Economic Depreciation

in

Telecommunications Cost Models

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Abstract

Forward-looking cost models are playing an increasingly important role in setting and assessing access prices and determining universal service costs in Australia's telecommunications industry. Both the ACCC and the ACA have recently commissioned large consultancy projects to estimate the forward-looking costs of Telstra's network. In such models, depreciation usually accounts for a large proportion of total costs, and hence the appropriate method for estimating depreciation has been the focus of considerable attention by both regulators and industry operators.

Rather than the use of accounting depreciation, which simply allocates the historic cost of the asset over the periods which it is to be used, depreciation in forward-looking cost models should reflect the period on period decline in the market value of the asset – a concept known as economic depreciation. While it can be shown that under specific conditions accounting depreciation aligns with economic depreciation, these are not the conditions under which telecommunications operators in Australia are required to operate. Rather, competition and short duration contracts mean that the profile of depreciation is critical to meeting a firm's dual objectives of remaining competitive and recovering capital costs.

This paper identifies the difference between accounting and economic depreciation and shows that the regulatory and competitive state of Australia's telecommunications market makes the latter the appropriate for use in forward-looking cost models.

1 Introduction

Most capital goods are used up in the process of producing output. Through physical deterioration and obsolescence capital goods, with a few exceptions, eventually reach the end of their useful life. As assets deteriorate and are finally retired their productive capacity declines to zero. At the same time their market value declines.[1] This depreciation of value is a cost that must be subtracted from gross revenue in order to determine the income accruing to the asset. It is also the amount that must be added to the balance sheet in order to keep wealth intact (Hulten and Wykoff 1996).

While this concept of depreciation seems straightforward, there are many different ideas on what should be done about it. Numerous views exist not only on the appropriate definition of depreciation, but also on how the depreciation charge should be calculated. The Australian telecommunications industry is no exception. While the Australian Competition and Consumer Commission (ACCC) require the use of economic depreciation for the measurement of access charges, what has been done in practice is quite different. In contrast, the model commissioned by the Australian Communications Authority (ACA) used for estimating universal service costs requires the use of straight-line accounting depreciation, yet the assessment of USO costs has involved the use of different depreciation methods.

This paper is set out as follows.

Section 2 reviews some of the literature on economic and accounting depreciation. It discusses the definition of depreciation and methods that have been proposed to measure it.

Section 3 identifies some of the strengths and weaknesses of economic and accounting depreciation identified in the literature.

Section 4 examines the special set of conditions under which economic and accounting depreciation are equivalent.

Section 5 examines the approach to depreciation suggested by the ACCC in the context of assessing Telstra's PSTN Undertaking and discusses why this approach is incorrect.

Section 6 discusses the method of depreciation proposed by the ACA's consultants for the assessment of Telstra's 1997/98 USO claim and shows why this approach is inappropriate.

Section 7 concludes.

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1 The market value of an asset is defined as the remaining present value of the income accruing to the asset, and is the amount that a rational investor would be willing to pay to acquire the asset in a second-hand market.

2 Economic versus accounting depreciation

Views on the definition of depreciation can be divided into two broad categories — economic depreciation and accounting depreciation. The basic conceptual difference between them is that economic depreciation involves a process of valuation, while accounting depreciation deals with allocation.

Economic depreciation can be defined simply as the period-by-period change in the market value of an asset. The market value of an asset is equal to the present value of the income that the asset is expected to generate over the remainder of its useful life. In contrast, accounting depreciation reveals nothing about the decrease in market value of an asset over a period of time. Accounting depreciation, under historical cost accounting, simply means the allocation of the historical cost of a fixed asset to the periods in which services are received from the asset (Colditz, Gibbins and Noller 1988).

2.1 Accounting depreciation

Numerous methods have been proposed to calculate accounting depreciation charges. The most widely used include straight-line, declining-balance, sum-of-the years' digits and production or service output (Colditz et al 1988 and Barton 1984). Others include the constant percentage, the annuity and the sinking fund methods. Each of these accounting depreciation methods is discussed briefly below.

2.1.1 Straight-line method

The simplest and most widely used method of computing accounting depreciation is the straight-line method. Under this method, an equal portion of the initial cost of the asset is allocated to each period of use. Consequently, this method is most appropriate when usage of an asset is fairly uniform from year to year. The computation of the periodic charge for depreciation is made by deducting the estimated residual or salvage value from the cost of the asset and dividing the remaining depreciable cost by the years of estimated useful life:

$$D = \frac{C - S}{n}$$

Where: D is the annual depreciation charge;

C is the initial cost price;

S is the scrap or salvage value; and

n is the number of years of expected life.

The depreciation rate is simply the reciprocal of the life in years:

$$dr = \frac{1}{n}$$

2.1.2 Declining balance method

Declining balance is an accelerated depreciation method. Some accountants recognise that depreciation may be greatest in the early years of an asset's life and correspondingly less in the later years. This is because some assets are most efficient when new, and therefore contribute more and better services in the early years of useful life. The trend towards adoption of accelerated methods of depreciation is also explained by the increasingly rapid pace of technological change which makes obsolescence more important than physical deterioration (Colditz et al 1988). Also significant in the decision to use an accelerated method of depreciation is the prospect of reducing the current year's income tax burden by recognising a relatively large amount of depreciation expense.

Another argument for allocating a comparatively large share of the cost of a depreciable asset to the early years of use is that repair expenses tend to increase as assets grow older (Colditz et al, 1988). A method of depreciation which provides heavy depreciation charges in the first year and lessens depreciation charges in each subsequent year will tend to offset the rising trend of repair expenses. The combined expense of depreciation and repairs may be more uniform from year to year under an accelerated method of depreciation than when the straight-line method is followed.

In the declining balance method the normal rate of depreciation[2] is increased and applied to the declining balance (net book value) of the asset. For example, assume an asset is acquired at a cost of $4 000 and has an estimated useful life of ten years. The normal rate of depreciation under the straight-line method would be 10 per cent. To depreciate the asset by the declining-balance method the normal rate is increased, say by 50 per cent, to 15 per cent and applied to the cost. Depreciation expense in the first year would then amount to $600. In the second year, the depreciation expense would drop to $510, computed at 15 per cent of the remaining book value of $3 400. In the third year depreciation would be $434 and so on. At the end of the

2 For income tax purposes the 'normal' rate is determined by the taxation authorities.

tenth year accumulated depreciation totals $3 212 and the book value of the asset is $788.

Assuming that the asset is retired from use at the end of the tenth year, the undepreciated cost of $788 will be written off the books at the time of disposal. Any difference between the proceeds from sale and the book value will be recorded as either a gain or loss on the disposal of the asset. If the asset is used beyond the estimated life of ten years, depreciation will be continued at the 15 per cent rate on the undepreciated cost. When the declining-balance method is used, the cost of a depreciable asset will never be entirely written off as long as the asset continues in use.

Theoretically, the rate of depreciation applicable under the declining balance method is calculated as:

$$dr = 1 - \sqrt[n]{\frac{S}{C}}$$

where C is the initial cost price;

S is the scrap or salvage value; and

n is the number of years of expected life.

However, in practice the depreciation rate is obtained by applying a factor to the straight-line rate (Colditz et al 1988). In Australia a depreciation rate exceeding the straight-line rate by 50 per cent is applied to the net book value of the asset under the declining balance method, while in the United States double the straight-line rate is used (Barton 1984). This method is known as the double declining balance method. Finally, it should be noted that depreciation, in the case of declining balance, is taken on the cost of the asset, not cost less the scrap value, as in the straight-line method. If depreciation is calculated on cost less the scrap value the balance will not be reduced to the required amount.

2.1.3 Sum-of-the years' digits method

Sum-of-the years' digits is another method of accelerated depreciation. The depreciation rate to be used is a fraction, of which the numerator is the remaining years of useful life and the denominator is the sum of the years of useful life. For example, consider an asset with an initial cost of $40 000, an estimated life of four years and an estimated salvage value of $4 000. Since the asset has an estimated life of four years, the denominator of the fraction will be 10 (1 + 2 + 3 + 4 = 10). For the first year, the depreciation will be 4/10 x $36 000 or $14 400. For the second year, the depreciation will be 3 / 10 x $36 000 or $10 080. For the third year, the depreciation will be 2 / 10 x $36 000 or $7 200 and in the fourth year, 1 / 10 x $36 000 or $3 600.

2.1.4 Production or service output method

The depreciation charge using the production or service output method is obtained by dividing the original cost of the asset by the estimated units of output, rather than by the estimated years of useful life as in the straight-line method. Colditz et al (1988) notes that for some fixed assets this method of depreciation may provide a more equitable distribution of costs, however, it is not widely used because it is not very suitable to situations in which obsolescence is an important factor.

