TECHNOLOGY, REGULATION, AND

THE EMERGENCE OF COMPETITIVE ACCESS PROVIDERS[1]

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1. INTRODUCTION

Developments over the past decade have brought a new technology and a new competitor to local exchange markets. The technology is the metropolitan fiber ring. The carrier is called a competitive access provider (CAP).

This paper accomplishes two tasks. First, it constructs a formal model explaining the joint determination of fiber ring deployment and incidence of CAP entry. The model demonstrates how improvements in optical fiber technology and growing demand for reliable high-capacity services trigger these events.

The second and principal objective of the paper is to describe how various regulatory policies affect the equilibrium timing of deployment and entry. I first consider traditional rate-of-return regulation and then the recent price cap plans. I also look at policies peculiar to dedicated service markets including expanded

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interconnection between CAPs and local exchange carriers (LECs).

Unfortunately, the model is too general to predict the timing of entry and innovation without further restrictions. As a result we cannot be sure whether the observed patterns can be attributed to unconstrained market forces or to regulatory policies. Nevertheless, the model provides a framework in which to conduct positive analysis which serves to educate regulators about the consequences of various policies.[2]

2. DEVELOPMENTS IN DEDICATED SERVICE MARKETS

2.1 The Technology

A metropolitan fiber ring is an all-digital, all-fiber network that weaves its way through underground conduits in urban subway tunnels or along water, gas and power lines. The fiber is laid out in a "ring" that strings together users. This topology endows the network with a "self healing" quality. All communications travel around the ring in the same direction. A backup copy runs in the opposite direction along duplicate fiber strands. Should the network be severed, electronics instantly cut over to this "hot standby." To further raise the chance of surviving a line cut, the networks follow physically "diverse routes" that enter and leave buildings from different points. In principle, no user should be stranded without service.

2.2 The Entrants

Early deployments of fiber rings were undertaken by new

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[2] A normative analysis comparing certain regulated outcomes to welfare maxima can be found in Woroch (1991).

entrants into dedicated service markets. Starting in 1983, alternative carriers began installing rings in metropolitan areas known to have high levels of communications activity. Multiple new ventures appeared in some larger markets (e.g., New York, Washington, Boston). Some of the earliest CAPs (Teleport, Metropolitan Fiber Systems) now operate rings in several cities. As of yet, the different locations are not connected but multiple ring operators do offer users the convenience of one-stop shopping.

Figure 1 charts the growth of CAPs (through May 1991) in terms of numbers of operating rings, cities entered, and fiber miles. The 49 operating rings exclude 8 projects currently under construction plus an additional 64 rings that have been announced.

CAPs use fiber rings to provide high capacity, dedicated services, predominantly DS1 (24 voice equivalent circuits) and DS3 (672 circuits). They also offer lower rate transmission and some are connected to satellite uplinks. The bulk of CAPs' sales derive from interexchange carriers (IXCs) who purchase transport between their local points of presence (POPs). The other major revenue source is dedicated circuits connecting customers' premises to the IXCs' POPs.

CAPs have come from many corners of the industry and from outside. Subsidiaries and spinoffs of cable companies began by marketing excess capacity on their fiber backbones. In the same way, power companies realized another use for fiber networks they built for internal monitoring and billing. In fact, private networks owned by Merrill Lynch were the basis for several of

Teleport's rings.

The IXCs have not expanded into dedicated access but competition in the interstate toll market has raised their interest in access and transport alternatives. They benefit from improved POP-to-POP services as well as cheaper access to large users.

2.3 The Incumbents

LECs have also embraced this new technology: they graft rings onto their existing networks or run fiber links from large users to a secondary central office along a diverse route. By recent count, LECs have installed fiber rings or alternate routing in 56 cities.[3]

Whether LEC deployment of optical fiber and self-healing architectures are direct responses to the ALT challenge, or simply the timely modernization of the public network, is unclear. Without engaging in any counterfactual reasoning, few would disagree that LECs considered the CAP threat when adjusting their access tariffs.

2.3 Technological and Demand Conditions

The superiority of optical fiber as a transmission medium is undeniable. It provides enormous capacity and is virtually error free. Fiber cables take up little conduit space and the associated equipment is relatively compact, making it ideal for tight urban quarters. In addition, throughput can be expanded with a changeout of electronics.

