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Depreciation in the National Accounts

Derek Blades, Statistics Directorate, OECD

DEPRECIATION IN THE NATIONAL ACCOUNTS

Derek Blades*

A. Introduction

1. There are several ways in which capital consumption or depreciation (the terms are used interchangeably below) can be defined and measured.

2. In the former Soviet Union and other centrally planned economies, depreciation was measured at regular intervals by collecting information directly from enterprises. Typically, the central statistical or planning agency supplied enterprises with schedules listing the official, age-specific values of different kinds of assets which enterprises could use to calculate the net value of their assets and annual depreciation. The assets were, in principle, owned by the State and "rented" to enterprises. Depreciation was the main element in the calculation of the annual rents that enterprises were required to pay to the State for use of the assets.

3. In market economies, enterprises typically make several different estimates of depreciation. One estimate may be made for calculating taxable profits which will take advantage of any tax provisions designed to encourage investment outlays, another for published accounts which will be based on the historic or acquisition cost of assets and, perhaps, a third based on the current cost of replacing fixed assets.[i]

4. These various ways of looking at depreciation all have their uses for specific administrative and business purposes, but this note is concerned with the implementation of the 1993 SNA which requires that the accounts should measure economic depreciation. This is explained in the next section. The 1993 SNA notes that, in practice, national accountants will use either straight-line or geometric methods to approximate economic depreciation and this note is principally concerned with the choice between the two methods. Section C looks at how well each method fits a number of standard patterns of depreciation. Section D summarises the scanty empirical information on how the prices of assets - and by implication depreciation - change over the course of their service lives. Finally there are some conclusions and questions.

B. Depreciation in the SNA

5. In competitive markets, the value of a fixed capital asset at any given time is the present discounted value of the future income stream which the asset is expected to generate during the period it is expected to be retained in productive use. As each year passes, the market value will usually fall because the future income stream has shortened. This change in the market value of an asset is defined as economic depreciation and it is this amount, aggregated over all assets in the capital stock, that is required for estimating consumption of fixed capital in the 1993 SNA.[ii]

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*Derek Blades is a member of the OECD Statistics Directorate. The views expressed in this paper are those of the author and do not necessarily reflect those of the OECD Secretariat.

6. Capital consumption occurs because most capital assets have finite lives; there is no capital consumption for assets which have infinite lives, such as land, inventories and valuables. Service lives of most capital assets are finite because: (i) repair costs tend to rise as assets are employed in production so that it eventually becomes uneconomic to keep using them; (ii) technical innovation is likely to make obsolete either the production process for which the asset was bought or the product it was designed to make and (iii) some assets will be destroyed through fires, accidents or careless handling. These are the factors that are taken into account in estimating the expected service lives of assets. Expected service lives do not take account of physical losses caused by wars and natural catastrophes nor of exceptional obsolescence due, for example, to violent changes in relative prices (e.g., oil shocks) or the sudden removal of trade barriers; withdrawals of assets from production for any of these reasons are treated as capital losses and not as capital consumption.

C. Comparison of straight-line and geometric depreciation

7. Although capital consumption is defined as the difference in the market value of assets between two accounting periods, it cannot usually be measured in this way. This is because owners of assets do not generally keep records of their market values. Instead, both commercial accountants and national accountants use modeling techniques to simulate the decline in market values of assets over their lifetime. In the large majority of cases they use either straight-line or geometric depreciation; straight-line depreciation means that capital consumption is the same amount each year while geometric depreciation means that capital consumption occurs at the same rate each year. The 1993 SNA (para. 6.197) notes that "In practice, the choice of formula seems to rest between one or other of these two methods, and there seems little justification of the use of more complex formulae". The 1993 SNA also notes that estimates of capital consumption will generally be derived on estimates of the capital stock made by the "perpetual inventory method" (PIM). The PIM is particularly suitable for calculating capital consumption because the original asset values and service lives are explicit PIM variables.

8. For straight-line depreciation, annual capital consumption is calculated as P/L, where L is the expected service life in years and P is the original purchase price updated to current year prices or to the prices of a base-year. The straight-line method fully exhausts the value of the asset by the end of year L.

