Economic Depreciation and the Regulated Firm under Competition and Technological Change

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Abstract
Capital recovery is increasingly important to utilities, especially telephone companies, when technological change and competitive entry are occurring. In the absence of efficient capital recovery policies companies are going to see their equity eroded. In addition to losses by the companies there are likely to be losses to ratepayers in the form of reductions in service quality and higher rates in the future. To address the above problem this paper first reviews economic depreciation and capital recovery in the simple case of a regulated single product monopoly facing competitive entry. It employs the concept of economic depreciation to show how capital recovery policies will be front-loaded. It also develops the concept of the window of opportunity for capital recovery. There is a limited time for regulators to take remedial action, and if timely action is not taken there is no alternative but for the company to fail to recover some of its capital. These results are shown under both traditional rate of return and price caps.

1. Introduction

The economic theory of depreciation has long been of interest to economists, as evidenced by the early contributions of Fisher (1906) and Hotelling (1925). Recently, the importance of depreciation to regulated firms and the effects of depreciation policies on them has been examined by Awerbuch (1989), Burness and Patrick (1992), Rogerson (1992), and Schmalensee (1989). The purpose of the present paper is to examine the consequences for the regulated firm of alternative depreciation policies when the firm faces technological progress and competition in some of its product lines.

The normal way of evaluating alternative depreciation policies is to employ a discounted cash flow analysis. The approach becomes more interesting when technological progress and competition are present. As implied by Hotelling (1925), the former means that economic depreciation will be front-loaded (or accelerated), while competitive entry
provides restrictions on the price of output produced by an asset and therefore on the timing of cash flows generated by the asset.

The notion of the regulated firm facing competition in some of its lines of business and operating under conditions of technological change is common in regulated industries. For several years, local telephone companies and AT&T have faced this problem. Local exchange carriers (LECs) still are tightly regulated, with depreciation figuring significantly in the process. We show here how economic depreciation and capital recovery are affected by competition for both the traditional rate-of-return (RoR) regulated firm, as well as the regulated firm facing price-cap regulation as envisaged in the current United States model for telecommunications.

Section 2 provides an optimization model which illustrates the rather general applicability of the concepts of economic depreciation and relates these to competitive firms, to the RoR firm facing technological progress, and to the price-level regulated firm. It is shown that, under conditions of competition and technological progress, front-loading of capital recovery is essential if the regulated firm is to remain viable. In addition, if the introduction of accelerated capital recovery is delayed by regulators, they may effectively vitiate any opportunity of the firm to recover its invested capital. The breathing space, or period of time, that the regulators can delay introducing the application of efficient capital recovery without ultimately compromising the firm’s ability to recover its invested capital is called the “Window of Opportunity” (WOO). This same window of opportunity requires that the level of depreciation initially be set optimally. There are limited opportunities in the future, under technological change and competition, to rectify mistakes made now. Thus, in the case of price-cap regulation, if depreciation is set solely based upon the status quo, the initial price cap may be set at too low a level to allow full capital recovery. Section 3 summarizes our results and contrasts them with recent contributions to the literature. In addition, we suggest extensions of the analysis for future research. Our final remarks are normative, with a brief list of changes implied by our analysis for regulatory policy and firm behavior.

2. A Model of Economic Depreciation and Technological Change

In this section, we provide the basic framework for analyzing economic depreciation under technological change. The effects of technological change are captured by assuming that the same output can be produced in the next period more cheaply than in the current period. Thus, in a competitive market with free entry, new entrants can produce more cheaply than incumbents. Accordingly, the price of output declines and the cash flows from assets decrease over time with technological change. Formally, we assume that the price of output at time \( t \) is given by

\[
P(t) = e^{-\gamma t} \, P_0,
\]

where \( P_0 \) is the initial price.

We assume that a firm purchases an asset having an “original cost” of \( Z \) at time \( t = 0 \), and that the asset allows production of (a maximum) output of \( X \) units per year, where the firm can sell all \( X \) units as long as its price is not greater than \( P(t) \) and otherwise can sell nothing. Denote the value of the asset at time \( t \) by \( V(t) \), which is the net present value of cash flows.
Assuming no inflation, and with price of output given by (1), the value \( V(t) \) of the asset a time \( t \) is given by

\[
\int_t^T e^{-(r-\gamma)\tau} P(\tau) X \, d\tau = V(t),
\]

(2)

where \( r \) is the firm's cost of capital. Note that \( V(0) \) is not necessarily equal to \( Z \).