Unlike metallic alternatives, fiber is nonconductive, permitting it to share rights of way with power utilities and to

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[3] FCC, Fiber Deployment Update, April 1991, Table 7.

withstand lightning surges. And unlike short-haul digital microwave, it is unaffected by rainstorms and tall buildings.

The fall in fiber's price has been relentless. Improved manufacturing practices continue to increase "draw rates." New single-mode fiber controls optical dispersion, expanding the spacing between repeaters. These factors, combined with advances in splicing, laser technology, and multiplexing, give fiber transmission a cost advantage over copper, coaxial and microwave alternatives for high volume transmission. On the demand side, availability of PBXs and multiplexers permit large users to concentrate their toll traffic on site. This avails them to the volume discounts of dedicated access.

In addition, a persistent growth in data, facsimile and video applications further raises users' demand for high capacity circuits. Data traffic, in particular, attaches a high value to the quality of fiber optics and the survivability of new architectures.

3. REGULATION OF DEDICATED SERVICE MARKETS

3.1 Regulation of CAPs

When more than 10 percent of their traffic is interstate, CAPs fall in the FCC's jurisdiction. In that case, they are treated as non-dominant specialized carriers. This affords them streamlined treatment in several respects. CAPs construct and terminate interstate facilities at will as long as they file semi-annual Section 63.07 reports of initial or additional circuits. CAPs' rates must be nondiscriminatory but they need not file tariffs, thereby escaping the scrutiny and delay of traditional rate hearings.

On the state level, CAPs must usually apply for a certificate of public convenience and necessity, or for a municipal operating license. A select few of the CAPs voluntarily file intrastate tariffs.

Cable companies have successfully entered the private line market without running afoul of the cross-ownership rules. A structurally separate subsidiary generally satisfies the requirements. Surprisingly, power companies have encountered at least as much resistance to their participation in this market.

3.2 Dominant Carrier Regulation

Local operating companies have the status of dominant common carriers. They gain limited protection against competition plus a fair return on invested capital in exchange for an obligation to serve all customers at reasonable, nondiscriminatory rates.

The Modified Final Judgment confines LECs to their local access and transport areas (LATAs). CAPs, in comparison, freely cross LATA, state and company boundaries as they selectively choose who they will serve. LECs operate under a universal service obligation which, in part, motivates their choice of star topology for the public switched network.

3.3 Rate Restructuring

Rates for high-capacity dedicated circuits and their substitute services have gone through a major restructuring since the divestiture of AT&T. As the 1980s opened, the separations process was shifting large amounts of joint cost to the interstate jurisdiction. In the mid 1980s, the FCC embarked on a program to rectify this imbalance. First, it made adjustments to the separations rules that reduced the flow of cost assignments. Second, it undertook an access charge plan that began to recover non-traffic sensitive costs through flat charges to business and residential customers' monthly bills and to IXCs' circuits.

Nevertheless, the migration to special access and bypass facilities persisted. The LECs sought to stem the tide by maintaining relatively high special access rates. This was accomplished in part with rates for their new DS3 services customized for individual customers. The FCC concluded[4] that these "individual case basis" rates were too high and the service was generic enough to be tariffed. They boosted originating rates for switched access relative to terminating rates, and also applied a "leaky PBX" surcharge.

Until recently, rate of return regulation geared rates to a firm's invested capital. Price caps for LEC interstate services are now in place. Pricing flexibility is somewhat limited, however, in the special access elements: DS1 and DS3 special access services are placed in separate baskets and their annual rate changes are bounded above and below by five percent.[5]

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[4] FCC Docket 85-166, "Investigation of special access tariffs of local exchange carriers."

[5] FCC Docket 87-313, Supplemental NPRM (March 8, 1990).

4. A MODEL OF ENTRY AND TECHNOLOGY ADOPTION

4.1 Construction Cost

Firms must decide if and when to build a fiber ring. Let firm $i=1$ be the incumbent LEC and firm $i=2$ the (single) potential CAP. They both have access to the new technology, though possibly on different terms. Firm i incurs a one-time, nominal construction cost of $c_i(t)$ when it installs a fiber ring at t. This figure includes new or additional fiber and electronics as well as capitalized lease payments for rights of way.

Some of the LECs' imbedded investment in conduit and equipment structures can be re-used with fiber rings. In contrast, CAPs build from scratch. For these reasons, the LEC's construction cost is taken to be lower than the CAP's in each period: $c_1(t) < c_2(t)$. The difference between the two is the CAP's entry cost.[6] Both firms foresee costs steadily declining over time at a decreasing rate: $c_i'(t) < 0$ and $c_i''(t) > 0$.

