12 The Effect of Sunk Costs in Telecommunications Regulation

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Abstract - Under the Telecommunications Act of 1996, the FCC mandated forward looking cost-based prices for competitors to use unbundled local exchange company (LEC) facilities. The FCC does not permit any markup over cost to allow for the risk associated with investment in sunk assets; instead, it uses a total service long-run incremental cost (TSLRIC) type approach that attempts to estimate TSLRIC on a forward looking basis. TSLRIC allows for the recovery of the cost of investment and variable costs of providing the service over the economic lifetime of the investment. However, TSLRIC makes no allowance for the sunk and irreversible nature of telecommunications investment, so that it adopts the perfect contestability standard. This standard provides incorrect economic incentives for efficient investment once technological and economic uncertainty exist along with sunk investments. Equivalently, FCC regulation requires incumbent LECs to give a free option on the use of their sunk investment in network facilities to new entrants. Thus, the FCC has chosen the incorrect standard for setting regulated prices, which will be below the correct economic cost of the network investments. TSLRIC will lead to less innovation and decreased investment below economically efficient levels. Decreased consumer welfare will be the result of the FCC's policy.

1. CURRENT FCC APPROACH TO REGULATION OF UNBUNDLED ELEMENTS

The U.S. Congress passed the Telecommunications Act of 1996, which was the first basic change in the regulatory framework for telecommunications since 1934. The Congressional legislation called for less regulation, more competition, and the most modern, up-to-date telecommunications infrastructure: "[T]o provide for a pro-competitive, de-regulatory national policy framework designed to accelerate rapidly private sector deployment of advanced telecommunications and information technologies and services to all Americans by opening all telecommunications markets to competition."[2] The Federal Communications Commission (FCC) has instituted numerous regulatory rulemakings to implement the 1996 Telecommunications Act. The most important regulation so far has been the Local Competition and Interconnection Order of August 1996.[3] If implemented in its current form, this order will likely have serious negative effects on innovation and new investment in the local telephone network.[4]

This paper first considers the proper goal of regulation-set prices in telecommunications. Most economists agree that regulation should be used only when significant market power can lead to unregulated prices that are well above competitive levels.[5] The goal of regulators is then to set prices at "competitive levels." However, economists are much less explicit about how these competitive price levels can be estimated. Most economists would agree that perfect competition cannot yield the appropriate standard since prices set at marginal cost will not allow a privately owned utility to earn a return on capital that is sufficient to survive. The large fixed costs of telecommunications networks thus do not allow the price-equal marginal cost standard of perfect competition to be used.[6]

An alternative competitive standard has been proposed by William Baumol and his co-author, known as the "perfect contestability" standard. Baumol has proposed that regulators should require firms to set prices as if "the competitive pressures generated by fully unimpeded and costless entry and exit, contrary to fact, were to prevail."[7] However, costless entry and exit presumes that no sunk costs exist (i.e., costs that cannot be recovered upon exit by a firm). This assumption of no sunk costs is extremely far from economic and technological reality in telecommunications, where the essence of most investments is an extremely high proportion of sunk costs.

Consider the investment by an incumbent local exchange carrier (ILEC) in a new local fiber optic network that can provide new broadband services and high-speed internet access to residential customers. Most of the investment is sunk because if the broadband network does not succeed, the investment cannot be recovered. Thus, when either technological or economic uncertainty exists, "perfect contestability as a generalization of perfect competition" cannot provide the correct competitive standard.

In a perfectly contestable market, if the return to an investment decreases below the competitive return, the investment is immediately removed from the market and used elsewhere. This costless exit strategy is always available in a perfectly contestable market. However, the actual economics of telecommunications investment could not be further from such a perfectly contestable market.[8] When fiber optic networks are constructed, they are in large part sunk investments.[9] If their economic return falls below competitive levels, the firm cannot shift them to other uses because of their sunk and irreversible nature.[10] Thus, the use of a perfectly contestable market standard fails to recognize the important feature of sunk and irreversible investments: they eliminate costless exit. Because of its failure to take into account the sunk and irreversible nature of much telecommunications investment, the contestable market model has nothing of interest to say about competition in telecommunications.[11] An industry cannot be expected to behave in a manner that is fundamentally inconsistent with its underlying technological and economic characteristics.