2.1.5 Constant percentage method

The constant percentage method also results in depreciation being greatest in the earlier years of the life of an asset. It is based on a geometric progression and the successive book values of an asset over its useful life are the terms of the progression. The depreciation rate is calculated as:

$$dr = 1 - \exp\left[\frac{1}{n} \times \log\left(\frac{S}{C}\right)\right]$$

where C is the initial cost price;

S is the scrap or salvage value; and

n is the number of years of expected life.

$$BV_t = C \times \left[(1 - dr)^t\right]$$

The book value at the end of year *t* is then:

$$\left[C \times (1 - dr)^{(t-1)}\right] - BV_t$$

and the depreciation charge at the end of year *t* is:

2.1.6 Annuity

The principle underlying the annuity method is that it takes into account not only the cost of an asset but also the interest which the capital locked up in that asset would have earned had it been invested outside the business. The one advantage of the annuity method is that it recognises the interest, or cost of capital, factor. Although used at times for the amortisation of leases, it is rarely used for the depreciation of fixed assets(Webb 1954).

A tilted annuity takes into account future trends in the price of capital equipment and hence in service prices. For negative equipment price trends, a 'standard' annuity will underestimate the annualisation factor and for positive price trends it may overestimate it. The tilted annuity method results in more depreciation at the beginning of the asset life if a sufficiently high negative equipment price trend is anticipated, which is usually the case if technological progress is rapid. It should be noted that unlike the standard annuity, the value of a tilted annuity differs in each year of the asset life when price trends are non-zero.

2.1.7 Sinking fund method

The sinking fund method is mathematically akin to the annuity method. The difference is that an equal annual sum is actually taken out of the business and invested in an interest-bearing security. The annual installment is calculated so that its accumulation with interest will ultimately equal the original expenditure on the asset. At the end of the period the security is sold and the proceeds are used for the purchase of a new asset. The main advantage of this method is that, at the end of the specified time, a definite sum is available in cash to replace the worn out asset. The disadvantages of the sinking fund method are the difficulty of estimating the life of an asset, the risk of loss on realisation of investments and the difficulty in finding suitable investments which provide the desired rate of return.

2.2 Economic depreciation

The concept of economic depreciation was first considered by Hotelling (1925) who was dissatisfied with past treatments of depreciation. Previously, the value of an asset, referred to by Hotelling as its 'theoretical selling price', had been determined by the addition of a number of items, including depreciation. Depreciation was first computed by some rather arbitrary formula not involving the value of the asset, which was then found by adding depreciation to operating costs and dividing by the quantity of output. He likens this simple method to the 'naïve type of economic thought for which the only determiner of price is cost and which fails to consider the equally important role played by demand'.

Hotelling (1925) notes that the 'unit cost theory' partially addressed the problem by recognising the reciprocal relationship between the value of an asset and the value of its product. However, it does not recognise that the value of an asset must depend on the operating cost. All depreciation theories based on unit cost assume that the operating cost is known and the value of the asset is then calculated. But Hotelling (1925) argues that operating cost always includes elements which depend on value. This leads to the circularity problem that measuring operating costs requires knowledge of the value of the asset, which in turn requires operating costs to be known. Hotelling (1925) resolves this problem by solving a simple integral equation.

Hotelling begins his analysis from the viewpoint that the owner wishes to maximise the present value of the output minus the operating costs of the asset — the value of the asset[3]. Therefore, he expresses the value of an asset in terms of value of output (units of output produced per year multiplied by the value of a unit of output), operating costs and the life of the asset. If an asset with operating cost per year $O(\tau)$ produces $Y(\tau)$ units of output per year at time τ and if the value (theoretical selling price) of a unit of output is x, the annual rental value of the asset at time τ is:

$R(\tau) = xY(\tau) - O(\tau)$.

The value of the asset is then the sum of the anticipated rentals which it will yield, each multiplied by a discount factor to allow for interest, plus the scrap or salvage value, also discounted[4]. In the most general case the rate of interest will vary with time. If $S(n)$ is a function giving the salvage value at the time n when the asset is to

$$V(t) = \int_t^n \left[xY(\tau) - O(\tau)\right] e^{-\int_t^\tau \delta(v)dv} d\tau + S(n) e^{-\int_t^\tau \delta(v)dv}$$

be replaced, the value at time t is given by:

τ and ν being variables of integration representing time. The unknowns in the equation are then evaluated and depreciation is defined as the rate of decrease in the value of the asset. The unknowns may be the useful life of the asset, the value of a unit of output or, as is more often the case, both.

First, however, the circularity problem must be solved. To do this Hotelling (1925), writes $O(\tau)$ in the above equation as a function of $V(\tau)$ and τ which gives an integral equation to solve for the unknown function $V(t)$. Hotelling notes that the dependence of operating cost on value is ordinarily linear. Thus, taxes and insurance premiums are directly proportional to the value of the asset so operating costs can be written as:

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3 Following from this, Hotelling also assumes that the asset is always operated at full capacity.

4 The 'force of interest' $\delta(t)$ is defined as the rate of increase of an invested sum s divided by s.

$O(\tau) = A(\tau) + B(\tau)V(\tau)$,

Where $A(\tau)$ and $B(\tau)$ are functions which, like $Y(\tau)$ and $\delta(\tau)$ are supposed to have been determined, or at least estimated, on the basis of experience.

Hotelling's formula not only provides a method for calculating economic depreciation, but also establishes a link between depreciation and the replacement decision. By setting the value of the asset equal to the market value at which it is to be replaced, Hotelling's formula can be used to determine the useful life of the asset that is consistent with the concept of economic depreciation.

This method of calculating depreciation charges can result in constant, reducing or increasing depreciation charges over the asset’s life, depending on the estimates made of the future annual rentals it will yield and the discount factor used to allow for interest (Ma and Mathews 1979). A constant depreciation charge (corresponding to a straight-line allocation) implies a gradually diminishing periodic return in terms of undiscounted net rentals. This is a consequence of the fact that the net rentals figure in respect of a particular period is discounted less heavily as that period approaches closer to the time at which the discounting calculation is made. If the estimated annual net rentals diminish more rapidly than this, calculations of depreciation on the basis of present value comparisons can result in reducing (or frontloaded) depreciation charges. Similarly, when the estimated annual net rentals rise during an assets life, depreciation charges calculated using this method increase throughout the asset’s life (backloaded depreciation charges).

The theory of economic depreciation was later considered by Baumol (1971) in the context of public utilities. He describes the depreciation problem in terms of an intertemporal peak-load pricing problem (for a detailed discussion of peak-load pricing see Starrett 1988 and Rees 1984). The years in which the asset is used to capacity are the peak periods. It follows that during 'off-peak' years (years in which there is unused capacity), the long-run marginal cost of the firm's output should cover only operating costs (i.e. in such a period, it is equal to short-run marginal cost) and includes absolutely no contribution towards depreciation. During these years, increased use of the asset is always desirable so long as marginal operating costs are covered.

However, during the years when the asset is used to capacity, the depreciation charge should be determined by the demand function and consumers should be charged that price which just induces them to purchase the item's capacity output. The difference between that price and marginal operating cost will constitute the depreciation payment for the period in question. Therefore, Baumol’s depreciation policy would result in higher depreciation charges in periods of heavy usage to reduce congestion and lower depreciation charges in periods when unused capacity is available to increase utilisation.

The Hotelling (1925) and Baumol (1971) theories of economic depreciation discussed above have since been extended to the regulated firm. Jaffee (1973), Awerbuch

(1989), Schmalensee (1989), Rogerson (1992), Burness and Patrick (1992), Crew and Kleindorfer (1992) and Newbery (1997) have examined various issues concerning the effect of alternative depreciation practices and choice of depreciation paths on the regulated firm.

The most recent of this research examines the optimal recovery of capital costs for regulated firms. Burness and Patrick (1992) examine the optimal recovery of capital costs by the profit-maximising firm operating under a traditional rate-of-return constraint and for the regulator's problem of welfare maximisation such that revenues are sufficient to recover economic costs. They find that for the regulated firm seeking profits, once recovery begins, it continues at the most rapid rate until recovery of costs occurs. In terms of the welfare objective, the regulator is required to commit to full recovery over a finite time period and chooses a time path of recovery which differs quantitatively from that chosen by the firm.

For both the profit and welfare objectives, the authors find that optimal recovery requires 'backloading' (recovery increases through time) under a broad set of conditions. This finding, however, is inconsistent with depreciation paths that are used in practice among both firms and regulators. A possible explanation for this inconsistency is that the assumptions of limited technological progress and no competition made by Burness and Patrick (1992) do not apply to all types of assets. It is now common for regulated industries, in particular telecommunications companies, to face competition in some lines of business and to operate under conditions of rapid technological change.