4.2 Operating Profit

Firms must forecast net returns generated by the new facility. Firm i's nominal operating profit π_i^s depends on industry structure, s, which consists of the active firms and their technology choices. Let industry structure s take values n, 1, 2, or d depending, in turn, on whether neither firm has deployed a ring, the LEC alone has done so, the CAP has entered, or if both

[6] LECs' greater commitment to analog, metallic transmission systems counteract this cost advantage as they must install additional equipment (codecs, cross connects, optoelectronic converters) to ensure compatibility with the digital, optical technology of the ring.

have installed a ring (i.e., dual adoption).

(Notice that profits are time invariant. Results go through if we consider the more likely case where profits exogenously increase over time to reflect demand growth. Endogenous changes in profit are not so easily handled. This would happen if there was a reputation effect from early deployment or lower operating costs from the cumulative experience with this new technology. The latter phenomenon could stem from learning-by-using the fiber ring, or from a "snowball effect" that derives from network externalities.)

In all cases, revenue generated by the fiber ring covers the added operating costs, so that $\pi_i^s > 0$. Normalize pre-entry CAP profits to zero: $\pi_2^n = \pi_2^1 = 0$.

LECs are likely to have higher operating costs than startup firms. Older LEC networks require higher maintenance, and wages of its unionized workforce are also higher. Additional expenses are incurred because its network is composed of a mix of technologies. Altogether, this asymmetry argues for higher CAP profitability when both are active: $\pi_1^2 < \pi_2^2$ and $\pi_1^d < \pi_2^d$.

As a rule, provision of fiber ring service by one firm will increase its share of total traffic, leading to a reduction in its rival's profit: $\pi_i^j < \pi_i^n$ and $\pi_i^d < \pi_i^i$. Nevertheless, industry profits are higher when at least one of the two firms has the new technology, and highest when both firms have a ring:

$$\pi_1^d + \pi_2^d > \pi_1^i + \pi_2^i > \pi_1^n + \pi_2^n$$

Figure 2a displays per period return for one of the firms.[7] Notice how the profit level jumps up or down depending on whether the firm or its rival builds. Figure 2b plots one-time construction costs for the LEC and the CAP. Cumulative profit for different construction times is computed by summing up (discounted) operating profits and subtracting off (discounted) construction cost.

4.3 Equilibrium Timing of Deployment and Entry

The potential entrant decides either to enter the industry with a fiber ring, or to stay out.[8] The incumbent can either build a ring or continue to supply dedicated access with its existing network. Three critical dates are needed to describe equilibrium timing of these decisions.

First, the leader date for firm i, t_i^l, maximizes firm i's cumulative profit assuming rival j will build afterwards. It occurs when the firm's incremental loss in operating profit equals its incremental savings in construction cost from waiting one more period, both discounted:

$$[\pi_i^i - \pi_i^n]e^{-rt} = [rc_i(t) - c_i'(t)]e^{-rt}$$

Similarly define the follower date as the time t_i^f that maximizes firm i's cumulative profit when firm j has already adopted. The marginal condition becomes:

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[7] The inequalities on profit levels can be deduced from static monopoly and Cournot equilibria.

[8] I assume conditions hold that ensure the CAP would prefer to build a fiber ring rather than adopt an older, competing technology (e.g., digital microwave).

$$[\pi_i^d - \pi_i^j]e^{-rt} = [rc_i(t) - c_i'(t)]e^{-rt}$$

Figure 2c graphs the marginal curves for both cases.

The last critical time is the preemption date t_i^0 which occurs when firm i is indifferent between leading or letting firm j lead at that time. The formal expression equates cumulative profits under the two scenarios. A rearrangement yields:

$$[\pi_i^i - \pi_i^j]e^{-rt}/r - [\pi_i^i - \pi_i^d]\exp(-rt_i^f)/r - [\pi_i^d - \pi_i^j]e^{-rt}/r$$
$$= c_i(t)e^{-rt} - c_i(t_i^f)\exp(-rt_i^f)$$

at $t = t_i^0$.

The fundamental result from the literature on tournament type games of technology adoption[9] states that if $t_i^1 < t_j^1$ and $t_i^0 < t_j^0$, then in equilibrium firm i will deploy first in period $\min\{t_i^1, t_j^0\}$ while firm j will follow at t_j^f. In words, the more "impatient" of the two firms builds a ring first, and it does so either at its preferred time, t_i^1, or at the last possible instant before its opponent would steal the lead, namely t_j^0. In either event, the second deployment occurs at the best time to follow t_j^f.

