provides an empirical evaluation of these types of policies as a means of introducing competition in services markets. In particular, we examine the impact on the competitive process in these markets of the cross-subsidies allowed by vertical integration of the incumbent.

We consider a situation where two segments use a common (telecommunications) infrastructure. We envision the introduction of competition in one segment and service by an incumbent regulated firm in the other segment. In section II, we seek to model the manipulation phenomenon, via cross-subsidies, that could result from the accounting procedure of allocating common costs between the two services.

Even with accounting separation, the manipulation of moral hazard variables such as effort levels creates cross-subsidies when the regulated segment is subject to cost-plus regulation while the firm is residual claimant of its costs in the competitive segment. Section III shows how the size of such cross-subsidies varies with the power of incentives in the regulated sector, while section IV studies how these cross-subsidies may affect entry.

Section V presents some empirical results based on cost data obtained by simulation of an engineering cost optimization model (LECOM) for the case in which potential cross-subsidies may exist

[1]Under structural safeguards, local telephone companies are required to maintain a strict separation between the regulated and unregulated sectors of the company (see FCC (1971, 1980, and 1999)). The separation requirements include separate corporate structures, operating facilities, and physical locations. Information flows among divisions and joint marketing arrangements are also restricted. Accounting safeguards allow the firm to deploy labor and other inputs freely among divisions, but they impose cost allocation rules to separate the costs of the firm into regulated and unregulated sectors.

between the markets for basic (switched) telephone service and enhanced services supplied to a (unswitched) competitive sector using leased lines. Section VI contains some concluding remarks and an appendix provides some extra data that are used in the discussion of the empirical results.

II. Size of Cross-Subsidies due to Allocation of Common Costs

Consider a service territory composed of two markets. Market 1 is open to competitive entry, and market 2 has the technological characteristics of a natural monopoly. An incumbent firm operates in both markets with a technology described by a cost function C which can be written as

$$C(\beta,e_0,e_1,e_2,q_1,q_2)=C_1(\beta,e_1,q_1,q_2)+C_2(\beta,e_2,q_1,q_2)+C_0(\beta,e_0,q_1,q_2) \quad (1)$$

where $C_1(\cdot)$, $C_2(\cdot)$, and $C_0(\cdot)$ are functions that represent, respectively, incremental costs of the activities in markets 1 and 2 and costs that are common to the two activities; β is a technological parameter; e_0, e_1, and e_2 are efforts that reduce the respective components of the total cost; and q_1 and q_2 are output levels in markets 1 and 2.

Equation (1) assumes a particular decomposition of the cost function C in which both the effort variables e_0, e_1, and e_2 and the output variables q_1 and q_2 can be assigned to the functions C_0, C_1, and C_2, respectively. An important assumption in this decomposition is that the effort levels e_0, e_1, and e_2 can be individually applied to the component cost functions. This assumption is carried over to the function that gives the aggregate disutility generated by these effort levels for the incumbent. More specifically, we assume that this disutility of effort function is

$$\psi(\beta,e_0,e_1,e_2,q_1,q_2)=\psi_1(\beta,e_1,q_1)+\psi_2(\beta,e_2,q_2)+\psi_0(\beta,e_0) \quad (2)$$

This approach is in contrast to an alternative approach in which effort is viewed as a "public" input that is applied equally to all of the firm's activities. As explained in more detail in Section V, the latter approach is the one that we adopted in some of our previous work (see chapters V through 8 of Gasmi *et al.* (2002)), and it is the one that is consistent with our LECOM simulations of the total cost function, where we use the price of labor as a proxy for aggregate effort, In this paper, since we primarily deal with incremental cost functions, the interpretation of effort as a "private" input to each activity is more appropriate.[2]

We also assume that the decomposition property holds for the stand-alone cost functions corresponding to the two activities, SAC_1 and SAC_2:

$$SAC_1(\beta,e_0,e_1,q_1)=C_1(\beta,e_1,q_1,0)+C_0(\beta,e_0,q_1,0) \tag{3}$$

$$SAC_2(\beta,e_0,e_2,q_2)=C_2(\beta,e_2,0,q_2)+C_0(\beta,e_0,0,q_2) \tag{4}$$

Let us initially focus on cross-subsidies that the firm could achieve through the allocation of the common costs $C_0(\beta,e_0,q_1,q_2)$. Assume that the exogenous technological parameter β is known and that output and effort levels that affect the different cost components are given. Furthermore let $\delta\in[0, 1]$ represent a parameter that specifies the way common costs are allocated between the two activities. Specifically, δ represents the proportion of the common costs that is allocated by the firm to the potentially competitive segment (market 1). Omitting the arguments for simplicity, total cost of the firm can be written as

$$C=C_1+C_2+C_0=[C_1+\delta C_0]+[C_2+(1-\delta)C_0] \tag{5}$$

Equation (5) merely shows the decomposition of the total cost C into two parts corresponding to the total costs associated with each of the two activities.

A straightforward way of assessing the potential that the firm has for subsidization of activity 1 by activity 2 via the allocation of common costs is by evaluating the relative importance of these common costs. Clearly segment 1 would benefit from the highest

[2]The expression given in (2) also allows for disutility to depend on output levels. The implications of this assumption in the context of optimal regulation under incomplete information are discussed in chapters 4 and 6 of Gasmi *et al.* (2002).

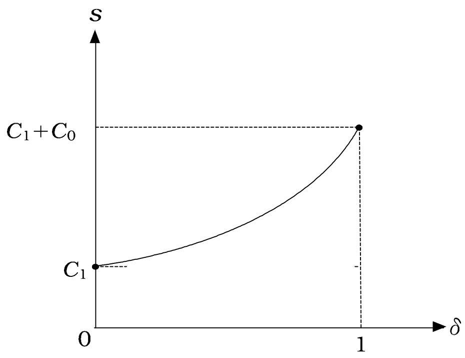

FIGURE 1

SIZE OF CROSS-SUBSIDIES THROUGH ALLOCATION OF COMMON COSTS

(cross-)subsidies when the common costs are totally allocated to segment 2, More formally, let $s(\delta)$ represent the total cost allocated by the vertically integrated firm to segment 1, namely,

$$s(\delta)=C_1+\delta C_0 \tag{6}$$

This function increases with δ from $s(0)=C_1$ to $s(1)=C_1+C_0$ (figure 1 displays the function s). If the parameter δ is under the control of the firm, the function s may be used as a basis for constructing some measures of the cost advantage that the vertically integrated firm possesses over ifs potential competitors in the liberalized sector. This advantage is due to the incumbent firm's ability to subsidize activity 1 from revenues earned in activity 2. This type of crows-subsidy may be particularly attractive to the firm when the market for activity 1 is competitive while activity 2 is regulated by a low-powered cost-based scheme.

III. Size of Effort Allocation Cross-Subsidies

When strict accounting rules are in place, cross-subsidization may still be possible far an integrated firm through ifs control of the effort variables e_0, e_1, and e_2. In order to evaluate the size of these strategic cross-subsidies, let us examine more closely how the incumbent firm sets these effort levels. We go back to the total cost function given in equation (1) and assume that the scheme under which the incumbent is regulated can be described by a cost-reimbursement rule. More specifically, we assume that the firm bears some given fractions α_1, α_2, and α_0 of the costs of activities 1 and 2, respectively, and of the costs common to these activities.[3]

