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# **ECONOMIC DEPRECIATION IN THE SNA**

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## Introduction

The purpose of this paper is to examine how economic depreciation should be interpreted in 1993 SNA terms. The economic theory of depreciation is based on the pioneering paper of Hotelling (1925). Its implications have been explored in a number of papers over the years including, for example, Hill (1979), Jorgensen (1989) and Hartwick and Hageman ( 1993 ).

Following Hotelling, depreciation is generally accepted to be measured by the decline in the value of a fixed asset resulting from its use in production. The value of an asset in production is given by the present value of the flow of services that it contributes to production over the remainder of its service life. This is the value that should be recorded in the SNA balance sheet. When proper markets exist for used fixed assets, the current market price of a fixed asset should equal the present value of its remaining services.

The economic theory of depreciation is equally applicable to the depletion. In the present context, it is actually more convenient to start by taking the example of the depletion of a natural asset, such as a deposit of some mineral or fuel, and then to return to consider the question of consumption of fixed capital afterwards. The conceptual issues are clearer for depletion.

Consider the simple example of the extraction of coal, oil or a mineral deposit. The value to its owner of the stock of some natural asset in the ground can only be realised by extracting the asset and then selling it off or using it as an input into a further process of production. (Of course, the ownership rights can be sold from one unit to another but whoever owns the asset can only realise its value by extracting it.) Suppose  $q_t$  units may be extracted each period where

$$0 \leq q_t \leq c \quad (1)$$

The imposition of an upper limit,  $c$ , to the amount that may be extracted each period is the crucial feature of the problem. It reflects the fact that for a combination of physical, technological and economic reasons, generally reflected in sharply rising marginal cost of extraction, there is effectively an upper limit to the rate of extraction per period. (In the case of a fixed asset, there is an upper limit to its rate of utilisation imposed by the simple fact that a fixed asset cannot be used more than 24 hours in any one day.)

Given the technology of extraction, the physical nature of the deposit and demand for the asset there will be an optimal rate of extraction, or production plan, which can be specified as a sequence of quantities to be extracted over  $n+1$  time periods, where  $n$  depends on the size of the deposit and the capacity of the extraction process. The value of the stock of the asset in the ground at the start of period  $t$ ,  $v_t$ , is then given by the present value of the receipts, less

costs of extraction, derived from the gradual extraction and sale, or other use, of the asset over the subsequent  $n+1$  periods.

$$v_t = f_t + \frac{f_{t+1}}{(1+r)} + \frac{f_{t+2}}{(1+r)^2} + \dots + \frac{f_{t+n}}{(1+r)^n} \quad (2)$$

where  $r$  is the rate of interest and  $f_t$  equals the receipts less extraction costs (the gross operating surplus in SNA terms) in period  $t$  derived from the actual (or imputed<sup>1</sup>) sales of the  $q_t$  units extracted that period. The  $f$ s are all expressed at the same general price level, that of period  $t$ .

The value of the stock of the asset would be greatest if all the quantities could be extracted and sold immediately, but this is impossible given the nature of the deposit and the capacity of the extraction process. This distinguishes the stock of a natural asset from a stock, or inventory, of produced goods which can all be withdrawn at once, if desired. The value of inventory in the SNA is obtained by valuing all the quantities at their current market price, but this is invalid for a stock for which there is a constraint on the rate at which the quantities can be withdrawn. Quantities which can only be withdrawn in the future must be valued at their forward prices and not at their current, or spot, prices. The forward price of a unit to be withdrawn, i.e. extracted,  $n$  periods in the future is  $1 / (1+r)^n$  times the current price.

Following the standard economic definition of depreciation, depletion is measured by the change in the value of the stock of the natural asset between the beginning and end of the accounting period resulting from extraction. That is, depletion, or  $d_t$ , is equal to  $(v_t - v_{t+1})$  where  $v_{t+1}$  is the present value at the start of period  $t + 1$  of the remaining stock.

By definition,

$$v_t = f_t + \frac{v_{t+1}}{(1+r)} \quad (3)$$

$$\text{so that } d_t = v_t - v_{t+1} = f_t - r(v_t - f_t) \quad (4)$$

The term  $(v_t - f_t)$  is the present value at the *start* of period  $t$  of the stock of the

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<sup>1</sup> When the unit extracting the asset uses it itself in the next stage of production, for example by refining crude oil, the value of the 'sale' has to be imputed.

asset remaining in the ground at the *end* of period  $t$  (or start of period  $t+1$ ). During the course of period  $t$ , the value of this stock increases by  $r(v_t - v_{t+1})$ , the second term in equation in (4). This increase is due to the fact that the forward prices of all the quantities remaining in stock at the end of the period are  $1 + r$  times higher than they were at the beginning as the quantities are one period closer to being extracted.

Equation (4) shows that depletion consists of two distinct, although interdependent, components. The first  $f_t$  is simply the current value of the quantities of the asset extracted, while the second measures the increase in the value of the quantities remaining in stock, as just explained. Whereas the first component increases the value of depletion, the second component reduces it. Equation (4) is a fundamental result which has been much discussed in the literature on depreciation: see, for example Chapter 2 of Hill (1979) and Hartwick and Hageman (1993), pp. 213 to 216.

