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Federal Communications Commission
Office of Secretary

July 12, 1996

William F. Caton
Secretary
Federal Communications Commission
1919 M Street, N.W. - Room 222
Washington, D.C. 20554

RE: Ex Parte Notice
CC Docket No. 96-98

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Dear Mr. Caton:

On July 11, 1996, Jerry A. Hausman (MacDonald Professor of Economics, M.I.T.) and Howard Shelanski (Kellogg, Huber, Hansen, Todd & Evans) and the undersigned - all representing USTA - met with representatives of the Common Carrier Bureau of the FCC. The Common Carrier Bureau members attending the meeting were Regina Keeney, Richard Metzger, Don Stockdale, Richard Lerner, Greg Rosston and Patrick DeGraba.

Professor Hausman presented the example contained in the attached, and distributed this attachment and the three publications excerpts also attached hereto. His comments were consistent with the affidavits he filed on behalf of USTA in the comment and reply rounds in this docket.

Because of the lateness of the meeting, this notice is being filed today. An original and one copy of this ex parte notice are being filed in the Office of the Secretary. Please include this notice in the public record of these proceedings.

Respectfully submitted,

Mary McDermott

Mary McDermott
Vice President -
Legal & Regulatory Affairs

attachments
cc: R. Keeney R. Metzger
D. Stockdale R. Lerner
P. DeGraba J. Hausman
H. Shelanski G. Rosston

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pends on what a firm can gain by waiting, and a firm that faces competitors risks losing the market to others if it should allow price to rise too far above cost. In fact, under perfect competition the option to remain uncommitted is worthless, since competition eliminates all profits. This raises the question of how irreversibilities affect investment in competitive equilibrium.

Somewhat surprisingly, this paper will show that the introduction of competition does not affect the timing of irreversible investment decisions at all. I shall consider the optimal policies of two types of firms. The first correctly anticipates how the strategies of other firms in the market will interact with prices and exogenous shocks. The second, like the firms in the literature on irreversible investment, completely ignores the effect that other firms exert on the price process. This firm in effect assumes that the industrywide stock of capital will remain fixed forever and that the price process will be driven solely by exogenous shocks. I shall call the policies of the second firm myopic. It is a special kind of myopia; the firm is farsighted in the sense that it calculates present values, but it is shortsighted in the sense that the price process which it uses to calculate profits is correct only so long as no other firms invest. Such a myopic firm has static expectations regarding industry output, but rational expectations regarding other shocks that influence price in the market.

The central result of this paper is that the prices that trigger investment by the two types of firms are identical even though the optimization problems that they face appear very different. I shall demonstrate this correspondence in a setting with homogeneous, constant-returns-to-scale firms, linear costs of investment, downward sloping demand, and uncertainty that follows a diffusion process.

The intuition underlying this result is straightforward. The decision to invest is similar to the decision to exercise an option. The investor trades the chance to own a unit of capital for the capital itself, and the strike price of this option is the cost of investment. The introduction of competition reduces the value of this option, but does so by reducing the value of the invested capital. Since competition reduces the value of actual and potential capital at the same time, the trade-off between the two is unaffected.

The correspondence between myopic and competitive investment has two practical implications. First, many of the lessons concerning the relationship between uncertainty and investment derived under the assumption of a solitary price-taking firm apply

the special case in which the price at which firms invest is independent of the size of the market. Section V extends the result to more general settings. Section VI is devoted to the connection between the myopic firm and the social planner. Section VII discusses possible extensions, as well as limitations, of the results. Section VIII concludes.

II. A Deterministic Setting

To fix ideas, let us begin with a simple example of a case in which a myopic firm that ignores the presence of competitors chooses to invest at the same price as a fully rational firm. Consider an industry in which price depends only on industry supply and a time trend:

$$p(q,t) = -\alpha q + \beta t.$$

Here t represents time, q is industry output, and α and β are positive constants. Suppose that firms produce output from capital with constant returns to scale; one unit of capital produces one unit of output. Suppose further that capital is infinitely divisible, and firms may add capital at a cost of k per unit. This investment is irreversible, and firms' discount future profits at the rate r.

Since firm size is indeterminant in competitive equilibrium with constant returns to scale, it is convenient to think of each infinitesimal unit of capital as a separate firm. Investment therefore consists of entry by infinitesimal firms each of which must pay an entry cost equal to k. This characterization has no effect on competitive equilibrium and has the advantage that it keeps the expected profits of the myopic firm finite in the case of constant returns to scale.

In this example, the industry price rises at a constant rate in the absence of entry. It is clear that the competitive equilibrium is for firms to allow this price to rise until it reaches rk, the rental cost of capital, and from that point on for firms to enter in sufficient quantities to keep price constant at this level. The competitive equilibrium price path is represented by p_c in Figure I. All firms make zero profits, and no firm has an incentive to invest earlier.

What is interesting is that the investment trigger does not depend on the endogeneity of the price process. A firm that ignored the presence of other firms and mistakenly believed that the price for its output would increase indefinitely with t, like price p_m in Figure I, would still wait until price reached the rental cost of

second-order conditions, and the myopic firm will choose the one that maximizes profits.

Now suppose that competitive firms follow the myopic policies; that is, at any point in time they behave as if industry supply will remain fixed forever at its current level and choose their entry times accordingly. Note that as investment takes place, q will in fact change, and firms' strategies will change to reflect the change in q. In spite of these changes, however, firms choose entry times as if q will remain fixed at its current level. They have static expectations regarding quantity, but rationally anticipate movements in the shock to demand.