To determine effort allocation between the two activities and common costs, the firm minimizes

$$\alpha_1 C_1(\beta,e_1,q_1,q_2)+\alpha_2 C_2(\beta,e_2,q_1,q_2)+\alpha_0 C_0(\beta,e_0,q_1,q_2) + \psi(\beta,e_0,e_1,e_2,q_1,q_2) \quad (7)$$

where ψ is given in equation (2). The first-order conditions of this problem are

$$\frac{\partial \psi_1}{\partial e_1}(\beta,e_1,q_1) \geq -\alpha_1 \frac{\partial C_1}{\partial e_1}(\beta,e_1,q_1,q_2) \quad (8)$$

$$\frac{\partial \psi_2}{\partial e_2}(\beta,e_2,q_2) \geq -\alpha_2 \frac{\partial C_2}{\partial e_2}(\beta,e_2,q_1,q_2) \quad (9)$$

$$\frac{\partial \psi_0}{\partial e_0}(\beta,e_0) \geq -\alpha_0 \frac{\partial C_0}{\partial e_0}(\beta,e_0,q_1,q_2) \quad (10)$$

where (8), (9), and (10) must hold as equalities if, respectively, $e_1>0$, $e_2>0$, or $e_0>0$. These first-order conditions can be solved to yield optimal effort levels $e_1^*(\beta,q_1,q_2,\alpha_1,\alpha_2,\alpha_0)$, $e_2^*(\beta,q_1,q_2,\alpha_1,\alpha_2,\alpha_0)$, and $e_0^*(\beta,q_1,q_2,\alpha_1,\alpha_2,\alpha_0)$. For given β, q_1 and q_2, substitution of the cost-minimizing effort levels into the respective component cost functions yields the "reduced form" cost functions $C_1^*=C_1^*(\alpha_1,\alpha_2,\alpha_0)$, $C_2^*=C_2^*(\alpha_1,\alpha_2,\alpha_0)$, and $C_0^*=C_0^*(\alpha_1,\alpha_2,\alpha_0)$.

By analogy to the function $s(\delta)$ defined in section II, we may define the function $t(\alpha_2,\delta)$ as

$$t(\alpha_2,\delta)=C_1^*(1,\alpha_2,\alpha_2)+\delta C_0^*(1,\alpha_2,\alpha_2) \quad (11)$$

[3]The higher the fraction of costs born by a firm (*i.e.*, the larger the costs for which it is accountable), the higher its incentives must be to minimize them. This faction is referred to in the literature as the "power" of the underlying incentive scheme (see chapter 4 of Gasmi *et al.* (2002) for more details).

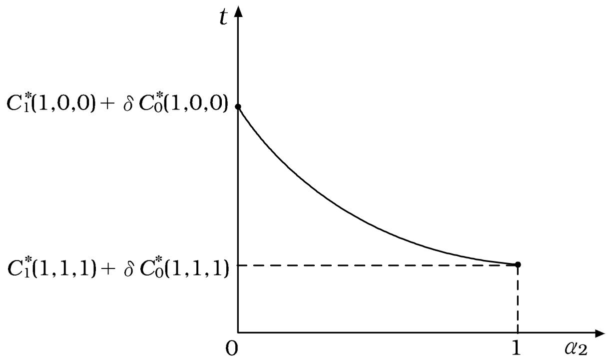

FIGURE 2

SIZE OF CROSS-SUBSIDIES THROUGH ALLOCATION OF EFFORTS

This expression assumes that competition in segment 1 makes the incumbent a residual claimant of its costs in that segment while a uniform regulatory regime with power α_2 is applied to the remaining costs of the firm. For a given δ, the function t is expected to decrease from $t(0,\delta) = C_1^*(1,0,0) + \delta C_0^*(1,0,0)$ to $t(1,\delta) = C_1^*(1,1,1) + \delta C_0^*(1,1,1)$ (see figure 2), and it could be used as a basis for measuring the size of the cross-subsidies that the incumbent can achieve through effort allocation.

IV. Strategic Cross-Subsidies through Effort Allocation under Accounting Separation

Section III defined the range of potential strategic cross-subsidies in a measure that is roughly comparable to the measure of the potential range for accounting cross-subsidies defined in section II. In this section we explore the possibility that strategic cross-subsidies may be used by an integrated firm to blockade entry when full accounting rules are in place that seek to prevent accounting cross-subsidization. To simplify the empirical analysis that we present in a later section, we seek to identify separately the two channels through which an integrated incumbent may interfere with entry. First we consider a setting where the incumbent does not have any technological cost advantage and we show how it can still have the ability to manipulate effort in order to undercut the entrant through disutility of effort. Then we consider the case where aggregate disutility of total effort is "neutral" (*i.e.*, held constant) and analyze the conditions under which the allocation of effort of the incumbent gives it a technological cost advantage.

A. The Cost-of-Effort Channel

Consider the situation where the incumbent (*I*) faces competition in segment 1 but is a cost-plus regulated monopoly in segment 2. We assume that strict accounting separation holds between its two subsidiaries. We further assume that imputation of common costs is defined on the basis of output so that total allocated costs $\hat{C}_1$ and $\hat{C}_2$ of the two subsidiaries are generically given by

$$\hat{C}_1 = C_1(\beta, e_1, q_1, q_2) + \frac{q_1}{q_1 + q_2} C_0(\beta, e_0, q_1, q_2) \tag{12}$$

$$\hat{C}_2 = C_2(\beta, e_2, q_1, q_2) + \frac{q_2}{q_1 + q_2} C_0(\beta, e_0, q_1, q_2) \tag{13}$$

Suppose that a firm *E* considers entry into the liberalized segment market (market 1) by relying on the same technology as the incumbent. Such an entrant, assumed to have "fair" access to the facilities that are common to the two segments, would have a total allocated cost function given by

$$\hat{C}_E = C_E(\beta, e_{E1}, q_{E1}, q_{I2}) + \frac{q_{E1}}{(q_{I1} + q_{E1}) + q_{I2}} C_0(\beta, e_{I0}, (q_{I1} + q_{E1}), q_{I2}) \tag{14}$$

where C_E is the incremental cost of the entering firm, e_{E1} and q_{E1} are its effort and output levels, respectively, and e_{I0}, q_{I1}, and q_{I2} are the incumbent's (common) cost-reducing effort and output levels in the competitive and regulated segments, respectively, once entry has occurred. We assume that C_E has the same functional form as C_1, the incumbent's incremental cost function in market 1.[4]

[4]These assumptions would be appropriate in situations where entrants

Since the entering firm uses the same technology as the incumbent and competition takes place in segment 1, efforts are conditionally optimal, and one can assume that the incumbent and the entrant share the market at the same level of output $(q_{I1}=q_{E1})$. The pecuniary costs of the incumbent are given by

$$\hat{C}_I = C_1(\beta, e_{I1}, q_{I1}, q_{I2}) + \frac{q_{I1}}{(q_{I1}+q_{E1})+q_{I2}} C_0(\beta, e_{I0}, (q_{I1}+q_{E1}), q_{I2}) \tag{15}$$

where e_{I1} is the incumbent's (incremental) cost-reducing effort in the competitive segment. If the incumbent matches the entrant's price, these costs are the same as the entrant's, and the incumbent must therefore match the entrant's effort level in the competitive segment. Under these conditions $e^*_{I1}(q_{I1})=e^*_{E1}(q_{E1})$.

Although there are no intrinsic technological cost advantages to the incumbent, the latter might still have the ability to block entry. Indeed, we might well have

$$\psi_E(\beta, e^*_{E1}, q_{E1}) \leq \psi(\beta, e^*_{I0}, e^*_{I1}, e^*_{I2}(q_{I2}), q_{I1}, q_{I2}) \tag{16}$$

yet

$$\psi_E(\beta, e^*_{E1}, q_{E1}) > \psi(\beta, e^*_{I0}, e^*_{I1}, e^{min}_{I2}, q_{I1}, q_{I2}) \tag{17}$$

where ψ_E is the disutility of effort function of the entrant (in the competitive segment), e^*_{E1} is the entrant's optimizing value of e_1, e^*_{I0}, and e^*_{I2} are the incumbent's optimizing values of e_0 and e_2, and e^{min}_{I2} is the minimal effort level that the incumbent can exert in reducing the corresponding cost component.