For such industries, the results of the Crew and Kleindorfer (1992) study are more useful because capital recovery policies are examined for the regulated firm facing technological progress and competition in some of its product lines. The results are shown for both traditional rate of return regulation and for price cap regulation. First, rate of return regulation is considered. Assuming zero operating costs and straight-line depreciation, a rate of return regulated firm is constrained in the time path of revenues it may charge. The effect of straight-line depreciation and rate of return regulation of a competitive firm is to reduce the firm's cash flow in the early years, relative to methods which depreciate more in the earlier years. In later years, the actual cash flow may be less than the firm is allowed to earn, making it impossible for the firm to recover capital by rate of return regulation and straight-line depreciation. 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.

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. Crew and Kleindorfer (1992) refer to this limited time as the 'window of opportunity' available for recovery of capital. The regulator might therefore provide relief on capital recovery grounds either by increasing the allowed rate of return or by increasing the allowed rate of capital recovery by accelerated depreciation allowance. Either of these will increase the achievable cash flows early on, before competitive forces make this infeasible.

Crew and Kleindorfer (1992) then show that the same problems also apply under price cap regulation. The effect of price caps is to reduce the firm's cash flow in the early years when the market price is still greater than the price cap, so that the competitive price is not an effective constraint on the firm's pricing. As technological change lowers the market price below the effective price cap, the firm will end up with an actual cash flow which may make it impossible to recover its capital. Thus, with competition and technological change, 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. Regulators can effect the window of opportunity by either changing the initial price cap index or giving the firm the benefits of a larger share of their relative productivity increase by decreasing the X-factor. Moreover, the more rapid the technological change and the stronger the competition facing the firm, the briefer the time the regulator and the firm have to change depreciation policies if the firm is to recover its capital.

Newbery (1997) examines the efficiency aspects of pricing for regulated network utilities. He finds there is an intrinsic conflict in pricing lumpy assets between efficient pricing and cost-based pricing, especially where cost-based prices are based on traditional forms of depreciation. If the asset is lumpy, like a pipeline, and if demand is growing, then initially the asset will be oversized and its marginal cost may be very low. As demand builds up, an efficient rationing price policy would allow the price to rise until it substantially exceeded the average new cost, defined as the rate of return and depreciation of a comparable new asset, and therefore would exceed the average cost, defined by the return on the written down value plus normal depreciation. The average cost would follow a saw-tooth, with the declining path running from new investment to the date just before the next unit of capacity. The efficient price would be exactly the inverse to this, dropping to its lowest level just after investment and rising to its highest level just before the next investment.

Newbery (1997) notes that this problem seems to be characteristic of regulated utilities and can have perverse effects if they are liberalised. He provides Heathrow Airport as an example. The accounting rules under which the airport must be legally regulated, together with international agreements, have the perverse effect that the growing commercial success of Heathrow’s other activities is used to subsidise the landing charge, and as Heathrow becomes more congested, so landing charges decrease. They will be allowed to increase again once a new terminal is constructed and the capacity tightness reduced.

While the theory of economic depreciation measurement has been considered at some length in the literature, relatively few studies have attempted to implement it in practice. The majority of empirical research on economic depreciation has been undertaken by Hulten and Wykoff.

Hulten and Wykoff (1996) show that the definition of economic depreciation is equal to the present value of the shift in asset efficiency from one age to the next. In other words, when an asset is used in the production of output over the course of a year, it is the erosion of current and future productive capacity that causes the erosion of asset value. This decline in efficiency, which is a key aspect of economic depreciation, is also identified by Jorgenson (1973) who calls it the mortality function. Hulten and Wykoff (1996) note that while every piece of capital probably has its own unique pattern of efficiency, the literature has focused on three cases:

1. **Constant efficiency or 'one-hoss-shay' pattern** – In the one-hoss-shay form, assets retain full efficiency until they completely fall apart. In this form, the efficiency sequence is completely characterised by the asset's service life, and the measurement problem reduces to the problem of estimating this.

2. **Straight-line pattern** – In the straight-line pattern efficiency falls off linearly until the date of retirement. In this form, efficiency decays in equal increments every year. As with the one-hoss-shay pattern, the service life of the asset completely determines the efficiency pattern

3. **Geometric decay** – With geometric decay the productive capacity of an asset decays at a constant rate.

These patterns describe the path of efficiency over time and should not be confused with the corresponding path of economic depreciation, although it is clear that the two paths are linked.[5] Only geometric decay has in its favour the dual property that its form describes both the path of efficiency and economic depreciation (Hulten and Wykoff 1996).

Unfortunately, the data required to estimate efficiency patterns are not directly observable. Instead, studies have been undertaken to identify the pattern of economic depreciation of a range of assets using second-hand asset resale price data (see for example, Hulten and Wykoff 1981a; Hulten and Wykoff 1981b; Hulten, Robertson and Wykoff 1989; and Wykoff 1989). The results of these studies can then be extended to assets for which no resale markets exist. If economic depreciation has the straight-line form, then a regression analysis, which uses flexible functional forms, should indicate that the asset's market price declines linearly with age. If the asset retains its full productive capacity up to the point of retirement, the one-hoss-shay, the analysis should indicate a pattern that declines more slowly than the straight-line pattern when the discount rate is positive. If depreciation has the geometric form, then the fitted pattern should decline at a constant rate with age.

Hulten and Wykoff have used this approach to study the depreciation patterns of a variety of fixed business assets in the United States. They find that the straight-line and one-hoss-shay patterns are strongly rejected. The geometric pattern is also

5 The one-hoss-shay pattern of efficiency implies straight-line depreciation with a zero rate of discount.

rejected, but the estimated patterns are extremely close to (though steeper than) the geometric form. This leads the authors to accept the geometric pattern as a reasonable approximation for broad groups of assets. They also extend their results to assets for which no resale markets exist by imputing depreciation rates based on an assumption relating the rate of geometric decline to the useful lives of assets. A summary of the estimates of asset class economic depreciation rates made by Hulten and Wykoff are provided in the table below.

Rates of Economic Depreciation

Asset Class	Approximate Depreciation Rate
	%
Producers' durable equipment	
Furniture and fixtures	12
Agricultural machinery	12
Industrial machinery and equipment	12
Construction tractors and equipment	18
Farm tractors	18
Service industry equipment	18
Electrical equipment	18
Aircraft	18
Trucks and autos	30
Office and computing equipment	30
Non-residential structures	3

Source: Hulten and Wykoff (1996).

While the most extensive empirical research on economic depreciation is that of Hulten and Wykoff (1981a; 1981b; 1981c), Hulten, Robertson and Wykoff (1989) and Wykoff (1989), important additional studies have been completed by the Office of Tax Analysis (1990; 1991a; 1991b) and Oliner (1993; 1996a; 1996b). Alternatives to the used-asset price approach have also been used to estimate efficiency patterns (see Jorgenson (1996) for a review of empirical studies of economic depreciation). For example, Doms (1996) estimates capital efficiency schedules by using a parameterised investment stream as a capital variable in a production function. The parameters of the production function are then simultaneously estimated with the parameters of the investment stream. His primary finding is that the estimated efficiency schedules follow a near geometric pattern, which is consistent with the estimates of Hulten and Wykoff. Additional support for the geometric pattern is provided by Fraumeni (forthcoming) who reviews the literature on economic depreciation and finds that the weight of evidence strongly supports this form of depreciation.

3 Strengths and weaknesses of economic and accounting depreciation

3.1 Accounting depreciation

The main benefit of accounting depreciation is that it is easy to implement in practice. The data required to calculate accounting depreciation are readily available, although it should be noted that the estimated expected life of an asset may be subject to substantial error (Barton 1984).

The major criticism of accounting depreciation lies in its definition. Marden (1957) suggests that accounting depreciation is not depreciation at all, but rather the allocation of the investment in the plant. Therefore, the information it supplies is limited and may be misleading. Hulten and Wykoff (1996) argue that accounting depreciation only provides knowledge of the historical pattern of investment, which is not sufficient to determine the amount of productive capacity in a firm, industry or economy. While the historical cost (and gross book value) of an asset is easily observable, it reveals little about the value of the asset that has been in operation for a number of years. Rather, it is the price that reflects the remaining present value of the income accruing to the asset that a rational investor would be willing to pay to acquire the asset in a second-hand market. This is clearly different from gross book value and also different, in practice from net book value (constructed using straight-line depreciation).

Hulten and Wykoff (1996) note that although net book value is intended to approximate the present value of the income accruing to an asset, such measures are problematic. This is because mechanical book value measures bear no necessary relationship to the remaining asset financial value after adjusting for true economic depreciation, unless the latter should happen to coincide with a straight-line depreciation pattern.