Simple exercises establish how equilibrium timing shifts for changes in operating profits. The effects on t_i^1 and t_j^f can be deduced with the aid of Figure 2c:

[9] Fudenberg and Tirole (1985), Katz and Shapiro (1987).

TABLE 1: Sensitivity Analysis on Operating Profits

	π_i^i	π_i^n	π_i^d	π_i^j	π_j^j	π_j^n	π_j^d	π_j^i
t_i^1	-	+	0	0	0	0	0	0
t_j^0	0	0	-	-	+	0	+/-*	+
t_j^f	0	0	0	0	0	0	-	+

* - According to whether t_i^f < / > t_j^f.

To pin down the effects of changes in construction costs, assume they take an exponential form $c_i(t) = a_i\exp(-b_i t) + C_i$ where the parameters a_i and b_i are positive scaling factors and C_i is asymptotic cost. Sensitivity analysis is again straightforward:

TABLE 2: Sensitivity Analysis on Construction Costs

	a_i	b_i	C_i	a_j	b_j	C_j
t_i^1	+	+	+	0	0	0
t_j^0	-	-	-	+	+/-*	-
t_j^f	0	0	0	+	+	+

* - According to whether $\log(t_i^0/t_i^f)$ </> $(b_i+r)(t_i^0-t_i^f)$

Notice how changes in a firm's cost parameters affect all critical dates in the same direction except for its preemption date.

Despite the restrictions placed on construction costs and operating profits, it is not possible to conclude which firm adopts first, or when it does, whether it chooses to preempt. This is unfortunate because the policy analysis is sensitive to the order of adoption. We can state that, if the LEC's construction cost advantage is negligible, then the CAP's operating cost advantage will lead it to deploy first, a conclusion consistent with empirical evidence.

5. REGULATORY POLICIES AFFECTING ENTRY AND INNOVATION

Each policy will be examined for its impact on the equilibrium timing of CAP entry and LEC ring deployment. I consider not only marginal changes in the timing of innovation but also speculate on nonmarginal changes large enough to alter the order in which the firms move. Tables 1 and 2 assist in both exercises.

5.1 Rate of Return Regulation

This term is a catchall for the complex institution of traditional public utility regulation in the U.S. I single out a few of its key aspects for analysis.

First and foremost, rate-of-return (ROR) regulation seeks to hold down static profit below monopoly levels. A particularly simple form would have the regulator suppress LEC's profits before CAP entry, but refrain from regulating *either* firm thereafter.[10]

This simple policy takes the form of a reduction in pre-entry profits π_1^n and π_1^1; all other profit levels remain at their unregulated levels. The equations defining the critical dates show that they are affected by π_1^n and π_1^1 only through their difference $\pi_1^1 - \pi_1^n$. Thus, from Table 1, if the two pre-entry

[10] Several states are currently considering whether CAPs should be forced to buy into the same regulatory bargain as the LEC.

profit levels fall by *equal* amounts, there will be no change in any date except t_1^0. The reduction in π_1^1 unambiguously makes waiting less attractive to the LEC, leading to an earlier preemption date t_1^0. In that case, the CAP will build the first ring earlier when it preempts the LEC.[11] A significant speed up in its preemption date may turn the lead over to the LEC.

The most famous implication of ROR regulation is the induced bias toward capital intensive production. Excessive investment in durable plant and equipment could reduce the LEC's incremental cost of deploying a fiber ring. From Table 2 we conclude that, on the margin, a reduction in the LEC's construction costs will speed up its leader and follower dates. If the LEC leads but does not preempt the CAP, then it will now do so earlier. If, instead, the CAP preempts the LEC, then once again this occurs earlier.

Additionally, the LEC's pre-adoption investment is highly *sunk*. This sunkness gives the LEC a strategic advantage over the CAP since it can credibly threaten to cut price down to its low avoidable cost. A redistribution of duopoly profits from the CAP to the LEC takes place: π_1^2 and π_1^d rise and π_2^2 and π_2^d fall. The magnitudes of the changes could be nearly the same in absolute changes so that the differences $\pi_1^d - \pi_1^2$ and $\pi_2^d - \pi_2^2$ do not change. In that case, only the preemption dates change in the expected directions: t_1^0 is advanced (t_2^0 is postponed) since

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[11] We might expect the difference to *rise* as when π_1^1 is reduced less than π_1^n due to a lag in regulator's response to innovation. This will have the effect of advancing the first adoption date t_1^1 when the LEC deploys first.

following (leading) for the LEC (CAP) is made relatively less attractive by the redistribution of duopoly profits. Thus, if the LEC (CAP) engages in preemption, ROR regulation will speed up (slow down) first deployment of a ring.