Inequalities (16) and (17) suggest that if the incumbent firm has its cost reimbursed at a minimum level of effort in the regulated segment (incremental cost and common costs), then it may have the ability to reduce its total disutility of effort to the point that it

make use of the incumbent's network through the purchase of unbundled network elements. In the United States, network elements are priced according to a TELRIC (total element long run incremental cost) methodology, which is interpreted as incremental cost augmented by a "reasonable" contribution to common costs. Later in this section we consider an alternative model of facilities-based entry.

is lower than the disutility of effort of the entrant. Hence, despite perfect accounting separation, complemented by a fair access price to the regulated sector, the incumbent can, by strategically manipulating effort levels, undercut an entrant, even if the latter happens to possess a comparable or even somewhat superior technology.

If the entrant uses a significantly better technology than the incumbent ($\beta_E << \beta$), the analysis of strategic manipulation of effort levels would allow us to compute the cost advantage it provides to the incumbent, but nothing general can be said about whether or not entry can be blockaded by the incumbent.

B. The Cost-of-Production Channel

We have just examined the possible ability that an incumbent would have to blockade entry into a liberalized sector by manipulating effort levels to the point of making its disutility of effort in the regulated sector lower than what first-best efficiency would dictate. A critical (perhaps too critical) role is played in this analysis by the disutility of effort functions of the incumbent and the entrant. From the standpoint of empirical analysis, this reliance on the properties of the disutility of effort functions is problematical because these functions are inherently unobservable, and we obtain them solely through calibration. Therefore in the remainder of this section we consider a simitar argument (blockade of entry) that is based only on the cost functions that the engineering cost model LECOM (see section V-A) allows us to estimate.

We impose, on both the incumbent and the entrant, a fixed level of disutility of effort $\bar{\psi}$.[5] We assume that the entrant and the incumbent have the same disutility of effort functions so that disutility for the entrant can be expressed as

$$\psi_E(\beta, e_{E0}, e_{E1}, q_{E1}) = \psi(\beta, e_{E0}, e_{E1}, 0, q_{E1}, 0) \tag{18}$$

Consider an entering firm that uses its own facilities and allocates effort between incremental and common costs. Hence, it would determine levels of e_0 and e_1 by minimizing its stand-alone

[5]For any output level this disutility is the result of an implicit level of effort e that serves as an indicator of the general level of effort in the industry. For example, effort can be said to be "high," "medium," or "low."

cost SAC_E (see equation 3) subject to the constraint

$$\psi(\beta, e_{E0}, e_{E1}, 0, q_{E1}, 0) = \bar{\psi} \qquad (19)$$

The first-order conditions of this problem, given by (19) and

$$\frac{\dfrac{\partial C_0}{\partial e_0}}{\dfrac{\partial \psi}{\partial e_0}} = \frac{\dfrac{\partial C_1}{\partial e_1}}{\dfrac{\partial \psi}{\partial e_1}} \qquad (20)$$

can be solved to yield optimal efforts $e^*_{E0}(\beta, q_{E1})$ and $e^*_{E1}(\beta, q_{E1})$ and a stand-alone cost function for the entrant given by

$$C_E(\beta, q_{E1}) \equiv C_1(\beta, e^*_{E1}(\beta, q_{E1}), q_{E1}, 0) + C_0(\beta, e^*_{E0}(\beta, q_{E1}), q_{E1} \quad . \qquad (21)$$

Substituting back these optimal efforts into the entrant's disutility of effort function yields the reduced form disutility of effort function

$$\psi_E(\beta, q_{E1}) \equiv \psi(\beta, e^*_{E0}(\beta, q_{E1}), e^*_{E1}(\beta, q_{E1}), 0, q_{E1} \quad . \qquad (22)$$

While the entrant exerts effort to reduce only its incremental and common costs, the incumbent has to allocate its effort among the three components of its cost function. Furthermore the incumbent is subject to regulation, which we assume is represented by a three-part cost-reimbursement scheme with powers α_1, α_2, and α_0 applied to the respective cost components. The incumbent's optimal choices of e_1, e_2, and e_0 are therefore obtained by minimizing total supported cost given by (7) subject to the constraint

$$\psi(\beta, e_0, e_1, e_2, q_1, q_2) = \bar{} . \qquad (23)$$

The first-order conditions to the incumbent's effort allocation problem are given by

$$\frac{\alpha_i \dfrac{\partial C_i}{\partial e_i}}{\dfrac{\partial \psi}{\partial e_i}} = \frac{\alpha_j \dfrac{\partial C_j}{\partial e_j}}{\dfrac{\partial \psi}{\partial e_j}} \qquad (21)$$

for i, $j=0$, 1, 2, $i \neq j$ and equation (23). These conditions implicitly define optimal effort functions $e^*_{I1}(\beta, q_{I1}, q_{I2}, \alpha_1, \alpha_2, \alpha_0, \bar{\psi})$, $e^*_{I2}(\beta, q_{I1}, q_{I2}, \alpha_1, \alpha_2, \alpha_0, \bar{\psi})$, and $e^*_{I0}(\beta, q_{I1}, q_{I2}, \alpha_1, \alpha_2, \alpha_0, \bar{\psi})$. Assuming accounting separation and imputation of common costs according to output as in the previous subsection, the cost function of the incumbent in activity 1, $\hat{C}_I(\beta, q_{I1}, q_{I2}, \alpha_1, \alpha_2, \alpha_0, \bar{\psi})$, which is the relevant one to consider as far as comparison with the entrant is concerned, is given by

$$
\begin{aligned}
& C_1(\beta, e^*_{I1}(\beta, q_{I1}, q_{I2}, \alpha_1, \alpha_2, \alpha_0, \bar{\psi}), q_{I1}, q_{I2}) \\
& + \frac{q_{I1}}{q_{I1}+q_{I2}} C_0(\beta, e^*_{I0}(\beta, q_{I1}, q_{I2}, \alpha_1, \alpha_2, \alpha_0, \bar{\psi}), q_{I1}, q_{I2})
\end{aligned}
\tag{25}
$$

The two functions C_E in equation (21) and $\hat{C}_I$ in equation (25) can be compared. For given values of the arguments, one can define the cost advantage of the incumbent (or handicap of the entrant) as the difference between these two costs, $\Delta \equiv (C_E - \hat{C}_I)$. Four factors are at work in the determination of Δ: the (dis)economies of scope between the two activities, the power of incentives of regulation, the common costs imputation rule, and the fact that the entrant firm has to allocate effort between only the two components of its stand-alone cost whereas the incumbent has to allocate it among three components.[6] It is worthwhile to note that the cost gap Δ depends on the respective powers of the incentive schemes. In the following section we will empirically analyze this dependence.

V. Empirical Results

A. Simulation of LECOM: Basic versus Enhanced Services

In our earlier work we used LECOM (local exchange cost optimization model) to simulate a telecommunications cost function in which outputs were represented as traffic, measured in CCS per access line (see chapters 6, 7, and 8 of Gasmi *et al.* (2002)) and access lines (see chapter 5).[7] Here we again consider cost as a

[6]Note that a positive Δ suggests that entry could potentially be blockaded.

[7]In chapter 5 of the book we analyzed the costs of access lines as a function of overall customer density, where the relative densities of the urban and rural sectors ars held constant. In chapter 8 we look at cost

function of the number of access lines, but we separate access lines into two distinct kinds, depending on the type of telecommunications service that they provide. Basic switched services, primarily sold to residential and small business users are essentially used for voice and low-speed data traffic. High-capacity leased lines (also called private lines) ale primarily used by larger business users for high-speed data and other enhanced services.

In both advanced and less developed countries, business and enhanced services have been open to competitive entry for many years, while the markets for residential switched services have retained the characteristics of natural monopoly, even where entry has been allowed or encouraged by the regulator. Thus switched access lines are priced subject to regulatory control in nearly all countries, while enhanced services are generally provided in a highly competitive environment. The issues of cross-subsidization, which this paper seeks to investigate, are therefore relevant for these markets.