One way to consider the problem is the situation of a new investment by an ILEC. Suppose a competitor wants to buy the unbundled elements associated with the investment. The ILEC could offer the new competitor a contract for the economic life of the investment - say ten years for investment in the local loop. The price of the unbundled element would be the total investment cost plus the operating costs each year for the unbundled element. If demand did not materialize or prices fell, the new entrant would bear the economic risk of this outcome.[12] However, regulation by total-service long-run incremental cost (TSLRIC) typically allows the new entrant to buy the use of the unbundled element on a month-by-month basis. Thus, if demand does not materialize or prices fall, the ILEC must bear the risk for the business case of the new competitor. Thus, the ILEC has been required by regulation to give a free option to the new entrant, where an option is the right, but not the obligation, to purchase the use of the unbundled elements.[13] The monthly price of the unbundled element should be significantly higher than the ten-year price of the element to reflect the risk inherent in the sunk investments, or equivalently, the value of the option given to the new entrant.[14] Regulators to date have not incorporated the value of the option, which arises from the sunk cost nature of much telecommunications investment, into their price setting.

Another way to consider the problem of regulation-set prices is to allow for the existence of the (all-knowing) social planner. Suppose a social planner is considering a new investment in a telecommunications network where the features of sunk and irreversible investments are important. The social planner wants to maximize the value of the social welfare integral over time subject to uncertainty. However, the investment is subject to both technological and economic uncertainty so that the cost of the investment may (randomly) decrease in the future. Thus, because of demand uncertainty, the social planner does not know whether the investment will be economically efficient. In making an optimal decision the social planner will take into account the sunk and irreversible nature of the investment because if the new service fails, the investment cannot be shifted to another use. Thus, assuming that sunk costs do not exist (which is the perfect contestability standard), when they are actually an extremely important part of the economic problem will lead to incorrect decisions and decreased economic efficiency. The economy will not reach its production possibility frontier.

2. REGULATION-SET PRICES FOR UNBUNDLED ELEMENTS

Under the Telecommunications Act of 1996, the FCC mandated forward looking cost-based prices for competitors to use unbundled LEC facilities.[15] The Commission did not permit any markup over cost to allow for the risk associated with investment in sunk assets; instead, it used a total service long-run incremental cost (TSLRIC) type approach that attempts to estimate the TSLRIC on a forward looking basis.[16] TSLRIC attempts to solve the perfect competition problem that price cannot equal marginal cost by allowing for the fixed costs of a given service to be recovered. TSLRIC allows for the recovery of the cost of investment and the variable costs of providing the service over the economic lifetime of the investment. However, TSLRIC makes no allowance for the sunk and irreversible nature of telecommunications investment, so that it adopts the perfect contestability standard. The perfect contestability standard provides the incorrect economic incentives for efficient investment once technological and economic uncertainty exist. The FCC has chosen the incorrect standard for setting regulated prices. TSLRIC will lead to less innovation and decreased investment below economically efficient levels.[17]

2.1 The TSLRIC Standard and R&D and Investment in New Services

The first and easiest example to consider is R&D and investment in new services. Many new telecommunications services do not succeed; recent failures include Picturephone services (AT&T and MCI within the past eight years) and the information service gateway services offered by many ILECs. These new gateway services required substantial sunk costs of development for the creation of large data bases to provide information service gateways. Now if a new service is successful, under TSLRIC regulation, an ILEC competitor can buy the service at TSLRIC. Thus, for a successful new service, the ILEC recovers at most its costs. For unsuccessful services, the ILEC recovers nothing and loses its sunk investment. Thus, the TSLRIC regulation is the analogue of a rule that would require pharmaceutical companies to sell their successful products to their generic competitors at incremental cost and would allow the pharmaceutical companies to recover their R&D and production costs on their successful new drugs, but to recover nothing on their unsuccessful attempts.