To show that these myopic policies yield a competitive equilibrium, we need to show that the present discounted value of profits at any time of entry is equal to the cost of entry k. We know from the properties of the myopic policies that at any time of investment the price is equal to rk. It remains to determine the present value of profits between investment times. To this end, suppose that entry takes place at t_1 and t_2 but not in between. Since no investment takes place on the interval $[t_1,t_2]$, q is constant, and the competitive and myopic price processes are the same. This implies that the present value of revenues on this interval can be no greater than $k(1 - e^{-r(t_2-t_1)})$, which is the gain from delaying the entry cost from t_1 to t_2, or else a myopic firm would not wait until t_2 to invest. On the other hand, revenues can be no less than $k(1 - e^{-r(t_2-t_1)})$, or some of the firms that invested at t_1 would find it optimal to postpone their entry until t_2.[4] Hence profits over the interval must be $k(1 - e^{-r(t_2-t_1)})$. Together with the fact that firms invest at rk, this implies that the present value of profit at any investment time is equal to k. We have therefore constructed a competitive equilibrium out of the myopic strategies. Myopic behavior is optimal in competitive equilibrium.

III. Uncertainty

I now introduce uncertainty into the analysis by treating the demand shock as a diffusion process. Uncertainty alters the policies of both the myopic and the competitive firm. In competitive equilibrium, investment tends to limit surprise increases in the

4. It is important that price be continuous (as a correspondence) in quantity so that entry by an infinitesimal firm does not alter the price process. Otherwise, the price process might depend on whether the marginal firm chose to enter at t_1 or t_2. I shall return to this point in Section VII.

scrap capital. They cannot let capital sit idle without disinvesting and there is no depreciation.[6]

Again, it is convenient to think of each infinitesimal unit of capital as a separate firm. In this case, investment is equivalent to entry by infinitesimal firms, and disinvestment is equivalent to exit. Each infinitesimal unit of capital faces a fixed entry cost equal to k and an exit cost equal to l. q_t represents the mass of firms in the market. Treating each unit of capital as a separate firm will allow us to compare the CRS competitive equilibrium investment strategies to the policy employed by the owner of a single investment project who ignores the effects of investment by others on the price process. I shall therefore adhere to this infinitesimal firm interpretation of the model throughout the remainder of the paper.

The shock x is the ultimate source of uncertainty in the model. I assume that it follows a time-independent diffusion process of the form,

$$dx = \mu(x)dt + \sigma(x)dw, \tag{2}$$

where w is a Wiener process.[7] This specification is slightly more general than that normally employed in models of investment under uncertainty. It covers a broad class of processes. If μ and σ are constant, then x is a Brownian motion or a continuous time random walk. If $\mu = \bar{x} - x$, then x is an Ornstein-Uhlenbeck process or a continuous time AR(1). If $\mu(x) = \mu x$ and $\sigma(x) = \sigma x$, then x is a geometric Brownian motion. Models of irreversible investment often employ this last process because the shock's average rate of growth is constant.

I assume that the inverse demand function satisfies standard regularity conditions which ensure that the price process is well behaved. In particular, $D(q_t,x_t)$ is twice continuously differentiable and strictly increasing in x, and continuously differentiable and diminishing in q. In addition,

$$E_t \int_0^\infty e^{-rt}[D(\hat{q},x_t) - c]\, dt < \infty$$

6. It is trivial to introduce depreciation. It only alters the discount rate.

7. It is assumed that $\mu(x)$ and $\sigma(x)$ satisfy the standard condition for a solution to (2) to exist: for some constant K and $x, y \in \mathbf{R}$,

$$|\mu(x) - \mu(y)| + |\sigma(x) - \sigma(y)| < K|x - y|,$$
$$|\mu(x)|^2 + |\sigma(x)|^2 < K^2(1 + |x|^2).$$

See Karatzas and Shreve (1988), p. 289.

Since the shock is Markov, the state of the economy at any given point in time is fully characterized by the ordered pair (q_t, x_t). It is therefore natural to consider strategies that depend only on these two variables. In this case, the optimal entry and exit policies are described by regions in the (q, x) plane. Let $\overline{X}(q)$ denote the level of the shock that triggers entry when there are q firms in the market. Similarly, let $\underline{X}(q)$ denote the exit trigger. The pair of functions $\{\overline{X}(q), \underline{X}(q)\}$ describe an entry-exit policy. Note that we must have $\overline{X}(q) > \underline{X}(q)$ for $q \geq 0$, as simultaneous entry and exit is costly.

It is often more intuitive to think of entry and exit in terms of prices, rather than levels of the shock. It is possible to eliminate x_t from equation (3) by appealing to equation (1) which defines x_t as an implicit function of p_t and q_t. Setting $x_t = \phi(p_t, q_t)$ and using (2) to eliminate dx results in a general expression for the price process in terms of prices and quantities:

$$dp = \hat{\delta}(p_t, q_t)dq + \hat{\mu}(p_t, q_t)dt + \hat{\sigma}(p_t, q_t)dw, \tag{4}$$

where

$$\hat{\delta}(p,q) = D_1(q_t, \phi(p_t, q_t)),$$

$$\hat{\mu}(p,q) = \mu(x)D_2(q,x) + \tfrac{1}{2}\sigma(x)^2 D_{22}(q,x)$$

$$\hat{\sigma}(p,q) = \sigma(x)D_2(q,x).$$

This characterization of the price process isolates two independent effects of investment. First, investment directly influences the level of prices through its effect on the current market equilibrium: given any value for the shock, more production implies a lower equilibrium price. This effect is captured by the first term in equation (4). Second, investment may change the character of the price process by altering its infinitesimal mean and variance. A change in the size of the market alters the relationship between the shock and the market price by shifting the equilibrium to a new portion of the demand curve. This effect is captured by the latter two terms in equation (4).