Using LECOM we are able to estimate the cost of providing both switched and unswitched access lines. We assume a city of fixed size consisting of three zones, a central business district, a mixed commercial and residential district, and a residential district. We also assume that customer density progressively increases as we move from the residential to the mixed and to the business districts.[8]

LECOM allows the user to specify the proportion of unswitched access lines in each region of the city. For the simulations, the percentage of private line customers varied from 0 to 100 percent in increments of 20 percent. The total population of the city varied from 6,000 to 100,000 subscribers.[9] Thus, by varying both the population of subscribers and the percentage of unswitched lines, we define a grid of output values that we use to simulate the total

functions for the urban and rural sectors individually.

[8]With a total subscriber population of 100,000 spread over a city with a total area of about 57.5 square miles, the customer densities in our simulation are 1,006 subscribers per square mile of the residential district, 2,278 per square mile of the mixed district and 7,260 per square mile of the business district. In the simulations, when the total subscriber population varies, the densities of the districts relative to each others are maintained constant.

[9]The actual total numbers of access lines were 6,000, 12,000, 20,000, 40,000, 70,000 and 100,000.

cost function of the integrated firm. The grid also includes a range of values for the multipliers of the price of capital and labor *PK* and *PL*, which are supposed to represent, respectively, the technology type β and effort e.[10] In order to simulate the stand-alone cost functions for both switched and unswitched access lines, we set the unswitched percentages equal to 0 and 1, respectively, and vary the total number of access lines in a manner consistent with our first grid. This exercise allows us to create the data for estimating the cost functions $C(\beta,e,q_1,q_2)$, $C_1(\beta,e,q_1,q_2)$, and $C_2(\beta,e,q_1,q_2)$ which are described above.[11]

We next explain the techniques that allow us to estimate the stand-alone cost functions defined in (1), (3), and (4) through simulations of LECOM and how we use these functions to derive the incremental and common cost functions. By letting the variables *PK* (the multiplier for the price of capital, our proxy for the technological parameter β), *PL* (the multiplier for the price of labor, our proxy for effort e), and q_1, and q_2 (measures of levels of output in markets 1 and 2) vary within a grid, we obtain the cost function $\tilde{C}(\beta,e,q_1,q_2)$.[12] This function represents the stand-alone cost of an integrated firm (the incumbent) serving markets 1 and 2. Using the same grid and restricting the outputs so that only $q_1>0$ and $q_2>0$, we estimate the cost functions $\widetilde{SAC}_1(\beta,e,q_1)$ and $\widetilde{SAC}_2(\beta,e,q_2)$ which represent the stand-alone costs of a nonintegrated firm serving markets 1 and 2, respectively. We note that these stand-alone cost functions do not correspond exactly to the theoretical stand-alone cost functions $C(\beta,e_0,e_1,e_2,q_1,q_2)$, $SAC_1(\beta,e_0,e_1,q_1)$ and $SAC_2(\beta,e_0,e_2,q_2)$ since they do not allow the firm to assign different effort levels to different activities or markets.

Using these three basic LECOM-generated cost functions $\tilde{C}$, $\widetilde{SAC}_1$ and $\widetilde{SAC}_2$, we define the empirical counterparts of the incremental

[10]More specifically, *PK*, *PL*=0.6, 0.8, 1.0, 1.2, 1.4.

[11]See below for more on the relationship between the theoretical cost functions and their empirical counterparts. The simulations produced data sets of 900 points. Because some of our cost functions require using zero as an argument, we fit out LECOM cost data to a functional form that is a second-degree polynomial of the appropriate variables rather than their natural logarithms as done in our previous work. The expression of the various cost functions rosed in this paper is given in the appendix.

[12]For clarity of exposition, we adopt the convention of designating by $\tilde{C}$ the (LECOM-estimated) empirical counterpart of a generic theoretical cost function C.

cost functions C_1 and C_2 and the common cost function C_0 as follows:

$$\tilde{C}_1(\beta,e_1,q_1,q_2)=\tilde{C}(\beta,e_1,q_1,q_2)-\widetilde{SAC}_2(\beta,e_1,q_2) \tag{26}$$

$$\tilde{C}_2(\beta,e_2,q_1,q_2)=\tilde{C}(\beta,e_2,q_1,q_2)-\widetilde{SAC}_1(\beta,e_2,q_1) \tag{27}$$

$$\tilde{C}_0(\beta,e_0,q_1,q_2)=\widetilde{SAC}_1(\beta,e_0,q_1)+\widetilde{SAC}_2(\beta,e_0,q_2) -\tilde{C}(\beta,e_0,q_1,q_2\ . \tag{28}$$

Substituting from (26) and (27) yields

$$\tilde{C}_0(\beta,e_0,q_1,q_2)=\tilde{C}(\beta,e_0,q_1,q_2)-\tilde{C}_1(\beta,e_0,q_1,q_2) -\tilde{C}_2(\beta,e_0,q_1,q_2) \tag{29}$$

Before discussing results on economies of scope between basic switched service and enhanced high-capacity service, let us say a few more words on the theoretical interpretation of the above simulated LECOM cost functions.

Our use of the LECOM input *PL* as a proxy for the firm's effort level implies a constraint on the way effort is allocated among the components of the cost function represented in equation (1). For any 4-tuple (PK,PL,q_1,q_2), which is our proxy for (β,e,q_1,q_2), a LECOM run searches for the network configuration and technological characteristics (number of switches, location, types of switches, distribution and transport plant, *etc.*) that minimize the total cost. For each run a common value of *PL*, representing a level of effort *e*, is used in both markets and for the common costs.[13]

Thus, the cost function $\tilde{C}(\beta,e,q_1,q_2)$ that LECOM simulates is that for an integrated firm that minimizes the sum of its three components

$$C_1(\beta,e_1,q_1,q_2)+C_2(\beta,e_2,q_1,q_2)+C_0(\beta,e_0,q_1,q_2) \tag{30}$$

subject to the constraint $e_0=e_1=e_2\equiv e$. Indeed, the solution to this minimization problem yields a total cost function

[13]In our analysis there is a one-to-one correspondence between the set of values of *PL* and that of values of *e*. This correspondence is defined by the relation $e=1.5-PL$ (see Gasmi *et al.* (2002), for more details).

$$C_1(\beta,e,q_1,q_2)+C_2(\beta,e,q_1,q_2)+C_0(\beta,e,q_1,q_2) \tag{31}$$

which has $\widetilde{C}(\beta,e,q_1,q_2)$ as its empirical counterpart as can be verified using (26), (27), and (28).

Note that (28) gives a direct indication of whether or not economies of scope between basic switched service and enhanced service exist. If these two services are provided by two separate firms, each firm would have to support the corresponding stand-alone cost and the total multifirm cost would then be equal to $(\widetilde{SAC}_1+\widetilde{SAC}_2)$. A single firm offering both services would bear the total cost $\widetilde{C}$. The difference between these two costs, $[(\widetilde{SAC}_1+\widetilde{SAC}_2)-\widetilde{C}]$, which represents the costs that are common to the two services, indicates the presence of economies or diseconomies of scope. For various combinations of outputs q_1 (number of unswitched access lines) and q_2 (number of switched access lines) in the range of output levels for which our LECOM cost functions were defined, and for the average values of the multipliers of price of capital and labor *PK* and *PL* (both equal to 1), we found this difference to be consistently positive, indicating the presence of economies of scope.[14]

B. Accounting and Strategic Cross-Subsidies

When strict separation of the accounts of the regulated (switched service) and the unregulated (unswitched service) sectors is not imposed, the integrated firm clearly has an incentive to allocate as much of the common costs as possible to the regulated sector.[15] In the notation of Section II, this is achieved when $\delta=0$, when the totality of the common costs are recorded on the regulated sector accounts. In contrast, when $\delta=1$, then all of the common costs are born by the unregulated sector. In fact, given the absence of strict accounting safeguards, a natural albeit imperfect measure of the potential for cross-subsidization that the integrated firm has

[14]The combinations of output levels for these calculations are described in the next subsection.

[15]This is true provided that the firm is regulated with a cost-plus type scheme.