Following Hotelling, define economic depreciation \( D(t) \) as the change in value of the asset in the period \( t \) to \( t+\Delta \) as

\[
D(t, t+\Delta) = V(t) - V(t+\Delta).
\]

(3)

Thus, instantaneous economic depreciation at time \( t \) is \(-dV/dt\) or, using (1)-(2),

\[
D(t) = -\frac{dV}{dt} = \int_t^T (e^{-r\tau} P_0 X) e^{-(r-\gamma)\tau} \, d\tau = \frac{P_0 X}{r+\gamma} (\gamma e^{-\gamma \tau} + re^{r(t-(r-\gamma)\tau)}).
\]

(4)

Technological change and \( r \) determine whether economic depreciation is "front loaded" \((dD/dt \leq 0)\). In particular, if \( r \leq \gamma \), the depreciation schedule is everywhere front loaded.

If \((\gamma/r)^2 \leq e^{-(r-\gamma)T}\), the economic depreciation schedule is everywhere increasing, i.e., "end-loaded" \((dD/dt \geq 0)\). Otherwise, economic depreciation first decreases and then increases, i.e., the economic depreciation schedule is both "front-loaded" and "end-loaded." Under RoR regulation, economic depreciation schedules will normally not obtain; rather, straight-line depreciation is typically employed. As we now show, this may lead to a number of problems for capital recovery when competition is present.

2.1. Rate-of-Return Regulation and Depreciation

We assume zero operating costs and straight-line (S-L) depreciation.\(^3\) A RoR regulated firm is constrained in the time path of revenues it may charge because of the effects of S-L depreciation and limitations on the rate of return it is allowed to earn in any period. The firm will be allowed to earn revenues in period \( t \) of

\[
R(t; s) = \frac{Z}{T} + s\left(Z - \frac{Z}{T}\right) = \frac{Z}{T}[1 + s(T-t)],
\]

(5)

where \( s \) is its allowed RoR and where depreciation is uniform and equal to \( Z/T \). However, actual revenue may be less than this, since price may not exceed \( P(t) \). Thus, actual revenues earned will be

\[
R(t; s) = \text{Min} \{e^{-\gamma} P_0 X, R(t; s)\},
\]

(6)

since \( P(t) = e^{-\gamma} P_0 \). Under assumptions developed below (see footnote 4), the effect of S-L depreciation and RoR regulation of a competitive firm is to reduce the firm's cash flow in the early years. In later years, the actual cash flow, \( e^{-\gamma} P_0 X \), may be less than \( R(t; s) \), making it impossible for the firm to recover capital by RoR regulation and S-L depreciation. Thus, with technological change and competition, the regulators may only have a limited time to change depreciation policy if the firm is to recover its capital fully. We refer to this limited time as the "window of opportunity" (WOO) available for recovery of capital.
To formalize WOO, we define WOOPS as the latest time \( w \) at which the firm can still earn its cost of capital, \( r \), assuming that the firm is unregulated for \( t \geq w \). We call this point WOOPS or “the time at which the window of opportunity is past,” because a firm which cannot earn a competitive return cannot attract the necessary capital for its continued operation. We illustrate the problem in Figure 1. There we show three revenue paths: the unregulated or competitive revenue path \( P(t;X) \) and the two revenue paths, \( R(t;s) \) and \( R(t;r) \), corresponding to (5) for the allowed rate of return, \( s \), and the cost of capital, \( r \), where we assume \( r \leq s \). We also show the revenue crossover points \( \hat{t}(\gamma, r) \) and \( \hat{t}(\gamma, s) \) where the regulated and unregulated revenue paths cross, e.g., for the allowed rate of return \( s \), \( \hat{t}(\gamma, s) \) is characterized by

\[
e^{-\hat{t}(\gamma, s)} P_0 X = \frac{Z}{T} \left[ 1 + s(T - \hat{t}(\gamma, s)) \right].
\]

(7)

As shown in Figure 1, WOOPS must occur before the revenue crossover point \( \hat{t}(\gamma, r) \) at which the revenue requirement \( R(t;r) \) implied by RoR/S-L just equals the competitive revenue \( P(t;X) \). To see this, we simply note from (5)-(6) that if the firm’s RoR/S-L price never exceeds the competitive level, its revenues will be precisely \( R(t;r) \) so that it will earn exactly its cost of capital, \( r \). Thus, if the firm ever encounters the competitive pricing constraint, it will clearly earn less than \( r \). To characterize WOOPS, we first define the function \( F(M;\gamma, r, s) \) as follows:

\[
F(M;\gamma, r, s) = \int_0^M e^{-r} R(t;s) dt + \int_M^T e^{-(r+s)} P_0 X dt.
\]

