

The Role of Competition in Stimulating Telecom Investment ¹

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Abstract

After booming in the second half of the 1990s, the telecom industry has fallen on hard times. Hundreds of large and small telecom firms that attempted to compete with the incumbent local exchange carriers (ILECs) have gone broke. Others are close to that fate. The ILECs blame this outcome on the CLECs (competing exchange carriers). The CLECs blame it on the ILECs. While the two sides and their supporters have been arguing, a ray of light has started to shine at the end of the industry's tunnel. The market share of new entrants has finally begun to increase sharply.

Is that increase a temporary phenomenon or a sign that markets are evolving as economic theory would predict? As demonstrated in this paper, strengthening competition in the telecom sector is the key to restoring telecom investment. Doing so has ramifications that range far beyond that particular sector. About two-thirds of our economy's growth is driven by innovations in information technology.² Telecom plays an essential role in information acquisition and dissemination and accounts for the lion's share of IT investment and innovation. A vibrant telecom sector is thus vital to the short- and long-term success of the economy.

This paper reaches its pro-competitive conclusions after considering the empirical evidence, reviewing basic lessons about monopoly behavior, and exploring a more realistic model of the industry and telecom policy. The empirical evidence connecting competition to telecom investment is striking. During 1996-2000, over a third of gross investment was done by the CLECs even though their revenue was only one fifteenth that

² See Jorgenson, Dale, "Information Technology and the U.S. Economy," *American Economic Review*, vol. 91, no. 1 (March 2001), 1-32. The Commerce Department's estimate of the contribution of information technology to economic growth is smaller.

of the ILECs.³ In 2000, at the peak of the investment boom, CLECs invested \$25 billion, which almost matched the \$27 billion of gross ILEC investment.

This evidence is hard to ignore, but is it a fluke or to be expected on the basis of economic theory? The answer requires modeling the telecom market in detail. Doing so is a challenge. The telecom market is characterized by imperfect competition, regulation, advanced technology, network externalities, strategic gaming, and entry. Policymakers who substitute their intuition for careful modeling of this market do so at their own peril. The same is true for telecom economists who rely on simple static models that miss the fundamental dynamics of markets of this type.

The arguments against unbundling are reviewed below, and we find that they rely exclusively on such static models. Worse yet, they discuss ILEC investment as if the ILECs were standard competitive firms that are simply being disadvantaged to a greater or lesser extent by government regulators. Indeed, many of the papers make no mention of the fact that the ILECs are essentially monopolists who achieve that position through their control of our local communications pipeline. Nor do they acknowledge that government regulators have been setting tariffs for use of that pipeline since the 1890s to keep ILECs from manipulating telephone prices by restricting supply.

In this paper we construct and simulate a strategic equilibrium model in which ILECs, CLECs, and cable companies compete over time for market share in interrelated and partially regulated local telecom services markets. Our model can study market dynamics under a variety of potential industry structures and handle critical factors overlooked in previous analyses.

³ Hall, Robert E. and William H. Lehr, "Rescuing Competition to Simulate Telecom Growth," mimeo, September 28, 2001. Revenues refers here to receipts earned from operations in the local telecom market.

Though highly stylized, our framework suggests a number of interesting results. First, telecom investment and output generally increase significantly and telecom prices decrease significantly when new firms enter a market. This is true whether or not the entry occurs because of normal economic forces or as a result of wholesaling arrangements under which competitors rent access to customers from incumbents. The improvement in market conditions can be quite striking, with capital investment, for example, increasing in some simulations by 40 to 60 percent while prices for local telephone service drop in the same simulations about 30 percent. Second, *unbundling* (forcing the ILECs to rent to the CLECs all or part of their network elements) can dramatically increase CLEC entry by lowering their costs of doing so. Third, competition raises consumer welfare relative to having a regulated monopoly in local voice and an unregulated duopoly in broadband.

Finally, declines in ILEC profits and share valuations can actually herald good news for the telecom industry as a whole as well as consumers. When we calibrate our model to current pricing conditions, competitive entry reduces monopoly profits. Nonetheless, the ILECs in our model typically do what they did in the real world, namely respond to increased competitive pressure by increasing, rather than reducing, their investment. The reason is that, in the presence of competition, investing less and, thereby, withholding product from the market no longer pays off in terms of higher prices.

Our model is highly stylized and does not yet incorporate the profits that the ILECs receive from being allowed to enter the long distance market in exchange for unbundling their networks. Still, the model's preliminary findings that ILEC monopoly

profits from local voice service may drop in response to even nascent competition may help explain the ILEC's sharply increased efforts in recent months to overturn TA96, as market conditions have begun to move in the direction implied by our theory. Indeed, when we incorporate unbundling in our model, our simulations are highly consistent with the empirical evidence, cited below, that TA96, when properly enforced, leads to sharp reductions in telecom prices, significant consumer savings, and major increases in telecom investment and output. The very recent experience in state markets such as New York and Michigan that have experimented with low unbundling prices looks very much like our simulations. Our model suggests that rigorous enforcement of TA96 in combination with the same type of low cost electronic switching of service providers that occurs in long distance could restore the levels of telecom investment to those observed in the late 1990s.

Introduction

A vibrant telecom industry plays an important role in accelerating the diffusion of new technology and increasing productivity and economic growth. The sector's recent woes are widely known. Three of the country's major telecom firms -- WorldCom, Global Crossing, LTD., and Qwest Communications International Inc. -- are bankrupt or close to it. Another 250 of the 330 CLECs (competitive local-exchange carriers) operating in 2000 have closed their doors. These failures as well as the struggles of ongoing telecom firms have, by one recent estimate, put a half million Americans out of work.⁴ Telecom company stockowners have also been hit very hard. In the past two years, telecom shares have declined by more than two thirds, with the loss in absolute dollars exceeding \$2 trillion. The collapse of the industry has decimated telecom investment. Capital spending by telecom firms fell by a quarter last year and will fall by a similar percentage this year.⁵

On the other hand, a number of indicators have begun to suggest that competition may finally be taking hold. As documented below, entrants are acquiring a rapidly increasing share of the local phone market. Clearly, restoring telecom investment has ramifications that range far beyond that particular sector. Our economy's growth is increasingly driven by innovations in information technology. In the past decade, roughly two-thirds of U.S. economic growth resulted from that source.⁶ Telecom plays an essential role in information acquisition and dissemination and accounts for much of

⁴ "As It Deepens, Telecom Bust is Taking a Heavy Human Toll," *The Wall Street Journal*, August 19, 2002, p. 1.

⁵ "FCC's Powell Says Telecom 'Crisis' May Allow a Bell to Buy WorldCom," *The Wall Street Journal*, July 15, 2002, p. 1.

⁶ See Jorgenson, Dale, "Information Technology and the U.S. Economy," *American Economic Review*, vol. 91, no. 1 (March 2001), 1-32. The Commerce Department's estimate of the contribution of information technology to economic growth is smaller.

the investment and innovation in the information technology sector. A vibrant telecom sector is thus vital to the long-term success of the economy. It can also play a major role in jumpstarting the economy in the short run.

In this paper, we do three things. First, we describe the recent rise and fall of telecom investment. Second, we examine the argument that the Telecommunications Act of 1996 (TA96) is responsible for the industry's recent distress. And third, we develop a model that allows us to evaluate the impact of TA96 on the industry as well as the results of recent empirical work and investigate whether there are signs that the Act is beginning to work as intended.

Our conclusions are fourfold. First, there is emerging empirical evidence that telecom competition promotes telecom investment. Second, there are solid theoretical arguments to explain that outcome. Third, the policy debate on telecom investment and regulation has been framed within a static model that fails to capture the dynamic and highly uncertain entry, pricing, and investment game being played by the ILECs, CLECs, and cable companies. Consequently, it is difficult to assess the relevance of many prior telecom studies to the actual telecom market. Finally, a model rich enough to capture the complexities of the telecom industry must a) be solved on the computer and b) carefully calibrated if it is to provide real insight into the policies and other factors affecting that critical market. We view this paper as a first step in that direction.

The Telecom Investment Boom, Bust, and Incipient Rebound

Table 1 shows total telecom investment since 1990 as well as the investment of the CLECs and ILECs. The first point to note is that TA96 triggered a huge expansion of investment. It did so by promising competing telecom companies that they would receive access to the *local network* or components (*elements*) of the local network at a reasonable price and on a timely basis. The local network refers to the local telephone lines, telephone poles, underground conduits, and switches that connect the American public to the outside world.

Table 1				
Telecom Gross Investment, 1992-2002				
(billions of dollars)				
	Year	CLECs	ILECs	
Total				
	1992	Na	17.5	17.5
	1993	Na	17.5	17.5
	1994	Na	17.5	17.5
	1995	Na	18.0	18.0
	1996	Na	20.8	20.8
	1997	5.0	21.5	26.5
	1998	9.2	22.2	31.4
	1999	16.8	22.8	39.6
	2000	21.7	27.8	49.5
	2001	12.3	28.1	40.4
	2002	10.7*	24.2*	34.9*

Source: ARMIS data provided by William Lehr. ILEC investment includes investment by GTE.

