"Depreciation and Resource Allocation in the Regulated Firm: A Dynamic Analysis with Technological Change"

90-06-05

Michael Crew and Paul Kleindorfer
Depreciation and Resource Allocation in the Regulated Firm:

A Dynamic Analysis with Technological Change

Michael A. Crew and Paul R. Kleindorfer*

June 1990

* The authors are respectively, Professor of Economics, Graduate School of Management, Rutgers University and Professor of Decision Sciences, The Wharton School, University of Pennsylvania. They would like to thank Noel Doherty, Terry Cooney and Dan Lane for helpful comments on an earlier version.
INTRODUCTION

After the notable early contributions of Fisher [1906] and Hotelling [1925], economists essentially abandoned the theory of depreciation. The dominant view appears to be that depreciation policies are the arcane province of accountants and should remain so. Despite the importance of depreciation to regulated firms the effects of depreciation policies on them has received little attention with few exceptions, for example, Awerbuch [1989] and Schmalensee [1999]. In this paper, we argue that depreciation policies can have important economic consequences on resource allocation and efficiency. Intuitively this is relatively straightforward to see since depreciation policy affects after-tax cash flows and returns and therefore the relative attractiveness of investments in various assets. Moreover, the normal cash flow evaluation of alternative depreciation policies become even more interesting when technological progress and competition are present. As implied by Hotelling [1925] the former means that economic depreciation must 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.

In this paper, we wish to consider these problems collectively for the rate-of-return (ROR) regulated firm facing competition in some of its lines of business and operating under conditions of technological change. These characteristics describe the current situation in telecommunications and they may be expected to spread to other areas of traditional regulatory oversight as well (e.g., the energy sector). The approach applies to the price-level or "price-cap" regulated firm, because of the proposed treatment of the depreciation under price cap regulation. Indeed price-cap regulation as currently proposed may end up with very similar consequences to ROR regulation at least with regard to depreciation and capital recovery issues. In section 1 we will begin our analysis with some simple illustrative examples intended to motivate the analytical framework and results which follow. Section 2 provides an optimization model which set out the concepts of economic depreciation and relates these to competitive firms, the ROR firm facing rapid technological progress and to the price-cap-regulated firm. We show that under these
conditions front loading of capital recovery is essential if the firm is to remain viable. Moreover, we show that if regulators delay the introduction of accelerated capital recovery long enough, they will effectively vitiate any opportunity that the firm will ever recover its invested capital. The period of time that the regulators can still delay without ultimately compromising the firm's ability to earn a fair rate of return on invested capital is called the "Window of Opportunity". This same window of opportunity applies to the price-cap regulated firm, as the fixing of the initial level of the price cap requires that the initial level of depreciation be set optimally. Thus, if depreciation is set solely based upon the status quo the price cap will be set initially at too low a level. Indeed with the built in real price reductions of the price cap it is conceivable that the proposed price-cap regulation may even reduce the window of opportunity. Section 3 concludes the paper with a discussion of some extensions to our analysis and policy implications for ROR regulation, price-cap regulation, tax policy, and new product pricing.

1. Capital Recovery Under Competition and Monopoly: Some Illustrative Examples

Accountants measure the income and expenses that occur over a particular accounting period, commonly a year. Where transactions occur wholly within the accounting period accountants can deal with them without problems. Thus the purchase of materials, the payment of wages, and the like are simply "expensed" during the accounting period. They are used solely within the accounting period in contrast to a specific asset, like a piece of machinery, which has a life over several accounting periods. Since the accountant's primary role is to provide the owner of the business with an accurate measure of net income for the period, specific assets present him with a problem. If the whole purchase price is expensed in the period it is first operated, this will represent an excessive charge to this period with a consequent understatement of income in that period and an overstatement of income in subsequent periods. Wright [1965, p81] neatly states the problem: "The problem of depreciation accounting is the problem of establishing these needed values without the objective verifiable basis which only external transactions can provide." Thus, rather than search in vain for the holy grail accountants "...reluctantly concluded that there
is no ‘true’ depreciation method, and that all the methods used or proposed are mere conventions..." [Lutz 1951, p7]. Unfortunately these "mere conventions" can cause significant distortions in resource allocation particularly for regulated firms in the presence of technological change. The essential framework for understanding such distortions was provided in the early literature on the nature of economic depreciation.