A similar argument is put forward by Zajac (1995) who suggests that the use of accounting depreciation may result in the value of an asset, as shown in a firm's book of accounts, as having little relation to its resale value. This means that a firm's book of accounts may give the shareholder a poor idea of the market value of an asset or, for that matter, the entire firm. More importantly, to the extent that book values are used in decision making, accounting depreciation can lead to a misallocation of resources. Equipment may be worth nothing on the firm's books, which might suggest that it should be replaced, when in fact is has considerable market value, and equipment whose book value is high might be technologically obsolete and might have a market value of zero.

Accounting depreciation is also unlikely to coincide with Baumol's definition of an optimal depreciation policy and hence result in the inefficient allocation of resources.

The amount that accounting depreciation will recover is the initial dollar cost of the asset which, as Baumol (1971) explains, will not ensure that the investment is worthwhile. Also, the most widely used method of depreciation, the straight-line method, contributes the same depreciation charge in each period, regardless of usage. Again this is inconsistent with the optimal depreciation rules outlined by Baumol (1971).

Given that the concept of accounting depreciation is found to be unsatisfactory from an economic viewpoint, it is not surprising that the proposed methods of accounting depreciation have also been the subject of criticism. Hotelling (1925) uses his asset value formula, which allows economic depreciation to be calculated, to examine the circumstances under which particular accounting depreciation methods are economically valid. He examines the straight-line, declining balance and sinking fund methods and finds that they all 'depend for their validity upon the satisfaction of conditions which are so special that the chances are overwhelmingly against the satisfaction of any of them in a particular case'.

3.2 Economic depreciation

Obviously, the major benefit of economic depreciation is that it is theoretically correct. It measures the period-by-period change in the market value of an asset and ensures the efficient allocation of resources. However, the implementation of economic depreciation is problematic. In particular, the estimates for market values might be speculative and subject to manipulation and the geometric form is questionable.

In practice, the market value of in-use assets is not used for estimating economic depreciation (Hicks (1973) discusses the problems associated with measuring the market value of assets). Instead, in most cases, used-asset market values are employed. One criticism of this approach which draws on the Ackerlof Lemons Model (Ackerlof 1970), is that assets resold in second-hand markets are not representative of the underlying population of assets, because only poorer quality units are sold when used. On the other hand it may be argued that assets are not resold because of asset quality, but because of events such as plant closings, shifts in product demand, or decisions related to tax optimisation, inventory control or liquidity requirements. Others express concerns about the thinness of resale markets, believing that it is sporadic in nature and is dominated by dealers who under-bid (Hulten and Wykoff 1996). The valuation of assets becomes even more difficult where no competitive market exists.

The geometric form has also been at the centre of much controversy (see for example the debate between Feldstein and Rothschild 1974 and Jorgenson 1973). Feldstein and Rothschild (1974) point out that the variables used to estimate efficiency patterns are subject to choices about the degree of utilisation and maintenance and other factors. They also note that depreciation can take many forms including increased down time through breakage or repair, loss in serviceability from wear and tear and wastage of materials. A theory of efficiency functions should capture all of this and, in principle, allow each asset to be different. Importantly, there is no reasonable expectation that the pattern is fixed, much less fixed with a geometric pattern.

The geometric form is also regarded by many observers as intuitively implausible because of the rapid loss of efficiency in the early years of asset life (for example, 34 per cent of an asset's productivity is lost over four years with a 10 per cent rate of depreciation). Moreover, pure geometric decline means that assets are never completely retired and this implies that the service life is infinite. When viewed from this intuitive standpoint, the most plausible pattern may well be the 'one-hoss-shay' in which capital appears to retain the bulk of its productive capacity throughout its useful life.

However, Hulten and Wykoff (1996) argue that while every single asset in a group of 1 000 assets may depreciate as a one-hoss-shay, the group as a whole experiences near-geometric depreciation. The fallacy of composition arises from the fact that different assets in the group have different useful lives — some may last only a year or two while others last ten to fifteen years. While they concede that there are applications in which the experience of one individual asset is at issue, they also suggest that most applications in growth, production analysis, environmental economics, industry studies and tax analysis are concerned primarily with the average experience of a heterogeneous population of capital.

The approach suggested by Hotelling (1925) may avoid many of the problems that arise in the Hulten and Wykoff methodology, however implementing it in practice may be difficult. The Hotelling (1925) methodology has been criticised on the ground that the allocation of a joint revenue stream to individual assets cannot be justified. Individual assets are not employed in isolation, but always jointly with other assets in the firm. The net rentals of the firm form a joint revenue stream, and because of asset interaction it is not possible to allocate this joint stream to individual input factors, except on an arbitrary basis (Ma and Mathews 1979). This problem may be overcome by aggregating associated assets for purposes of calculating depreciation charges. The main problem with this approach is that of differential useful lives of the individual asset components. This may be resolved by treating the aggregation of assets as a perpetual inventory, the value of which is diminished by annual depreciation charges and increased by the cost of major additions and net replacements (Ma and Mathews 1979).

The Hotelling approach also assumes that the asset is always operated at full capacity. Hotelling (1925) recognises that there are very important cases in which this is not even approximately true. In these cases the unknowns that require consideration are not only the useful life, value and depreciation, but also the functions $Y(t)$ and $A(t)$. That is, the owner may voluntarily run the asset at less than full capacity and wishes to know how fast to let it run in order to maximise profits. If this is the case, the demand function must be known in order to give a solution.

4 The alignment of economic and accounting depreciation

There exists a special set of circumstances under which the profile of depreciation charges over time is irrelevant. In this case, any method of accounting depreciation will determine the pattern of economic depreciation. This special case has been recognised in the literature on depreciation and regulation, most notably by Schmalensee (1989). Schmalensee shows that if a regulated firm is allowed to earn its cost of capital and if actual earnings equal allowed earnings, then the net present value of all investments is zero for any method of computing depreciation. Similarly, Zajac (1995) states that in the absence of competition, depreciation allows greater flexibility in the regulatory contract. The regulator and firm can spread the costs of assets over their service lives in any fashion that is convenient. The prices and associated revenues charged for the utility's products are a residual or a revenue requirement – simply the sum of depreciation, operating costs and the opportunity cost of capital.

While the implications of Schmalensee's findings are important for regulated depreciation schedules, equally important are the limited conditions under which these findings hold and how these compare with the conditions under which regulated firms are required to operate.

There are two sets of conditions under which accounting and economic depreciation are equivalent and hence the choice between them irrelevant.

1. In a regulated market with no competition in which the regulator commits to full capital recovery over the assets' lives (ie the regulator commits to a zero NPV for the firm's total investment), Schmalensee's result holds and the regulated firm will be indifferent between depreciation profiles.

2. In a competitive market with long-term contracts the precise pattern of depreciation will also be irrelevant as long as the contract amount fully recovers the initial capital investment and the contract period is equal to the asset life.

If these conditions do not hold then the profile of depreciation is critical to meeting the firm's dual objectives of remaining competitive and recovering capital costs.

In a regulated market if a firm faces competition then its prices and revenue are no longer determined by the regulatory process but are set exogenously. In other words, the regulator and the regulated firm are no longer "price makers" but instead are "price takers". In this case, it is the prices that prevail in the competitive market that determine the depreciation profile of the firm. If competition is likely to drive prices down in future years, then the firm must accelerate depreciation (and increase prices) in the early years of the asset's life to ensure full capital recovery. Therefore, competition constrains the profile of depreciation for both the firm and the regulator. Without an accelerated depreciation profile full capital recovery may never be achieved, an outcome that is made far more likely by rapid technological change.

In a competitive market with no regulation a firm that does not enter into long-term contracts will account for the risk of competitive by-pass by recovering a larger proportion of costs in the early years of the asset's life and less in later years when competition is more likely to force prices down. Indeed, even a firm that does enter into long term contracts will, in practice, take account of the effect of the likely pattern of "spot market" prices over time in setting the path of prices in the long term contract. This is so as to minimise the risk of breach, since that risk generally rises with the extent of the gap between the contract price and the best alternative price open to the buyer (usually the spot price). As a result, many long term contracts include price amendment clauses (see Goldberg 1985).

5 Depreciation in the ACCC assessment of Telstra's PSTN Undertaking

A major element of the ACCC's assessment of Telstra's PSTN Undertaking involved the development of forward looking cost estimates of customer access and call conveyance. The cost model used for the basis of these estimates was developed by a UK based firm, National Economic Research Associates (NERA). As one of the alternative approaches to annualising the capital investment estimates produced by the NERA model, the ACCC instructed NERA to use a standard annuity. The results obtained from the standard annuity provided the basis for the ACCC draft determination on Telstra's PSTN Undertaking.