Estimate for CLECs provided by William Lehr.
Estimate for ILECs based on a May 8, 2002 Banc of America Securities.
Na – not available, * indicates preliminary estimate for the year from those sources

TA96 expanded use of this vital communications pipeline bottleneck by a) eliminating the ILECs' legal status as monopoly franchises and b) requiring the ILECs to rent access to the local network to incipient, would-be competitors. The act further required the ILECs to rent access to (to *unbundle*) the local network on either a component-by-component basis or on a package-of-components basis as requested by their competitors.⁷ Finally, rents were to be set at a compensatory price that included a fair profit.

With regard to stimulating investment, the Act at first appeared successful. During the 1996-2000 telecom investment, over a third of gross and over one half of net investment was done by the *CLECs* even though they were fifteen times smaller than the ILECs when measured in terms of revenues.⁸ In 2000, at the peak of the investment boom, CLECs invested \$25 billion, which almost matched the \$27 billion of new ILEC investment.

Despite investing two-thirds of their revenues, as compared to one quarter by the ILECs, the CLEC investment boom left them at the end of 2000 with only 8.5 percent of nationwide access lines and only 4.6 percent of residential and small business lines. The explanation for this is straightforward. CLECs concentrated their investment in dense metropolitan areas to a) capture scale and density economies and b) bypass ILEC control

⁷ Because local network assets were acquired by the ILECs under concessionary conditions and paid for by the public over decades in the form of very high, regulated telephone rates for local and long distance telephone calls, even these "compensatory" rents may be too high.

⁸ Hall, Robert E. and William H. Lehr, "Rescuing Competition to Simulate Telecom Growth," mimeo, September 28, 2001. Revenues refers here to receipts earned from operations in the local telecom market.

of the local network via the construction of their own pipelines feeding into high-traffic office buildings. CLECs attribute this need to bypass the ILECs to the fact that the ILECs used and continue to use a variety of mechanisms to restrict access to the local network. Their proposed list of abuses here includes charging exorbitant prices for unbundling their components (*elements*), delaying the transfer (*handoff*) of loops (wires) from their own switches to those of competitors, using slow and error-prone *manual* rather than electronic handoffs, charging high prices to CLECs for renting space in ILEC local service offices to collect these loops, and simply opting to pay fines rather than obey the law. Their claim is that the ILEC practices succeeded in killing off the lion's share of competing local exchange carriers. While there has been a great deal of turmoil, the latest data indicate that today there exists a core of resilient CLECs that are making money and appear to have a viable business plan for success assuming TA96 is enforced."⁹

This latest development is likely attributable to the reaction of several state public utility companies (PUCs) to the demise of most of the CLECs. They have begun to enforce TA96 more vigorously. PUCs in New York, California, Illinois, Michigan and other states have taken the lead in lowering the prices charged by ILECs for unbundling their facilities and in requiring them to expedite their unbundling processes. These efforts have begun to significantly alter the structure of the telecommunications industry in these states, with CLEC market share rising and local voice and broadband retail prices falling.

⁹ Hall, Robert E. and William H. Lehr, "Rescuing Competition to Simulate Telecom Growth," mimeo, September 28, 2001.

To give some examples, one recent estimate finds that local phone customers that switch to CLEC providers can save \$11.40 per month in California.¹⁰ This price reduction will save state residents an estimated up to \$527 million per year on local phone service, depending on customer actions, according to an estimate by the Telecommunications Research and Action Center (TRAC). In New York, where the PUC has been particularly aggressive in enforcing TA96, more than 5 million consumers have recently changed their local or long distance phone company to CLECs and are projected to save as much as \$324 annually per line. Aggregate consumer and business savings in New York could reach \$416 million a year on local calls, according to TRAC.¹¹

The surge in telecom investment in the last decade was not unique to the United States. According to a recent Organization for Economic Cooperation and Development (OECD) review of telecommunications policy in OECD member nations, “The evidence indicates that opening access networks and network elements to competitive forces increases investment and the pace of development. Nearly all OECD governments have already introduced such policies or taken decisions to introduce such policies, in respect to telecommunications networks.”¹²

This evidence is, however, anecdotal. There have been few careful attempts to measure the effects of unbundling on price and investment. One exception -- Willig, Lehr, Bigelow, and Levinson (2002) -- gathered detailed data on ILEC investment and regulatory regimes and found that lower UNE (unbundled network elements) prices are associated with higher ILEC investment in a statistically significant manner. CLEC

¹⁰ See <http://www.trac.policy.net/proactive/newsroom/release.vtml?id=18900>.

¹¹ Source: <http://www.trac.policy.net/proactive/newsroom/release.vtml?id=18740>.

activity was found to follow the same pattern – a pattern, which, incidentally, is predicted by the model we present below.

Empirically, then, TA96 appears to have sparked an investment boom on the part of both the ILECs and the CLECs. While that boom could be attributed to other factors, Willig *et al*'s work suggests that the regulatory regime may well be the most important factor. Second, the investment boom ended when most of the CLECs left or were driven out of the market

The ILEC View

As one would expect, the ILECs have a much different view than do the CLECs of the 1996-2001 Telecom boom and bust. Their explanation of CLEC business failures is that these companies had bad business plans, over-invested in telecom, and were poorly managed. With respect to their own investment, they argue that absent TA96 and its associated *TELRIC* (Total Elemental Long-Run Incremental Cost) pricing, they would be introducing broadband much more rapidly throughout the country. Indeed, the ILECs are increasingly blaming their current low levels of profitability on the Act, lobbying intensively for its explicit or implicit repeal, and claiming that the Act is greatly limiting their incentives to invest.

The intellectual basis for this position is spelled out in a number of papers prepared by ILEC experts. It is beyond the scope of this paper to address their arguments in detail, but a brief overview of their general approach clarifies the need for improved modeling. The ILEC's central argument is developed by Jorde, Sidak and Teece (2000), Hausman (1997, 1998, 2000, and 20002), Kahn (1998), and Sidak and Spulber (1997)

¹² See Organization for Economic Cooperation and Development (2001), p.4.

and involves a explicitly or implicitly a *cost of capital* approach. Under such an approach investment occurs up to the point that its *expected* marginal return just equals its marginal cost. The term *expected return* refers to the return the investment will generate on average. Investment itself is viewed as a one-shot decision determined on the basis of the following condition:

$$(1) \quad I_b MR_b MPK_b + I_g MR_g MPK_g = c,$$

where I_b is the probability of the bad state with low demand and I_g is the probability of the good state with high demand. The term $MR_i MPK_i$ references the marginal revenue earned by capital in state i . The term c is the cost of using an additional unit of capital. The condition states that the expected marginal return from investment (acquiring and using an extra unit of capital) equals the marginal cost of purchasing and installing that capital.

The product $MR_i MPK_i$ for $i=b$ or $i=g$ depends on the amount of capital the firm acquires; i.e., the amount it invests. Given the size of c , firms adjust their investment until the value of this product comes into line with (exactly equals) c . The level of investment (the choice of capital) that ends up satisfying the equation is the optimal amount because it maximizes profits.¹³ If the left-hand-side of (1) were larger than c , the expected return from an extra unit of capital would exceed the cost of the extra unit, and the firm would make a profit by acquiring that extra unit.¹⁴ On the other hand, if the left-hand-side of (1) is smaller than c , the marginal expected return from an extra unit of

¹³ Because capital takes time to install, the decision about how much capital to acquire (how much to invest) must occur before the firm knows the state of nature. The same may or may not be true of the decision to hire labor.

¹⁴ This statement holds MR_i fixed, but since MR_i also changes when firms alter their investment, the impact of investing on this terms is also taken into account.

capital is less than its marginal costs, and there is money to be made by cutting back on the amount of capital to be acquired and used.

In the product $MR_i \times MPK_i$, the term MR_i stands for *marginal revenue* in state i . It indicates the additional total revenue associated with selling an extra unit of output in that state. The later term MPK_i is the *marginal product of capital* in state i – the additional output in state i that can be generated by using an extra unit of capital, given the amount of labor being hired. Stated differently, MPK_i indicates how much extra output is generated by having an extra unit of capital, and MR_i indicates how much extra revenue each of those additional units of output will generate. The product of the two terms is called the *marginal revenue product* of capital and indicates the extra revenue generated by having one more unit of capital.

In considering this equation, the above-cited authors proceed on the basis of a critical, but unstated assumption, namely that under “proper” TELRIC pricing of unbundled elements, each of the terms on the left-hand and right-hand sides of equation (1) would have exactly the same values as would arise with a benevolent unrestricted monopoly. Put differently, the analysis applies in the nonexistent case where the actions of the monopolist reproduce the outcome of a competitive market place, and hence are in the public good. This view of TELRIC pricing is certainly not what the government had in mind when it enacted TA96. The underlying rationale for TA96 was to ensure that equation (1) was satisfied with values that conform not to the dictates of a monopolized market, but to those of a competitive market.