An entry-exit policy $\{\overline{X}(q), \underline{X}(q)\}$ will be associated with a pair of price triggers $\{\overline{P}(q), \underline{P}(q)\}$, which are its image according to

that would result if all firms followed policies $\overline{P}(q)$ and $\underline{P}(q)$; entry and exit at the triggers keep the price process within the triggers. The fourth condition ensures that no individual firm will rationally choose to follow any other policy. The final item is the free entry condition.

Constructing an equilibrium is equivalent to finding two functions $\overline{P}(q)$ and $\underline{P}(q)$ such that the present discounted value of profits for the price process regulated by these functions is k at the entry barrier and $-l$ at the exit barrier. If this is the case, then at the upper barrier inactive firms will be indifferent between remaining idle or entering the market, while at the lower barrier active firms will be indifferent between remaining active or exiting the market. Furthermore, since the present discounted value of profits is strictly increasing in the price level for any given market size, no firm will find it in its best interest to follow any alternative policy.

In general, constructing such an equilibrium would appear to be an extremely difficult task due to the variety of effects that investment has on the price process. Not only does it directly affect the level of prices by altering supply, but it also affects the sensitivity of prices to demand shocks by shifting equilibrium to a new portion of the demand curve. To calculate the present discounted value of profits under a given set of policies, we have to analyze the entire evolution of prices for each possible realization of the shock in order to determine in what ways entry and exit influenced the level, mean, and variance of the price process.

In the next two sections I show that we can construct a competitive equilibrium much more simply from the policies of a myopic firm. I shall pursue this result in two steps. I first demonstrate this construction in a special case in which investment has no effect on the infinitesimal mean or variance of the price process. This restriction greatly simplifies the optimal policies and allows us to concentrate on the effect that investment has on the level of prices. I then show that more general cases can be reduced to the case in which the mean and variance of the price process are independent of the size of the market.

IV. A Simple Intermediate Case

Let us consider cases in which the demand curve and the shock process are chosen so that entry has no effect on the mean and variance of the price process. This would be the case, for example, if

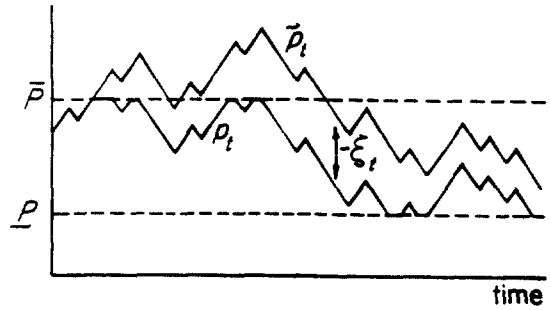

FIGURE II

process as an exogenous diffusion process whose mean and variance are a fixed function of the price level.[12]

PROPOSITION 1. Let $\bar{P}$ and $\underline{P}$ be the optimal entry and exit levels for the exogenous price process defined by

$$d\bar{p}\ \hat{\mu} = \mu(\bar{p})dt + \hat{\sigma}(\bar{p})dw. \tag{6}$$

Then $\bar{P}$ and $\underline{P}$ are competitive equilibrium entry and exit triggers for the endogenous price process:

$$dp = \hat{\delta}(p,q)dq + \hat{\mu}(p)dt + \hat{\sigma}(p)dw. \tag{5}$$

Proof. See Appendix.

The proof of Proposition 1 is easy to sketch. Suppose that all firms enter and exit at prices p_u and p_l, respectively, where $p_l < \underline{P} < \bar{P} < p_u$ and $\underline{P}$ and $\bar{P}$ are the myopic triggers. Is this a Nash equilibrium? The answer is no, since a firm does better by following the myopic policies. The reason follows from Bellman's principle: if a firm wants to be active tomorrow at p_u, the optimal policy today is entry at $\bar{P}$, because the myopic price process and the competitive price process are identical until p_u. Taking the limit as $p_u \to \bar{P}$ and $p_l \to \underline{P}$ shows that $\{\underline{P},\bar{P}\}$ is a Nash equilibrium. Continuity of the optimal policies then shows that this equilibrium exists.

To illustrate this result, I present a simple example in which investment is irreversible.

12. Dixit [1991a] proves a similar result in the case of price ceilings. Price ceilings differ from regulation, however, in that a price ceiling only bounds the price process over the period for which price would have been excessively high in the absence of the price ceiling. With a price ceiling at $\bar{p}$, the price process becomes $\hat{p}_t = \min\{\bar{p}_t,\bar{p}\}$. Regulation through entry and exit alters the level of the price process itself as can be seen from Figure II.

It is now easily confirmed that $\Pi(\overline{P})$ equals k, and, since firms entering the market at $\overline{P}$ earn zero profits, we have constructed a competitive equilibrium from the myopic policy.

To get some intuition for what is happening, consider $\Pi(p)$ more closely. Let T denote the first time that price reaches $\overline{P}$. Because the present value of profits at T is k,

$$\Pi(p_t) = E_t \int_t^T e^{-rs} p_s \, ds + e^{-rT} k.$$

A little algebraic manipulation yields

$$\Pi(p_t) = \frac{p_t}{r - \mu} - E_t e^{-rT} \left(\frac{p_T}{r - \mu} - k \right).$$

does this imply $q \neq 1$?

The first term is the present value of profits if there is no further investment in the market. This is the value of an active myopic firm. The second term is the value of waiting until T, investing, and receiving an active myopic firm. This is the value of an idle myopic firm. The difference between the value of an active and an inactive competitive firm is therefore the same as that between an active and an inactive myopic firm. Competition therefore does not alter the incentive to trade an idle firm for an active firm.