As discussed in Section 2, the standard annuity method annualises the once off capital investment estimates produced by the model by incorporating both depreciation and the cost of capital in a single calculation. The value of the annuity, which is applied to the once-off capital investment estimate, is determined by the cost of capital (CoC) and the estimated life of the asset (N), with the cost of depreciation being calculated implicitly:

$$Annuity = CoC \Big/ \left[1 - \left(1/\left(1 + CoC\right)\right)^{N}\right]$$

This approach to estimating depreciation is incorrect for the following reasons:

- The conditions under which Telstra is required to operate are not consistent with the set of special circumstances that make accounting and economic depreciation equivalent. In a competitive environment with short-term access contracts, the choice of depreciation is critical to meeting a firm's dual objectives of remaining competitive and recovering costs.

- A standard annuity approach is completely inconsistent with the concept of economic depreciation. In their final report, NERA explained why the annuity approach is inappropriate for annualising the investment costs of the PSTN.

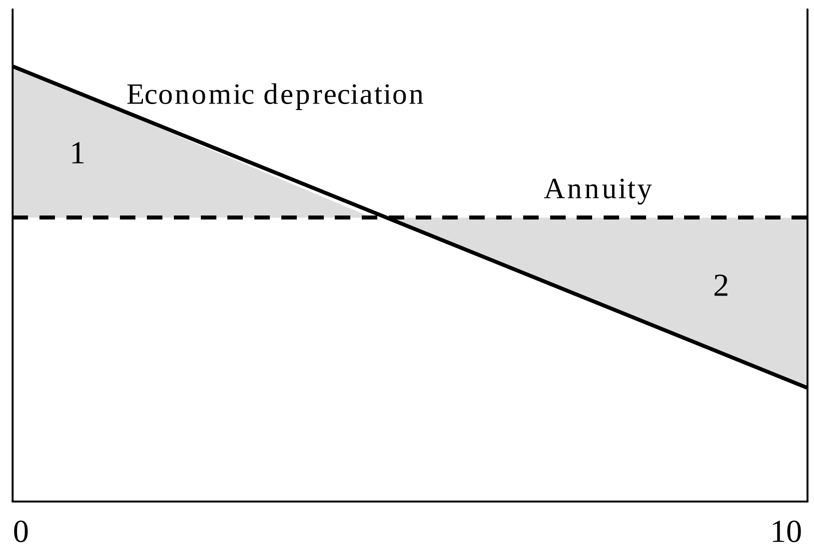
Instead of using the economic depreciation approach recommended by NERA, the ACCC adopted an approach which is contrary to economic theory and inconsistent with their own Access Pricing Principles.

- The standard annuity approach ignores the need for ongoing investment in the network to maintain service potential. In effect, a standard annuity approach assumes that as the capital base of the network declines, output of the network remains constant. This is inconsistent with network investment in practice and is contrary to the underlying logic of a dynamic TSLRIC model.

Each of these issues is discussed separately below.

5.1 Economic depreciation and accounting depreciation are not equivalent

To illustrate why economic depreciation and the depreciation profile created by the annuity method are not equivalent, consider the following diagram.



Assume that the area under the unbroken line reflects the revenue requirements of a firm without long-term contracting, operating in a competitive market with no regulation. The firm accelerates depreciation in the early years of the asset's life to ensure capital recovery, as rapidly changing technology and competition means that revenue returns in the later years of the asset's life are likely to be lower. Assume also that the area under the broken line reflects the regulated revenue from the annuity, as suggested by the ACCC.

If the annuity return was set for the length of the asset life and the regulated firm faced no competition then the firm would be indifferent between the depreciation profiles. The lower recovery under the annuity in the early years of the asset's life compared with the higher recovery under economic depreciation (the area marked

1) would be exactly offset by the higher recovery under the annuity in the later years of the asset's life (the area marked 2). Similarly, in a competitive market a firm would be indifferent between the depreciation profiles presented above so long as the customer contract fully recovered costs and the term of the contract was the length of the asset life.

In contrast to these scenarios, Telstra is constrained by both competition and short-term contracts. In particular, the following aspects of Telstra's operating environment make the choice of the depreciation profile critical.

- Telstra operates in a regulated market which is open to competitive entry.
- Telstra operates in an industry characterised by rapidly changing technology.
- The ACCC revises Telstra's access prices regularly on the basis of forward looking costs.
- The maximum period for the PSTN Access Undertaking is three years.

The result of these conditions is that Telstra's capital recovery is constrained by competition and by short-term contracts, not only with customers but also with the regulator. Even in the absence of competitive by-pass, the ACCC attempts to simulate the constraint that would be imposed on Telstra if it did face competition. This is achieved by setting access prices on the basis of forward looking cost estimates and revising these estimates at frequent intervals. This effectively discourages access seekers from entering into long-term access contracts with Telstra[6]. Therefore, in order for Telstra to remain competitive and to recover costs, the regulated depreciation schedule must reflect the economic depreciation profile that would exist in a competitive market with short-term contracts.

It is entirely inconsistent for the Commission to simulate the conditions of competition and short-term contracting and then to require Telstra to recover costs as if these conditions did not exist. If the ACCC imposes worse conditions on Telstra than would be applied in the market in which it has attempted to simulate the consequences will be reflected in the quality and availability of supply of T/O access.

5.2 Inconsistent with economic depreciation

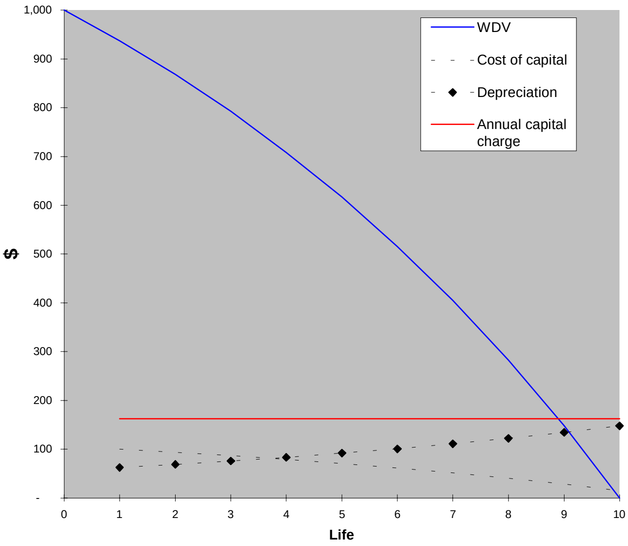
A major problem with the standard annuity approach is that it results in a backloaded depreciation profile over time. As the capital charge is falling over time, the depreciation charge must be increasing to keep the capital charge equal in each

[6] It is also highly likely that such conditions discourage the development of efficient, facilities-based competition, since firms whose costs are lower than Telstra's actual costs nonetheless face a price determined by best-practice costs. In contrast, if access prices were based on Telstra's actual costs, firms with costs lower than Telstra's would have an incentive to enter the market.

year of the asset's life. The depreciation profile created by applying the standard annuity approach is illustrated in the figure below. This example clearly displays, that to maintain a constant annualised capital charge in each year of the asset's life, the depreciation component of the capital charge must increase over time.

Variables	
Cost of capital	10.00%
Economic life	10
Capital investment	1000

Year	WDV	Cost of capital	Depreciation	Annual capital charge
0	1,000			
1	937	100.00	62.75	162.75
2	868	93.73	69.02	162.75
3	792	86.82	75.92	162.75
4	709	79.23	83.51	162.75
5	617	70.88	91.87	162.75
6	516	61.69	101.05	162.75
7	405	51.59	111.16	162.75
8	282	40.47	122.27	162.75
9	148	28.25	134.50	162.75
10	0	14.80	147.95	162.75
		627.45	1,000.00	



This is totally inconsistent with the concept of economic depreciation, one of the key requirements identified by the ACCC for the measurement of TSLRIC. In their Access Pricing Principles, the Commission state that:

> *Consistent with the TSLRIC methodology, depreciation schedules should be constructed and based on the expected decline in the economic value of assets using a forward-looking replacement cost methodology. The decline in the economic value of an asset is determined by a range of factors including its expected operational life and expectations concerning technological obsolescence.*

However, the Commission assumes that all PSTN assets deteriorate in value at a faster rate toward the end of their lives[7] -- an assumption quite at odds with the actual pattern of value change. Additionally, the ACCC's standard annuity approach results in a depreciation profile which in no way accounts for the risk associated with technological obsolescence or competition. In fact, the Commission's approach to annualising the capital charge implies that an efficient operator, constructing a PSTN network in 1997/98, would face a zero risk of having their assets made obsolete, either by technological progress or competition, before the end of their accounting lives.