Pursuing this line of argument further, the claim is made that TA96 a) lowers ILEC values of the left-hand side of equation (1) at any given value of capital and b)

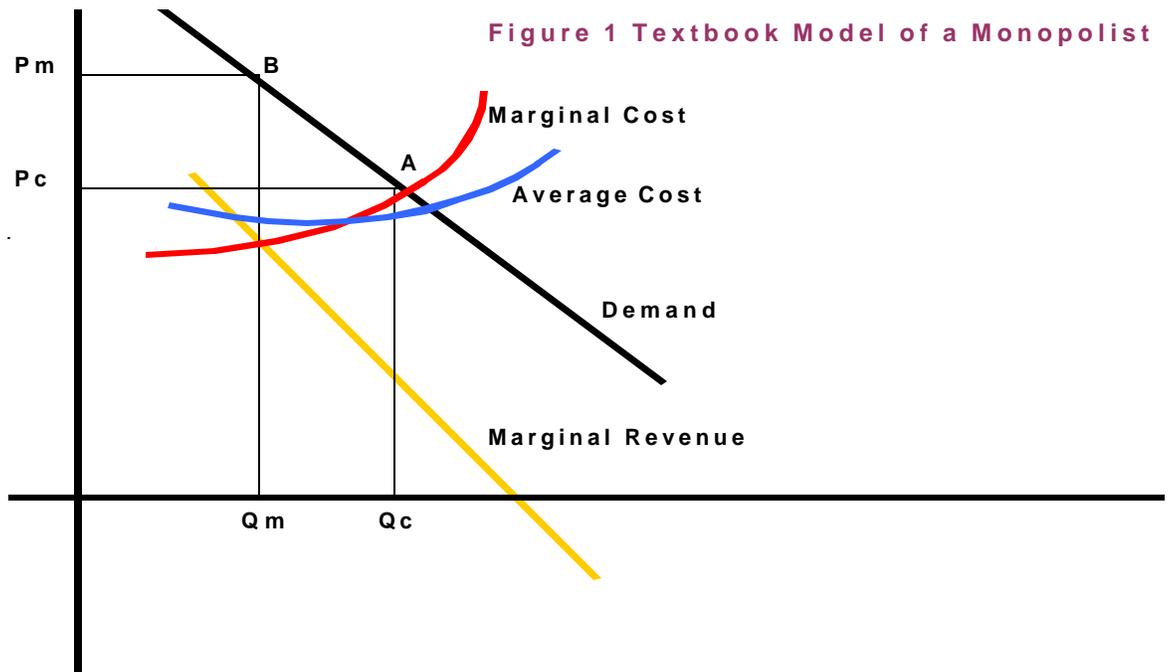
raises ILEC c , the marginal cost of capital, via several different channels. In both cases a and b, the actual value of capital that ends up making the left-hand side of the equation match the right-hand side is smaller than would otherwise be the case. This forms the basis for saying that TA96 lowers ILEC investment. Numerous extensions of this basic point have been made, with additional arguments suggesting that TELRIC prices may be set too low and that “cherry picking” might be a potential problem. However, all of these studies take entry as given, ignore strategic/game theoretic considerations, and appear to ignore a crucial textbook lesson about the regulation of monopoly – a lesson to which we now turn. This lesson provides key intuition for the more complex model we introduce in the subsequent section.

What Textbook Analysis Tells Us About Telecom Investment

As indicated, the above-cited papers discuss ILEC investment as if the ILECs were standard competitive firms that are simply being disadvantaged to a greater or lesser extent by mindless government regulators. Indeed, many of the articles make no mention of the fact that the ILECs are essentially monopolists who achieve that position through their control of the local network pipeline.

It’s worth, therefore, reviewing the basic message of economic theory about the effects of imposing competitive pricing on a monopolist through either regulation or the direct introduction of competition. Figure 1 shows the demand curve, marginal revenue curve, and marginal cost curve facing a monopolist. In a competitive equilibrium, the economy operates at point A, where there is a relatively low price and a relatively high output. The monopolist increases its profits by raising price above marginal cost, moving the economy to point B, where marginal revenue equals marginal cost. Since output is

low and price is high, consumer welfare drops, and there is a role for price regulation. An alternative is to have the regulators force the monopolist to allow entry. In this case, the new entrants and the monopolist play a strategic game over the market place, with the game's outcome generally entailing more output, a lower price, and higher consumer welfare than at point B, that is, the equilibrium will fall somewhere between B and A.



In the case of telecom, figure 1 might need to be redrawn as figure 2 since the local network pipeline may represent a *natural monopoly*. The key characteristic of a natural monopoly is that average cost declines over the range of output around which the demand curve intersects the average cost curve. For pipeline providers, a declining average cost curve is what one would expect. There is a fixed cost to installing the pipeline. If the marginal cost of adding more users of the pipeline is constant or, as

drawn, declining, average cost per transmission will fall the larger the quantity of transmissions.¹⁵

This is also critical information. As in the former case, absent regulation, the “natural” monopolist will restrict production to raise the price it receives for its product. In figure 2, the monopolist produces quantity Q_m , because at that quantity marginal revenue equals marginal cost. If the monopolist were to produce more than Q_m , the cost at the margin of doing so would exceed the additional revenue earned, and the monopolist’s profits would fall. If the monopolist were to produce less than Q_m , the loss of revenue would exceed the cost saving, and again, the monopolist’s profits would fall. Note that in setting output at Q_m , the monopolist is able to secure a price of P_m and earn positive profits since this price, which is received on each unit sold, exceeds the average cost incurred by the monopolist on each unit sold.

The economic problem with the monopoly outcome is not that the monopolist makes money, but rather that the level of production is economically inefficient. At Q_m – the point at which the monopolist produces -- the price consumers are willing to pay for an extra unit of the product – P_m – exceeds the marginal cost of producing that extra unit. Hence, producing more output is socially beneficial. Indeed, as long as the price consumers pay exceeds the marginal cost of production, it’s economically efficient to produce more. In the figure, this occurs through the output level Q_e , which is the efficient level of output. If regulators were primarily concerned with maximizing social welfare, they would require the monopolist to produce Q_e and sell product at price P_e .

¹⁵ Average cost can decline over a wide range of output even if marginal cost rises provided marginal cost is relatively low relative to the fixed cost and doesn’t rise too rapidly.

The practical problem with this socially optimal form of regulation is that the monopolist will incur a loss if it produces Q_e because average cost per unit sold at that quantity of output exceeds the price received per unit sold. The solution is for the government to provide the monopolist with a fixed payment to make up the loss. This requires an external revenue source that is collected without engendering efficiency losses that exceed the efficiency gains from imposing *marginal cost pricing* on the monopolist.

When regulators don't have access to outside funds to cover monopoly losses, they may choose to set a price at which the monopolist just breaks even. In the diagram, this price is P_r , and the quantity that the monopolist produces under such *average cost pricing* is Q_r .

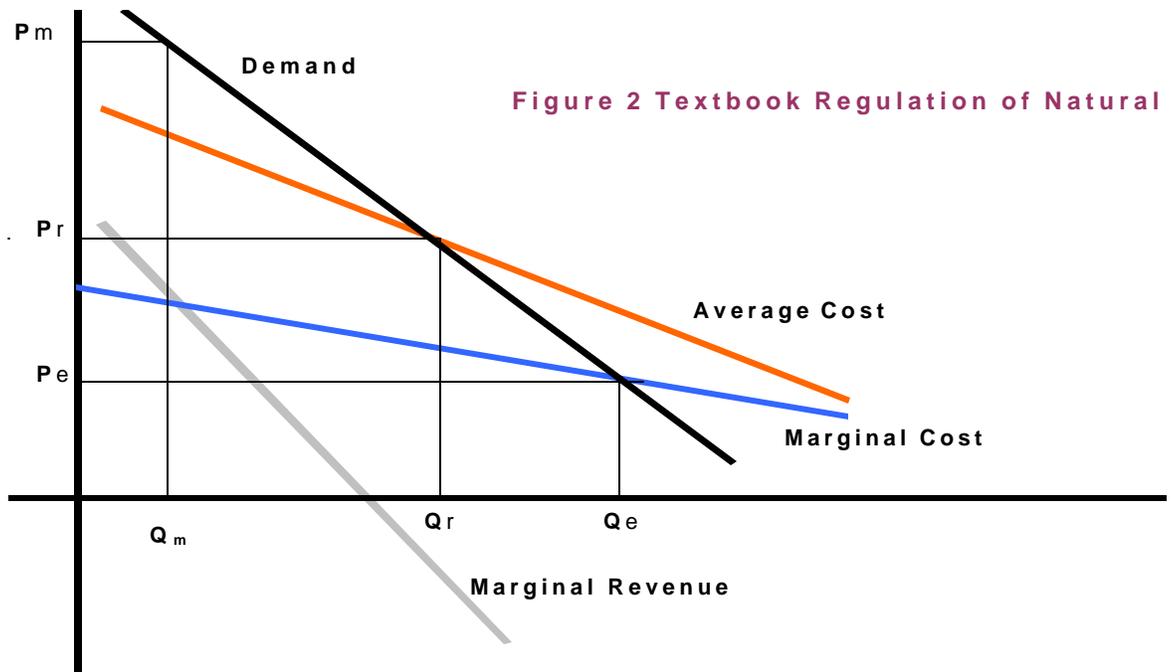


Figure 2 Textbook Regulation of Natural Mono

While the FCC has the ability to raise access charges to cover potential ILEC losses associated with pricing unbundled elements at their true marginal costs, it has chosen instead to establish TELRIC pricing, which prices these elements at average cost. Hence, from the perspective of economic efficiency, TELRIC pricing, as defined by statute, is too *high*, at least if its implementation accords with the theory. Indeed, it appears to be far too high since the margin costs of using many of the elements of the local network are close to zero.