(8)
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\( F(M; \gamma, r, s) \) is just the discounted value, at rate \( r \), of the revenues obtainable to the firm if it is allowed to earn the regulated revenues determined by (5) until time \( M \) and thereafter if it earns the competitive revenues \( P(t)X \). Note, however, that this revenue trajectory is not feasible if \( M \) is greater than \( \hat{R}(\gamma, s) \), since the firm cannot charge more than the competitive price \( P(t) = P_0 e^{-rt} \) after \( \hat{R}(\gamma, s) \) and, by definition, \( R(t; s) > P(t)X \) for \( t > \hat{R}(\gamma, s) \), as shown in figure 1. From this observation, we have two possible cases:

Case i: \( F(\hat{R}(\gamma, s); \gamma, r, s) > Z \)

In this case, the allowed rate of return is sufficiently high and competition and technological progress sufficiently unconstraining that the firm can earn its cost of capital by following the allowable revenue trajectory \( R(t; s) \) until \( \hat{R}(\gamma, s) \) and then, as it must, switching to the competitive revenue trajectory \( P(t)X \). In this case, full capital recovery occurs, and the regulator does not have to be concerned about WOO or WOOPS.

Case ii: \( F(\hat{R}(\gamma, s); \gamma, r, s) \leq Z \)

In this case, we see from (8) and figure 1 that, even if the firm follows its maximum allowable revenue trajectory \( R(t; s) \) until \( \hat{R}(\gamma, s) \) and then, as it must, switches to the competitive revenue trajectory \( P(t)X \), it cannot earn its cost of capital \( r \). If it is to earn its cost of capital, it must therefore earn more than \( R(t; s) \) during some interval prior to \( \hat{R}(\gamma, s) \). To fix a scenario, suppose that the firm follows \( R(t; s) \) until some point in time \( w > 0 \) and then becomes unregulated and follows the revenue path \( P(t)X \) for \( t \geq w \). From (8) and the above logic, the latest point in time \( w \) at which this switch could occur and still allow the firm to recover its capital is then given by the solution \( w \in [0, \hat{R}(\gamma, s)] \) to

\[
F(w; \gamma, r, s) = Z \tag{9}
\]

With an eye on (8), equation (9) indicates that the firm earns a return of exactly \( r \) over the asset’s life if the firm becomes unregulated at time \( w \leq \hat{R}(\gamma, s) \). Assuming that there is a solution \( w \in [0, \hat{R}(\gamma, s)] \) to (9), we can characterize this \( w = \text{WOOPS} \) by integrating (8), using (5), to obtain \( w \) as the solution to

\[
\frac{P_0 X}{r + \gamma} \left[ e^{-(r+\gamma)w} - e^{-(r+\gamma)T} \right] + Z \left[ \frac{r s T + r - s}{r T} \right] \left( 1 - e^{-r w} - \left( \frac{sw}{r T} e^{-r w} \right) \right) = Z. \tag{10}
\]

To see whether (9) has a solution in the interval \([0, \hat{R}(\gamma, s)]\), note the following. If the l.h.s. of (9) (i.e., \( F(w; \gamma, r, s) \)) is less than \( Z \) at \( w = 0 \), then the firm can never earn its allowed rate of return, since (see figure 1) if the firm cannot recover its asset cost \( Z \) when charging the competitive price from \( w = 0 \) onward, then it cannot recover its capital if required to charge the regulated price (which is less than the competitive price for \( t < \hat{R}(\gamma, s) \)) for the time period \( t \in [0, w] \), and then follow the competitive price trajectory for \( t \in (w, T] \). But the l.h.s. of (9) (or equivalently of (10)) is less than \( Z \) at \( w = 0 \) precisely when

\[
\frac{P_0 X}{r + \gamma} \left( 1 - e^{-(r+\gamma)T} \right) < Z, \tag{11}
\]
so that when (11) obtains, the firm cannot earn its cost of capital; its window of opportunity is already closed at time 0. Thus, assuming (11) does not obtain and that $F(t(\gamma, t); \gamma, r, s) \leq Z$ (our Case ii assumption), there is a unique WOOPS = $w(\gamma, r, s) \in [0, t(\gamma, t)]$. The comparative statics of $w(\gamma, r, s)$ are intuitive from figure 1 and are given by

$$\frac{\partial w}{\partial \gamma} < 0, \frac{\partial w}{\partial r} < 0, \frac{\partial w}{\partial s} > 0.$$ (12)