In Section V we shall see another reason why the timing of the marginal investment decision is the same in both situations: both are reflections of the same maximization problem. Competitive equilibrium maximizes aggregate consumer surplus, whereas the myopic firm maximizes its individual contribution to consumer surplus.

V. A More General Case

So far, I have abstracted from the effects that entry may have on the infinitesimal mean and variance of the price process. I now show that firms may safely ignore these effects as well. To calculate the competitive equilibrium entry and exit barriers, firms need only consider the current mean and variance of innovations in prices. Changes in these parameters due to future entry and exit will, of course, alter future polices, but they have no influence on current decisions.

In the case in which entry and exit alter the mean and variance of the price process, the competitive entry and exit barriers may be calculated from the following algorithm. Given that the market size is $\bar{q}$ and that prices follow the process identified in equation (4),

investment decision depends only on the current characteristics of the price process.

This discussion ignores one way in which the future might influence the present: future changes may alter the timing of the next investment decision. The proof of Proposition 2 makes use of the continuity of the model which implies that a small change in the capital stock has only a small change on the characteristics of the price process. Future changes in the price process therefore have a negligible impact on the next investor's investment decision, and hence the time at which today's investor receives k or $-l$.

VI. The Social Planner's Problem

Together Propositions 1 and 2 show that firms can ignore other firms when deciding when to invest. To better understand the reason that firms may ignore so much, it is useful to take a look at the problem from another perspective. This will give us some intuition as to the generality of the results, as well as to where and why they might fail.

Recall from the introduction that competitive equilibrium and myopic behavior are not only directly connected, but are also indirectly connected through the social planner's problem. Since the relationship between competitive equilibrium and the social planner's problem is well-known (see Debreu [1954] and Lucas and Prescott [1971]), I shall take this correspondence as given, and instead concentrate on the relationship between the social planner's problem and that of a myopic firm. The purpose of this discussion is to illustrate the connection between the planner's optimal control problem and the firm's optimal stopping problem. Readers interested in a more rigorous treatment may consult Karatzas and Shreve [1984] or El Karoui and Karatzas [1988]. Leahy [1993] provides a discrete time treatment.

Consider a social planner who maximizes the present discounted value of social welfare in the form of consumer surplus:

$$\max_{q_t} E\left\{\int_0^\infty \int_0^{q_t} e^{-rt}[D(z, x_t) - c]\, dz\, dt - \int_0^\infty e^{-rt} k\, dq_t^+ - \int_0^\infty e^{-rt} l\, dq_t^-\right\}, \tag{9}$$

where q_t^+ and q_t^- represent cumulative increases and decreases in the capital stock, respectively.

(*) and Definition (*). Without constant returns, entry and exit would not have occurred at fixed levels, complicating the proof of Proposition 1. Without free entry, the value of an active firm would not have been equal to k at the point of entry, complicating the proof of Proposition 2. Finally, without the continuity of demand, infinitesimal investment, and the continuity of the shock, the myopic triggers would not have been continuous in q, complicating both proofs. The purpose of this section is to indicate directions in which these assumptions may be relaxed and ways in which relaxing the assumptions will endanger the myopia result.

This discussion makes two general points. First, if one considers the strategies of a myopic firm, a competitive firm, and a social planner, and one notes that one of these strategies is related to the other two, then it must be the case that the other two are related to each other. Hence whenever competitive equilibrium is Pareto optimal, and the planner's optimal control problem may be recast as an optimal stopping problem, myopic policies will be competitive. Conversely, if any two of these policies are unrelated, then it cannot be the case that both of these policies are related to the third. Hence any violation of the Arrow-Debreu assumptions that invalidates the second welfare theorem, and hence the correspondence between competitive equilibrium and the social planner's problem, endangers the optimality of the myopic policies in competitive equilibrium.

A. Limitations

There are several conditions that are necessary for the myopic policies to be optimal in competitive equilibrium.

First, it is important that investment projects be infinitely divisible. To see this, suppose that all firms were to follow the myopic policies when investment is discrete. If they invest at the myopic entry trigger, then their entry will reduce the price discretely, and all firms will lose money. If they target their postinvestment price to the myopic trigger, then they will have to allow the preinvestment price to rise well above this trigger. These high prices, however, will allow firms already in the market to earn positive profits. Hence the myopic policies cannot be a competitive equilibrium.[15] A similar problem arises if demand is discontinuous.

15. This is why Dixit [1989b] solves a linked option problem in his model of equilibrium entry and exit. Investment in his model is discrete; therefore, all of his firm's investment decisions are interdependent. The profitability of one depends on the timing of the next.

aversion, future entry and exit will always occur in such a way as to keep the expected utility of the payoff stream equal to the cost of entry.

A fourth possible extension is to more general stochastic processes for the shock, including discrete time processes, continuous time jump processes, as well as non-Markov processes. I base this conjecture on the connection between the problem of the myopic firm and the social planner. The intuition underlying this connection does not appear to depend on the specification of the shock.

VIII. Conclusion

This paper has considered three types of investment strategies: the policies of a competitive firm, the policies of a social planner, and the policies of a myopic firm that treats the evolution of the price process as independent of the strategies of other firms. While the connection between the first two types of strategies is generally known, the role of the latter is new. By demonstrating the relationship between the myopic policies and the social planner's policies, the paper illustrates a general connection between optimal stopping problems and optimal control problems that may be useful in many economic applications. By demonstrating the optimality of the myopic policies in competitive equilibrium, the paper makes possible the direct application to competitive equilibrium of the considerable research on the optimal investment strategy of an individual price-taking firm.