Applying the Textbook Lesson to Telecom

The key point of both diagrams is that lowering the price facing the monopolist (moving from A to B in figure 1 or from P_m to P_r or, even better, P_e in figure 2) leads the monopolist to produce *more*, not less, output. Producing more output requires employing more inputs, which means hiring more labor and acquiring more capital (engaging in more investment).

Intuitively, monopolists are highly sensitive to the impact that producing more output (pushing more product on the market) has on the price they'll receive, not just on the last unit, but on all units they sell. Stated differently, monopolists limit their production to jack up product prices. Such an outcome is not farfetched in this particular application. ILECs, for example, cannibalize their own second-line and T1 services when they roll out DSL. If customers are captive, then such cannibalization can lead to very slow deployment of DSL.

Regulation changes this calculus by changing the *shape* of the demand curve facing the monopolist from a downward sloping curve to a horizontal line intersecting the

vertical axis at the regulated price. Faced with a flat demand curve, a monopolist can no longer hope to raise price by cutting back on production. Instead, it acts like a price taker and does its best to maximize profits under this condition.¹⁶

Hence, requiring the ILECs to price at closer to competitive levels will, absent entry, lead them to invest more, not less. TA96 achieves this end albeit indirectly with the help of the market. That is, it leads to lower prices, but also yields market share to new entrants. In this case, total market capital must increase, but depending on the share captured by the CLEC, ILEC capital may go up or down. Rather than mandating prices for a variety of telecom products below the levels the ILECs would voluntarily charge, TA96 uses competition from the CLECs to achieve this retail price reduction.¹⁷

¹⁶ For example, if the regulator sets the price at P_r , the monopolist will produce up to Q_r , because marginal revenue up to that point is just P_r , which exceeds marginal cost. Producing beyond Q_r is not profitable for the regulated monopolist because it would entail lowering the price below P_r . Doing so would not only entail positive marginal costs, but, as the diagram indicates, it would generate negative marginal revenue.

¹⁷ How does this diagram and discussion square with the marginal investment criterion in equation (1)? How can it be that lowering the price received by an ILEC raises the left-hand side of the equation for any value of k and leads to more investment? Phrasing the question differently, won't lowering the price received by the ILEC reduce the left-hand side of (1) by lowering the prices ILECs receive for their products and thus reduce the marginal revenue they earn at any given level of output? The answer is that the marginal revenue an ILEC earns from hiring additional capital consists of two components. The first is the price at which the ILEC can sell the extra unit of output. The second is the reduction in price needed to sell the extra unit which then is applied (multiplied by) all units to be sold. Equation (2), which decomposes marginal revenue into these two components, makes this clear.

$$(2) \quad \frac{\Delta TR_g}{\Delta Q}(Q(K, L)) = p(Q) + \frac{\Delta P}{\Delta Q}(Q)Q(K, L)$$

The telecom investment papers focus on $p(Q)$ -- the first term on the right-hand side of equation (2), arguing that TA96 lowers its value. But the second term, $\frac{\Delta P}{\Delta Q}(Q)Q(K, L)$, is of major import. The

term $\frac{\Delta P}{\Delta Q}(Q)$ is determined by the slope of the demand curve. It indicates how much producing an extra unit of output will lower the price at which not just the marginal, but all infra-marginal units of output as well are sold. These infra-marginal units are captured in the term $Q(K, L)$ that multiplies the price change term. The key thing to notice here is that TA96 eliminates this second term for the simple reason that prices are set by competition, rather than by the monopolist. Hence, while TA96 lowers the first term, it eliminates the second term, which is a negative number. As the diagram indicates, the net impact of this

Moreover, and this is very important, TA96 makes the ILECs wholesale producers with respect to their transactions with the CLECs. Consequently, much of the final output sold by and attributed to the CLECs must instead be attributed to the ILECs because their value added, in the form of pipeline services, comprises a major component of the total value added of the products the CLECs are selling. This point is important in assessing the unbundling simulations presented below.

To summarize, TA96 needs to be understood as part of a general strategy of restraining a natural monopolist from exercising monopoly power. The unbundling requirements of TA96 enforce competitive pricing. While this lowers the prices the ILECs receive for their products, they are still likely to produce and invest more, either directly or through their sale of inputs to the CLECs, as they realize that limiting supply to increase prices will no longer work. Thus, when one frames the discussion of TA96 as part of a policy to restrict monopoly power and compares the impact of TA96 with the price fixing and cutbacks in supply that its absence would foster, the conclusion that TA96 stimulates overall telecom output and investment is unavoidable and the proposition that it even stimulates ILEC production and investment is highly plausible.

Analyzing Telecom Investment as a Dynamic Game

The previous section provided the intuition for many of the results we generate in our model of the telecom sector. The ability of TA96 to restrain the ILECs from monopolizing the pricing of telecom products depends critically on the degree to which the law encourages CLECs to enter and compete in local telecom markets. In this section

policy in the standard natural monopoly case is to make the right hand side of equation (2) larger, not smaller, which leads the ILEC to produce and invest more, not less.

we develop an economic model that accounts for these factors and report on the preliminary results of some initial simulations.

A serious appraisal of TA96 and its impact on investment, product pricing, and consumer welfare requires a dynamic model that incorporates multiple telecom products, entry and exit decisions, heterogeneity in local telecom demand, the first-mover advantage of the ILECs, the ability of multiple competitors to unbundle and use the local network pipeline, the cost of unbundling, competition from cable companies, the nature of local telecom competition at any point in time given current entrants, the degree of economies of scale in entering and investing in geographically adjacent telecom markets, and the option values of both waiting to invest and not waiting to invest.¹⁸ The remainder of this section outlines such a model. A formal presentation of the model is relegated to Appendix.

Besides helping us see how dynamic considerations can influence policy impacts, the model's presentation makes clear that the workings of the telecom market are highly complex and cannot be completely understood via a static analysis. Presenting our model also clarifies the range of issues that need to be confronted before one can hope to have a fully informed discussion of the impact of TA96.

Players, Products, and Location

Our model is written to accommodate a variable number of players, products, and local markets. But for illustrative purposes let's assume that there are three players – an ILEC, a CLEC, and a Cable, three products – local voice, data, and TV/video, and N

¹⁸ Hausman's concern about option values affecting telecom investment decisions is certainly appropriate, but there is no way to evaluate TELRIC pricing without a fully articulated dynamic model in which the

local telecom markets located on a grid. The players need to decide each period whether to remain in squares in which they have been operating or whether to enter squares in which they haven't been operating.¹⁹

The Structure of Demand

Demand differs in each square and can change over time. Specifically, we assume that each square can have a different number of consumers with a different level of per capita income. The following grid illustrates this point by showing pictures of cities and towns with different population sizes and living standards at a given point in time.

The Telecom Board Game

-- Illustrating the Distribution of Demand



options available to both the ILECs and CLECs are made explicit. Since Hausman fails to present such a model, he provides no substantiation for his allegation that TELRIC prices are set too low.

¹⁹ This sequencing of decision-making over grid positions suggests calling our model the *Telecom Board Game*.

The State of Entry

At the beginning of each period, there is a *state of entry* that indicates which players were operating in the square in the previous period. In the grid diagram below, blue denotes local telephone service, red denotes broadband, and green denotes TV\video. Hence, the middle square indicates that at the beginning of the period being considered there is an ILEC and a CLEC competing in the local telephone market, an ILEC, a Cable, and a CLEC offering broadband, and a Cable and a CLEC offering TV/Video. Note that, in theory, there may be some squares where no broadband being offered.²⁰

The Telecom Board Game

-- Illustrating a State of Entry

<p>CLEC</p> <p>ILEC</p> <p>CABLE</p>	<p>ILEC</p> <p>CABLE</p>	<p>ILEC</p> <p>ILEC</p> <p>CABLE CLEC</p> <p>CABLE</p>
<p>ILEC</p> <p>ILEC</p> <p>CABLE</p> <p>ILEC</p> <p>CABLE</p>	<p>ILECs CLEC</p> <p>ILEC CABLE</p> <p>CLEC</p> <p>CABLE</p> <p>CLEC</p>	<p>ILEC</p> <p>CLEC</p> <p>CABLE</p>
<p>ILEC</p> <p>ILEC</p> <p>CABLE</p>	<p>ILEC CLEC</p> <p>CABLE</p> <p>CABLE</p>	<p>ILEC</p> <p>ILEC</p> <p>CABLE</p>

Note: Blue denotes local telephone service, red denotes broadband, and green denotes TV\video.