This truncation of returns where a successful new telecommunications service recovers its cost (but no more), and unsuccessful new services recover nothing decreases economic incentives for innovative new services from regulated telecommunications companies. By eliminating the right tail of the distribution of returns as demonstrated in Figure 1, TSLRIC regulation decreases the mean of the expected return of a new project. For example, consider a project with returns, y, which follow a normal distribution with mean μ and standard deviation σ. The expected value of the return when it is truncated at cost c is:

$$E(y|y<c) = \mu - \sigma M(c) \quad (1)$$

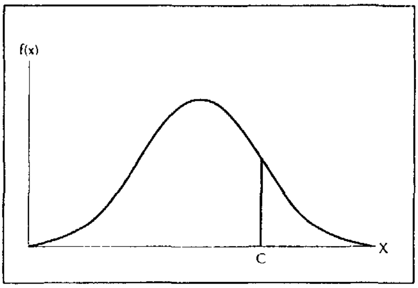

Figure 1

where M(c) is the inverse Mills ratio evaluated at c.[18] The tighter the cost standard, the lower the incentives to innovate, as expected. More importantly, as the returns to the innovation become more uncertain, the expected return and the incentives to innovate also decrease. Thus, even in the absence of sunk and irreversible investments, a TSLRIC pricing policy will decrease the economic incentives for investment in innovative services, and may eliminate these economic incentives to invest altogether.

Regulators could allow for something similar to patent protection for new services to provide economic incentives for ILECs to innovate.[19] However, this policy option is a recipe to delay new telecommunications services for ten years or more and bring enormous consumer welfare losses as occurred with voice messaging and cellular telephone.[20] Currently, it takes the U.S. Patent Office, on average, over two years to grant a patent (longer time periods are not uncommon). However, no opponent of the patent is allowed to be part of the process. In a regulatory setting where competitors would attempt to delay the introduction of new services, as happened with both voice messaging and cellular telephones, as discussed in Hausman (1997), one would expect much longer delays. Thus, the patent approach will not solve the problem.

A better approach would be not to regulate new services. Given the large welfare gains from new services and price cap regulation for existing services, ILECs should be permitted to offer new services with no prior approval or price regulation. The gains in consumer welfare from successful new services would lead to significant gains for consumers. Attempting to "fine tune" prices of new services through cost-based regulation will lead to overall consumer losses. However, regulators find it extremely difficult not to regulate any new service of a regulated company.[21]

2.2 The Effect of Sunk and Irreversible Investments [22]

TSLRIC assumes that all capital invested now will be used over the entire economic life of the new investment and that prices for the capital goods or the service being offered will not decrease over time. With changing demand conditions, changing prices, or changing technology, these assumptions are not necessarily true. Thus, TSLRIC assumes a world of certainty where the actual world is one of uncertainty in the future. Significant economic effects can arise from the effects that the sunk nature of investment has on the calculation of TSLRIC.

Consider the value of a project under no demand uncertainty with a risk-adjusted discount rate of r and an assumed known exponential economic depreciation at rate α. This assumption on depreciation can be thought of as the price of the capital decreasing over time at this rate due to technological progress. Assume that price, net of the effect of economic depreciation of the capital goods, is expected to decrease with growth rate $-\alpha$.[23] The initial price of output is P. The value of the project is:

$$V(P)=\int_0^\infty \lambda \exp(-\lambda t)\, P\, \frac{1-\exp(-\delta t)}{\delta}\, dt = P/(\lambda+\delta) \tag{2}$$

where $\lambda = r + \alpha$. Note that δ is added to the expression to account for the decreasing price of capital goods. This term, omitted from TSLRIC calculations, accounts for technological progress in equipment prices, which is one economic factor that leads to lower prices over time. Suppose that the cost of the investment is I. The rule for a competitive firm is to invest if $V(P) > I$. Equivalently, from equation (2), $P > (\lambda + \delta)\, I$. The economic interpretation of this expression is that the price (or price minus variable cost) must exceed the cost of capital, which includes the change in the price of the capital good to make the investment worthwhile.[24] Note that the net change in the output price and the price of the capital good both enter the efficient investment rule that a firm invests when $V(P) > I$. TSLRIC calculations ignore the basic economic fact that when technological change is present, (quality adjusted) capital goods prices tend to decline over time. This economic factor needs to be taken into account or economic inefficiency will result.

A simplified example demonstrates the potential importance of changing capital goods prices when competition exists. Suppose a new investment is considered that uses computer technology in a significant manner. Because computer technology is advancing rapidly, the price of the capital good used in the investment will decrease over time. Consider the following example where a competitive firm priced according to equation (2), but did not take account of changing prices of capital goods due to technological progress (i.e., $\delta = 0$ is assumed). A company "New Telecom" decides to enter the Internet access business. The company goes and buys a switch (router) that costs $10,000. It expects to serve 100 customers each year with variable costs at $500 per year. The firm's cost of capital is 10 percent and it expects to use the router for five years, at which time the resale (scrap) value of the router will be zero.[25] The discounted cost of the project over five years is $11,895, which is the TSLRIC. On a per-customer basis, the cost is $118.95 so that if the price were set at $31.38 per year, the net present value (NPV) of the project is zero. Thus, the price based on TSLRIC is $31.38 per year. Unfortunately, the company will lose money at this price and so the investment will never be made. There is a reason for this conclusion.