In contrast to the ACCC's approach, economic depreciation requires the depreciation profile to be accelerated in the early years of the asset's life to ensure full capital

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7 In addition, NERA state that "even where asset prices are not falling over time, declining output and rising operating costs may still require a declining depreciation schedule".

recovery in situations where an asset is at risk of becoming obsolete as a result of rapidly changing technology and/or competition. Clearly, operators in the Australian telecommunications industry face substantial risk of both.

In their final report, NERA recognise the problems associated with using depreciation profiles that do not approximate economic depreciation:

> *If the depreciation profile that is actually used fails to mirror the economic depreciation profile this will lead to a failure to recover the cost of investment over an asset's life. This can be seen from the fact that, as price and output falls and costs increase over the lifetime of an asset, it will become progressively more difficult to finance depreciation.*

NERA also explain why the standard annuity approach, in particular, will not provide a reasonable approximation to economic depreciation:

> *Annuity depreciation profiles are even less appropriate because a constant annualised capital cost (depreciation plus cost of capital) means that depreciation increases each year, ie it is actually "back loaded". While it is possible to tilt the annuity to allow for price and output declines, it requires a large tilt to achieve a declining depreciation profile over time.*

The annuity method has also been criticised by NERA in its assessment of the UK bottom-up model developed to estimate BT's incremental costs. In this case NERA noted that annuity depreciation profiles are generally used where the value of output is reasonably clear, such as with leases or mortgage repayments, but are harder to justify in a general investment context. In particular, NERA argued that it is hard to reconcile the assumptions behind an annuity depreciation profile and the judgement of the economic asset lives, and that the annuity formula fails to take account of the profile of operating costs over the lifetime of the asset.

As a result, NERA recommended that the annuity approach to estimating the annual capital charge used in the UK bottom-up model be replaced with the sum of economic depreciation and the relevant capital charge. Subsequently, economic depreciation profiles were developed for each of the main categories of assets in the model.

5.3 Ongoing investment requirements

The ACCC's annuity approach assumes that new investment occurs in the network only at the end of an asset's life. That is, the annuity assumes that the depreciation costs that are returned to the asset owner every period will be held until the end of the asset's life at which time this amount will be used to replace the asset. This does not reflect the pattern of investment in the PSTN and does not allow for declining output as the network assets deteriorate over time.

In Telstra's PSTN, new investments are made on an ongoing basis. This investment does not simply reflect the retirement of assets as their useful life expires, but also the ongoing investment required to keep the service potential of the PSTN constant, to maintain a constant level of output and to meet unforeseen demand.

To illustrate the difference between the two approaches, consider the following example. Suppose that the initial capital investment required to build the PSTN is $100, the useful life of all PSTN assets is 10 years, the economic depreciation rate is 20 per cent and the opportunity cost of capital is 15 per cent. Assume also that the replacement cost of all PSTN assets falls by 5 per cent per year.

In scenario 1, new investment occurs over the life of the assets to maintain the service potential of the network. However, since replacement costs are declining the total value of depreciation that is required to maintain service potential every year is reduced by 5 per cent. The resulting annual capital charges over the life of the PSTN are shown under scenario 1 in the table below. As can be seen from this table, very little difference exists between the total capital charge values in each year. The difference that does exists reflects the declining replacement cost of the PSTN assets.

In scenario 2, the ACCC's annuity approach is used to calculate the annual capital charge. Under this scenario, no capital investment occurs over the asset's life to keep the service potential of the PSTN constant and no new investment (or increase in O&M outlays) occurs as the output of the PSTN declines as a result of asset deterioration. Therefore, the annuity approach substantially underestimates the annual capital cost associated with the PSTN.

Asset life	Depreciation	Capital value	Cost of capital	Scenario 1: Total capital charge	Scenario 2: Annuity capital charge
1	$20.00	$99.00	$15.00	$35.00	$19.93
2	$19.80	$98.01	$14.85	$34.65	$19.93
3	$19.60	$97.03	$14.70	$34.30	$19.93
4	$19.41	$96.06	$14.55	$33.96	$19.93
5	$19.21	$95.10	$14.41	$33.62	$19.93
6	$19.02	$94.15	$14.26	$33.28	$19.93
7	$18.83	$93.21	$14.12	$32.95	$19.93
8	$18.64	$92.27	$13.98	$32.62	$19.93
9	$18.45	$91.35	$13.84	$32.30	$19.93
10	$18.27	$90.44	$13.70	$31.97	$19.93

6 Depreciation in the ACA's assessment of Telstra's 1997/98 USO claim

In 1996 the ACA commissioned a US based company, Bellcore, to develop a forward looking cost model of Telstra's USO network to assess the costs and revenues associated with providing universal telecommunications services in Australia. In this model, Bellcore recommended the use of straight-line accounting depreciation applied to the total investment cost of assets that would be used in a forward looking USO network. This approach was agreed to by all participants – Telstra, Optus, Vodafone and the ACA – for use in the 1997/98 USO claim.

In assessing Telstra's 1997/98 USO claim, the ACA is now concerned that, whilst appropriate for "Year 1", this approach provides a higher than typical return across the life of the asset. The ACA believes that in subsequent years the capital costs should be lower as the asset base declines. Also, if the year 1 return was achieved in each and every year of the asset life the USO provider would be over-compensated. The ACA consequently requested the Allens Consulting Group (ACG) to examine the appropriateness of "levelising" in the USO costing context. In response to the ACA's request, ACG recommended that an annuity be used to levelise total USO costs.

In addition to the problems associated with the annuity approach that are identified in the previous section, additional problems arise with the ACG annuity proposal in the context of the USO. In particular, the ACG argues that the risks associated with USO investment - unexpected effects of technological change, competitive bypass, demand fluctuations and regulatory decisions - are symmetric and diversifiable, however, as explained below, this assertion is incorrect

6.1 Critical examination of the ACG annuity approach

As discussed previously, the principle underlying the annuity method is that it takes into account not only the cost of an asset but also the opportunity cost of capital. Essentially it involves calculating the depreciation and the cost of capital over the life of the asset that, if realised as an equal value each year, would return (in NPV terms) the original investment value. The annuity approach is rarely used for the depreciation of fixed assets because as the cost of capital declines over time, the annuity implicitly assumes a backloaded depreciation profile. Although they do not appear to have recognised this problem, ACG made a number of adjustments to the standard annuity calculation which may leave readers with the impression that their method does not backload depreciation. In fact, despite ACG's explicit reference to straight line depreciation, this is not what results from their proposal.

In cases where asset prices are forecast to change, the ACG proposes the use of a "tilted" annuity which results in different capital charges in each year of the asset's life. The ACG then performs several "adjustments" to the capital returns in an attempt to separately identify depreciation and the cost of capital. The ACG assumes that depreciation is straight line and deducts depreciation from the total capital charge to arrive at what they label the "notional return on capital". They then state that it is the "notional return on capital" which should be used to estimate the cost of capital that Telstra should receive for its USO assets rather than the WACC.

In fact, what the ACG has done is to calculate a standard annuity when prices are not changing and a tilted annuity when prices are changing. They then attempt to avoid the problem of a backloaded depreciation profile by simply assuming that the annuity is consistent with straight line depreciation. However, this approach is incorrect and amounts to redefining some depreciation expenses as part of the cost of capital in a way that gives the impression that a straight line depreciation schedule is being used. The correct approach to separating the depreciation and the cost of capital components of the annuity is to calculate the cost of capital on the basis of the WACC and deduct this value from the total capital charge to calculate depreciation. In fact the ACG recognises that this is the correct approach. In their report the ACG state that "the actual return on capital is calculated using the WACC, not the annuity factor, while depreciation is the difference between the total capital return and the actual return on capital."

When depreciation and the cost of capital are separated using the correct approach it is clear that the annuity and the tilted annuity both result in a backloaded depreciation profile. Unless price changes included in the tilted annuity are very large, this will always be the case.

The ACG annuity proposal also assumes that the depreciation and return on capital as set out in the ACG examples will be realised in each year of the asset's life. Obviously, if any year of the returns are not fully achieved, the NPV of the capital return would not equal the purchase price of the asset, as it should. For example, if the achieved useful life is shorter than assumed, the level of return delivered by an annuity approach will be inadequate. This is likely to be the case in the telecommunications industry generally where the pace of technological advance has been rapid over the last decade and is likely to accelerate over the approaching decade. Importantly, in the USO context this is likely to be the case as the asset life estimates used in Telstra's USO claim are based on historical accounting lives which are generally longer than economic lifetimes. Consequently, there is and will continue to be a significant propensity for asset lives to be shorter than the accounting lives envisaged at the time of purchase and/or establishment of the annuity. Moreover, the fact that the USO is reassessed every year implies that the returns allowed every year are likely to fall compared to those calculated in the annuity for the current period. In this environment the annuity approach will not provide the correct return.