5.2 Price Cap Regulation

A basic goal of price cap (PC) regulation is to stimulate innovation by allowing progressive firms to retain some or all of the cost savings. It accomplishes this by imposing a price ceiling that falls exogenously over time, unrelated to cost levels.

The impact of a PC plan on equilibrium deployment of a new technology depends on when the ceiling is binding. Unconstrained prices drop with deployment of a ring and entry by a CAP. Formally, $p^n > p^1 > p^2 > p^d$ where p^s is the price level under industry structure s. The LEC's operating profit π_1^s will fall (relative to the unregulated level) whenever the ceiling binds. CAP's profit will likely increase if the LEC is constrained since the CAP should realize an increase in its residual demand.

To make matters simple, assume initially that the price cap is set at cost so that $\pi_1^n = 0$.[12] Also assume that price is held at this level from that time on. The incentive effects of this policy then depend on the pattern of future profit. Two cases need be examined: the innovation is *drastic* or it is *nondrastic*.

The innovation is nondrastic when post-innovation monopoly

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[12] This same assumption was used by Cabral and Riordan (1989). They find that lowering the post-adoption ceiling will encourage a monopolist to make cost-reducing investments up to a point beyond which it will curtail all investment and take the option of a classical ROR review.

price is still higher than pre-innovation cost. The binding price ceiling translates into a reduction in π_1^1. As long as none of the other profit levels is affected, the analysis proceeds just as with the simple version of ROR regulation which tended to speed up adoption.

When the innovation is drastic--so that a monopolist would price under the ceiling after adoption--LEC profit π_1^1 is unchanged. The larger profit increment, $\pi_1^1 - \pi_1^n = \pi_1^1$, will advance the LEC's leader date t_1^1. In this way, PC regulation again speeds up the first deployment of a ring, leaving second deployment unaffected.

A complication arises when, as is inevitable, the price cap formula is revisited at some future date. Suppose at that time the ceiling is adjusted downward to the *prevailing* cost level. If the review occurs *after* the last adoption, this effectively reduces the LEC's profit π_1^d down to 0. Separating out the consequences of this feature, note that it unambiguously delays the LEC's follower date t_1^f and the CAP's preemption date t_2^0. Therefore, it reverses the effects that sunk investment had under ROR regulation: t_1^0 is delayed (t_2^0 is accelerated) since t_1^0 (t_2^0) since leading (following) is made relatively less attractive by redistributing duopoly profits. Thus, if the LEC (CAP) engages in preemption, ROR regulation will speed up (postpone) the first deployment of a ring.

As discussed earlier, the PC plan for LECs includes price floors on DS1 and DS3 special access rates which limits LECs' price response to entry, and reduces its returns under duopoly. Both π_1^2

and π_1^d should fall relative to the unregulated levels, advancing the LEC's preemption date t_1^0 but delaying the CAP preemption date t_2^0.

5.3 Dominant Carrier Delay

Before a LEC can adopt any new technology, it must certify the facilities and tariff the service. The required procedures and public hearings all take time, during which a new entrant could be building its facilities and marketing the service.[13]

Unlike the previous policies, the delay associated with dominant carrier regulation bears directly on firms' timing decisions. Imagine that some minimum time T must elapse between the incumbent's application and completion of a fiber ring. Obviously the application process cannot begin before the date when this technology was first available (early 1980s) so that service would not be available any earlier than T. Construction can begin any time after the application is approved but the LEC retains the option of waiting to build later.

I examine the effect of a delay when the (unregulated) incumbent takes the lead. (The case when roles are reversed is straightforward.) If the dominant carrier delay is very long, then the LEC will *never* take the lead. The CAP will simply enter at its preferred time t_2^1 and the LEC will eventually deploy a ring at

[13] In addition the process may reveal to potential entrants details about the facilities the LEC intends to install and the nature of the new services. Origins of this asymmetric treatment are found in FCC's "Competitive Common Carrier Policy" (Docket 79-252) which extends "forbearance" to nondominant carriers by suspending tariffing, certification, and reporting requirements.