The price of routers, switches, fiber optic electronics, and other telecommunications equipment is decreasing with technological progress, e.g., Groves' law for microprocessors. Assume that the price of the router declines by $1000 each year, but all other costs remain the same. For a market entrant in year 2, the TSLRIC calculation would lead to a discounted cost of $10,895 (exactly $1000 less if no further price reductions occurred) so that the TSLRIC-set price will be $28.74 per year. Now the initial entrant, New Telecom, will be forced to decrease its price by $2.64 and it will lose money on each customer (taking the original cost of capital into account). Indeed, as expected, New Telecom will lose $760 on the project. The story will continue the next year when the router price falls to $8000. Thus, TSLRIC-based prices cause the initial entrant to lose money even in a world of complete certainty because of decreasing capital costs. Instead of charging $31.38 for each year as TSLRIC implies, New Telecom must charge decreasing prices of ($36.65, $33.75, $30.85, $27.95, and $25.04) due to competition. Where does TSLRIC go wrong?[26]

TSLRIC fails to recognize that the change in the price of the equipment needs to be included in the cost of capital, which has been recognized by economic theory for many years. Indeed, the competitive price would not be the TSLRIC answer of $31.38. The correct answer is that New Telecom must charge $36.65 the first year and then decrease its price to \$33.75 the next year, and so on, because of the decreased price of the router. Thus, the TSLRIC-set price is too low by about 17 percent for the first year because it ignores the falling price of capital goods.

Now, the usual TSLRIC calculation does not include δ, but it instead assumes that both the prices of capital goods and output do not change over time. This assumption is extremely inaccurate. Take a Class 5 Central Office Switch (COS), for example. Ten years ago an AT&T Class 5 switch (5-ESS) was sold to an ILEC for approximately \$200 per line.[27] Today, the price of AT&T 5-ESS switches and similar NTI switches are in the \$70 per line or lower range. A TSLRIC calculation would be based on the \$70 price. An ILEC who paid \$200 per line made the efficient investment decision when it purchased its COS. But TSLRIC, by omitting economic depreciation due to technological progress, leads to a systematically downward-biased estimate of costs. Indeed, the economic depreciation of central office switches has been near 8% per year over the past five years, while the cost of fiber optic carrier systems has decreased at approximately 7 percent per year over the same period.[28] The omitted economic factor δ can be quite large relative to r for telecommunications switching or transmission equipment due to technological progress.

TSLRIC calculations make the following further assumptions: 1) the investment is always used at full capacity, 2) the demand curve does not shift inwards over time, and 3) a new or improved technology does not appear that leads to lower costs of production. Of course, these conditions are unlikely to hold true over the life of the sunk investment. Thus, uncertainty needs to be added to the calculation because of the sunk nature of the investment.

It is possible to account for the sunk nature of the investment and its interaction with fundamental economic and technological uncertainty.[29] Given the fundamental uncertainty and the sunk nature of the investment, a "reward for waiting" occurs because over time, some uncertainty is resolved. The uncertainty can arise from at least four factors: 1) demand uncertainty, 2) price uncertainty, 3) technological progress (input price) uncertainty, and 4) interest rate uncertainty.[30] Now the fundamental decision rule for investment changes to:

$$P^s > \frac{\beta_1}{\beta_1 - 1}(\delta + \lambda)I \tag{3}$$

where $\beta_1 > 1$ so that $m = \beta_1/(\beta_1 - 1) > 1$. The parameter β_1 takes into account the sunk cost nature of the investment coupled with inherent economic uncertainty.[31] Parameter m is the markup factor required to account for the effect of uncertain economic factors on the cost of sunk and irreversible investments. Thus, the critical cutoff point for investment is $P^S > P$ from equation (2).