Let us now consider the implications of the concept of economic depreciation when technological change is present in an industry. In simple terms, the effect of technological change (e.g., in process technology) may be seen as lowering costs over time. This implies that the same output can be produced in the next period cheaper than it can be produced in the current period.¹ In a competitive market with free entry this implies that entrants can produce more cheaply (or at higher quality) than incumbents. Accordingly the price which the incumbent can charge per unit of output declines and the cash flows from the asset decrease over time with technological change.

The effect of technological change on a monopoly differs from its effect under competition. We compare two cases (i) a firm faced with competition, e.g. a former monopolist, like telephone operating companies, faced with entry of competitors into its business, (ii) a monopolist where entry by competitors is barred e.g. telephone companies of several years ago. In both cases technological changes results in the ability to produce the same output at lower cost with the new technology or the ability to produce a higher quality product at the same or lower relative cost as the old product. However, the effect of technological change differs completely in the two cases, as do the implications for capital recovery.

We first illustrate this by means of some simple numerical examples. Assets are considered valuable if they provide cash flows, defined as revenues per period less operating costs per period. As the effect of technological change is to reduce costs, cash flows will be affected accordingly. In Case (i) the fall in production costs results in decreased prices. From the point of view of the incumbent this means that the cash flows of his existing asset decline with technological change. Table 1 shows the

¹ Technological change may also have the effect of raising quality or enabling the introduction of new products or services. While we do not consider these issues here, they clearly have the same effect as cost reductions—the value of an existing asset is reduced by technological change.
effect of a 10 percent rate of technological change on cash flows. The faster the rate of technological change the faster the rate of decline in cash flows.

<table>
<thead>
<tr>
<th>Rate of Tech</th>
<th>Time Period</th>
<th>Potential Cash Flows</th>
<th>Asset Value Start</th>
<th>Economic Deprec’n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Change 10.00%</td>
<td>1</td>
<td>$288.73</td>
<td>$1,000.00</td>
<td>$218.73</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>$262.49</td>
<td>$781.27</td>
<td>$207.80</td>
</tr>
<tr>
<td>Internal</td>
<td>3</td>
<td>$238.62</td>
<td>$573.47</td>
<td>$198.48</td>
</tr>
<tr>
<td>Rate of Return</td>
<td>4</td>
<td>$216.93</td>
<td>$374.99</td>
<td>$190.68</td>
</tr>
<tr>
<td>7.00%</td>
<td>5</td>
<td>$197.21</td>
<td>$184.31</td>
<td>$184.31</td>
</tr>
<tr>
<td>NPV</td>
<td></td>
<td>$1,000.00</td>
<td></td>
<td>$1,000.00</td>
</tr>
</tbody>
</table>

Contrast this with Case (ii) where the monopolist can maintain constant cash flows with a particular asset, or replace it with the new technology which allows him to retain all the benefits of the new technology. Thus if he replaces his existing technology with the new technology he can get increased cash flows from the fact that operating costs are lower and revenues are the same because of the absence of competition.

To see why capital recovery policies are different in cases (i) and (ii) we first need to review the nature of economic depreciation. Economic depreciation is simply the difference in the value of an asset at the start of the period and at the end of the period. An asset’s value at any time is the discounted value of the services from the asset can still produce. Thus in Table 1 for decreasing cash flows with 10 percent rate of technological change the cash flows decline and the economic depreciation schedule requires that more of the capital has to be recovered up front. The faster the rate of technological change the more depreciation has to be collected up front. Contrast with Table 1 (next page) where the cash flows increase. Here capital is economically recovered at the end of its life—capital recovery is end-loaded.