Appendix: Proofs of the Propositions

A few preliminaries will simplify the exposition of the proofs. The main needs are to set out some notation and to prove that the myopic policies are continuous in the parameters.

Suppose that a firm faces an exogenous price process of the form,

$$dp = \mu(p,q)dt + \sigma(p,q)dw, \tag{A1}$$

where q is a fixed parameter and μ and σ are continuous in p and q. Let $V(p,\bar{p},\underline{p},q)$ represent the value of an idle firm when the price process follows (A1), the current price is p, the entry and exit policy is $\{\bar{p},\underline{p}\}$, and q is fixed for all time. Similarly, let $J(p,\bar{p},\underline{p},q)$ denote

Finally, let $\bar{p}^*(q)$ and $\underline{p}^*(q)$ denote the policy choices that maximize V and J.

LEMMA. V^* and J^* are continuous in p and q. $\bar{p}^*(q)$ and $\underline{p}^*(q)$ are continuous correspondences in q.

Proof. First note that the V and J are continuous in all of their arguments. Continuity in p results from the continuity and infinite variation of the price process. Continuity in $\bar{p}$ and $\underline{p}$ results from the fact that path by path the value of a policy is continuous in the trigger or target unless the trigger or target is a local maximum or minimum for the process, and the latter event is of measure zero. Finally, continuity in q follows from the continuity of $\mu(q)$ and $\sigma(q)$ and standard arguments on the continuity of the solution to a differential equation.[19]

The first statement now follows directly from an application of the Theorem of the Maximum (see Stokey and Lucas [1989], p. 62).

The Theorem of the Maximum also implies that $\bar{p}^*(q)$ and $\underline{p}^*(q)$ are upper hemicontinuous. To get continuity, we prove that the correspondences are convex valued. Suppose that $\{\bar{p}_1, \underline{p}_1\}$ and $\{\bar{p}_2, \underline{p}_2\}$ are both optimal for a given q. Let $p_u = \min\{\bar{p}_1, \bar{p}_2\}$ and $\underline{p}_l = \max\{\underline{p}_1, \underline{p}_2\}$. Now as both policies are maximal, we have $V(p,\bar{p}_1, \underline{p}_1,q) = V(p,\bar{p}_2, \underline{p}_2,q)$ and $J(p,\bar{p}_1, \underline{p}_1,q) = J(p,\bar{p}_2, \underline{p}_2,q)$ for all $p \in [\underline{p}_l, p_u]$.

Without loss of generality assume that $\bar{p}_1 < \bar{p}_2$. Define $G(p,\bar{p}, \underline{p},q) = J(p,\bar{p}_2, \underline{p}_2,q) - V(p,\bar{p}_2, \underline{p}_2,q)$. Then G must solve,

$$rG - \mu(p,q)G_p - \tfrac{1}{2}\sigma(p,q)^2 G_{pp} = p - c,$$

subject to the boundary conditions,

$$G(p,\bar{p},\underline{p},q) = k, \qquad \forall p \geq \bar{p}_2 \text{ and } p = \bar{p}_1,$$

$$G(p,\bar{p},\underline{p},q) = -l, \qquad \forall p \leq \underline{p}_2.$$

Since G is well set and since G equals k at both $\bar{p}_1$ and $\bar{p}_2$, G must equal k at all points in between. But this implies that all $p \in [\bar{p}_1, \bar{p}_2]$ satisfy the boundary conditions (A2) and are points of entry with the same value as $\bar{p}_1$ and $\bar{p}_2$. A similar argument applies to the exit trigger. This shows that the optimal entry and exit triggers form a convex valued correspondence and completes the proof.

19. For example an argument may be based on Birkhoff and Rota [1978, Theorem 6.5, Lemma (p. 156), Theorem 10.11].

longer optimal to enter. Then it must be that the value of holding an active firm at p_u is less than k, and since it is not optimal to invest, the value of holding an idle firm is zero:

$$0 = V^*(p_u) \geq J^*(p_u) - k. \tag{A5}$$

Let $\bar{p}_u$ denote the supremum of the set for which (A5) holds. Applying the lemma, V^* and J^* are continuous functions, so that (A5) holds with equality at $\bar{p}_u$, and the firm is indifferent between entry and remaining inactive. The previous argument therefore implies that the optimal entry point is $\overline{P} \leq \bar{p}_u$. Suppose that $\overline{P} < \bar{p}_u$. As V^* equals zero, there is no value to being an idle firm. J^* is therefore equal to the present discounted value of profits until exit less the present discounted value of the exit cost. This value is strictly monotonic in price, as for each possible path of the shock raising the initial price can only raise future prices.[22] As $\overline{P} < \bar{p}_u$, this implies that $J(\overline{P}) < k$, which contradicts the assertion that $\overline{P}$ is the optimal entry level. Therefore, it must be the case that $\bar{p}_u = \overline{P}$ and for all $p_u > \overline{P}$ it is optimal to be active at p_u. A similar argument shows that for all $p_l > \underline{P}$ it is optimal to be inactive at p_l. This completes the proof.