Switching from depletion to consumption of fixed capital is simply a matter of reinterpreting the  $f_t$ s. In the case of a fixed asset the  $f_t$ s represent the values of the 'services' contributed by the asset to the process of production. The flow of 'services' over the life of the asset is typically believed either to be constant until the asset disintegrates (the light bulb or "one-hoss shay" case) or to decline exponentially. The value of the fixed asset to be recorded in the balance sheet of its owner at any moment of time is then given by the present value of the flow of remaining services. Consumption of fixed capital is then measured by that part of the change in this value between the beginning and end of the accounting period which is attributable to its use in production (*cf.* Jorgenson (1989)).

Consumption of fixed capital therefore also consists of two distinct components: the value, at current prices, of the services used up in the course of production *less* the increase in the present value of the remaining services to be released by the asset over its remaining service life. Useful insights into the properties of depreciation, or capital consumption, can be gained by considering the ways in which these two separate components behave over the life of the asset. For example, if  $f_t$  is constant, depreciation cannot be constant: it must increase over the life of the asset, as the term  $(v_t - f_t)$  must decrease as the asset gets older and  $v_t$  gets smaller. Straight line depreciation requires the flow of services to decline at a constant linear rate until the asset disintegrates at some point (see Hill (1979), pp. 28 and 29 for further details). It should also be noted that it is possible for depreciation to be positive if the second term in equation (4) is greater than the first. This may happen when the asset is used so little in the period in question that the increase in the present value of the remaining services exceeds the cost of the services actually used up in the current period. This may occur when the production plan requires the asset to be used much more intensively in its later years.

The main question addressed in this paper is how these two components of depletion and capital consumption ought to be treated in the SNA. It is clear that the first component, the current value of the quantities extracted or 'services' used up, should be recorded as a cost in the production account. It is not so obvious, however, how the second component should be treated. The increase

in the present value of the quantities remaining in stock, or of the remaining 'services' that the asset is capable of providing, looks at first sight as though it constitutes a holding gain that should be recorded in the revaluation account and not in the production account. To do so would drastically increase the cost of capital consumption as compared with the way in which it has traditionally been calculated. Net value added would be correspondingly reduced. This issue is examined in the second part of this paper.

### **The treatment of changes in assets in the 1993 SNA**

The 1993 SNA provides an exhaustive framework for accounting for changes in the values of assets between the opening and closing balance sheets for any period, assets always being valued at their prices at the times the balance sheets are compiled. There are effectively three ways in which the value of the stock of some asset may change over time.

- (1) The stock of some asset may change because quantities are acquired or disposed of in transactions with other economic units or because quantities are consumed by the economic activities of production or consumption. Such changes are recorded somewhere in the set of transactions accounts in the SNA ranging from the production account to the financial account. Because of double entry book keeping they are in fact recorded twice. For example, a change in the quantity of inventories would be recorded both in the production account and the capital account of the producer in question.
- (2) The stock may change because of events which are not connected with economic transactions or activities, such as natural disasters. Such changes are recorded in the "other changes in volume of assets account".
- (3) Changes may occur because of changes in the prices of the assets. These generate holding gains or losses which are recorded in the "revaluation account".

Depreciation therefore has to be restricted to the change in the value of some asset which is directly attributable to its use in production. It does not include any changes which would be listed under (2) and (3) above and recorded in the "other changes in assets account" of the 1993 SNA. First changes that have nothing to do with production, such as the destruction of fixed assets by exceptional events such as earthquakes or major floods or fires, must be excluded from the consumption of fixed capital. However, when events such as floods or fires occur so frequently and regularly that a producer should expect a certain number of them to occur merely by engaging in production over a long period of time, they should not be excluded from depreciation. For this reason, "normal" rates of accidental damage are included in capital consumption in the SNA just as "normal" rates of wastage are included in changes in inventories.

Similarly, changes in the values of natural or fixed assets that are attributable to changes in their prices during the accounting period should also be excluded from depletion or consumption of fixed capital. They are recorded as holding gains or losses. The question therefore arises as to how the increase between

the opening and closing balance sheets in the present value of the unextracted quantities remaining in the closing stock of a natural asset, or of the unused 'services' of a fixed asset that remain to be exploited in the future, should be treated in the SNA. These increases are attributable to increases in the forward prices of the unextracted quantities, or unused services, with the passage of time.

Quantities of some good that are available at different locations or different points of time are not the same, however, from an economic point of view even though they may be physically identical otherwise. They must be treated as different qualities which may be expected to sell at different prices. In the present context, quantities of a natural asset which may be initially inaccessible must be treated as changing qualitatively as the extraction of other quantities brings them closer to the point at which they also can be extracted. Their economic value is increased, not as a result of any price change, but as a consequence of the process of extraction. The increase in value cannot be a holding gain when there is no price change. It must be offset against the reduction in the value of the stock resulting from the disposal of the quantities extracted in the current period. In other words, it should be treated as negative depletion, as it is in equation (4) above.