Both Tables 1 and 2 represent polar cases. In Table 1 the effects of technological change are felt
instantaneously and the full brunt of technological change and entry are borne by the incumbent. In Table 2 the monopolist is instantly able to appropriate all the benefits of technological change. Reality would lie somewhere in between these two cases, but clearly capital recovery is significantly more constrained in the competitive case. Thus, capital recovery policies of regulated companies cannot just continue as they have in the past where regulated companies are facing entry by competitors and technological change. If depreciation schedules continue to be based on long lives and straight-line methods, the regulated firm facing competition will not recover its capital.

<table>
<thead>
<tr>
<th>TABLE 2: EFFECTS OF TECHNOLOGICAL CHANGE UNDER MONOPOLY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rate of Tech Change 10.00%</td>
</tr>
<tr>
<td>------------------------------</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Internal</td>
</tr>
<tr>
<td>Rate of Return</td>
</tr>
<tr>
<td>Return 12%</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>NPV</td>
</tr>
</tbody>
</table>

This can be seen utilizing the example in Table 1. Assume that the firm faces price cap regulation, so that price increases may not exceed (some index of) the rate of inflation minus a productivity offset, the X-factor. To make matters simple, assume zero inflation and an X-factor of 3 percent, so that price in period t+1 can be no more than 97 percent of price in period t. Let us illustrate what happens if the price cap is set too low initially in a case of free competition. If straight line depreciation of $200 were charged, the firm would under recover its capital. We illustrate this in Table 3.


**TABLE 3: EFFECTS OF PRICE CAPS WITH TECHNOLOGICAL CHANGE UNDER COMPETITION**

<table>
<thead>
<tr>
<th>Rate of Tech Change 10.00%</th>
<th>Time Period</th>
<th>Price-Capped Cash Flows = Capital</th>
<th>Actual Deprec’n Recovered</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal 1</td>
<td>1</td>
<td>$270.00</td>
<td>$200.00</td>
</tr>
<tr>
<td>Rate of Return 7.00%</td>
<td>2</td>
<td>$261.90</td>
<td>$199.41</td>
</tr>
<tr>
<td>Rate of Return 7.00%</td>
<td>3</td>
<td>$238.32</td>
<td>$198.48</td>
</tr>
<tr>
<td>Rate of Return 7.00%</td>
<td>4</td>
<td>$216.93</td>
<td>$190.68</td>
</tr>
<tr>
<td>Rate of Return 7.00%</td>
<td>5</td>
<td>$197.21</td>
<td>$184.31</td>
</tr>
<tr>
<td>NPV</td>
<td></td>
<td>$981.73</td>
<td>$972.88</td>
</tr>
</tbody>
</table>

Suppose a price cap of $270.00 (assuming $200 depreciation) is set in period 1. Assuming no inflation and an X-factor of 3 percent (so that the price cap in period 2 is 97 per cent of $270 = $261.90) the firm will under recover capital by $27.22. The problem is that around year 2, the price cap is in excess of what the competitive market will bear, forcing the company to cut its prices to the competitive level. Thus the firm fails to recover its capital because the price cap was set too low initially.

Let us now look at a slightly more complicated case. Table 4, where a firm still has some monopoly power but is facing increasing entry. Here with the price cap set at $279.89 initially the firm can recover its capital. However, if the cap is set too low initially at $270 (which would be the amount implied by straight-line depreciation) and then changed in period 4 to $223.01, which is the amount needed to make the firm whole, the firm is unable to avail itself of the relaxed price cap because of the stringency of competition in period 4. Thus, there is a window of opportunity for capital recovery under price caps. Once the window closes it never re-opens, a point which we now demonstrate through a more rigorous mathematical analysis.