TABLE 1

CROSS-SUBSIDIES THROUGH ALLOCATION OF COMMON COSTS

$[\tilde{C}_0/\tilde{C}] \times 100$

	$q_2=5K$	$10K$	$15K$	$20K$	$25K$	$30K$	$35K$	$40K$	$45K$	$50K$
$q_1=5K$	48.21	39.27	32.98	28.35	24.83	22.08	19.90	18.14	16.71	15.53
$10K$	32.23	27.23	23.50	20.63	18.37	16.57	15.12	13.94	12.97	12.17
$15K$	22.51	19.46	17.09	15.23	13.73	12.52	11.54	10.74	10.08	9.54
$20K$	16.10	14.13	12.57	11.32	10.30	9.48	8.81	8.27	7.83	7.48
$25K$	11.67	10.34	9.28	8.42	7.73	7.17	6.71	6.35	6.07	5.85
$30K$	8.49	7.58	6.84	6.25	5.77	5.39	5.10	4.87	4.69	4.57
$35K$	6.18	5.54	5.02	4.61	4.29	4.04	3.85	3.71	3.63	3.58
$40K$	4.49	4.03	3.67	3.38	3.17	3.01	2.90	2.84	2.81	2.81
$45K$	3.25	2.92	2.66	2.47	2.33	2.24	2.19	2.18	2.19	2.24
$50K$	2.35	2.12	1.94	1.81	1.73	1.69	1.68	1.71	1.75	1.83

would merely be the magnitude of the common costs relative to total costs. Table 1 gives an evaluation of these common costs as a percentage of total cost for various combinations of outputs given in thousands (K) of access lines.[16]

From Table 1 we can see that as q_i increases relative to q_j, $i, j = 1, 2, i \neq j$, the relative importance of common costs diminishes. Note that since the area of the city in our simulations is held constant, an increase in access lines corresponds to an increase in customer density. As any of the two types of markets relative to the other or both markets simultaneously gain in maturity, the two activities can be (technologically) separated leaving less room for cross-subsidization of segment 1 with segment 2 through accounting manipulation of the costs that are common to these segments.

An alternative way to express this ability of the integrated firm to use the allocation of common costs as a means of cross-subsidization is the potential per unit subsidy σ, which we define as $\sigma = \tilde{C}_0/q_1 = [s(1) - s(0)]/q_1$. Table 2 gives the value of this measure for different combinations of outputs.[17] This table shows that, for any level of q_2, σ decreases with q_1. A slightly different result holds when we fix the level of q_1 and let q_2 vary. In this

[16]In the notation of section II, this measure is equal to $[(s(1) - s(0))/C] \times 100$.

[17]The relative importance of these access line potential subsidies can be appreciated from table A-7 of the appendix where the values of average costs are provided for different values of outputs.

TABLE 2

POTENTIAL PER UNIT CROSS-SUBSIDIZATION DUE TO ACCOUNTING MANIPULATION

$\sigma = \widetilde{C}_0/q_1$

	q_2=5K	10K	15K	20K	25K	30K	35K	40K	45K	50K
q_1=5K	528.18	515.84	505.06	495.84	488.17	482.07	477.53	474.54	473.11	473.25
10K	227.86	222.12	217.16	212.97	209.57	206.94	205.09	204.03	203.74	204.23
15K	129.74	126.20	123.17	120.67	118.68	117.22	116.27	115.84	115.94	116.55
20K	82.17	79.73	77.67	76.00	74.73	73.84	73.34	73.24	73.52	74.19
25K	54.82	53.03	51.56	50.40	49.55	49.01	48.78	48.87	49.26	49.97
30K	37.58	36.23	35.14	34.32	33.75	33.44	33.40	33.61	34.08	34.82
35K	26.11	25.08	24.27	23.68	23.32	23.18	23.26	23.56	24.09	24.84
40K	18.26	17.46	16.86	16.45	16.24	16.22	16.40	16.77	17.34	18.10
45K	12.81	12.20	11.76	11.49	11.40	11.48	11.73	12.15	12.75	13.53
50K	9.05	8.58	8.27	8.11	8.12	8.27	8.59	9.05	9.68	10.46

Note: Units are in annualized US dollars per unswitched access line.

case σ decreases up to some level of q_2 and then increases beyond that level. As the fixed value of q_1 increases, the minimum value of σ is reached for smaller values of q_2.

The ability of an integrated firm to cross-subsidize through an allocation of common costs can be substantially reduced by strict accounting rules. However, as discussed in section III, besides common costs, the firm could also allocate unobservable effort between its two activities. Such a discretionary action allows the firm to cross-subsidize, and we first seek to quantify this type of cross-subsidization.

Effort allocation depends on the power of the incentive schemes that regulate the two activities of the firm. Equations (8), (9), and (10) define the optimal effort levels e_1^*, e_2^*, and e_0^* that are allocated to the three components of the cost function. We assume that the integrated firm is a residual claimant of any reductions of its costs on the unswitched service market ($\alpha_1 = 1$) and that the incremental costs associated with the switched service market and the common costs are under regulation with the same incentive power ($\alpha_2 = \alpha_0$). From the results on the size of cross-subsidization due to the accounting manipulation discussed above, we let $\delta = 1$ in order to calibrate the level of cross-subsidization due to effort allocation.[18] We then calculate the optimal effort levels for different combin-

[18]By allocating entirely the common costs to segment 1 ($\delta = 1$), the aim is to obtain the most significant effort allocation cross-subsidization effect.

TABLE 3

POTENTIAL PER UNIT CROSS-SUBSIDIZATION DUE TO EFFORT ALLOCATION

$\tau = [t(0,1) - t(1,1)]/q_1$

	$q_2 = 5K$	$10K$	$15K$	$20K$	$25K$	$30K$	$35K$	$40K$	$45K$	$50K$
$q_1 = 5K$	224.00	220.84	217.71	214.60	211.51	208.44	205.39	202.37	199.37	196.39
$10K$	91.19	89.76	88.35	86.95	85.56	84.18	82.81	81.45	80.11	78.78
$15K$	48.34	47.50	46.66	45.83	45.00	44.18	43.38	42.58	41.78	41.00
$20K$	27.99	27.43	26.88	26.33	25.79	25.26	24.73	24.21	23.69	23.18
$25K$	16.63	16.25	15.87	15.49	15.12	14.76	14.40	14.04	13.69	13.34
$30K$	9.77	9.50	9.24	8.98	8.72	8.47	8.22	7.97	7.73	7.49
$35K$	5.48	5.30	5.11	4.94	4.76	4.59	4.42	4.25	4.09	3.93
$40K$	2.80	2.68	2.56	2.44	2.32	2.21	2.10	1.99	1.89	1.79
$45K$	1.19	1.11	1.04	0.97	0.90	0.84	0.77	0.71	0.65	0.60
$50K$	0.33	0.29	0.26	0.22	0.19	0.16	0.14	0.11	0.09	0.07

Note: Units are in annualized US dollars per unswitched access line.

ations of outputs q_1 and q_2 and for different values of α_2. These effort levels can be substituted back into the incremental cost function C_1 and the common cost function C_0 to find the value of the total allocated cost function t defined in (11).[19] It is worthwhile to note that in contrast with the function s previously analyzed, the value taken by this allocated cost function t depends on the power of the incentive scheme (α_2) that regulates the switched service sector.

In the same vein as σ, we can compute a per unit subsidy τ on the basis of the function t as $\tau = [t(0,1) - t(1,1)]/q_1$. Table 3 gives the value of τ for different combinations of outputs. Note that, besides nearly following the same pattern as the potential per unit subsidy due to the accounting manipulation of common costs σ (see table 2), this potential subsidy due to effort allocation represents less than 1 percent of the former for high values of outputs but can get as large as 40 percent for low values of outputs.[20] We should also note that this subsidy potential decreases with jointly increasing outputs. This is because as the two activities become more important, they independently require higher effort, so effort allocation cross-subsidization is less of a

[19]Recall that the function $t(\alpha_2, \delta)$ measures the allocated cost of activity 1 given the common costs allocation parameter δ and the faction α_2 of the incremental cost of activity 2 born by the incumbent.