To see how important this consideration of sunk costs can be, the markup factor m can be evaluated. The parameters β_1 and m depend on a number of economic factors. It can be demonstrated that as uncertainty increases (i.e., the variance of the underlying stochastic process), β_1 decreases and the m factor increases.[32] Also, as δ increases, β_1 increases, which means that the m factor decreases. As r increases, β_1 decreases so that the m factor increases. MacDonald and Siegel (1986) and Dixit and Pindyck (1994, p.153) calculate m = 2 so that, for instance, $V^S = 2I$. A TSLRIC calculation that ignores the sunk cost feature of telecommunications network investments would thus be off by a factor of two.

Using parameters for ILECs and taking account of the decrease in capital prices due to technological progress (which Dixit and Pindyck assume to be zero in their calculation) and because the expected change in (real) prices of most telecommunications services is also negative given the decreasing capital prices, the value of m can be calculated to be around 3.2 to 3.4.[33] Thus, a markup factor must be applied to the investment cost component of TSLRIC to account for the interaction of uncertainty with sunk and irreversible costs of investment.[34] Depending on the ratio of sunk costs to fixed and variable costs, the overall markup on TSLRIC will vary, but the markup will be significant given the importance of sunk costs in most telecommunications investments. Note that this same markup over TSLRIC would be used by the hypothetical social planner to choose optimal investment in a telecommunications network since the social planner would face the same inherent economic and technological uncertainty over future demand and cost factors.

Now when the markup for sunk and irreversible investment is applied, it should only be used for assets that are sunk (e.g., potentially stranded). Other investments that are fixed, but not sunk, would not have the markup. This methodology can be applied to transport links and ports, which are treated as unbundled elements by U.S. regulation. The proportion of sunk costs for links is 0.59 so that the markup factor for the overall investment using a markup factor of m = 3.3 is approximately 2.35 times TSLRIC. By contrast, the proportion of sunk costs for ports is about 0.10, so that the markup factor becomes 1.23 times TSLRIC. The markup over TSLRIC that takes account of sunk costs and uncertainty is the value of the free option that regulators force incumbent providers to grant to new entrants (in this case, 1.35 times TSLRIC for links and 0.23 times TSLRIC for ports). Thus, the proportion of sunk costs has an important effect on the correct value of regulated prices when sunk costs are taken into account.

Regulators, by failing to apply a markup to TSLRIC, will set too low a regulated price for telecommunications services from new investment. The result will be to decrease new investment in telecommunications below economically efficient levels, contrary to the stated purpose of the Telecommunications Act of 1996 in the United States and enabling legislation in other countries. Thus, through its focus on static cost efficiency considerations in setting regulated prices equal to TSLRIC, regulators will miss the negative effect on dynamic efficiency that TSLRIC-based prices will cause. Because the examples of voice messaging, cellular telephone, and the Internet demonstrate that the dynamic efficiency effects are quite large in telecommunications, the use of TSLRIC to set regulated prices will likely cause substantial welfare losses to consumers similar to past FCC regulatory policy in the United States.

3. CONCLUSIONS

The cost-based regulation of telecommunications (e.g., rate-of-return regulation in the United States) had significant negative effects on innovation while it was claimed that it led to excessive capital investment. Most economists conclude that cost-based regulation led to significant consumer harm. During the 1980s price cap regulation was implemented instead of cost-based regulation in most countries when telephone companies and other utilities were privatized. In the majority of U.S. states, rate-of-return regulation has been replaced by price cap regulation. Price cap regulation has important economic incentive attributes for innovation and investment in networks by the incumbent firms in telecommunications.

During the 1990s cost-based regulation has reappeared because of the necessity to set prices for unbundled network elements sold by incumbent firms to their competitors. Unfortunately, the adoption of TSLRIC as a cost basis to set the prices for unbundled elements has negative economic incentive effects for innovation and for new investment in telecommunications networks.

Regulators' failure to recognize the sunk cost character of much network investment leads to the grant of a free option to the competitors of the incumbent. Causing the shareholders of the incumbent firm to fund the free option for the competition will lead to underinvestment. Given the amount of uncertainty in a dynamic industry with rapidly changing technology and economics, this misguided regulatory policy can have an especially large effect on investment incentives because the value of the option is high. The losers will be consumers and businesses who will not have access to the most up-to-date service that would be provided if regulators did not create disincentives to new investment.

NOTES

1 Presented at a conference at Columbia University, October 2, 1998. I thank Nick Hausman and Dr. My Cahouy for research assistance. Parts of this paper have appeared previously in J. Hausman. 1997. "Valuation and the Effect of Regulation on New Services in Telecommunications," *Brookings Papers on Economic Activity: Microeconomics*. Further discussion of the effects of regulation on innovation can be found in that paper.