---

2 We have attempted to capture residual market power by having the cash flows decay at 8% rather than the 10% that would be implied in the polar competitive case illustrated in Table 1.
TABLE 4: EFFECTS OF PRICE CAPS WITH DECAYING MONOPOLY

<table>
<thead>
<tr>
<th>Rate of Decay = 8.00%</th>
<th>Time Period</th>
<th>Potential Cash Flows</th>
<th>Asset Value Start</th>
<th>Economic Deprec’n</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>($1,000.00)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Internal</td>
<td>2</td>
<td>$279.89</td>
<td>$790.11</td>
<td>$203.85</td>
</tr>
<tr>
<td>Rate of Return</td>
<td>3</td>
<td>$259.16</td>
<td>$586.26</td>
<td>$198.92</td>
</tr>
<tr>
<td>7.00%</td>
<td>4</td>
<td>$222.18</td>
<td>$387.34</td>
<td>$195.07</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>$205.73</td>
<td>$192.27</td>
<td>$192.27</td>
</tr>
<tr>
<td>NPV</td>
<td></td>
<td>$1,000.00</td>
<td></td>
<td>$1,000.00</td>
</tr>
</tbody>
</table>

2. A SIMPLE MODEL OF ECONOMIC DEPRECIATION AND TECHNOLOGICAL CHANGE

In this section we provide the analytical framework underlying the illustrative numerical results of section 1. Throughout we will continue to employ the concept of economic depreciation. In equation (1) where we incorporate the effects of technological change. In simple terms the effect of technological change may be seen as lowering costs over time. This implies that the same output can be produced in the next period cheaper than it can be produced in the current period.\(^1\) In a competitive market with free entry this implies that entrants can produce more cheaply than incumbents. Accordingly the price of the output declines and the cash flows from the asset decrease over time with technological change.\(^2\) We incorporate this effect of technological change by assuming that the cash flows of an asset decline over time. More formally, we suppose that the firm purchases an asset of value \(V\) at time \(t = 0\), and that it faces a competitive market subject to technological change at a constant rate \(\delta\). To make matters intuitive, assume that the asset allows production of (a maximum) output of \(X\) units per year. Since the market is competitive, price at any time \(t\) will be given by
\[ P(t) = e^{-\delta t} P_0 \]  

We assume that the firm can sell all \( X \) units as long as its price is not greater than \( P(t) \) and otherwise can sell nothing.

Assuming no inflation, the internal rate-of-return earned by an unregulated firm on the asset would be given by the solution \( r_o \) to

\[ \int_{0}^{T} e^{-r_o t} P(t) X \, dt = V \]  

From (2) the expression for economic depreciation, \( D_t \), in period \( t \), readily follows:

\[ D_t = V_{t-1} - V_t \]  

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

\[ \frac{dV}{dt} = \frac{d}{dt} \int_{0}^{T} (e^{-\delta t} P_0 X)e^{-r_o (t-\delta)} \, dt = \frac{P_0 X}{r_o + \delta} \left( \delta e^{-\delta t} + r_o e^{-r_o (t+\delta)T} \right) \]  

Technological change and \( r_o \) determine whether depreciation is "front loaded". In particular if \( r_o \lesssim \delta \), the depreciation schedule is everywhere front loaded. If \( (\delta/r_o)^2 \lesssim e^{-(\delta+\delta)T} \), the depreciation schedule is everywhere increasing, i.e. "end-loaded". Otherwise, depreciation first decreases and then increases, i.e. the depreciation schedule is both "front-loaded" and "end-loaded". Let us contrast this with a ROR regulated firm.