[20]We should note though that the nonmonotonicity of σ found when q_1 is fixed and q_2 varies does not occur in the case of τ.

problem.

So far our main goal was to gain a sense of how much an integrated firm can use its regulated activity to cross-subsidize its competitive one. We chose exercises that provide useful information on the ranges of cost variations associated with the allocation of both common costs and effort. We now seek to explore further the conditions under which the allocation of effort, which remains a cross-subsidization instrument at the firm's disposal even under strict accounting safeguards, can affect entry. While assuming that the integrated incumbent firm has to comply with a strict rule of allocation of common costs, we will identify conditions under which the mechanism of effort allocation among its cost components enables the firm to undercut potential entrants into the competitive unswitched service segment.

Our empirical exercise follows the analysis presented in subsection IV-*B*. Recall that we imposed a fixed level of disutility of effort $\bar{\psi}$ on both the incumbent and the entrant and that, as was mentioned, this level of disutility corresponds to an implicit level of effort that can be used as an indicator of the aggregate level of effort in the industry. We therefore organize the empirical results according to low, medium, and high level of effort, or equivalently, low, medium, and high level of disutility of effort.

Given accounting separation and the rule of allocating common costs imposed on the incumbent firm, one way to "neutralize" strategic cross-subsidization is by implementing a high-powered incentive scheme. To show how it works, we first assume that the incumbent firm is subject to regulation described by the triplet of incentive power values $(\alpha_1, \alpha_2, \alpha_0)=(1,1,1)$.[21] Given these fixed values of the power of incentives and that a common costs imputation rule is imposed, two effects can still be identified from this exercise: that of the (dis)economies of scope and that of the number of activities among which effort should be allocated (see subsection IV-*B*). Table 4 gives the value of the incumbent's cost advantage (per unswitched access line) over a potential entrant due to effort allocation for this reference case of "perfect" regulation, under a medium level of industry effort that corresponds to a value of *PL* that is in the midrange of our data points.[22] Tables with

[21]Note that for the case of activity 1 which is competitive, high-powered regulation is implicit.

TABLE 4

INCUMBENT PER UNIT COST ADVANTAGE UNDER HIGH-POWERED REGULATION AND MEDIUM EFFORT

$\Delta / q_1 = (C_E - \hat{C}_I) / q_1$

	$q_2 = 5K$	$10K$	$15K$	$20K$	$25K$	$30K$	$35K$	$40K$	$45K$	$50K$
$q_1 = 5K$	224.01	292.18	320.70	334.35	341.39	345.33	347.95	350.21	352.69	355.78
$10K$	53.43	81.01	95.21	103.20	108.01	111.15	113.47	115.45	117.40	119.55
$15K$	15.19	28.35	35.71	40.08	42.81	44.66	46.06	47.30	48.55	49.95
$20K$	1.16	8.13	12.05	14.36	15.78	16.72	17.44	18.11	18.84	19.70
$25K$	-5.42	-1.44	0.65	1.78	2.39	2.75	3.01	3.29	3.65	4.14
$30K$	-9.06	-6.58	-5.50	-5.06	-4.94	-4.96	-5.00	-4.99	-4.88	-4.64
$35K$	-11.31	-9.61	-9.08	-9.04	-9.22	-9.47	-9.71	-9.88	-9.94	-9.87
$40K$	-12.84	-11.50	-11.28	-11.47	-11.82	-12.21	-12.57	-12.85	-13.03	-13.08
$45K$	-13.96	-12.76	-12.69	-12.99	-13.43	-13.90	-14.33	-14.68	-14.93	-15.06
$50K$	-14.83	-13.63	-13.61	-13.96	-14.44	-14.95	-15.41	-15.80	-16.10	-16.28

Note: Units are in annualized US dollars per unswitched access line.

the results for high and low levels of effort are given in the appendix.

These various tables show that for each level of (fixed) aggregate disutility of effort in the industry, the entrant firm has a cost advantage (since $\Delta < 0$) provided that q_1 is large relative to q_2. As the competitive market becomes increasingly important relative to the regulated market, the integrated firm has less leverage in terms of subsidizing the former by the latter. A cross-examination of these three tables also shows that entry becomes viable for smaller outputs of q_1 as the aggregate level of disutility of effort imposed on the firms is larger. Indeed, as effort increases, costs decrease and the strategic allocation of costs is less of a problem.

The next step is to examine the sensitivity of the difference between the incumbent's cost and the entrant's cost to the "quality" of regulation in market 2 as measured by the power of the incentive scheme that regulates the market. As expected, less than perfect regulation of activity 2 opens the door for more cross-subsidization, and an comparison of table 4 with tables 5 and 6 illustrates the point for medium level of effort. Tables 5 and 6 show the values of Δ / q_1 under incentive schemes whose power values 0.5 and 0.2 respectively. In the three effort levels, we find that for some representative combinations of output, the incumbent's cost advantage Δ changes sign from negative to positive when α_2

[22]By perfect regulation we mean regulation with a high-powered scheme.

TABLE 5
INCUMBENT PER UNIT COST ADVANTAGE UNDER MEDIUM-POWERED REGULATION AND MEDIUM EFFORT

$\Delta/q_1 = (C_E - \hat{C}_I)/q_1$

	q_2=5K	10K	15K	20K	25K	30K	35K	40K	45K	50K
q_1=5K	237.41	312.99	345.03	360.69	368.99	373.80	377.04	379.78	382.64	386.03
10K	61.52	94.73	112.30	122.50	128.87	133.16	136.34	138.99	141.48	144.06
15K	22.45	39.66	49.78	56.16	60.43	63.47	65.83	67.85	69.74	71.66
20K	8.66	18.50	24.62	28.65	31.46	33.54	35.20	36.67	38.07	39.51
25K	2.58	8.61	12.42	14.99	16.82	18.21	19.36	20.41	21.44	22.52
30K	-0.51	3.39	5.81	7.45	8.63	9.54	10.32	11.05	11.80	12.62
35K	-2.26	0.39	1.96	2.99	3.73	4.31	4.82	5.32	5.87	6.50
40K	-3.35	-1.44	-0.42	0.22	0.66	1.01	1.33	1.67	2.07	2.55
45K	-4.11	-2.63	-1.95	-1.57	-1.32	-1.13	-0.94	-0.72	-0.43	-0.06
50K	-4.68	-3.45	-2.98	-2.76	-2.64	-2.56	-2.46	-2.32	-2.11	-1.82

Note: Units are in annualized US dollars per unswitched access line.

TABLE 6
INCUMBENT PER UNIT COST ADVANTAGE UNDER LOW-POWERED REGULATION AND MEDIUM EFFORT

$\Delta/q_1 = (C_E - \hat{C}_I)/q_1$

	q_2=5K	10K	15K	20K	25K	30K	35K	40K	45K	50K
q_1=5K	234.03	321.94	360.79	380.96	392.59	400.01	405.40	409.95	414.40	419.20
10K	57.84	97.17	118.83	132.06	140.81	147.06	151.91	156.01	159.78	163.50
15K	20.94	41.52	54.23	62.69	68.69	73.22	76.88	80.06	83.00	85.88
20K	8.96	20.76	28.57	34.07	38.16	41.38	44.07	46.48	48.74	50.99
25K	4.22	11.38	16.34	19.97	22.77	25.05	27.03	28.84	30.58	32.34
30K	2.10	6.63	9.84	12.26	14.18	15.80	17.25	18.61	19.97	21.36
35K	1.07	4.00	6.10	7.73	9.05	10.20	11.26	12.30	13.35	14.47
40K	0.49	2.43	3.82	4.90	5.81	6.63	7.41	8.21	9.05	9.95
45K	0.10	1.42	2.34	3.06	3.69	4.27	4.85	5.47	6.14	6.89
50K	-0.21	0.71	1.32	1.80	2.23	2.65	3.09	3.58	4.13	4.76

Note: Units are in annualized US dollars per unswitched access line.

decreases. This says that for some given market size, as the quality of regulation deteriorates in term of the incentives that regulation gives the firm for cost minimization, entry can be blockaded more easily by the incumbent.