PROPOSITION 2. The competitive entry and exit strategies $\overline{P}(q)$ and $\underline{P}(q)$ can be calculated as follows. Pick an arbitrary $\bar{q}$. Let $\bar{p}$ and $\underline{p}$ be equilibrium entry and exit barriers for the price process defined by

$$dp = \hat{\delta}(p,q)dq + \hat{\mu}(p_t,\bar{q})dt + \hat{\sigma}(p_t,\bar{q})dw, \tag{A6}$$

where $\bar{q}$ is fixed at the chosen level. Then, given that the current industry output is $\bar{q}$, $\bar{p}$ and $\underline{p}$ are equilibrium entry and exit barriers for

$$dp = \hat{\delta}(p,q)dq + \hat{\mu}(p_t,q)dt + \hat{\sigma}(p_t,q)dw. \tag{A7}$$

So $\overline{P}(\bar{q}) = \bar{p}$ and $\underline{P}(\bar{q}) = \underline{p}$.

Proof. Suppose that there are $\bar{q}$ firms in the market, that the entry and exit strategies $\overline{P}(q)$ and $\underline{P}(q)$ have been constructed in accordance with the proposition, and that price follows (A7). We wish to show that the present discounted value of profits is k when the market price equals $\overline{P}(\bar{q})$ and $-l$ when the market price equals $\underline{P}(\bar{q})$.

22. See Caplin and Leahy [1991] for this monotonicity argument.

Taking the sum path by path, we are left with

$$V(\omega,T_0) = \gamma(\omega,T_0) = \begin{cases} k, & \text{if entry at } T_0; \\ -l, & \text{if exit at } T_0, \end{cases}$$

which confirms that $\overline{P}(q)$ and $\underline{P}(q)$ are in fact equilibrium policies for (A7).

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Comments on DOJ's TSLRIC Pricing Analysis

By Jerry A. Hausman[1] - July 11, 1996

1. In these comments I discuss how DOJ's approach to TSLRIC fails to account for fundamental features of telecommunications networks, including sunk costs and lumpy investment (i.e. investment made in large, discrete blocks rather than continually over time). I demonstrate that DOJ's approach also ignores technological progress, decreasing equipment prices, and uncertainty. All of these economic factors are extremely important when investments are sunk and expected lives of networks are long. Contrary to DOJ's assertion, a competitive firm in this economic situation which sets its price according to TSLRIC, as advocated by DOJ, would lose money and go out of business.

2. I then review DOJ's estimates of consumer gains from its recommended policy. DOJ's estimates disregard economic reality because they assume that ILECs are currently earning supra-normal profits, which no one has shown. DOJ's estimates also assume that basic, local, residential service does not receive a subsidy from other services, which is contrary to almost universally accepted calculations for ILECs.[2] The DOJ cost estimates are not based on sound economics. They are based on the Hatfield Model, whose conclusions and methodology DOJ acknowledges it has never evaluated (p. A3 n.7). That model assumes a new telecommunications network built on a "green field" basis and ignores the reality of the current network. As a result, the DOJ calculations do not reflect consumer gains from more efficient telecommunications prices; instead, they reflect an assumed monetary transfer from ILEC shareholders to consumers. But this transfer will not occur in the real world; it is a figment of DOJ's mistaken economic assumptions.

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[1] MacDonald Professor of Economics, M.I.T.

[2] See, e.g., Robert W. Crandall and Leonard Waverman, Talk is Cheap (1996) p.78 & n. 7.

I. DOJ's Adoption of the "Green Field" Approach to TSLRIC

3. DOJ adopts the principle that the calculation of TSLRIC should exclude "overinvestment" and should focus on the "efficient provider" standard (p. 10). But lumpy investment is not "overinvestment," contrary to what DOJ and the big IXCs have contended. By adopting the "efficient provider" standard, DOJ never recognizes the sunk nature of investments in telecommunications networks. And by not recognizing the effect of sunk costs, DOJ misunderstands how competition works in an industry with lumpy investment and technological progress [3] Application of the DOJ approach would cause a competitive firm to lose money on all of its investments. The unfortunate firm would soon go out of business.

A. Lumpy Investment and Overinvestment

4. Economists have recognized for decades that in many industries "lumpy investment" is the cost minimizing strategy. Indeed, an optimal strategy in many industries takes the form of setting an upper and lower bound on capacity utilization. For instance, if expected growth will cause capacity utilization next year to be above X% (say 90%) the rule is to do enough new investment so that capacity utilization will be at Y% (say 60%). The upper and lower bounds, X% and Y%, depend on many economic factors including the fixed cost of investment, the rate of technological progress, variation in demand, and economies of scale. The local telephone network presents an extreme situation where the distribution plant is sized so that no plant additions are expected to be required because of the extremely high cost of expansion.[4] Switches are also a lumpy investment, although they can be

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[3] DOJ's omission of a consideration of sunk costs is especially surprising given the emphasis on sunk costs in the DOJ and FTC Merger Guidelines (April 2, 1996) "Firms considering entry that requires significant sunk costs must evaluate the profitability of the entry on the basis of long term participation in the market, because the underlying assets will be committed to the market until they are economically depreciated." (¶ 3.0)

[4] However, even these plans do not always work out. For example, unexpected increased demand caused by home computers has required additional investment recently.

increased in size over the life of the switch.

5. At any given point in time, say July 1, 1996, a hypothetical network could be designed with no excess capacity. The cost of this network, which DOJ advocates as the correct cost standard, will be less than that of any real world network that serves the same amount of demand. But the DOJ network will not be the economically efficient network for July 2, 1996 or July 1, 1997 or any other date. As soon as demand grows, the trenches will have to be opened to expand transmission lines, the switches will need new line cards and other expansion items, and other costs of expansion will have to be undertaken. Thus, what DOJ claims is overinvestment is instead the cost minimizing approach to network expansion given the lumpiness of investment in local telephone networks.[5]

B. Sunk Investment with Technological Progress

6. The "green field" approach advocated by DOJ is especially poor economic analysis in the presence of sunk costs and technological progress. Consider the following example where a competitive firm sets prices according to the TSLRIC standard put forward by DOJ. A new company, DOJ Telcom, decides to enter the Internet access business. The company buys a switch (router) which costs $10,000. It expects to serve 100 customers each year with variable costs of $500 per year. The firm's cost of capital is 10% and it expects to use the router for 5 years at which time the resale (scrap) value of the router will be zero.[6] The discounted cost of the project over 5 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, DOJ's advice to the Commission would be to set

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[5] I am not claiming that no network engineer ever made a mistake or that actual growth is not sometimes less that expected growth due to unexpected economic downturns. However, ILECs have no economic incentive to overinvest in their networks given the incentive type of regulation adopted by the FCC and the majority of the state PUCs.