Assuming zero operating costs, the RoR regulated firm using straight-line depreciation will be allowed to earn revenues in period \( t \) of
\[ R(t) = \frac{V}{T} + s(V - \frac{rV}{T}) = \frac{V}{T}(1 + s(T-t)) \]  \hspace{1cm} (5)

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

\[ R(t) = \min \{ e^{-\delta t} P_0 X, \ R(t) \}, \]  \hspace{1cm} (6)

since \( P(t) = e^{st} P_0 \). The effect of straight-line 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, \( e^{st} P_0 X \) may be less than \( R(t) \) making it impossible for the firm to recover capital by RoR regulation and straight-line depreciation. Thus with technological change and competition the regulators may only have a limited time to change depreciation policy if the firm is fully to recover its capital. There may only be a limited "window of opportunity" (WO) available for recovery of capital.

We define WP as the latest time \( w \) at which the firm can still earn its allowed RoR, assuming that the firm is unregulated for \( t \geq w \). We call this point WP 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. Thus, we imagine a growing capital recovery deficiency in the period \( t < w \) during which the firm is regulated and uses straight-line (S-L) depreciation. The effects of this deficiency may be so severe that if this regime is continued beyond WP, the firm cannot earn the allowed RoR even if it is completely free of regulation thereafter.

In this model, WP occurs before the revenue crossover point where, from (5)-(6), the revenue requirement \( R(t) \) implied by RoR/S-L implies a price greater than the competitive price \( P(t) \), i.e. WP occurs before the \( t \) satisfying

\[ e^{-\delta t} P_0 X = \frac{V}{T}(1 + s(T-t)) \]  \hspace{1cm} (7)
To see why this is so, we simply note that if the firm's RoR/S-L price never exceeds the competitive level, it earns exactly its allowed RoR, \( s \). Thus if the firm ever encounters the competitive pricing constraint, it will clearly earn less than \( s \). In fact, by definition WP occurs at the point \( w \) at which

\[
\int_0^w e^{-sR(t)} dt + \int_w^T e^{-(s+\delta)P_0X} dt = V
\]

since the firm will earn \( R(t) \) until \( w \) and thereafter will charge the competitive price \( P(t) = P_0e^{-st} \). Equation (8) says that the firm earns a return of exactly \( s \) over the asset's life. From (5) and (8), we obtain by integration the following expression characterizing WP:

\[
F(w) = \frac{A}{s+\delta} e^{-s\Delta} - (1 - \frac{w}{T})e^{-\Delta} = \frac{A}{s+\delta} e^{-(s+\delta)T} = C
\]

where \( A = P_0X/V \) and \( C \) = a constant. It is clear that \( w = 0 \) must obtain if

\[
V > \frac{P_0X}{s+\delta}(1 - e^{-(s+\delta)T}),
\]

since \( s \) would be higher than the competitive return. Assuming (10) does not obtain, one shows by comparative statics that WP satisfies

\[
\frac{\partial w}{\partial s} < 0, \quad \frac{\partial w}{\partial r_o} < 0, \quad \frac{\partial w}{\partial r_o} > 0
\]

The simple model of (1-11) has shown that, in the presence of technological change, where a regulator employs straight-line depreciation with ROR regulation of a competitive firm the regulator faces a number of constraints, violation of which results in under-recovery of capital. If the industry is genuinely competitive this under-recovery will result in the disinvestment in the industry, which is the competitive
capital market's response to the signal of under-recovery. However, it is not very common for most ROR regulated industries to be fully competitive. They are mostly monopolistic, in which case even with rapid technological change for a high enough $r_0$ capital could still be fully recovered, i.e. WP might never occur. In this case ROR regulation with straight-line depreciation imposes price control non-uniformly over time, reducing prices relatively in the earlier years. It does not as such lead to major resource misallocations beyond the usual effects derived from static analysis of regulation.

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 WP 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 WP has occurred for the other part of the business. This would imply distortion in resource allocation. The regulator would, in such an instance, change resource allocation and income distribution favoring current generations at the expense of future.