A few observations on the above are in order. First, we have derived WOO and WOOPS for capital recovery at the firm’s cost of capital, $r$. A similar analysis is straightforward for the WOO and WOOPS corresponding to the firm’s allowed rate of return, $s$. One need only substitute $r = s$ everywhere in the above analysis to obtain the results for this case. Note in particular from (12) that $r < s$ would imply that the window of opportunity for recovering capital at the firm’s cost of capital may be somewhat longer than that for recovering its allowed rate of return. Regarding figure 1, we see that the regulator might therefore provide relief on capital recovery grounds either by increasing the allowed rate of return, $s$, or by increasing the allowed rate of capital recovery by accelerated depreciation allowance. Either of these will increase the achievable cashflows early on, before competitive forces make this infeasible.

The simple model of (1-11) has shown that, in the presence of technological change, where a regulator employs S-L depreciation with RoR regulation of a firm facing competition, the regulator faces a number of constraints, violation of which result in under-recovery of capital. If the industry is genuinely competitive, this under-recovery will result in disinvestment in the industry, which is the competitive capital market’s response to the signal of under-recovery.

The main impact of the above analysis is not to be found on RoR regulation of purely competitive or purely monopolistic industries, but rather where an RoR regulated monopoly faces competition in some of its activities but remains a traditional monopoly in others. In such cases, WOOPS may occur in some parts of the business but not others. As the regulator bases regulation on the whole firm, the whole rate base, the regulator may allow recovery of capital from the monopoly customers even though WOOPS has occurred for the other part of the business. This would imply distortion in resource allocation, and cross subsidies of competitive services by the monopoly services.

2.2. Price-Cap Regulation and Depreciation

In view of the importance currently being attached to price caps as a means of resolving the regulatory and entry problems faced by telephone companies, we are now going to show that the above problems also apply under price-cap regulation. Assume again zero operating costs. We suppose that one of the firms (hereafter "the firm") in the market is required to set prices no higher than $PC(t)$, the price cap in effect at time $t$, so that the firm’s price must be no greater than $PC(t)$ and, of course, also no greater than $P(t)$ given in equation (1). We assume that the price cap $PC(t)$ is computed along similar lines to price caps currently employed, for example, with British Telecom, AT&T, and the FCC plan for Local Exchange Carriers (LECs), which require that prices decline in real terms by the amount of an "X-factor." In terms of our model this is achieved by means of the following:
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\[ PC(t) = e^{-\xi t} PC(0), \]  

(13)

where \( \xi \leq \gamma \). In particular, note that \( dPC(t)/dt = -\xi PC(t) \), i.e., the firm's prices are required to decrease at a rate at least equal to \( \xi \). To relax the price cap, the regulator must increase \( PC(0) \) or decrease \( \xi \). Now assuming no interaction of the firm's present price with its future market share, it is clear that the optimal price for the firm to charge is simply

\[ P^*(t) = \text{Min} \left[ P(t), PC(t) \right] = \text{Min} \left[ e^{-\gamma t} P_0, e^{-\xi t} PC(0) \right]. \]  

(14)

since the firm has nothing to gain from charging a lower price than allowed.

Let us now consider the relationship between competition, technological change, and price caps with capital recovery. The effect of price caps is to reduce the firm's cash flow in the early years, when \( e^{-\gamma t} P_0 \) is still greater than \( e^{-\xi t} PC(0) \), so that the competitive price is not an effective constraint on the firm's pricing. As technological change lowers the market price \( P(t) \) below the effective price cap \( PC(t) = e^{-\xi t} PC(0) \), the firm will end up with an actual cash flow of \( e^{-\gamma t} P_0 \) which may make it impossible for the firm to recover its capital. Thus, with technological change and competition, regulators may have only a limited time in which to allow the firm to price so as to fully recover its capital. After this "window of opportunity" has closed, competition will effectively have foreclosed the possibility that the firm can ever recover its capital. It should be clear from the structure of price-cap regulation that regulators can effect the window of opportunity in two ways:

1. The regulator can change the initial price cap index \( PC(0) \).

2. The regulator can give the firm the benefits of a larger share of their relative productivity increase by decreasing \( \xi \) (known in price-cap regulation as "the X-factor").