6.2 Net USO cost and the ACG annuity approach

The ACG levelisation analysis is limited to the total capital cost of the USO and therefore fails to identify one of the serious flaws in the proposed approach. The 1997/98 USO claim is based on the *net* cost of the USO which is determined as the difference between avoidable costs and revenues foregone. ACG propose the use of a levelised total USO cost, but do not consider the impact of setting levelised costs against annual USO revenues which fluctuate from year to year. By extending the results of the levelisation approach proposed by ACG to the net cost of the USO, it is clear the proposal gives incorrect results.

Consider the simple example in which there are no price changes, all asset lifetimes are equal and the infrastructure owner allows the network to run down over time in line with depreciation. Using the values from the ACG report, the year on year USO costs for a particular potential net loss area (PNLA) with a total capital avoidable cost of $100 would be as follows:

Year	(1) USO asset value	(2) Depreciation $100 * 10%	(3) Return on capital (1) * 9%	(4) Annual capital charge (2) + (3)
1	$100.00	$10.00	$9.00	$19.00
2	$90.00	$10.00	$8.10	$18.10
3	$80.00	$10.00	$7.20	$17.20
4	$70.00	$10.00	$6.30	$16.30
5	$60.00	$10.00	$5.40	$15.40
6	$50.00	$10.00	$4.50	$14.50
7	$40.00	$10.00	$3.60	$13.60
8	$30.00	$10.00	$2.70	$12.70
9	$20.00	$10.00	$1.80	$11.80
10	$10.00	$10.00	$0.90	$10.90

This is straight forward and identical to results presented in Table 2.1 of the ACG report. Now consider the total annual costs incurred in each year – the annual capital charge plus annual O&M expenses – set against the annual USO revenues received that give the net USO cost in each year. Assume for simplicity that annual O&M expenses remain constant over time at 10 per cent of the initial investment value. In addition, USO revenues fluctuate from year to year in line with demand fluctuations as set out in the table below.

Year	(1) Annual capital charge (4) from above	(2) O&M expenses 100 * 10%	(3) Annual USO cost (1) + (2)	(4) Annual USO revenues	(5) Net USO cost (3) – (4) if > 0
1	$19.00	$10.00	$29.00	$26.00	$3.00
2	$18.10	$10.00	$28.10	$15.00	$13.10

3	$17.20	$10.00	$27.20	$20.00	$7.20
4	$16.30	$10.00	$26.30	$28.00	$0.00
5	$15.40	$10.00	$25.40	$30.00	$0.00
6	$14.50	$10.00	$24.50	$19.00	$5.50
7	$13.60	$10.00	$23.60	$24.00	$0.00
8	$12.70	$10.00	$22.70	$35.00	$0.00
9	$11.80	$10.00	$21.80	$26.00	$0.00
10	$10.90	$10.00	$20.90	$23.00	$0.00

In this example, the net USO cost included in the claim fluctuates from year to year and is determined, as it should be, by both the USO costs incurred in that year and the USO revenue received. In contrast, the annuity approach proposed by ACG levelises the annual capital charges over time, but fails to recognise the distorting impact this has on the net USO cost. In the table below the actual net USO cost as calculated above is compared with the net USO cost obtained from a levelised capital charge based on the ACG annuity proposal.

Year	(1) Levelised capital charge from ACG annuity	(2) O&M expenses 100* 10%	(3) Annual USO revenues	(4) Levelised net USO cost (1) + (2) – (3) if > 0	(5) Actual net USO cost From (5) above
1	$15.58	$10.00	$26.00	$0.00	$3.00
2	$15.58	$10.00	$15.00	$10.58	$13.10
3	$15.58	$10.00	$20.00	$5.58	$7.20
4	$15.58	$10.00	$28.00	$0.00	$0.00
5	$15.58	$10.00	$30.00	$0.00	$0.00
6	$15.58	$10.00	$19.00	$6.58	$5.50
7	$15.58	$10.00	$24.00	$1.58	$0.00
8	$15.58	$10.00	$35.00	$0.00	$0.00
9	$15.58	$10.00	$26.00	$0.00	$0.00
10	$15.58	$10.00	$23.00	$2.58	$0.00
NPV @ 9%				$19.10	$22.62

This simple example illustrates that when the USO status of a PNLA changes over the levelisation period, the approach proposed by ACG would distort the actual net cost of the USO. In some years, when the actual avoidable costs of the USO are higher than revenue forgone, the use of levelised total costs will result in some net loss areas being excluded from the USO claim (in year 1 of the example above). In other years when actual avoidable costs are lower than foregone USO revenues, the ACG's levelisation approach will include profitable areas in the USO claim (in year 7 and 10 in the example above). In all other years, even if an area is correctly included in the USO claim, the ACG's levelisation approach would underestimate (as in year 2 and 3 above) or overestimate (as in year 6 in the above example) the net USO cost. Over the life of the assets, the NPV of the net USO costs calculated under the ACG's approach will not equate with NPV of the actual net USO costs.

Instead, the correct approach would be to levelise both costs and revenues by levelising the stream of *net* USO payments that a USO provider building a network today would expect to secure. However, the difficulty with this approach is that the future revenue stream is determined by customer demand for PSTN services which is highly uncertain over the levelisation period. Moreover, even if it were possible to accurately forecast demand for PSTN services over the life of the network assets, the resulting net USO cost would have to be put in place for the same time horizon. This is clearly unrealistic in the current environment, but highlights a further conceptual weakness of the approach advocated by ACG.

6.3 The Effect of Forecasting Errors in the USO Regime

It has been claimed by ACG that any risks involved in the estimation of a depreciation schedule are symmetric and diversifiable and hence the bearer of this risk does not need compensation. This argument would have some merit if the provision of USO service were based on a long term contract. If a depreciation profile were agreed *ex ante* and fixed for the (expected) life of the asset, there is a risk of error but this is a symmetric risk. However this is not how the USO regime operates in practice.

The depreciation provisions within the USO regime require regular reassessments of the lifetime of the relevant assets. In practice, these re-evaluations arise from the optimising process inherent within regulation based on forward looking TSLRICs. Indeed, ACG explicitly propose a sequence of ad-hoc adjustments to compensate for the errors that will regularly arise, should their approach be adopted. They suggest that these adjustments will provide adequate compensation for the forecasting errors.

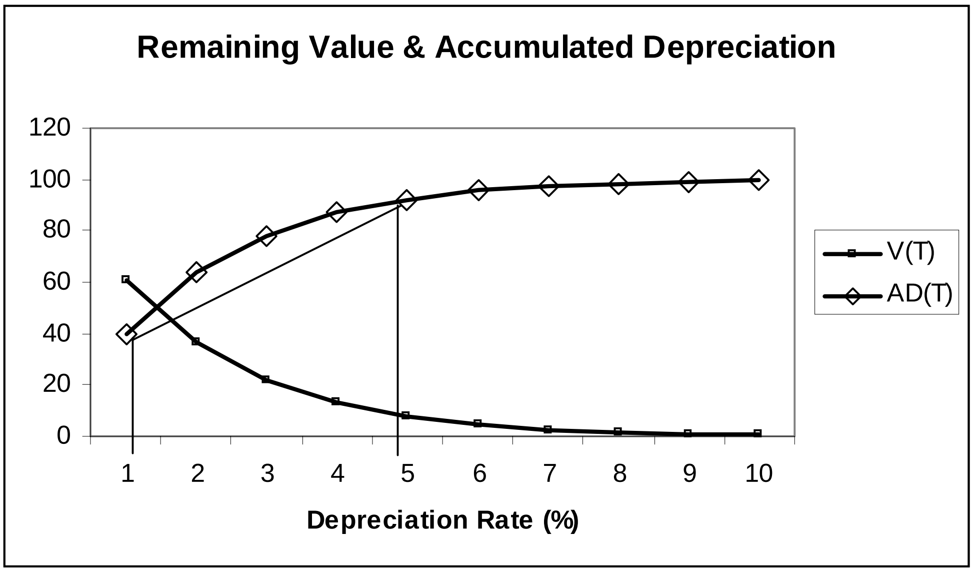
The purpose of this section is to demonstrate that ACG's reasoning on this issue is fallacious. Our analysis shows that under very plausible assumptions the cumulative effect of the ad-hoc adjustments proposed by ACG will skew the distribution of accumulated depreciation at any future time period. This will unambiguously back-load the depreciation schedule and hence increase the risk of asset stranding relative to the outcome under a long term contract.

It is not difficult to show that the ACG approach, which introduces uncertainty over the future sequence of depreciation schedules, induces an asymmetric risk for the firm. This result occurs even when the individual random shocks that would lead to

ACG's ad-hoc adjustments are independent drawings from a symmetric distribution.