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 consider the impact of a price cap. Assume for simplicity 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 to account for technological progress according to the following formula:

$$PC(t) = e^{-\beta t}PC(0)$$  \hspace{1cm} (12)

where $\beta \leq \delta$. In particular, note that $dPC(t)/dt = -\beta PC(t)$, i.e. the firm's prices are required to decrease
at a rate at least equal to \( \beta \). To relax the price cap, the regulator must increase \( PC(0) \) or decrease \( \beta \).³

Now assuming no interaction of the firm’s present share with its future market share,⁴ it is clear that the optimal price for the firm to charge is simply

\[
P^*(t) = \text{Min} \{ P(t), PC(t) \} = \text{Min} \{ e^{\delta t} P_0, e^{-\beta t} PC(0) \},
\]

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 \( e^{\delta t} P_0 \) is still greater than \( e^{-\beta t} PC(0) \), so that the competitive price is not an effective constraint on the firm’s pricing. As technological change lowers the market \( P(t) \) price below the effective price cap \( PC(t) = e^{\delta t} PC(0) \), the firm will end up with an actual cash flow of \( e^{-\beta t} P X \) 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 \( PC(0) \) (or, as explained above, what comes to the same thing, they can allow the firm to adjust its initial price \( P_0 \) and cap the rate of change of prices).

³ Alternatively, we think of the price cap as regulating the rate of change of prices, as in the current FCC proposal, then relaxing the price cap can also be accomplished by increasing the initial price which serves as the basis for initiating price cap regulation.

⁴ See Crew and Kleindorfer [1986] for a discussion of the interaction of market share and price dynamics for the partially regulated firm. When present price affects future market share (e.g. if the firm charges a high price, some consumers elect competitive bypass and are lost to the firm for good), the results below on the window of opportunity will be further confounded and constrained by market share dynamics.
2. The regulator can give the firm the benefits of a larger share of their relative productivity increase by decreasing the X factor $\beta$.

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 is the interval $[0, w]$. After time $w$, it will be too late to make up any 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 (13) 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

$$\int_0^w e^{-rt}PC(t)X \, dt + \int_w^T e^{-rt}P(t)X \, dt = V$$  \hspace{1cm} (14)$$

which can be rewritten, using (13), as

$$\int_0^w e^{-(r-\beta^*)t}P(t)X \, dt = \int_w^T e^{-(r-\beta^*)t}P(t)X \, dt = V$$  \hspace{1cm} (15)$$

It is straightforward to show that either no solution $w$ exists to (15), 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 through increases in either $PC(0)$ or the initial base price) in order to fully recover capital.

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

\[ dw/d\beta < 0 \] -- as the X factor increases the window of opportunity for capital recovery decreases;

\[ dw/dPC(0) > 0 \] -- as the initial price (or price cap) level is relaxed for the firm, w increases;

\[ dw/dP_c > 0 \] -- as the competitive price level increases, w increases;

\[ dw/d\delta < 0 \] -- as the rate of technological progress increases, w decreases;

\[ dw/dr < 0 \] -- as the competitive rate of return (or cost of capital) increases, w decreases.

These facts are, of course, partially illustrated in our previous examples. They are also supported by 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 w may shrink to zero.
3. EXTENSIONS AND IMPLICATIONS

The above analysis shows that where technological change is present there exists a window of opportunity (WO) for capital recovery. The more rapid the rate of technological change the shorter is WO. The existence of this window means that economic depreciation is larger at the beginning of an asset's life, declining as it gets older. Thus, with technological change and competition, depreciation schedules need to be front-loaded, if capital is to be fully recovered with technological change. We now develop some extensions and implications for ROR and price cap regulation, tax policy, new product pricing and capital markets.

The implications of the analysis for ROR regulated firms is straightforward. Where competition and technological change are present the firm may not be able to recover its capital under ROR regulation and straight-line depreciation, particularly if the depreciation lives are long. Technological change and competition result in a decline in the cash flows from an asset implying normally that economic depreciation will decrease over time. By truncating the amount of depreciation allowed in the early years ROR regulation results in under earning in later years. Moreover the under recovery in the early years means that the firm cannot make up the deficit in later years should the regulator decide that under recovery had occurred. There is a brief window of opportunity for action.