Entry and Exit Decisions

At the beginning of each period, the three players decide whether or not to offer each of the products in each of the squares. There is a fixed cost for entering a square and offering services if the player is not already operating there.²¹ We refer to this cost as the fixed entry cost. There is also a fixed cost per service offered of operating in a given square in a given period. We refer to this cost as the service-specific fixed operating cost.

The fact that incumbents don't need to pay an entry cost, while new entrants do, captures the advantage of moving first (being an incumbent). And the fact that the entry cost per square is independent of the number of products being offered means there is an economy of scope with respect to producing multiple products.

Entry costs differ across players and are influenced by policy. In addition, the fixed entrance cost may be lower if the player is already operating in an adjacent square. This captures the economies in investment associated with installing infrastructure in nearby markets. We mention this in passing, but reserve the investigation of this location externality to future work.

Players that exit a market are assumed to abandon their infrastructure. Hence, if they choose at a future date to enter a square, they will need to repay the fixed entry cost. This feature may lead players to remain in a square in the short run even if they are losing money on current operations.

Since there are several products, an "in or out" decision on each, and multiple squares, there are many different entry strategies over which each player must choose. This choice is whittled down by solving for the set of *pure strategy Nash equilibria*,

²⁰ We abstract here from satellite and wireless telecom and TV/video services as well as long distance phone service, but those products could also be included in this framework.

which refers to the set of strategies in which each player is making a set of entry decisions with respect to each product and each square that generates the largest expected profits, measured in present value, given the entry decisions (the strategies sets) of the other two players.

The reason that players consider not just their current profits from entry, but also their future profits reflects the fact that once a player enters a square, she/he can remain there indefinitely without incurring the fixed entrance cost. Hence, the one-time entrance cost needs to be set against the potential ongoing stream of profits associated with remaining and competing in the square through time.

Multiple Equilibria

In entry games of this type it's common for there to be a large number of Nash equilibria. This is referred to as *multiple equilibria*. Intuitively, if player A enters a market it may be optimal for player B to stay out. But if player A stays out, it may be optimal for player B to go in. Which outcome arises (which equilibrium ends up being played) can be thought of as a fluke of timing since there is nothing in the model we've developed to tell us which equilibrium is selected.

Resolving the Problem of Multiple Equilibria

Our method of resolving the problem of multiple Nash equilibria in a given period is to assume that each of the Nash equilibria is played with the same probability.²² The players realize that this randomly determined *correlation* on particular Nash equilibria

²¹ Establishing each service entails paying a different fixed cost.

²² This assumption that a particular equilibrium of the many available is selected is Aumann's (1974) *correlated equilibrium*.

will occur not only in the present, but also at every future date. And they take this into account in determining their best current entry strategy for each of the possible current entry strategies of their fellow players.

Within-Period Product Competition

Once entry and exit decisions have been made, the players operating in a given square must decide how much to produce. We assume that each player decides on her/his output taking the output decisions of the other producers of the product as given. This is the well-known *Cournot Model* of oligopolistic competition. It has the reasonable property that, other things equal, the more players there are in a square selling a given product, the lower will be that product's price. Hence, the more entrants to a given square, the more competition that will prevail and the better off will be consumers.²³ Another appealing feature of the Cournot within-period equilibrium is that producers with lower marginal costs produce more output than those with higher marginal cost. Finally, the Cournot Model delivers the result that the reduction in product prices associated with more competition can lead the ILEC to invest more and produce more output.

While the Cournot model has lots of appealing features, it doesn't include the bundling of products that players would likely use to achieve a competitive advantage. Such product bundling will also be examined in future work.

Option Valuation

The model is solved using dynamic programming, which starts in the model's last period and works backward to the present.²⁴ This dynamic program captures all the options available to the players with respect either to delaying or accelerating their investment decisions. Consequently, it deals explicitly with the concerns raised by Hausman (1998, 2002) that evaluating TA96's effects requires incorporating into the analysis the fact that ILECs have the option to wait to invest. While our model does not formally incorporate exogenous pricing uncertainty, future prices are uncertain because of the correlation on randomly selected equilibria, and hence, there can be a value to waiting in order to ascertain whether other firms choose to enter a square.

Preliminary Findings

This model could ultimately be calibrated to capture highly disaggregated investment patterns by letting each square be a county, for example, with characteristics that determine the profitability of entry and operation. Our ongoing work attempts just such an application. But in this paper we seek to understand the likely range of results one can plausibly generate within such a model, using current prices and cost data as an anchor for our investigation. We begin with a 1-period static version of the model and then consider a 3-period version. Both models yield similar and interesting conclusions, but a great deal of caution in interpreting the magnitude of our effects is certainly in order.

²³ This assumes that new entrants do not have higher marginal costs, on average, than incumbents.

²⁴ If the last period is set sufficiently far into the future, its choice will not affect the model's predicted current behavior.

To focus the model on the current debate, we assume that there are two markets, voice and data, and that the ILEC offers voice in each square (i.e., the ILEC has entered each square in the initial period's state of entry.) In some simulations the ILEC has already entered the data market as well. There is a CLEC, which can enter either product market, but with higher fixed costs. When the ILEC is the sole provider of local voice services, we assume it faces a regulated price that is a markup over its average cost. In a moment we will introduce a cable company as well, and discuss the impact on our results of its presence.

We assume four squares, located on a 2 by 2 grid. Income differs in each square, but preferences are the same. By varying income across squares we are able to capture in a stylized fashion the impact on different potential equilibria of local conditions that affect profitability. We chose the variation that we do in order to document the different possible equilibria. How closely each square captures real world circumstances is an empirical issue that we return to after presenting our results.

We consider two policies – no unbundling and unbundling. With unbundling the CLEC can access the ILEC's infrastructure, but must pay a rental cost for use of the ILEC's capital. With no unbundling, the CLEC must pay its fixed entry cost to enter a square and, in addition, pay its fixed and marginal operating costs. We assume that the fixed entry and operating costs facing the CLEC are significant, but that its marginal costs are lower than those of the ILEC, reflecting the fact that the CLEC has access to a less expensive workforce and, potentially, more advanced transmission technology.

Consumers are assumed to spend three percent of their incomes on telecom communication products (roughly matching data from the Consumer Expenditure

Survey), with three quarters of this expenditure spent on local voice and one quarter spent on data. This share determines the Cobb-Douglass preference parameter that helps pin down demand in each market.

We assume that there are 10,000 identical households in each square and that each household has an income of \$20,000 in square 1,1, \$40,000 in square 1,2, \$80,000 in square 2,1, and \$160,000 in square 2,2. We also assume that the initial market condition is a regulated monopoly with an initial price of \$30 per month for voice services and \$50 per month for data. At these prices, the local monopoly is highly profitable given our other assumptions. It is worth noting that any benefit from unbundling will be smaller to the extent that regulators have established the pre-unbundling price closer to the societal ideal.

In determining the UNE-P (the unbundling price charged to receive all network elements comprising the local loop) price we have used empirical data taken from Willig *et al.* (2002). These data are also used as a guide to the setting of our fixed and marginal costs, although there is not enough information available to fully calibrate our model with certainty. In these first tables, the fixed entry cost for the CLEC is \$3,000,000. The fixed operating cost for the ILEC and the cable company is \$1,000,000. It's \$2,000,000 for the CLEC. The marginal cost for the ILEC is \$10 in the case of voice and \$20 in the case of data. The marginal cost for the cable company is \$20 in providing data. And the marginal cost for the CLEC is \$8 for voice and \$17 for data. We assume that for every four dollars of output produced by each of the three types of firms, a dollar of capital is required. This assumption permits us to connect production to capital acquisition.²⁵

²⁵ Additional calibration information and the computer program for the model are available from the authors upon request.

In modeling unbundling of local voice, we assume that the CLEC pays a \$12.50 unbundling price for voice to the ILEC. We further assume that this is for half of the CLEC's output and that the CLEC pays its own marginal cost to produce the other half of its output. Finally, we assume that the CLEC pays the ILEC's marginal cost for data plus 2 percent for half of its output and pays its own marginal cost for the other half of its data output. These assumptions capture the fact that the CLEC will have to invest in order to offer service, and the ILEC must invest in wholesale capital in order to provide service. Since we are unaware of there being any data available to guide these proportions, we chose 50-50, but are examining alternative shares in our ongoing sensitivity analysis. Clearly, any theoretical predictions about ILEC capital will depend on this proportion.