To explain this effect, we explicitly derive the probability distribution of eventual capital recovery under the relevant conditions. This approach shows how a series of random re-evaluations of asset life generates any asymmetric risk for the investor. We find that even when there is an equal chance of re-evaluations being positive or negative, the fact that these re-evaluations have cumulative effects generates a negative asymmetric risk. Under reasonable assumptions this risk is lognormally distributed with the result that the extent of the asymmetry is increasing in the variance of the annual shock.

It is also possible to understand this issue without enduring the details of the distribution theory below. First, observe that under exponential depreciation, the total amount of depreciation recovered at time T is a strictly concave function of the depreciation rate δ (and the remaining asset value V is a strictly convex function of the same parameter)[8]. The situation is shown in the following graph for an asset with an initial value of 100 and T = 50.



Now note that the chord connecting any two points on the AD(T) line, such as the one drawn on the above diagram, is everywhere below the AD(T) line. We want to compare the accumulated depreciation at T=50 under two possible scenarios. First suppose that the depreciation rate was constant at 3% over these 50 years. In this

8 This is readily verified by noting that the remaining value at time T, denoted V_T is equal to $V_0(1-\delta)^T$ and that accumulated depreciation is simply $V_0 - V_T$. A function f(x) is convex if $tf(x) + (1-t)f(y) \geq f(tx + (1-t)y)$ for any t such that $0<t<1$.

case, the height of the AD(T) line above the 3% mark on the horizontal axis tells us that the firm would have recovered about $80 by the 50 year mark.

Now suppose that instead of always using 3% depreciation, the rates used were 1% and 5% with equal probability at all time periods leading up to T=50. The amount of accumulated depreciation at T under this particularly simple form of uncertainty, would be equal to average of the AD(T) heights at 1% and 5%. This is simply the height of the chord at its midpoint (3%).

Since the chord is everywhere below the curve, this amount must be less than the accumulated depreciation had there been a constant depreciation rate of 3% in each period. This is true for any choice of T and shows how uncertainty leads to under-recovery[9] at any given time period, relative to what would be achieved with a long term contract.

Thus, it is simply not true that uncertainty over the rate of depreciation (or equivalently over the remaining asset lifetime) may under- or over-recover capital. Uncertainty will always reduce the amount of capital recovered at a given date.

A similar result occurs when straight-line depreciation is used. In this case, the accumulated depreciation function is a straight line, rather than a concave curve. Uncertainty towards the end of the asset's life results in two possible effects: the lifetime is either extended, or prematurely ended. Extension delays capital recovery while premature "death" results in under-recovery. The total effect is therefore also asymmetric. Distribution Theory

In this section we prove essentially the same result but in a different way. The value of the asset at the start of period t is denoted V_t and the depreciation allowance for the same period is D_t. Hence the asset value evolves as:

$$V_t = V_{t-1} - D_{t-1}$$

Assume that the depreciation profile is exponential so that a constant proportion of the current value of the asset is written off each period. In this case, the depreciation expense is:

$$D_t = \delta V_t$$

with the result that the negative of the change in asset value between consecutive periods is just:

(1) $$-(V_t - V_{t-1}) = \delta V_{t-1}$$

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9 This is an application of Jensen's inequality. For a related argument in a different setting, see R. Hartman, "The Effects of Price and Cost Uncertainty on Investment" Journal of Economic Theory, 1972, pp. 258-66.

Assume that the depreciation rate δ fluctuates randomly from year to year as a result of changes in the perceived lifetime of the asset. To emphasise the main point, suppose that the depreciation rate at time t, denoted δ_t, is given by:

(2) $\delta_t = \delta + \varepsilon_t$; where $\varepsilon_t \sim NI(0, \sigma^2)$

Thus says that the depreciation rate is δ on average across all time periods but the rate used in any period is subject to independent random shocks which are drawings from a normal (and hence symmetric) distribution. Combining (1) and (2) we get:

$-(V_t - V_{t-1}) / V_{t-1} = \delta_t$

and summing over T periods gives:

(3) $$\sum_{t=0}^{T} \frac{-(V_t - V_{t-1})}{V_{t-1}} = \sum_{t=0}^{T} \delta_t = T\delta + \sum_{t=0}^{T} \varepsilon_t .$$

Now, if each individual change is small then we have:

(4) $$\sum_{t=0}^{T} \frac{-(V_t - V_{t-1})}{V_{t-1}} \approx \int_{V_0}^{V_T} \frac{dV}{V} = \log(V_T) - \log(V_0)$$

and combining the final terms of equations (3) and (4) gives:

$$\log(V_T) = \log(V_0) - T\delta - \varepsilon_0 - \varepsilon_1 - .... - \varepsilon_T$$

which is more conveniently written as:

(5) $$-\log(V_t) = T\delta - \log(V_0) + \varepsilon_0 + \varepsilon_1 + ... + \varepsilon_T.$$

Since the right hand side of this expression is normally distributed, by the additive form of the central limit theorem, $\log(V_T)$ is asymptotically normally distributed and hence $-V_T$ is lognormally distributed[10].

This theory shows that under reasonable assumptions, the interaction between successive normally distributed random shocks to the expected lifetime of the asset generates a terminal value, and hence a level accumulated depreciation which is lognormally distributed. As is well known, the lognormal distribution is asymmetric. Hence, the importance of this result: the cumulative effect of successive symmetrically distributed random shocks can be asymmetric.

Note that it is the *negative* of V_T which follows a lognormal distribution. The implication of this (see Aitchison and Brown section 2.9) is that V_T is also lognormal but with a negative skew[11]. Equivalently, the distribution of accumulated depreciation is positively skewed, with the effect that the mean recovery overstates the usual recovery so that it is much more likely that depreciation will be too slow than too fast[12]. Put another way, if regulators target the mean long run depreciation rate, but re-set the rate at regular intervals, there is a greater long run probability of under-recovery than over-recovery.

6.3.1 Diversifiability

It should be clear from the above that the method proposed by ACG for dealing with the so-called year one problem introduces a significant risk of under-recovery of USO capital. For completeness, however, we need to consider whether it is possible for investors to diversify this risk, since no compensation is require to the extent that this is possible.

There are several reasons for believing that the risks described in this section are not readily diversifiable. First, they are not symmetric. This means that any counterbalancing asset (or portfolio of assets) would need to have a positive bias under the same events that lead to the negative bias for USO assets. We have been unable to think of an asset which produces higher returns when the volatility of asset life for USO capital increases.

Secondly, even if one could think of such an asset, the return on it would need to be capitalised in order to match the USO provider's ultimate risk which is asset

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10 For a more rigorous proof of this result, see J. Aitchison and J.A.C Brown "The Lognormal Distribution with special reference to its uses in economics, Cambridge University Press, 1957, p 23.

11 Negatively skewed distributions have more mass to the right of the mean; for positively skewed distributions the "lump" of probability mass is located closer to the left hand end of the support.

12 An analogy with the best known skewed distribution may help to interpret this. The distribution of personal income across populations is skewed with a large mass at the left and a long but thin right hand tail. A person was sampled at random is therefore more likely to have below-mean earnings than above mean earnings.

stranding. The appropriate compensation for the risks identified here is insurance against their impact. This impact is either zero or very large in any given period, a pattern which would need to be matched by the counterbalancing asset if diversification was to be feasible.

Since insurance is required, the actuarially fair cost of this insurance is the appropriate compensation. It is highly unlikely that a third party would be willing to assume this risk, however, in part because of the moral hazard that this could create for the managers of USO assets. We therefore conclude that the risks identified in this section are not diversifiable.

7 Conclusion

In a competitive market, firms contract in a game involving customers and competitors. In a regulated market, the relevant contract is with the regulator. The regulators' commitments -- in this case, to revise prices frequently on the basis of changes in forward looking costs -- set the conditions within which the supplier must decide the terms on which it is willing to supply. If the regulator attempts to impose worse terms, supply will dry up.

Both the ACCC and the ACA have assessed access prices and USO costs on the basis of forward looking costs, with the objective of simulating the outcome that would exist in a competitive market. It is also a constraint that the Undertaking is limited to three years and USO reviews will occur at least every three years. Given this, the approach to depreciation and levelisation that is consistent with the regulatory contract is as follows:

- levelisation should occur only over the same period as TSLRIC revisions or USO cost reviews;
- the annual capital charges that are levelised should be based on economic depreciation which properly accounts for the risk associated with technological obsolescence and competitive by-pass;
- for the USO, it is net costs rather than total costs that should be levelised;
- the annual capital charges that are levelised should correctly reflect the year on year costs of the PSTN including:
  - the ongoing investment required to maintain the service potential of the PSTN;
  - the increase in capital and / or O&M outlays required to accommodate falling output as PSTN assets deteriorate over time; and
  - the cost of demand growth in each year if growth is not accounted for in the initial cost estimates.

8 References

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