There is evidence to suggest that the window of opportunity is closing. After an effort by AT&T and its former operating companies to reform capital recovery polices there is scant recognition of the problem of capital recovery in price cap proposals for the Bell operating companies (BOC's) and the current practice for AT&T. As Hillman and Braeutigam [1989] so clearly demonstrate price caps are no regulatory panacea, which eliminates the problems of ROR regulation. Indeed for capital recovery the price-cap proposal retains the problems of capital recovery present in ROR regulation. The proposal essentially maintains the status quo. In particular the base from which the price cap begins is not increased to reflect the front-loaded depreciation that is implied by the technological change and
competition facing the BOC's. Depreciation is treated as an "endogenous factor", something that is the firm's internal concern. At first sight, this would not present a problem, except for the potential for monopoly exploitation, if the companies were allowed to set their depreciation to determine the initial level of the price cap. However, the price cap does not work in this way. The level of depreciation is based upon the levels currently in existence which had been determined by a highly regulated and far from endogenous process.

Depreciation under price caps, in the absence of significant modification of the proposal, is essentially the same as under ROR regulation. If the regulators chose to have the price caps reflect economic depreciation major problems of determining the actual amounts would occur. According to the theory the depreciation levels would start high and then decline rapidly. Realistically, the political and regulatory problems of an immediate large increase in rates may be insurmountable. However, while such considerations are beyond the scope of this paper the analysis aims at least to provide a starting point for addressing the problems of depreciation in price cap regulation.

The analysis has implication beyond the regulated firm, for example, tax policy. Taxation based upon straight-line depreciation has the effect of discriminating against high tech and innovative firms. A high tech asset and a low tech asset with the same before tax rate of return will have different after tax returns if economic depreciation is not used in the tax computation. If straight-line depreciation is there will be a lower after-tax return in the high tech asset. Aside from the distributive implications of this there may be serious efficiency consequences as under investment in high tech assets will occur as a result. The Tax Reform Act of 1986 by eliminating the "Accelerated Cost Recovery System" and "Investment Tax Credit" (ACRS/ITC) meant that for tax purposes much less front-loading of depreciation than previously. Thus despite all the claims from Washington that competitiveness and high tech investment be encouraged the major overhaul of the tax system contains the opposite incentives. While further discussion is beyond the scope the of the paper it does point to more general application of the analysis.

Interestingly the analysis is related to an older literature on new product pricing in the spirit of
Dean [1951]. Dean argued that new products should be introduced at a high price and be reduced in price over time. Such a policy may be a reflection not just of declining market power over time but the realities of efficient capital recovery. This would be particularly true in the case of high tech products. Without economic depreciation the accounting returns are going to overstate economic profits in early years and understate them in later years. From the point of view of accounting new front loaded depreciation schedules would be required. By making accounting profits a better estimate of economic profits additional information would be provided to capital markets. It is not clear whether capital markets are currently able to get behind the facade of depreciation in evaluating the real cost of capital in high tech industries.

This paper then represents a starting point for the extension and application of the theory of economic depreciation not only to the regulation of utilities but to several other important problems. Of immediate concern is the role of depreciation under price cap regulation. If existing proposals for extension of price caps beyond AT&T proceed telephone operating companies will face serious capital recovery. While this paper has not provided a blueprint for incorporating economic depreciation into price cap regulation, it does hold some promise in this area. Indeed the requirement for front loading of depreciation under technological change might imply an initial major increase in the price cap with larger promised reduction in the real price cap by means of the productivity deduction in later years. Such possibilities would seem to imply that a further extension of the theory of economic depreciation to price cap regulation should be a high priority on the research agenda.
REFERENCES


J. Dean, Managerial Economics, Prentice-Hall, Englewood Cliffs, 1951 F.M.