Table 2 provides results for a 1-period model in which the ILEC and CLEC are the only players, i.e., there is no cable company. The table assumes that the ILEC has entered voice and data markets in each square. Given this, the CLEC chooses whether or not to enter in each of the four squares and given entry, whether to supply voice and/or data. In these simulations, the entering CLEC acquires a share of the market, but also expands the size of the market size by enforcing a lower price. With the unbundling policy, this CLEC entry leads to less ILEC retail sales of telecom services, but more wholesale sales.

Table 2 contains results for this setup assuming no unbundling. Because of the high entry cost it faces, the CLEC enters only in the higher-income squares. When the CLEC enters, it has a significant impact on the price of local voice and data service since it has lower marginal costs of delivering both services. The price of local voice drops 40 percent, and the price of broadband service drops 26 percent. The entry also stimulates a

significant increase in overall industry investment, with marginal capital (not counting fixed costs of investment) increasing by 61 percent. Interestingly, relative to the monopoly case, ILEC profits drop sharply, even though output and investment surge.

Table 2

One-Period Model with No Unbundling and No Cable Company

(all variables measured relative to monopoly outcome unless otherwise noted)

	Location			
	1,1	1,2	2,1	2,2
Voice Price	1.00	1.00	0.60	0.60
Broadband Price	1.00	1.00	0.74	0.74
Voice Output	1.00	1.00	1.67	1.67
Broadband Output	1.00	1.00	1.35	1.35
ILEC Profit	1.00	1.00	0.26	0.29
CLEC Profit *	0	0	0.60	1.11
Total Capital	1.00	1.00	1.61	1.61
ILEC Capital	1.00	1.00	0.72	0.72
CLEC Capital *	0	0	1.24	1.24

* Measured relative to ILEC values in this equilibrium.

In table 3 we present the same static simulation for the case with unbundling. Recall, in these simulations, the CLEC pays a UNE-p rate of \$12.50 to the ILEC to rent half its capital, and its own marginal cost for the other half. We make these assumptions to capture the fact that the CLEC will still have to invest in a workforce and in capital

beyond the “last mile.” In contrast to the previous case, the CLEC now enters a market that it previously avoided. Interestingly, the result is more output in that market, but less, relative to the previous case with no unbundling, in the very high-income square. This is because of our assumption that unbundling forces the CLEC to pay, at the margin, not just its own marginal operating cost, but also an additional marginal cost representing its rent payment on the ILEC capital. Hence, CLEC marginal costs are higher under unbundling in squares they would otherwise have entered in the absence of unbundling. Since very little CLEC entry was observed prior to TA96, this possibility is likely of little empirical significance, but does help refine our theoretical understanding of the possible effects of unbundling.

Nonetheless, in all of the squares that the CLEC operates in, prices are significantly lower, and output and capital significantly higher than in the regulated monopoly case. The voice price drops by 32 percent and the data price drops by 23 percent, while total capital increases by 45 percent. Even though monopoly profits drop, ILEC investment surges.

The increase occurs because of the provision of wholesale capital. The size of this demand relative to the CLEC’s own demand for capital is not a known parameter, however. To the extent that the CLECs meet the demand for their product with their own capital, this result could be reversed.

Table 3**One-Period Model with Unbundling and No Cable Company**

(all variables measured relative to monopoly outcome)

	Location			
	1,1	1,2	2,1	2,2
Voice Price	1.00	0.68	0.68	0.68
Broadband Price	1.00	0.77	0.77	0.77
Voice Output	1.00	1.48	1.48	1.48
Broadband Output	1.00	1.29	1.29	1.29
ILEC Profit	1.00	0.34	0.38	0.40
CLEC Profit *	0	0.44	0.72	0.82
Total Capital	1.00	1.45	1.45	1.45
ILEC Capital	1.00	1.09	1.09	1.09
CLEC Capital *	0	0.33	0.33	0.33

* Measured relative to ILEC values in this equilibrium.

Table 4 returns to the no unbundling assumption, but adds a cable company that operates in each grid. Given our model's preference structure, there is a connection between the state of the cable market and the decision of the CLEC to enter. The CLEC will earn lower profit in the data market because of the presence of the cable company. Hence, it may be discouraged from entering squares and, thus supplying voice and data, if the revenue from selling both local voice and data no longer cover the squares' fixed entry costs. Clearly, this interconnection arises not because of the structure of demand, but rather because of the structure of supply, namely the ability of a CLEC to economize on entry costs by offering local voice and broadband in the same geographic location. While theoretically possible, for the base-case parameters we have chosen, this outcome

does not arise. Instead the CLEC enters squares 2,1 and 2,2, and stays out of 1,1 and 1,2, with effects on prices and output that are similar to those in the previous simulation.

Table 5 replays table 4's model, but incorporates unbundling. Now we have CLEC entry into the three highest demand markets and very sharp price reductions in broadband and local voice prices. Clearly, the presence of the cable company does not have a significant effect on the equilibria given our base-case parameters.

Table 6 extends the model to three periods, and for brevity we begin with the simulation that includes the cable company and unbundling. That is, it features an incumbent cable company marketing data in each square as well as an incumbent ILEC marketing data and local voice in each square. Since there are more periods over which the CLEC can recoup its fixed entry costs, the CLEC now has a greater incentive to invest on its own. As the table shows, the CLEC enters the three best markets. The price of voice drops 32 percentage points, and the price of data drops 27 percent. Output of voice increases 48 percent, and output of data increases 36 percent. Thus, unbundling unambiguously improves consumer welfare, as in our earlier simulations.

Sensitivity analysis (not reported) suggests that this result is not, however, a theoretical necessity. Since the importance of fixed entry costs diminishes as more periods are added, it is again possible that unbundling could lead to a less desirable equilibrium, but this possibility is restricted to circumstances where the CLEC will enter the market even if there is no unbundling, and unbundling increases the marginal cost of the CLEC. Since there was essentially no CLEC entry prior to TA96, we conclude that unbundling has unambiguously increased entry and, thereby, lowered consumer prices. This view is strongly supported by the Willig, Lehr, Bigelow, and Levinson (2002) study.

Table 4**One-Period Model with No Unbundling and a Cable Company**

(all variables measured relative to monopoly outcome unless otherwise noted)

	Location			
	1,1	1,2	2,1	2,2
Voice Price	1.00	1.00	0.60	0.60
Broadband Price	1.00	1.00	0.71	0.71
Voice Output	1.00	1.00	1.67	1.67
Broadband Output	1.00	1.00	1.40	1.40
ILEC Profit	1.00	1.00	0.25	0.28
CLEC Profit *	0	0	1.47	1.54
Total Capital	1.00	1.00	1.61	1.61
ILEC Capital	1.00	1.00	0.75	0.75
CLEC Capital *	0	0	1.26	1.26

* Measured relative to ILEC values in this equilibrium.

Table 5**One-Period Model with Unbundling and a Cable Company**

(all variables measured relative to monopoly outcome unless otherwise noted)

	Location			
	1,1	1,2	2,1	2,2
Voice Price	1.00	0.68	0.68	0.68
Broadband Price	1.00	0.73	0.73	0.73
Voice Output	1.00	1.48	1.48	1.48
Broadband Output	1.00	1.36	1.36	1.36
ILEC Profit	1.00	0.33	0.38	0.41
CLEC Profit *	0	0.31	0.66	0.79
Total Capital	1.00	1.46	1.46	1.46
ILEC Capital	1.00	1.14	1.14	1.14
CLEC Capital *	0	0.33	0.33	0.33

* Measured relative to ILEC values in this equilibrium.

Table 6**Three-Period Model with Unbundling, ILEC Initially in Data and Voice, and a Cable Company**

(all variables measured relative to monopoly outcome unless otherwise noted)

	Location			
	1,1	1,2	2,1	2,2
Voice Price	1.00	0.68	0.68	0.68
Broadband Price	1.00	0.73	0.73	0.73
Voice Output	1.00	1.48	1.48	1.48
Broadband Output	1.00	1.36	1.36	1.36
ILEC Profit	1.00	0.33	0.38	0.41
CLEC Profit *	0	0.31	0.66	0.79
Total Capital	1.00	1.46	1.46	1.46
ILEC Capital	1.00	1.14	1.14	1.14
CLEC Capital *	0	0.33	0.33	0.33

* Measured relative to ILEC values in this equilibrium.

Table 7

Three-Period Model with Unbundling, ILEC Is not Initially in Data, and a Cable Company

(all variables measured relative to monopoly outcome unless otherwise noted)

	Location			
	1,1	1,2	2,1	2,2
Voice Price	1.00	0.68	0.68	0.68
Broadband Price	1.00	0.59	0.59	0.59
Voice Output	1.00	1.48	1.48	1.48
Broadband Output	1.00	1.70	1.70	1.70
ILEC Profit	1.00	0.36	0.43	0.47
CLEC Profit *	0	0.38	0.76	0.88
Total Capital	1.00	1.61	1.61	1.61
ILEC Capital	1.00	1.27	1.27	1.27
CLEC Capital *	0	0.36	0.36	0.36

* Measured relative to ILEC values in this equilibrium.