To characterize the window of opportunity formally, let us define \( w \) as the latest time at which the firm can still earn a competitive rate of return \( r \); assuming that the firm is unregulated for \( t > w \) (i.e., price-cap regulation is removed at time \( w \)). Clearly the window of opportunity \( \text{WOO} = \text{WOO} \) is the interval \( [0, w] \). After time \( w = \text{WOOP} \), it will be too late to make up any depreciation reserve deficiency accrued at that point, since the effective price for the firm after time \( w \) will be dictated by competition. Let us now characterize \( w \).

Define \( t^* \) as the point at which the competitive pricing constraint just becomes effective, i.e., \( P(t^*) = PC(t^*) \) in (14) with \( P^*(t) = P(t) \) for \( t > t^* \). Now clearly \( w \leq t^* \), since \( w \) is defined as the latest point at which a switch to the price trajectory \( P(t) \) will still yield a competitive rate of return \( r \) and the firm must switch to \( P(t) \) no later than \( t^* \) since price is dictated by competition thereafter. Thus, \( w \) is characterized by the solution \( w \leq t^* \) satisfying

\[ \int_0^w e^{-\gamma t} PC(t) X \, dt + \int_w^{T} e^{-\gamma t} P(t) X \, dt = Z, \]  

(15)

which can be rewritten, using (1) and (13), as

\[ \int_0^w e^{-(r+\xi) t} PC(0) X \, dt + \int_w^{T} e^{-(r+\gamma) t} P_0 X \, dt = Z. \]  

(16)

It is straightforward to show that either no solution \( w \) exists to (16), which means that the window of opportunity is already past, or there is a unique solution \( w \) in the interval \( [0,T] \).
In the event that no solution exists, clearly the price cap must be relaxed (e.g., upon initiation either through an increase in \(PC(0)\) or a decrease in the X-factor, \(\xi\)) in order to recover capital fully.

When a solution \(w \in (0,T)\) to (15) does exist, it can be established that the following comparative statics results hold:

\[
\frac{\partial w}{\partial \xi} < 0, \quad \frac{\partial w}{\partial PC(0)} > 0, \quad \frac{\partial w}{\partial \gamma} < 0, \quad \frac{\partial w}{\partial P_0} > 0, \quad \frac{\partial w}{\partial \sigma} < 0
\]  

(17)

Thus, the window of opportunity for capital recovery decreases as the X factor \(\xi\) increases; as the initial price (or price-cap) level \(PC(0)\) decreases; as the competitive price level \(P_0\) decreases; as the rate \(\gamma\) of technological progress increases; or as the firm’s cost of capital increases. These facts are in line with intuition. Essentially, as technological progress or the stringency of competition increases, it becomes increasingly important to adjust price caps upwards early or the window of opportunity WOO may shrink to zero.

### 3. Implications for Policy and Future Research

While the motivation for the study of capital recovery has clearly come from the problems facing LECs, it also applies to other industries facing competition and technological change, for example, postal service, and possibly to other partially deregulated firms. As some of our results are apparently quite different from the earlier literature, we will now review briefly their significance and application.

Our analysis differs from others in that we have explicitly incorporated the effects of competition and technological change. Then matters change significantly, as we showed in Section 2 for a single market and a single asset. We demonstrated how technological change interacts with competition in affecting feasible capital recovery policies. Under these conditions, accelerated depreciation is required to assure full capital recovery. Moreover, the more rapid the technological change and the stronger the competition facing the firm, the sooner the time the regulator and the firm have to change depreciation policies if the firm is to recover its capital. This notion of a “window of opportunity” is particularly foreign to regulators and regulated companies. Traditionally there has always been the sense among regulators and utilities that problems could be put right “at the next rate case.” This state of mind is clearly inappropriate in a world of competition and technological change.