$\min\{T,t_1^f\}$. This automatically reverses the order of deployment if the LEC was the leader initially.

Interestingly, even a very short delay could reverse the order. The reason lies in the fact that the LEC can commit to *not* deploy a ring before some date by waiting to file its application.

Suppose that, in absence of regulation, the LEC would normally build a ring first at time t_1^1. If $t_1^1 > T$, then it will simply initiate the application process well in advance--provided that its payoff from leading at t_1^1 exceeds its payoff from following at t_1^f.

In the second scenario, the (unregulated) LEC prefers to *preempt* the CAP, but it is constrained by the delay: $t_2^0 < T$. Then equilibrium changes drastically. For first adoption times slightly later than t_2^0, both firms see profits from leading rise as adoption is delayed. Knowing that the LEC cannot deploy a ring before $T > t_2^0$, the CAP can reap the higher leader profit by entering a bit ahead of this time. The lead switches from the LEC to the CAP.

Surprisingly the LEC might *prefer* to delay its service application so that it can *not* adopt by time t_2^0. This is possible even if the delay does not bind (i.e., $t_2^0 > T$). Let t^a be its application date prior to t_2^0. In the presence of negative spillovers, the profit from following increases with the first adoption date. In that case it could happen that the LEC's profit from following at $t^a + T$ exceeds the profit it would earn by leading at t_2^0. Generally the CAP will enter just before $t^a + T$ because it receives a higher profit from leading after date t_2^0.

5.4 Expanded Interconnection

Interconnection alters the economics of network industries. Carlton and Klammer (1983) surmise that interconnection *discourages* innovation. They point to reduced incentives to adopt an innovation in a subnetwork for fear that it will not be adopted in distant parts of the system, resulting in a technical incompatibility. On the other hand, if coordination can somehow be achieved, the much wider market for the innovation will raise expected rewards for an innovator.

Fiber rings can operate independent of the local network. But confined to intra-ring communications, the new entrants face a severe critical mass problem. Connection with the ubiquitous public network would allow them to tap into a much wider audience.

In an important development, the FCC has responded to petitions by Teleport and Metropolitan Fiber Systems with a Proposed Rulemaking that expands interconnection between CAPs and the LEC network.[14] The rulemaking proposes to extend "collocation" to CAPs and to restructure special access tariffs. Specifically, they could connect their fibers at the LEC central office. At the LEC's discretion, collocation could be "physical", in which case the CAPs terminate their fiber at their own equipment located inside the LEC central office. Alternatively, it could be "virtual" where the two meet at a point nearby the central office but the connection would be electronically equivalent.

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[14] FCC Docket 91-141, "Expanded interconnection with local telephone company facilities," June 6, 1991.

To fix ideas, suppose that the incumbent originally provides all the familiar switched and dedicated "core" services. Fiber rings make possible enhanced dedicated service. A CAP can provide this same service with a fiber ring but it would be inferior to the LEC version by its lack of perfect interconnection with the public network. Expanded interconnection makes the CAP service more complementary with the LEC's core services.[15]

Expanded interconnection should not affect the incumbent's profits π_1^1 when it is first to adopt. When the entrant is first, the higher complementarity with the LEC's core services should increase profits for itself. Whoever innovates first, interconnection offers consumers an improved service selection. Part of the higher surplus will turn up as profit. Therefore, π_1^2 and π_2^2 should both increase.

How the additional profit is shared between the two firms depends on specification of interconnection policy. When both firms adopt, the nature of duopoly competition will dictate the division of this surplus. Assume that the CAP captures the full increase in industry profits, and then some. Formally, π_1^d falls and π_2^d rises.

If, in equilibrium, the LEC deploys a ring first at $\min\{t_1^1, t_2^0\}$ and entry occurs at t_2^f. The fall in π_1^d and the rise in π_2^d leaves t_1^1 unaffected but causes both t_2^0 and t_2^f to advance, so that both adoptions take place earlier. Speedier deployment of

[15] Interconnection should also reduce the entry cost of the CAP.

fiber rings results from expanded interconnection. Apparently, given that CAPs were typically the first to deploy rings, poor interconnection could not be held up as a crucial deterrent. At the same time, expanded interconnection will likely fuel the growth of this new industry.