So far, the discussion has only considered cases where the ILEC has already entered, and hence does not have a strategic motive to preempt CLEC entry. Thus, our simulations can be viewed as characterizing a “mature” market. Such a strategic motive can easily be introduced into the model, however.

Now that the ILEC is choosing to enter, there is the possibility that there will be multiple equilibria. For example, depending on the characteristics of the square that is “in play” it is possible to construct equilibria wherein the CLEC will enter if the ILEC is not there, and where the ILEC will enter when the CLEC is not there. Thus, there may be

multiple Nash equilibria, which, as mentioned above, we assume is resolved by random chance.

Since our game is dynamic as well, one can find parameters for which the optimal strategy may include the possibility of preemptive investment. Such investment may occur if, for example, income is growing over time in a square, and profits in the future will be very high, but profits currently are negative. If a player takes losses today, it can make sure that the future Nash equilibria that may arise are ones where it has entered the market either by itself or with a smaller set of competitors. Notice that this strategy can lead to sometimes paradoxical results. Unbundling, for example, may increase the incentive to invest preemptively, since it increases the probability that a monopoly may face a future competitor.

For our base case parameters, however, these new runs basically support earlier tables. Since the ILEC is already providing voice services in every square, it turns out that the choice to enter the data market is an easy one, except for the case of the lowest income squares. Table 7 provides the results for this case with ILEC entry. Once again, we find for our base case parameters that CLEC entry significantly reduces consumer prices and increases capital and output, with these effects roughly the same size as in earlier simulations.

Thorough sensitivity analysis of these possible cases leads to an interesting conclusion. To the extent that one can generate dynamic simulations wherein the introduction of unbundling reduces capital in a market, those equilibria have a particular form. Such an eventuality can occur if the ILEC has a lower entry cost, and hence has a preemptive motive to invest early (and take short term losses) in order to acquire

monopoly in the market in the future profitable periods. In this case, then the introduction of unbundling can make it no longer profitable for the ILEC to invest preemptively, which will lower or eliminate investment in the non-profitable periods.

If, for example, an ILEC finds it optimal to take losses in period 1 so that it can have a monopoly in period 2 if there is no unbundling, then unbundling can, in theory, lower capital investment in period 1 by precluding the possibility that the ILEC earns monopoly profits in period 2. With unbundling, the ILEC waits until period 2 to invest (and at that point the CLEC enters) since there is no point earning losses in period 1. This is an analytically plausible outcome, but one can easily see why it has not been adopted as a theoretical argument by the ILECs. Unbundling unambiguously increases consumer welfare (and capital) even in this special case in period 2. The lower investment is a temporary phenomenon that does not characterize the steady state.

It is also possible for the model to produce unusual equilibria in the opposite direction. Suppose that the demand for data services is growing over time, and the ILEC incurs losses if it enters in the current period, but profits later on once it has entered and demand is higher. In such a case, unbundling can nonetheless induce the ILEC to move today in order to gain a foothold on a square and not lose the entire square to a strategic CLEC entrant. One must, of course, be careful moving from this theoretical discussion to real world application. But having a well calibrated, reasonable model of dynamic entry that fully incorporates both the options of early and delayed entry seems an improvement over the casual discussions of option values presented by Hausman (1998, 2002) and others.

Clearly, the model's simulation identifies the potential for improving market equilibria via rules that make it easier for entry, but the practical success of such efforts will depend critically on the ability of regulators to vigorously and competently enforce such rules. One possible explanation for the bust in the telecom market is that amorphous rule enforcement raised costs and uncertainty for entrants to such an extent that the CLECs began to fall by the wayside. Many conservative critics of regulators argue persuasively that indecision limited TA96's potential to foster competition, and that regulatory errors are so endemic that theoretically appealing policies are not implemental. Such views, if well founded, suggest two possible strategies. One, shuttering the FCC, is unrealistic. The alternative would be devising rules and systems that can easily be enforced, with the ultimate objective of moving sufficiently far in the direction of the competitive market place that regulation is no longer needed. This has already mostly occurred in the long distance market, and recent penetration by CLECs into local markets suggests that it may be happening there as well.

To foster this process, the state PUCs as well as the FCC could start requiring the BOCs to provide electronic rather than manual switching of loops, and significantly lower the fixed cost of CLEC entry. As described in Kotlikoff (2002), the costs of implementing such *Electronic Loop Provisioning* (ELP) are very low relative to potential benefits.

Conclusion

In the late 19th Century, thousands of local telephone companies operated in the United States and, having worked out their interconnection problems, competed with one another.²⁶ But in the early 1900s, the Bell System began to create a monopoly, both by denying these small companies access to long distance and by aggressively purchasing them. Almost a century later, the Telecom Act of 1996 attempted to create an environment where small, medium, and large companies could once again enter and compete. The final results of this policy remain to be seen, but our simulations and the evidence from a variety of states suggest that the policy may well be beginning to work. The recent experience in markets that have experimented with low unbundling prices looks very much like our simulations. When CLECs enter because of unbundling, prices decline, output and investment increase, and ILEC monopoly profits and share prices decline.

While the ILECs are understandably chagrined to lose any of their monopoly rents, their increasingly loud complaints about TA96 are a clear sign that the law is working and that the public is benefiting. An even stronger sign are the price reductions and cost savings that the public is enjoying in states that are aggressively enforcing TA96. It's too early to know whether this incipient rebirth of telecom competition will spread to the entire country. But if it does, it will not only rejuvenate the telecom industry but also help revive the overall economy.

²⁶ See Barnett and Carroll (1993).

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Appendix

Modeling Telecom Investment as a Dynamic Game

The Framework

Time goes from $t=1$ to $t=T$.

There are Z players. (We start with three – a ILEC, a CLEC, and a Cable.)

There are V transmission products. (We start with two – local voice and data and consider adding TV/video, wireless, and long distance.)

There are $F = H \times M$ squares, where H is the number of north-south squares and M is the number of east-west squares. For each product and for each player, there are $N=2^F$ possible states of entry at the beginning of any period, where a state of entry is a description of the squares in which the player has already entered.

Entry Space

The possible states of entry of any player i with respect to any product k at the beginning of any time t are given by the N rows of the $N \times F$ matrix E , which are given below. A value of 0 indicates entry has not yet occurred. An value of 1 indicates entry has occurred. Note that there are F elements in each row vector – one for each square.

$$\begin{aligned} e_1 &= (0,0,0,0,\dots,0) \\ e_2 &= (1,0,0,0, \dots,0) \\ e_3 &= (0,1,0,0,\dots,0) \\ e_4 &= (1,1,0,0,\dots,0) \\ e_5 &= (0,0,1,0,\dots,0) \\ e_6 &= (1,0,1,0, \dots,0) \\ e_7 &= (0,1,1,0, \dots,0) \\ e_8 &= (1,1,1,0,\dots,0) \\ &\cdot \quad \quad \cdot \\ &\cdot \quad \quad \cdot \\ &\cdot \quad \quad \cdot \\ e_N &= (1,1,1, \dots,1) \end{aligned}$$

The State of Entry

Let m_{ikt} denote the entry state of player i with respect to product k at the beginning of time t . The value of m_{ikt} is a number ranging 1 through N indicating which of the N row vectors of E is applicable.

The entry state of all players at the beginning of time t is given by the $Z \times V$ matrix A_t , whose row vectors (one for each player) are given below.

$$\begin{aligned}
a_{1t} &= (m_{11t}, m_{12t} \dots, m_{1Vt}) \\
a_{2t} &= (m_{21t}, m_{22t} \dots, m_{2Vt}) \\
&\vdots \\
&\vdots \\
&\vdots \\
a_{Zt} &= (m_{Z1t}, m_{Z2t} \dots, m_{ZVt})
\end{aligned}$$

Each element in A_t can take on N different values. Hence, there are N^{ZV} different possible states of nature (A_t matrices) at time t .

Strategies

In each period each player can play any of the rows of E ; i.e., players can stay where they are in terms of entry, chose to leave squares they entered in the past, or choose to enter squares in which they were not operating in the previous period.

There are $G = N^V$ different strategies for each player because there are V products and N possible entry vectors for each product. Index these strategies by g , where $g = 1, \dots, G$. Let $s_{g(i)t}$ refers to strategy g undertaken by player i at time t , where strategy vector $s_{g(i)t} = (j_{g(i)1t}, j_{g(i)2t}, \dots, j_{g(i)Vt})$, for $g(i) = 1, \dots, G$. This vector indicates the entry decisions made by player i at time t for each product given that player i is playing strategy $g(i)$. For example, suppose there are three products (V equals 3) and consider $s_{g(i)t} = (4, 7, 2)$. This strategy entails player i

- a) entering the market for product 1 in all the squares determined by the row vector e_4 .
- b) entering the market for product 2 in all the squares determined by the row vector e_7 .
- c) entering the market for product 3 in all the squares determined by the row vector e_2 .