2 Conference Report to the Telecommunications Act of 1996, Pub. L. No. 104–104, 110 Stat. 56.

3 FCC, "First Report and Order, CC docket No. 96-98 and 95-185," August 1, 1996.

4 The FCC is being challenged by the incumbent local exchange carriers (ILECs) in Federal Court. The U.S. Supreme Court reversed and remanded for further consideration the FCC's regulatory approach in January 1999. See AT&T Corp. *v.* Iowa Utils. Bd., 119 S. Ct. 721 (1999). The key issue remanded to the FCC is what network elements should be unbundled. Justice Breyer, in his separate opinion, discussed the effect of the FCC approach on prices of unbundled elements and the likely negative effect on new investment and innovation in local networks, which is the subject of this paper.

5 In considering the regulation of unbundled elements, the FCC has failed to consider whether, in the absence of regulation, market power could be exercised by the ILECs. Instead, the FCC has adopted a "competitor welfare standard," which is inconsistent with the economic analysis of competition and the modern antitrust law. In contrast, Canadian regulators have taken competitive considerations into account in their decision on which elements should be unbundled. Hausman and Tardiff (1995) discuss competitive considerations in unbundling.

6 Economists have long agreed on this point. See, e.g., Kahn (1988) for a discussion.

7 W. J. Baumol and J. Gregory Sidak (1994), p. 28. and pp. 31 ff.

8 To the extent that some network elements are fixed, but not sunk, investments should not be unbundled by regulators because new entrants can enter and exit markets using these elements without undergoing sunk investments, which can create entry (and exit) barriers.

9 The electronics used in the networks need not be sunk, but much of the actual dark fiber will be a sunk investment.

10 This feature of sunk and irreversible investment has been widely recognized by economic research for over a decade. See MacDonald and Siegel (1986) and for a recent comprehensive textbook treatment, see Dixit and Pindyck (1994).

11 The contestable model of competition has been highly criticized as relating to real-world situations. Previous criticisms of its attempted application to telecommunications include Armstrong and Vickers (1995), "In fact, of course, the industry does not remotely resemble a contestable market..."

12 The contract (or regulation) could allow the new entrant to sell the use of the unbundled element to another firm if it decided to exit the business.

13 The use of real options analysis extends far beyond the evaluation of sunk and irreversible investments. See, e.g., Treigeorgis (1996) and his paper in this volume.

14 In contracts between unregulated telecommunications companies (e.g., long distance carriers) and their customers, significant discounts are given for multi-year contracts.

15 The FCC decision is currently under remand by the FCC. In the FCC proceeding the author provided testimony on behalf of the ILECs.

16 The FCC chose a variant of TSLRIC, called TELRIC for total element LRIC. However, the essential economic problem of TSLRIC also exists in TELRIC. The FCC is currently constructing a TELRIC model to be used in future regulatory proceedings.

[17] TSLRIC would provide the correct approach in a world with no uncertainty, so long as economic depreciation was done correctly. However, given the dynamic technological advances in telecommunications, considerable uncertainty exists, especially over the long economic lifetimes of much investment in telecommunications.

[18] The inverse Mills ratio is the ratio of the density function and distribution function of the standard normal distribution evaluated at $(c - \mu)/\sigma$. The inverse Mills ratio M(C) increases monotonically as c decreases for given μ and σ, e.g., Greene (1990), p. 718.

[19] The FCC chief economist, Joseph Farrell (1997) considered this option.

[20] See Hausman (1997) for a discussion on consumer losses from this policy.

[21] The FCC, remarkably enough, has proposed to regulate new services under TSLRIC-type regulation, even when the FCC itself has found that significant competition currently exists for these services. See Deployment of Wireline Services Offering Advanced Telecommunications Capability, Memorandum Opinion and Order and Notice of Proposed Rulemaking, CC Dkt. Nos. 98–147, 98-11, 98-26, 98-32, 98-15, 98-78, 98-91, 13 F.C.C. Rcd. 24,011, 24,055-59 and Inquiry Concerning the Deployment of Advanced Telecommunications Capability to All Americans in a Reasonable and Timely Fashion, and Possible Steps to Accelerate Such Deployment Pursuant to Section 706 of the Telecommunications Act of 1996, Report, CC Dkt. No. 98-146, (released Feb. 2, 1999). The FCC is proposing to regulate new services even when no regulation is required since no market failure exists. This unnecessary regulation is potentially extremely harmful to consumers (the "public interest") as I discuss in Hausman (1997), where previous FCC regulation of new services led to billions of dollars in consumer harm. See Hausman (1998) and Hausman and Shelanski (1999) for a discussion of why regulation should consider consumer welfare to be the primary factor in "public interest" regulation, not the "competitor welfare" standard that the FCC has adopted.