There is a close parallel from a methodological point of view with the treatment of zero coupon bills and bonds in the SNA. Other things being equal, the market value of such a bond at the end of the period is  $1+r$  times its value at the beginning because the holder is one period closer to being repaid the face value of the bond. This increase is not a price increase, however, because the bond changes qualitatively as a result of the accumulation of accruing interest. The bond grows. Its price does not increase. The increase in value is not a holding gain and is not recorded in the revaluation account. The reasoning is spelled out more fully in para. 12.110 of the 1993 SNA and also in Hill (1996) pp. 60,61. The accounting treatment may be summarised as follows. The increase in the market value of the bond is treated as interest accruing to the holder and recorded as such in the primary income account of the SNA. The interest is then treated as being reinvested in the bond and the additional lending by the holder to the issuer of the bond is recorded in the financial accounts of both parties. There is no holding gain and no entry in the revaluation account despite the fact that the price of the bond has increased on the market. Of course, holding gains and losses can, and do, occur on such bonds when their prices change in response to changes in market rates of interest, but not when the value of the bond grows as a result of the reinvestment of accruing interest.

The underlying issue is the same as for the second component of depletion. When dealing with a change in the market value of an asset over time, it is necessary to determine not merely whether its price has changed but whether the physical or economic characteristics of the asset itself have also changed, in which case the change in price must be adjusted in order to isolate the true price change and holding gain. The adjustment required is similar to adjusting for quality change when calculating a price index. The problem is partly semantic. If an asset changes during the course of the accounting period it is no longer the same asset at the end and its price is no longer directly comparable with its price at the beginning. This happens with many assets,

both financial and non-financial.

The second component of consumption of fixed capital, namely the increase in the value of the remaining unused services 'locked-up' in the fixed asset, must be treated in the same way as the quantities of a natural asset which remain in the ground but which have become more accessible as a result of the extraction carried out in the current period. The first component of consumption of fixed capital in equation (4), or  $f_t$ , which represents the value of the asset's services used up in the course of production in the current period, must clearly be charged as a cost in the production account. This cost is partly offset, however, by the second component, or  $r(v_t - f_t)$ , which represents the increase in the value of the remaining services available for use in later periods as a result of their being one period closer to being utilised. The increase in their value reflects this change in their characteristics. There is no price change and there can be no holding gain.

This increase in the value of the remaining services has to be recorded somewhere in the system of accounts. As it is a direct consequence of the use of the fixed asset in production, it must be recorded in the production account. The procedure which is implicitly adopted when a single figure is recorded for consumption of fixed capital is to offset it against the cost of the services actually used up and to show only the algebraic difference between the two components in the production account. This avoids the somewhat paradoxical result of showing a negative component of depreciation, or negative 'cost', explicitly.

In order to throw more light on the properties of economic depreciation, two apparently similar but economically different situations may be compared. Suppose first that the optimal production plan requires an asset to be installed but that, once installed, it is necessary to wait one period before it is actually used in production, perhaps because other necessary assets can only be installed after the asset in question is in place. The first component of consumption of fixed capital for the asset,  $f_t$ , is zero by assumption while the second is positive. The asset actually increases in value as the waiting period is reduced and the time approaches when it can be used in production. Capital consumption as normally defined is negative. Compare this case with one in which production has inadvertently to be stopped for one period and the whole production schedule put back one period. In this case,  $f_t$  is zero as before but the value of the remaining services does not increase because they are no closer to being realised than they were at the beginning of the period when the entire production schedule has been postponed by one period. Consumption of fixed capital is zero in this case because both components are zero. Thus, merely observing the fact that an asset remains unused for one period does not provide sufficient information to calculate depreciation. whether it is unused by design or by accident.

## **Conclusions**

The decomposition of depreciation into two interdependent components, one denoting the current cost of the 'services' contributed by the fixed asset to production and the other the consequential change in the present value of the remaining unused services, has been well known for many years in the theoretical literature on economic depreciation. As the two components are very different, valuable insights into the economic significance, properties and behaviour of depreciation are gained by keeping them separate, at least for analytical purposes. Moreover, the two components, when taken separately, look very different from a national accounts perspective, and the present paper addresses the question of how each should be treated in the SNA. While one is clearly a cost of production, the other represents the increase in present value of the asset's unused 'services' carried forward into the next period and looks very much as though it were a holding gain which ought to be recorded in the revaluation account of the SNA. This would have drastic implications for the measurement of consumption of fixed capital and net value added. It is concluded, however, that despite its superficial similarity with a holding gain, the increase in the value of the unused 'services' is not a holding gain because the time which it is necessary to wait before the 'services' can be released by the asset for purposes of production is one of their important economic characteristics, and this characteristic is changed by using the fixed asset in current production. The increase in the value of the services therefore implicitly reflects an improvement in their quality. There is no price change and no holding gain. The best way to record it is in the production account, in which case it may as well be consolidated with the other component of depreciation which is, in fact, the conventional treatment.

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