6. CONCLUSIONS

Clearly, the timing of entry and innovation bears a complex relationship to the prevailing demand, cost, and regulatory conditions. To predict the consequences of policy initiatives on the evolution of dedicated services market entails a detailed knowledge of initial conditions and of active and potential firms' perception of future conditions. So while regulators can hope to correct blatant inefficiencies, the fine tuning of rewards for innovation in search of the social optimum is an insurmountable challenge--one best left to the prodigious information processing powers of the market.

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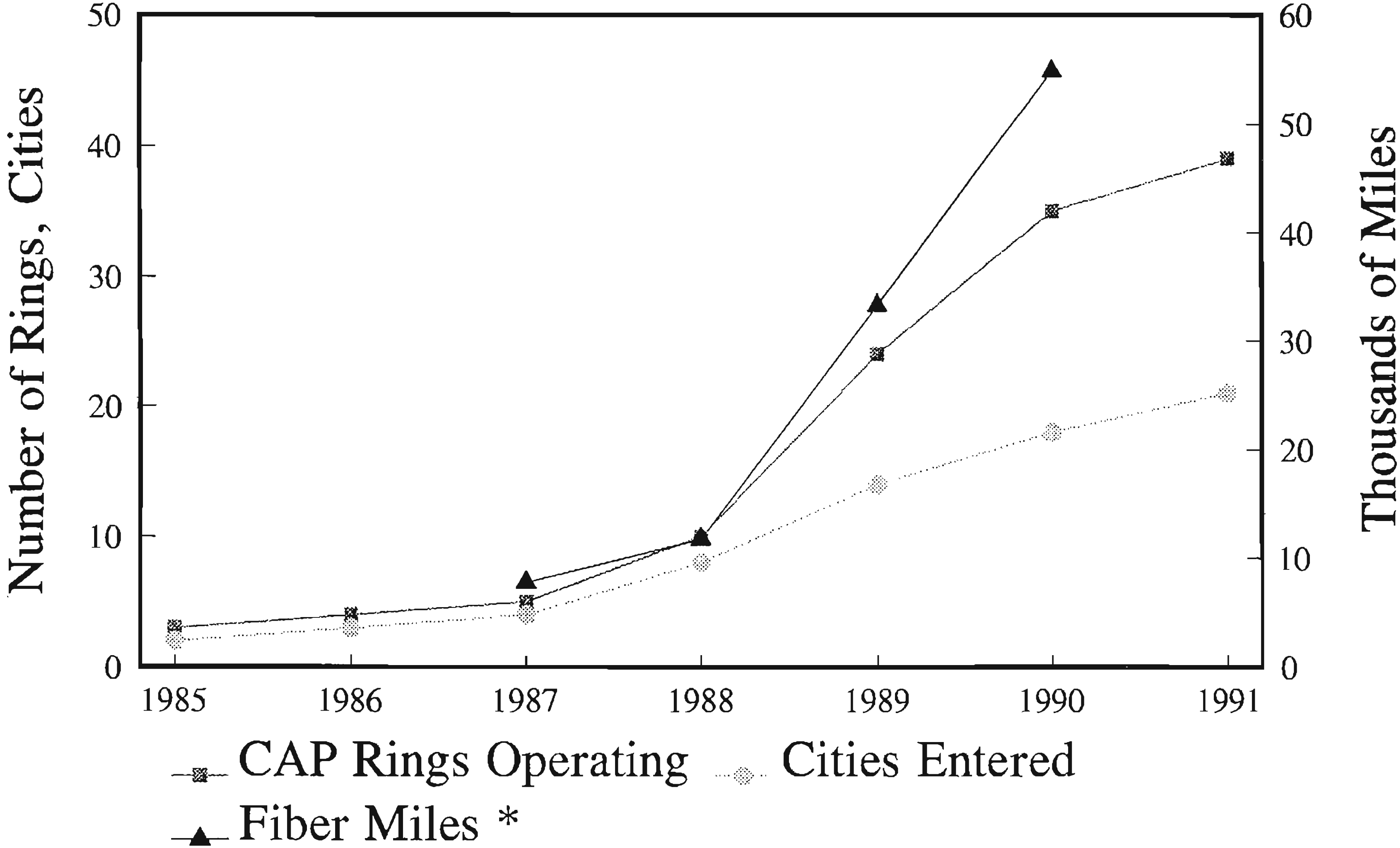
Figure 1
GROWTH OF COMPETTITIVE ACCESS INDUSTRY