[22] This discussion follows Hausman (1996). See also Laffont and Tirole (1996).

[23] This factor arises due to changes in demand and changes in total factor productivity.

[24] For simplicity, this calculation assumes only capital costs and no variable costs. Variable costs can be included by reinterpreting P to be price minus variable costs, which will lead to the same solution.

[25] The terminal value assumption can be changed with no change in the conclusions to the analysis.

[26] TSLRIC-type formulae can be corrected by using equation (2) with δ not equal to zero to account for decreasing capital prices. However, to the best of my knowledge, these corrections have not been undertaken by regulators.

[27] Hausman and Kohlberg (1989), p. 204.

[28] Testimony of Prof. Jerry Hausman before the CPUC, April 1998.

[29] Salinger (1998) attempts to generalize the approach of equation (2) to allow for uncertainty by appending various ad hoc assumptions on randomness to the equation. However, his approach has severe limitations, of which only two are mentioned here. First, he assumes away the effect of lumpy investment by assuming that investment occurs continuously, while the technological nature of much investment in telecommunications depends on its lumpiness. Second, he assumes that regulators update their depreciation formulae in continuous time so that the option value discussed in this paper decreases in importance. These assumptions bear a similarity to the contestability assumptions (instantaneous free entry and exit) which, as discussed above, bear no relationship to the actual technology of much investment in telecommunications networks.

[30] The FCC incorrectly assumed that taking account of *expected* price changes in capital goods and economic depreciation is sufficient to estimate the effect of changing technology and demand conditions; see the FCC "First Report and Order," para. 686. Thus, the FCC implicitly assumed that the variances of the stochastic processes that determine the uncertainty are zero, i.e., that no uncertainty exists. Under the FCC approach, the values of all traded options should be zero (contrary to stock market fact), since the expected price change of the underlying stock does not enter the option value formula. It is the uncertainty related to the stochastic process as well as the time to expiration that gives value to the

option as all option pricing formulae demonstrate (e.g., the Black-Scholes formula). See, for example, (Hull) 1997 for a discussion of the value of options.

[31] This equation is the solution to a differential equation. For a derivation see, for example, Dixit and Pindyck (1994), pp. 254-256, pp. 279-280, and p. 369. The parameter β_1 depends on the expected risk-adjusted discount rate of r, expected exponential economic depreciation δ, the net expected price $-\alpha$, and the amount of uncertainty in the underlying stochastic process. Note that this result holds under imperfect competition and other types of market structure, not just under monopoly, as some critics have claimed incorrectly. See, for example, Dixit and Pindyck (1994), Ch. 8, "Dynamic Equilibrium in a Competitive Industry." Imperfect competition is the expected competitive outcome in telecommunications because of the significant fixed and common costs that exist.

[32] See, for example, Dixit and Pindyck (1994), p.153.

[33] Because of the expected decrease in the price of capital goods, even if the standard deviation of the underlying stochastic process were 0.25 as high as a typical stock, the markup factor would still be 2.1. For a standard deviation 0.5 as high, the markup factor is 2.4. I have also explored the effect of the finite expected economic lifetimes of the capital investments in telecommunications infrastructure. Using expected lifetimes of 10-15 years leads to only small changes in the option value formulas, e.g., for a project with a 12-year economic life, the markup factor of 2.0 changes to 1.9.

[34] It is the advent of competition which requires correct regulatory policy to apply the markup. Previously, when regulatory policy did not allow for competition, regulators could (incorrectly) set prices based on historic capital costs. Given the onset of competition arising from the Telecommunications Act of 1996 and the regulatory removal of barriers to competition, regulators must now account for changes in prices over time. Otherwise, ILECs will decrease their investment below economically-efficient levels because their expected returns, adjusted for risk, will be too low to justify the new investment.

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