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

the price at TSLRIC, or $31.38 per year. Unfortunately, the company will lose money at this price and so the investment will never be made. I now explain the two reasons for this conclusion.

7. First, the price of routers, switches, fiber optic electronics, and other telecommunications equipment is decreasing with technological progress. I will 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, DOJ Telcom, will be forced to decrease its price by $2.64 and it will lose money on each customer (taking the cost of capital into account). Indeed, DOJ Telcom can expect to lose $760 on the project in that year. The story will continue the next year when the router price falls to, say, $8000. Thus, TSLRIC prices causes the initial entrant to lose money even in a world of complete certainty. Instead of charging $31.38 for each year as TSLRIC implies, DOJ Telcom must charge decreasing prices over the 5-year horizon of $36.65, $33.75, $30.85, $27.95, and $25.04, due to competition. Where did DOJ Telcom go wrong?

8. For sunk investments, it has been known in the economics literature since at least 1963 that the change in the price of the equipment needs to be included in the cost of capital.[7] However, TSLRIC does not include this factor. Instead, TSLRIC assumes a monopoly situation where no new entry can force down price and where regulators can base prices on historical cost as they did for decades using rate of return regulation. Thus, it is incorrect that TSLRIC leads to competitive market prices. TSLRIC is designed for monopoly regulation, not for the competition in the presence of technological progress. For DOJ Telcom, the competitive price would not be the TSLRIC answer of $31.38. Rather, DOJ Telcom must charge $36.65 the first year and then decrease its price to $33.75 the next year, and so on, because of the

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[7] See D. Jorgenson, "Capital Theory and Investment Behavior," American Economic Review, 53:247-259, 1963.

decreased price of the router.[8] Thus, the TSLRIC price is too low by about 17% for the first year because it ignores the falling price of capital goods.

C. Sunk Investment with Uncertainty

9. My example assumed complete certainty. However, uncertainty over future economic events must also be considered. The DOJ Telcom Internet service could face competition in the future from cable TV-based Internet services and from wireless-based Internet services. If this new entry occurs, the price of Internet services is likely to decrease. Since DOJ Telcom's investment is sunk, when it lowers its price it will not recover its investment. Thus, DOJ Telcom will lose money. Good luck could strike and increase demand for Internet services. However, price is unlikely to increase because new entry or expansion by existing companies will at best keep price near its original level. Thus, uncertainty will create an additional risk premium which will need to be included in the original investment decision. Competition with the current technology places a ceiling on the price and cuts off the "upside potential" of the investment, but new technologies with lower costs and prices will create "downside potential" which must be paid for. The premium due to uncertainty is substantial for long-lived sunk investments, as I discussed in my previous statement.[9]

10. Thus, DOJ in its TSLRIC recommendation has ignored both technological progress and the effect of uncertainty, two economic factors that are very important in analyzing the future of telecommunications. DOJ has also ignored yet another factor. In competitive markets, unexpected shifts in demand can lead to higher prices for a given period of time before new entry occurs. However, regulation eliminates these possible upward price movements and so lowers the expected value of an investment relative to the

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[8] This decreasing price over time with technological progress is observed in the semiconductor industry, e.g. microprocessors, and many other industries.

[9] Note that this uncertainty premium is calculated for a risk neutral firm.

competitive situation.[10] If price regulation continues for any of the services offered by ILECs, DOJ has further biased the results against the ILECs by assuming the absence of regulation. DOJ's recommendation is similar to forcing pharmaceutical company shareholders to finance new drug R&D where the shareholders bear all losses for unsuccessful projects, but if a successful new drug is found the price can only be set to achieve a "normal" rate of return on that individual project. Investment in the pharmaceutical industry would quickly decline in this type of regulated situation.

II. DOJ Ignores Current Price Regulation of ILECs

11. DOJ ignores two facts which are almost universally agreed to by economists: (1) ILECs are closely regulated and no economic study has shown that FCC and state regulation have allowed ILECs to earn supra-normal (monopoly) profits, and (2) residential service is priced below any relevant measure of cost, including TSLRIC. Taking these two economic factors together, some ILEC services must be priced above costs or the ILEC will run a deficit. The realities of current telecom regulation cannot be assumed away.

A. Current Regulation Sets Some Service Prices Below Cost So That Other Service Prices Must Be Set Above Cost to Permit a Normal Return

12. DOJ recommends that no restrictions on regulatory arbitrage by resellers should be permitted. (pp. 23-31) Thus, the DOJ proposal would allow businesses that are required to use measured rate service to buy below-cost, flat-rate residential service. Indeed, a business customer could hook up a PBX to flat rate lines and send about 6 times the average business traffic over a residential line. Economists are not in favor of below-cost residential service. But regulators have created this situation. Allowing regulatory arbitrage ignores this regulatory reality. DOJ's recommendation asks the FCC to impose a substantial loss on ILEC shareowners, rather than

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[10] The DOJ discussion of competitive markets (p. 20) with uncertainty fails to note that regulated markets differ because regulation removes the upside potential by placing an upper limit on prices.

correctly recommending that regulatory subsidies first be eliminated, before arbitrage restrictions are eliminated.