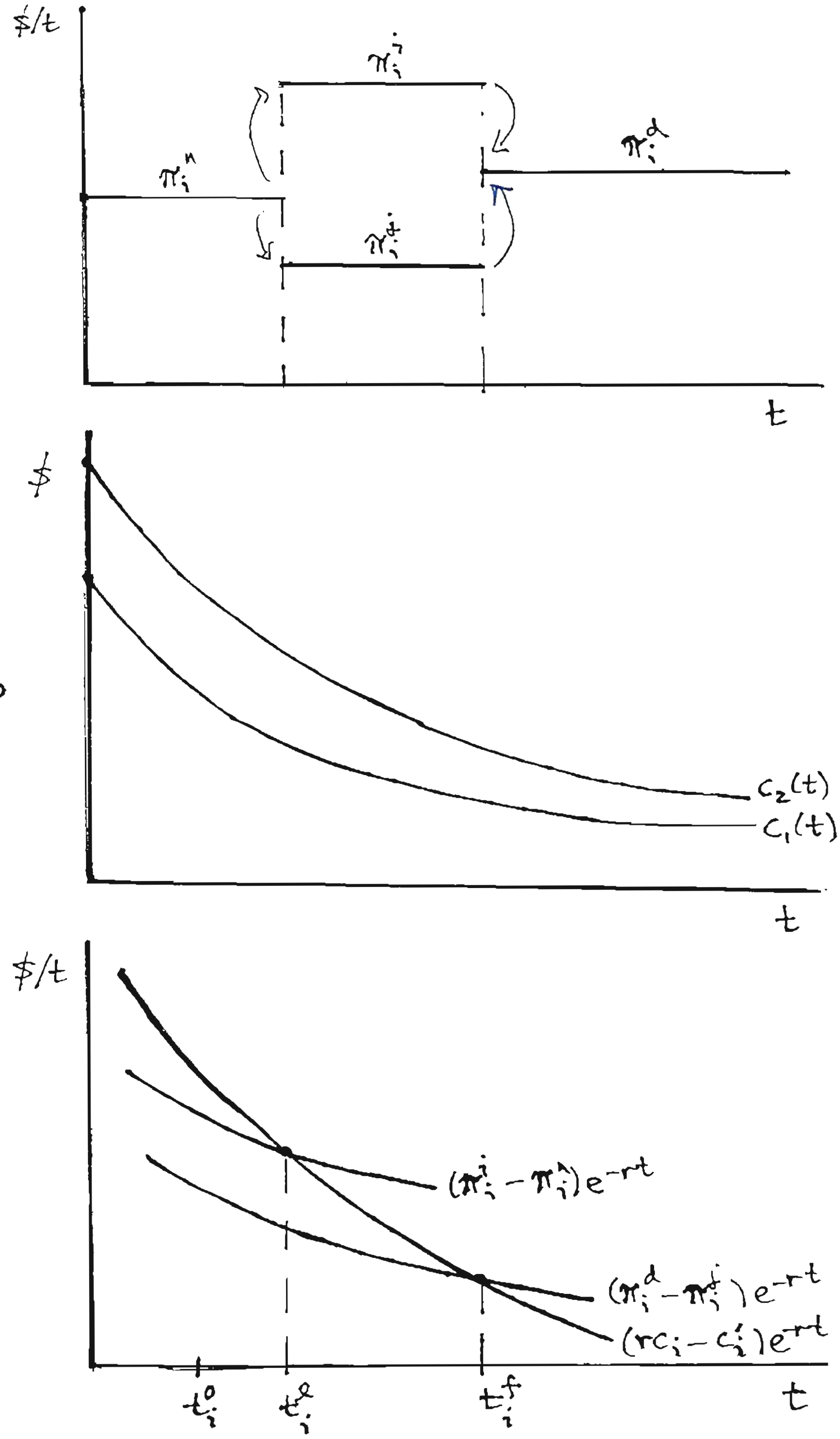
Source: FCC(1987-90),Consulting Reports, Newsreleases through May 1991.
* - 15 Largest CAPs Only

FIGURE 2

a

b

c


$/t
π_i^n
π_i^i
π_i^j
π_i^d
t
$
$c_2(t)$
$c_1(t)$
t
$/t
$(\pi_i^i - \pi_i^n)e^{-rt}$
$(\pi_i^d - \pi_i^j)e^{-rt}$
$(rc_i - c_i')e^{-rt}$
t_i^0
t_i^e
t_i^f
t