As an illustration, consider the output combination $(q_1, q_2) =$ (30,000, 35,000). Under high-powered regulation ($\alpha_2 = 1$), Δ/q_1 is negative, suggesting that entry is viable. However, for this same output combination and under medium-powered regulation ($\alpha_2 =$

0.5), the incumbent firm acquires a cost advantage, as shown by the positive value of Δ/q_1, by which the incumbent can implement a pricing strategy for blockading entry. The same effect can be seen in processing from medium-powered to low-powered regulation ($\alpha_2 = 0.2$) for the combination of outputs $(q_1,q_2)=(45{,}000, 50{,}000)$. The implication is that if an incumbent firm's noncompetitive segments are not properly regulated, through effort allocation the firm can succeed in protecting its competitive segments by cross-subsidizing them with its regulated segments, and thus affect market's structure. Thus, regulation can be circumvented by an incumbent firm to blockade entry into liberalized markets.

IV. Conclusion

In this paper we introduced methodology that combines theoretical ideas from regulation and an empirical analysis in order to explore the impact of cross-subsidies allowed by vertical integration on entry into liberalized segments of the telecommunications industry. Our first task was to quantify the phenomenon of cross-subsidies in the case of an incumbent regulated in a market for switched access lines and facing competition in a market for unswitched access lines. From the properties of some basic cost functions estimated using LECOM, the engineering cost proxy model that we have used in the empirical regulation work reported in our book (Gasmi *et al.* 2002), we produced measures of two types of cross-subsidies that an incumbent firm might enjoy against a potential entrant. The first of these involved evaluating a range of straightforward cross-subsidies favoring the incumbent's competitive segment to which a small fraction of common costs are allocated by an accounting manipulation. The second exercise concerned cross-subsidies stemming from the allocation of effort by the incumbent between its competitive and regulated segments. Theses two cross-subsidies were expressed in terms of the potential cost advantage that the incumbent would have over a potential cost entrant for each unswitched access line. From this measure we obtained an idea of the extent to which an incumbent can (unfairly) undercut its competitors.

While the adverse effect on entry of the first type of cross-subsidy largely be alleviated by imposing strong accounting safeguards, since effort is inherently unobservable, the second type of cross-subsidy is considerably more difficult for the regulator to monitor. Much of this paper was devoted to the impact of cross-subsidies on the process of entry into liberalized segments. Using LECOM, we were able to proxy the incumbent's and thus to closely examine the mechanism by which the incumbent can allocate effort among its (regulated) switched service segment and its (competitive) unswitched segments. In analyzing this mechanism of effort allocation, we emphasized the role of the power an incentive regulatory scheme in affecting costs, and we identified situations where the incumbent achieved lower costs than a potential competitor. Our analysis illustrated that regulation, which is designed to foster competition, may actually hinder competition if it does not give the incumbent firm appropriate incentives to efficiently allocate managerial effort among the division of the firm.

Appendix

In this appendix we present in table A-1 through A-7 empirical results that complement the discussion in the main text, and the quadratic estimations of the cost functions used in the analysis.

TABLE A-1

INCUMBENT PER UNIT COST ADVANTAGE UNDER HIGH-POWERED REGULATION AND LOW EFFORT

$\Delta/q_1=(C_E-\hat{C}_I)/q_1$

	$q_2=5K$	$10K$	$15K$	$20K$	$25K$	$30K$	$35K$	$40K$	$45K$	$50K$
$q_1=5K$	286.05	373.97	412.48	432.20	443.30	450.17	454.97	458.91	462.73	466.87
$10K$	78.46	116.62	137.36	149.84	157.97	163.67	168.02	171.66	175.00	178.31
$15K$	30.70	50.23	62.02	69.70	75.04	79.00	82.15	84.87	87.39	89.88
$20K$	13.07	24.12	31.15	35.95	39.42	42.09	44.29	46.24	48.10	49.96
$25K$	4.93	11.62	15.95	18.97	21.22	22.99	24.50	25.89	27.24	28.64
$30K$	0.62	4.89	7.61	9.52	10.96	12.12	13.14	14.11	15.10	16.14
$35K$	-1.88	0.99	2.72	3.92	4.81	5.55	6.23	6.90	7.61	8.40
$40K$	-3.43	-1.40	-0.28	0.45	0.99	1.44	1.87	2.33	2.85	3.45
$45K$	-4.45	-2.91	-2.18	-1.75	-1.45	1.19	-0.93	-0.62	-0.24	0.22
$50K$	-5.14	-3.89	-3.40	-3.16	-3.01	-2.88	-2.73	-2.53	-2.53	-1.89

Note: Units are in annualized US dollars per unswitched access line.

TABLE A-2

INCUMBENT PER UNIT COST ADVANTAGE UNDER HIGH-POWERED REGULATION AND HIGH EFFORT

$\Delta/q_1=(C_E-\hat{C}_I)/q_1$

	$q_2=5K$	$10K$	$15K$	$20K$	$25K$	$30K$	$35K$	$40K$	$45K$	$50K$
$q_1=5K$	168.31	216.78	235.10	242.44	245.16	245.98	246.22	246.63	247.63	249.52
$10K$	32.22	48.96	56.46	59.80	61.15	61.61	61.78	61.99	62.46	63.35
$15K$	2.81	9.08	11.78	12.67	12.68	12.32	11.88	11.56	11.47	11.69
$20K$	-7.88	-5.73	-5.20	-5.45	-6.30	-7.18	-8.02	-8.71	-9.17	-9.36
$25K$	-13.02	-12.61	-13.09	-14.04	-15.19	-16.35	-17.42	-18.32	-19.02	-19.47
$30K$	-16.00	-16.32	-17.24	-18.48	-19.80	-21.10	-22.28	-23.30	-24.13	-24.74
$35K$	-18.00	-18.55	-19.63	-20.96	-22.35	-23.69	-24.92	-26.00	-26.89	-27.59
$40K$	-19.50	-20.01	-21.10	-22.43	-23.81	-25.15	-26.37	-27.46	-28.39	-29.14
$45K$	-20.71	-21.05	-22.06	-23.33	-24.66	-25.96	-27.16	-28.23	-29.16	-29.93
$50K$	-21.74	-21.83	-22.71	-23.89	-25.15	-26.39	-27.55	-28.59	-29.51	-30.28

Note: Units are in annualized US dollars per unswitched access line.

TABLE A-3

INCUMBENT PER UNIT COST ADVANTAGE UNDER MEDIUM-POWERED REGULATION AND HIGH EFFORT

$\Delta/q_1=(C_E-\hat{C}_I)/q_1$

	$q_2=5K$	$10K$	$15K$	$20K$	$25K$	$30K$	$35K$	$40K$	$45K$	$50K$
$q_1=5K$	191.82	254.50	279.65	290.89	296.07	298.53	299.94	301.21	302.89	305.30
$10K$	44.68	71.73	85.37	92.78	97.00	99.57	101.34	102.79	104.26	105.94
$15K$	13.35	27.17	34.90	39.44	42.21	44.01	45.30	46.38	47.45	48.64
$20K$	2.73	10.54	15.12	17.89	19.64	20.79	21.64	22.38	23.12	23.96
$25K$	-1.79	2.95	5.73	7.42	8.47	9.16	9.69	10.15	10.65	11.24
$30K$	-4.05	-0.98	0.73	1.73	2.33	2.70	2.98	3.25	3.56	3.97
$35K$	-5.35	-3.23	-2.16	-1.60	-1.31	-1.16	-1.05	-0.92	-0.74	-0.46
$40K$	-6.21	-4.64	-3.96	-3.68	-3.59	-3.58	-3.59	-3.56	-3.47	-3.29
$45K$	-6.87	-5.59	-5.16	-5.05	-5.08	-5.17	-5.26	-5.30	-5.28	-5.16
$50K$	-7.44	-6.30	-6.00	-5.99	-6.10	-6.25	-6.39	-6.48	-6.50	-6.43

Note: Units are in annualized US dollars per unswitched access line.