13. Currently, interstate access rates are well above cost in order to help cover the joint and common costs of the network, and to support local residential rates that are generally below cost. According to my analysis, the correct way to move access prices closer to LRIC is to increase the residential SLC.[11] Good economic efficiency reasons exist for this change, and almost all the economists at the FCC forum on May 20, 1996 agreed that the SLC should be increased and access prices decreased. But DOJ does not call for regulatory reform; instead, it states that no restrictions should be permitted on access arbitrage (pp. 24-25). DOJ fails to note that access revenues are at least 30% of the ILECs' net revenues, so that elimination of these revenues without replacement would create a significant economic problem for ILECs.

14. DOJ is implying that the FCC has not done its job. For ILEC revenues to decrease by 30% with no economic or financial problem implies that the FCC has permitted ILECs to earn supra-normal profits currently. Otherwise, such a change would not satisfy the Telecommunication Act of 1996 that the ILECs recover their "reasonable costs", let alone earn a "reasonable profit". DOJ has not shown that ILECs have earned supra-normal profits which should be decreased by changes in regulation. To the contrary, there is no evidence that ILECs have earned anything above normal, risk-adjusted returns, which is the usual economist's test for the exercise of market power.[12] Regulatory distortions should be removed, but changes must be balanced by raising other prices to cost. DOJ instead again endorses a "green field" approach for services currently priced above cost and takes no account of how current regulatory policy forces ILECs to offer other services below cost.

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[11] See J. Hausman, "Proliferation of Networks in Telecommunications", in W. Sichel and D. Alexander, Networks, Infrastructure, and the New Task for Regulation, (University of Michigan Press, 1995).

[12] This is the proper test where data exist to do the calculations.

B. DOJ's Estimates for Residential Consumers Defy Economic Reality

15. DOJ estimates that its recommendation will benefit consumers by $12 billion, or more, annually. (p. 31, p. A3) DOJ makes a fundamental economic error in its estimation procedure. It bases its cost estimate on the Hatfield model, but the Hatfield model does not describe any real telephone network. The Hatfield model attempts to estimate costs for a hypothetical, new, local telecommunications network.[3] However, ILEC costs, including forward looking costs (LRIC or TSLRIC), depend on existing networks. For example, Hatfield estimates that a "green field" network can provide a loop at $8.26 per month while Pacific Bell, for example, estimates its LRIC to be $15.07 per month.[14] DOJ never analyzes whether the Hatfield loop cost estimates are close to reality; it just accepts them. If Hatfield were correct, an economist would expect Hatfield's clients, AT&T and MCI, to begin construction of their own networks. Instead, AT&T has announced it plans mainly to resell ILEC services. Market actions speak much more clearly than simulation models, especially when the models are constructed for advocacy purposes.

16. DOJ also claims that both intrastate and interstate toll service prices would fall, leading to a savings of $12 billion per year, without any change in the current level of basic local service for residential customers. This statement also defies economic reality. IntraLATA toll and interLATA access are both priced above cost to provide contribution (subsidy) for coverage of various joint and common network costs and for below-cost, local, residential service. However, DOJ's calculation comes to the incredible conclusion that basic residential service receives almost no current subsidy based on a TSLRIC calculation from the Hatfield model (DOJ Reply Comments, p. A-5) This estimate is inconsistent with almost all estimates that I am aware

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[13] The Hatfield model assumes an unrealistically high capacity utilization figure and assumes that the network is put into place instantaneously which unrealistically biases cost estimates downwards. But networks are not put into place instantaneously; they grow over time.

[14] Hatfield Model, May 30, 1996 version. Pacific Bell submission to CPUC, California Universal Service Subsidy Proceeding, 1996.

of and certainly with what regulators believe. If DOJ were correct, ILECs should be earning supra-normal profits, which they are not.

17. DOJ then assumes that access would decrease to incremental cost, causing both intrastate and interstate long distance prices to decrease. These estimates are incorrect for two reasons. First, they assume that long distance prices decrease with no corresponding increase in local rates. Thus, DOJ rejects the common belief that residential local service receives a subsidy which I discussed above. DOJ's second mistake is to assume that there are no joint and common costs between local service and long distance access. To the contrary, the common costs are quite large since the same switches, central offices, and feeder plant are used to provide both local service and long distance access. DOJ has recognized previously that joint and common costs exist, but DOJ doesn't include them in its current estimate. With competition a competitive firm must still cover its joint and common costs or it will not survive.

18. Unfortunately, DOJ does just the wrong calculation. Consumer welfare would increase with regulatory reform which (1) increases the SLC, i.e. the price of basic local service, and (2) reduces long distance access. The reason for the welfare gain is because the price elasticity of local access is very near zero (-.005) while the price elasticity of long distance is significantly higher.[15] Indeed, I have calculated the gains in consumer welfare and economic efficiency from this kind of regulatory reform.[16] Thus, more efficient pricing of telephone services does lead to a gain to consumers of over $1 billion per year. But, DOJ is not evaluating more efficient pricing of telephone services in their estimate. DOJ is merely assuming a transfer of surplus from ILECs to consumers. But this transfer will not occur in the real world because there is no such surplus to be transferred. DOJ's

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[15] See J. Hausman, et. al., "The Effect of the Breakup of AT&T on Local Telephone Penetration", American Economic Review, 1993 for the elasticity estimates.

[16] See J. Hausman, "Proliferation of Networks in Telecommunications", op. cit.