Determination of Entry at Time T

The determination of entry decisions at time T needs to be made for each possible state of entry matrix A_T . For each possible state of entry matrix we calculate all the economy's pure strategy equilibria at time T . We then assume that each of these equilibria arises at time T with equal probability; i.e., that there is a random correlation mechanism that chooses the equilibrium.

Calculating Pure Strategy Equilibria at Time T

Let $\mathbf{p}_{it}(s_{g(1)1t}, s_{g(2)2t}, \dots, s_{g(Z)Zt}; A_t)$ for $g(1) = 1 \dots G; g(2) = 1 \dots G, \dots; \dots; g(Z) = 1 \dots G$ specify the net income earned by firm i in period t given the state of entry is A_t from playing strategy s_{git} given that player 1 plays $s_{g(1)1t}$, player 2 plays $s_{g(2)2t}$, etc. For $(s_{g(1)1T}, s_{g(2)2T}, \dots, s_{g(i)iT}, \dots, s_{g(Z)ZT}; A_T)$ to be a pure strategy at T , it must be the case that,

$$\begin{aligned} \mathbf{p}_{1T}(s_{g(1)1T}, s_{g(2)2T}, \dots, s_{g(Z)ZT}; A_T) &\geq \mathbf{p}_{1T}(s_{jT}, s_{g(2)2T}, \dots, s_{g(Z)ZT}; A_T) \text{ for all } j \neq g(1). \\ \mathbf{p}_{2T}(s_{g(1)1T}, s_{g(2)2T}, \dots, s_{g(Z)ZT}; A_T) &\geq \mathbf{p}_{2T}(s_{g(1)1T}, s_{jT}, \dots, s_{g(Z)ZT}; A_T) \text{ for all } j \neq g(2). \\ &\vdots \\ \mathbf{p}_{ZT}(s_{g(1)1T}, s_{g(2)2T}, \dots, s_{g(Z)ZT}; A_T) &\geq \mathbf{p}_{ZT}(s_{g(1)1T}, s_{g(2)2T}, \dots, s_{jT}; A_T) \text{ for all } j \neq g(Z). \end{aligned}$$

Determination of Entry at $t < T$

The determination of entry decisions at time t needs to be made for each possible state of entry matrix A_t . For each possible state of entry matrix we calculate all the economy's pure strategy equilibria at time t . We then assume that each of these equilibria arises at time t with equal probability; i.e., that there is a random correlation mechanism that chooses the equilibrium.

Calculating Pure Strategy Equilibria at Time t

Let $N_t(A_t)$ equal the number of pure strategy equilibria at time t given that the entry state at time t is A_t . Let $n_t = 1, \dots, N_t(A_t)$ reference these equilibria.

Define $V_{it}(A_t)$ as the expected present value of net income earned by firm i calculated at the beginning of time t given the entry state at time t is A_t .

$$V_{it}(A_t) = \sum_{n_t=1}^{N_t(A_t)} \frac{\mathbf{p}_{it}(n_t; A_t) + dV_{it+1}(A_{t+1}(n_t))}{N_t(A_t)},$$

where $V_{iT+1}(A_{T+1}) = 0$.

The term d is the discount factor. The index n_t , which references the pure strategy equilibrium played at time t , determines the entry state that will prevail at time $t+1$. Hence, A_{t+1} is written as a function of n_t .

For $(s_{g(1)1t}, s_{g(2)2t}, \dots, s_{g(i)it}, \dots, s_{g(Z)Zt}; A_t)$ to be a pure strategy at t , it must be the case that,

$$\mathbf{p}_{1t}(s_{g(1)1t}, s_{g(2)2t}, \dots, s_{g(Z)Zt}; A_t) + dV_{1t+1}(A_{t+1}(s_{g(1)1t}, s_{g(2)2t}, \dots, s_{g(Z)Zt})) \geq$$

$$p_{1t}(s_{j1t}, s_{g(2)2t}, \dots, s_{g(Z)Zt}; A_t) + dV_{1t+1}(A_{t+1}(s_{j1t}, s_{g(2)2t}, \dots, s_{g(Z)Zt})) \quad \text{for all } j \neq g(1).$$

$$p_{1t}(s_{g(1)1t}, s_{g(2)2t}, \dots, s_{g(Z)Zt}; A_t) + dV_{1t+1}(A_{t+1}(s_{g(1)t}, s_{g(2)t}, \dots, s_{g(Z)t})) \quad \text{3}$$

$$p_{1t}(s_{jt}, s_{g(2)t}, \dots, s_{g(Z)t}; A_t) + dV_{1t+1}(A_{t+1}(s_{jt}, s_{g(2)t}, \dots, s_{g(Z)t})) \quad \text{for all } j \neq g(2).$$

$$\vdots$$

$$p_{1t}(s_{g(1)t}, s_{g(2)t}, \dots, s_{g(Z)t}; A_t) + dV_{1t+1}(A_{t+1}(s_{g(1)t}, s_{g(2)t}, \dots, s_{g(Z)t})) \quad \text{3}$$

$$p_{1t}(s_{g(1)t}, s_{g(2)t}, \dots, s_{g(Z)t}; A_t) + dV_{1t+1}(A_{t+1}(s_{g(1)t}, s_{g(2)t}, \dots, s_{jt})) \quad \text{for all } j \neq g(Z).$$

The equations for finding the pure strategy equilibria are the same as for time T except that the players consider not simply current net revenue from playing a particular strategy, but also the present expected value of future revenue associated with entering the next period from the entry state to which their own strategic entry decisions as well as those of their competitors lead.

The Structure of Demand and Supply

Assume the utility of agents is Cobb-Douglas in communications, c , and other goods, d , where

$$U(c,d) = c^a h^{(1-a)}$$

Each agent's demand for communications is given by $c = ay/p_c$, where y stands for income and p_c stands for the price of communications. Each agent produces communications based on a Cobb-Douglas production function that takes as inputs the V communications products that include local telephone and data. Each agent's production function is given by

$$c = Hq_1^{b_1} q_2^{b_2} \dots q_V^{b_V}, \text{ where } \mathbf{b}_V = 1 - \sum_{j=1}^{j=V} \mathbf{b}_j$$

Cost minimization implies that input expenditure shares equal their production coefficients.

$$p_i q_i = \mathbf{b}_i E$$

The constant returns property means that total costs equal total expenditures. Hence,

$$p_c c = E, \text{ where } p_i \text{ is the price (user cost) of input } i.$$

And since $p_c c = ay$, we have

$$p_i q_i = \mathbf{b}_i a y$$

or

$$q_i = \mathbf{b}_i a y / p_i$$

The aggregate demand for telecom input i in the telecom market in question, Q_i , is then, $Q_i = \mathbf{b}_i a Y / p_i$, where Y is aggregate income in the local telecom market.

The Cournot Game

A player j producing telecom input i playing Cournot will set

$$h q_{ji} = (p_i - mc_{ji}) / p_i,$$

where h is the inverse demand elasticity in the market for the input, q_{ji} is the output share of player j in the production of good i , and mc_{ji} is the marginal cost of player j in producing input i . In this model, $h = 1$. Summing the above equation over all players j , we have that

$$p_i = \sum_{j=1}^{v_i} mc_{ij} / (v_i - 1), \text{ where } v_i \text{ is the number of players in the market.}$$

Summarizing and Evaluating the Solution

This solution is simple. In each square for each configuration of entrants being considered, we simply add up the marginal costs of the players, divide by one less than their number, and that's the price that will prevail. The formula, $Q_i = \mathbf{b}_i a Y / p_i$ can be used to determine Q_i and each entrant j 's output can be determined by multiplying $q_j = \mathbf{q}_j Q_i$, where $\mathbf{q}_j = (p_i - mc_{ji}) / p_i$. Player j 's profit for operating in the square in the period in question is given by $p_i q_j - fec_j - foc_j - mc_j q_j$, where fec_j refers to the fixed cost of entry for player j if she hasn't already entered the market and foc_j stands for player j 's fixed operating cost.

The downside of this method of modeling demand is that the solution is not well defined in the case of a monopolist because the demand elasticity for each telecom input equals unity. We can assume that when there is a single player supplying an input in a given market, that the player is forced by regulators to price at prices chose to roughly match current actual circumstances. This solution has the property that a player's profits in producing one telecom input don't depend on the amount of the other telecom inputs he supplies in the market (square). The reason is that the demand curve for input i depends only on its own price and not the prices of the other inputs. Were this not the case, a Cournot player in a square supplying more than one input would have to consider how her supply of one input altered the price and thus demand for the other input(s) she supplies. Entertaining different preferences or production functions for communications will generate this problem and make things very complicated.