TABLE A-4

INCUMBENT PER UNIT COST ADVANTAGE UNDER LOW-POWERED REGULATION AND HIGH EFFORT

$\Delta / q_1 = (C_E - \hat{C}_I) / q_1$

	$q_2=5K$	$10K$	$15K$	$20K$	$25K$	$30K$	$35K$	$40K$	$45K$	$50K$
$q_1=5K$	186.13	316.39	305.85	324.88	335.89	343.00	348.29	352.87	357.44	362.44
$10K$	38.43	75.55	95.94	108.37	116.59	122.47	127.07	131.01	134.67	138.33
$15K$	10.52	30.03	42.04	50.02	55.67	59.95	63.43	66.47	69.31	72.12
$20K$	2.75	14.01	21.44	26.65	30.53	33.59	36.16	38.47	40.66	42.85
$25K$	0.34	7.24	11.99	15.46	18.13	20.32	22.21	23.96	25.66	27.39
$30K$	-0.38	4.03	7.14	9.47	11.33	12.89	14.29	15.62	16.95	18.33
$35K$	-0.56	2.35	4.42	6.00	7.29	8.41	9.46	10.48	11.52	12.63
$40K$	-0.61	1.37	2.76	3.84	4.74	5.55	6.33	7.12	7.95	8.86
$45K$	-0.69	0.71	1.65	2.39	3.02	3.61	4.19	4.81	5.49	6.25
$50K$	-0.84	0.18	0.83	1.34	1.78	2.21	2.66	3.16	3.72	4.36

Note: Units are in annualized US dollars per unswitched access line.

TABLE A-5

INCUMBENT PER UNIT COST ADVANTAGE UNDER MEDIUM-POWERED REGULATION AND LOW EFFORT

$\Delta / q_1 = (C_E - \hat{C}_I) / q_1$

	$q_2=5K$	$10K$	$15K$	$20K$	$25K$	$30K$	$35K$	$40K$	$45K$	$50K$
$q_1=5K$	290.23	380.24	419.77	440.07	451.55	458.68	463.67	467.76	471.70	475.95
$10K$	81.37	121.17	142.92	156.08	164.68	170.72	175.34	179.18	182.68	186.13
$15K$	33.47	54.13	66.75	75.05	80.86	85.18	88.63	91.59	94.31	96.96
$20K$	16.00	27.78	34.45	40.77	44.67	47.69	50.18	52.38	54.45	56.49
$25K$	8.08	15.20	20.02	23.48	26.09	28.19	29.97	31.60	33.16	34.74
$30K$	4.00	8.48	11.56	13.82	15.57	17.02	18.29	19.49	20.67	21.90
$35K$	1.69	4.61	6.59	8.07	9.24	10.23	11.13	12.01	12.92	13.88
$40K$	0.30	2.25	3.54	4.50	5.26	5.94	6.58	7.23	7.92	8.69
$45K$	-0.58	0.77	1.60	2.21	2.71	3.16	3.62	4.10	4.64	5.26
$50K$	-1.17	-0.19	0.35	0.73	1.05	1.35	1.67	2.04	2.47	2.98

Note: Units are in annualized US dollars per unswitched access line.

TABLE A-6

INCUMBENT PER UNIT COST ADVANTAGE UNDER LOW-POWERED REGULATION AND LOW EFFORT

$\Delta / q_1 = (C_E - \hat{C}_I)/q_1$

	$q_2=5K$	$10K$	$15K$	$20K$	$25K$	$30K$	$35K$	$40K$	$45K$	$50K$
$q_1=5K$	289.15	383.20	424.93	446.65	459.18	467.11	472.75	477.40	481.81	486.50
$10K$	80.19	122.03	145.15	159.32	168.70	175.39	180.55	184.86	188.78	192.59
$15K$	33.05	54.80	68.29	77.28	83.67	88.47	92.36	95.70	98.77	101.74
$20K$	16.22	28.59	36.83	42.64	46.96	50.36	53.19	55.70	58.05	60.36
$25K$	8.78	16.20	21.39	25.19	28.13	30.52	32.58	34.45	36.25	38.06
$30K$	5.03	9.65	12.97	15.48	17.48	19.15	20.65	22.05	23.44	24.86
$35K$	2.98	5.90	8.04	9.70	11.06	12.24	13.32	14.38	15.45	16.58
$40K$	1.77	3.64	5.02	6.11	7.03	7.86	8.65	9.45	10.29	11.20
$45K$	1.02	2.22	3.10	3.81	4.43	5.01	5.59	6.20	6.87	7.62
$50K$	0.52	1.29	1.85	2.30	2.72	3.13	3.56	4.04	4.59	5.21

Note: Units are in annualized US dollars per unswitched access line.

TABLE A-7

AVERAGE COST

	$q_2=5K$	$10K$	$15K$	$20K$	$25K$	$30K$	$35K$	$40K$	$45K$	$50K$
$q_1=5K$	547.78	437.90	382.87	349.79	327.68	311.84	299.91	290.60	283.12	276.97
$10K$	471.34	407.82	369.65	344.14	325.87	312.13	301.40	292.79	285.71	279.78
$15K$	432.29	389.12	360.28	339.63	324.11	311.99	302.27	294.28	287.59	281.91
$20K$	408.20	376.10	353.12	335.84	322.36	311.55	302.67	295.25	288.94	283.50
$25K$	391.59	366.32	347.33	332.52	320.64	310.89	302.73	295.81	289.85	284.66
$30K$	379.25	358.58	342.46	329.54	318.93	310.06	302.53	296.06	290.42	285.47
$35K$	369.59	352.19	338.24	326.79	317.23	309.11	302.12	296.05	290.71	285.98
$40K$	361.70	346.75	334.48	324.23	315.53	308.05	301.55	295.84	290.78	286.26
$45K$	355.06	342.00	331.08	321.81	313.85	306.92	300.84	295.46	290.65	286.33
$50K$	349.33	337.76	327.94	319.50	312.16	305.72	300.02	294.93	290.36	286.23

Note: Units are in annualized US dollars per unswitched access line.

- Total cost function of a firm providing basic switched service (Q_2) and enhanced service (Q_1):

$$\widetilde{C}(PK,PL,Q_1,Q_2) = 171091.81 + 1454911.26(PK) + 1104000.39(PL) + 67750298.35(Q_1) + 31289871.04(Q_2) - 2505.49(PK)^2 + 72057.43\ (PL)^2 - 0.0003(Q_1)^2 - 0.00003(Q_2)^2 - 27128.04(PK)(PL) + 132.28(PK)(Q_1) +$$

$92.70(PK)(Q_2)+124.23(PL)(Q_1)+95.50(PL)(Q_2)-0.0002(Q_1)(Q_2)$

- Stand-alone cost function of enhanced service:

$$\widetilde{SAC}_1(PK,PL,Q_1)=381439.96+1522860.60(PK)+1250412.60(PL)+26.21(Q_1)-27484.81(PK)^2-22795.98(PL)^2+0.0003(Q_1)^2+32344.01(PK)(PL)+113.62(PK)(Q_1)+102.19(PL)(Q_1)$$

- Stand-alone cost function of basic switched service:

$$\widetilde{SAC}_2(PK,PL,Q_2)=654277.80+386698.07(PK)+1360048.55(PL)+18.22(Q_2)+650541,14(PK)^2+137066.82(PL)^2+0.0001(Q_1)^2-446276.91(PK)(PL)+91.84(PK)(Q_2)+93.91(PL)(Q_2)$$

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