Further research would include extending this model to two goods, one of which is sold in a competitive (by-pass) market. This is likely to be complicated, as it will have to take into account market dynamics and will require a simultaneous analysis of not only capital recovery policy but pricing policy. The regulatory implications are likely to be similar to the above analysis. These are that regulatory authorities can act in a penny-wise, pound-foolish manner with respect to capital recovery; attempts to decelerate capital recovery, when anticipated by the regulated firm, lead to under-investment, cost increases, and welfare decreases. They may also lead to viability problems for the firm to the extent that competitive forces become the driving force in pricing, thus preempting regulatory capital recovery pricing trajectories.
Our results stand out in contrast to the results of other recent contributors to the literature, notably Schmalensee (1989) and Rogerson (1992), whose analyses provide important contributions on the role of depreciation in the traditional RoR firm. In particular, our results appear quite different from the "invariance principle" of Schmalensee. The difference arises in part from the strong assumptions made by Schmalensee. He assumes that the regulator always allows the firm its cost of capital and the firm always earns its cost of capital. In addition, he expressly excludes competition and technological change. In principle, as long as his strong conditions on the firm earning its cost of capital are present, then the invariance principle will apply and depreciation takes on less significance. However, assuring this is very difficult under traditional RoR regulation, and is likely to be effectively impossible under conditions of competitive entry in some market(s), as envisaged here. One interpretation of our results is that the "invariance principle" must be reinterpreted to be a "constrained invariance principle" under conditions of competition and technological change. Thus, at least when WOOPS is greater than zero, there still exists a wide class of depreciation schedules, each assuring full recovery of capital at the firm's cost of capital, \( r \). However, as we have seen, this class may need to be significantly more accelerated than traditional S-L methods, i.e., the invariance principle holds only for a restricted class of depreciation schedules under the conditions of this paper.

Similarly, our results differ from those of Rogerson (1992) again because of differences in assumptions. His treatment differs from Schmalensee in that he allows the firm to earn something different from its cost of capital by explicitly incorporating regulatory lag in his analysis. His "least acceleration principle" (LAP)—which implies end-loaded depreciation rather than front-loaded depreciation—shows that if there is regulatory lag, but no competition and technological change, then LAP depreciation is optimal in providing the right incentives for investment. Note that in Rogerson investment is definitely cost reducing as in the present paper. His analysis—modified to take taxes into account—may be relevant to electric utilities facing limited competition and now very slow technological change.

While we do claim that our results are important for regulated firms facing competition and technological change, we certainly are not going to claim the last word on this critical subject. Indeed, we hope that further research will be stimulated in this area and companies and regulators will immediately take steps to resolve the practical problems of introducing efficient capital recovery schedules. In this regard, the recent interest in incentive regulation in the form of price caps may indicate some progress. However, as we have demonstrated, the mere introduction of price-cap regulation in itself will not solve the capital recovery problem. Such reforms in regulation must strike a proper balance between the transactions cost of regulation and the benefits of intervening in the interconnected capital recovery, investment, and price-setting policies of the (partially) regulated firm.

Notes

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1. This is a strong assumption, made for analytical simplicity. More generally, the regulated firm is likely to face an elastic demand curve, e.g., based on a model of a competitive fringe or oligopolistic competition. Introducing nonzero demand elasticity would complicate the analysis without altering its basic conclusions. We should note, however, that if the regulated firm has considerable residual market power relative to competitors, then the conclusions we draw here on capital recovery problems would be less stark. On the other hand, if competition occurred in the more profitable lines of business, and the regulated firm, because of traditional obligations to serve, ended up with the less profitable business, then capital recovery would be more difficult. Such multi-product, competitive effects are not analyzed in this paper.

2. In particular, if technological progress is absent (γ = 0), then economic depreciation schedules are end-loaded, as in Rogerson (1992).

3. A similar analysis would obtain for other depreciation methods. However, as will become clear below, the impact of technological change and competition on the regulated firm's capital recovery would be ameliorated if more accelerated depreciation methods were allowed. Since the point of our analysis is to emphasize the importance of allowing accelerated depreciation methods under conditions of technological change and competition, the use of S-L depreciation as the benchmark seems the appropriate starting point.

4. We are assuming here that \( \bar{r}(\gamma) < \gamma \) so that WOOPS occurs before the end of the life of the asset \( Z \). If competition is sufficiently slack so that the RoR-S-L price constraint (corresponding to the cost of capital, \( r \)) lies everywhere below the competitive price, then \( \bar{r}(\gamma) \geq \gamma \) and the window of opportunity is non-binding—WOOPS never occurs. As discussed below, WOOPS may also not occur if the allowed rate of return, \( s \), is sufficiently greater than \( r \).

5. In view of the assumption that \( s > r \), it is conceivable that the firm might be able to earn its cost of capital, \( r \), even if WOOPS = 0 for its allowed rate of return, \( s \). However, empirical evidence suggests that in practice \( s \) is not likely to be significantly greater than \( r \) (Thompson 1991). Note that if WOOPS = 0, then the firm will not earn the cost of capital, \( r \), through its investments in the asset \( Z \). In this case, unless \( s \) exceeds \( r \) by a significant amount, the firm may not invest in \( Z \) at all, unless obligated to do so.


References