9. With geometric depreciation, the decline in asset values is asymptotic and the annual amounts calculated will never sum to the full value of the asset. The OECD countries that use geometric depreciation are all believed to use a cut-off point of 10 per cent; the remaining value of the asset is included in capital consumption in the year when the total of past capital consumption reaches 90 per cent of the initial value of the asset. If C is the desired cut-off point (expressed as a percentage) and L is the service life, geometric capital consumption is obtained by dividing the remaining value of the asset by (1/C)1/L and taking the differences between successive asset values.[iii]

10. To simplify the presentation, the expressions given above for calculating both straight-line and geometric depreciation assume that capital assets are acquired at the beginning of the year so that the first year's investment is depreciated by the full amount. The more realistic assumption, which is usually adopted in practice, is that assets are acquired in the middle of the year and continue in use up to the middle of year L+1.

11. Some years ago, the OECD Statistics Directorate asked Member countries about the methods used to calculate capital consumption. At that time, geometric depreciation was being used in Japan, Iceland, Belgium and Sweden while straight line depreciation was used in the United States, Canada, New Zealand, Australia, Norway, Austria, Finland, Germany and the United Kingdom. Straight line depreciation may be preferred because it does not require the arbitrary selection of a cut-off point. The table below shows the annual capital consumption of an asset with an initial value of 100 and a service life of 10 years using three alternative cut-off points - 15 per cent, 10 per cent and 5 per cent. For capital consumption, the differences are not negligible in the early years although they converge from year 4 onwards; the remaining values, however, are very different in all years so that estimates of the net capital stock are significantly affected by choice of cut-off point.

Table 1. Geometric capital consumption using alternative cut-off points
(Original value of asset = 100; L=10)

Year	Cut off points					
	15 per cent		10 per cent		5 per cent	
	Remaining value of asset	Capital consumption	Remaining value of asset	Value Capital consumption	Remaining value of asset	Capital consumption
1	83	17	79	21	74	26
2	68	15	63	16	55	19
3	57	11	50	13	41	14
4	47	10	40	10	30	11
5	39	8	32	8	22	8
6	32	7	25	7	17	6
7	27	5	20	5	12	5
8	22	5	16	4	9	3
9	18	4	13	3	7	2
10	15	3	10	3	5	2

12. The choice between straight-line or geometric methods should be determined by the ways in which market prices of assets behave in the real world. Some empirical evidence from studies in the United States is given below but it is useful to consider first how well each method approximates to some standard schedules of capital consumption.

13. As already noted, capital consumption is the change in the market values of assets during their lifetimes and these values are determined by the present values of the streams of income which the assets are expected to generate. Because they are determined by present values, these prices depend, therefore, both on the total amounts of income that are expected and on their timing; two assets may generate an identical amount of income over their lifetimes but their market values will be very different if one, say a freight truck, generates that income in steady amounts throughout its life while another, say a timber tract, produces its income only in its final year. Annex 1 contains numerical examples for five assets each of which has a service life of six years and which earns 100 units in the first year. In line with the simplifying assumption made earlier for capital investment, the assumption made here is that the assets generate all their income on the last day of the year; this means that each year's income, including that of the first and last years; are discounted by the same factor. The discount rate, which is the interest rate at which the investor can borrow or lend, is here set at 10 per cent per annum. In all four cases, therefore, the first year's income is discounted to 100/1.10 = 90.9.

14. After the first year, five different situations are considered. First, the asset continues to generate exactly the same income in the remaining five years of its life; second the income falls by a constant amount each year - 7 units in this case; the third, fourth and fifth cases assume constant rates of decline in income at 5 per cent, 8 per cent and 15 per cent per annum.

15. Table 2 below shows the capital consumption and asset values which result from these five assumptions.

Table 2. Capital consumption and asset values
using different assumptions about the pattern of annual income

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
Case a): constant income flow	100	100	100	100	100	100
value of asset	435	379	317	249	173	91
capital consumption	56	62	68	75	83	91
Case b): income declines by 7 units per year	100	93	86	79	72	65
value of asset	368	305	242	180	119	59
capital consumption	63	63	62	61	60	59
Case c): income declines by 5 % per year	100	95	91	86	82	78
value of asset	392	331	269	205	140	71
capital consumption	61	62	64	66	68	71
Case d): income declines by 8 % per year	100	93	86	79	73	68
value of asset	370	307	245	184	123	62
capital consumption	63	62	61	61	61	62
Case e): income declines by 15 % per year	100	87	76	66	57	50
value of asset	328	261	200	144	93	45
capital consumption	67	61	56	51	48	45

Source: Annex tables 1.1 to 1.5.

16. The first case (a) - constant returns throughout the asset's life - is introduced in the 1993 SNA by reference to a light bulb which gives a steady flow of production (lumens) each year until it goes pop. This case is commonly referred to in the literature as the "one-hoss shay" after the cart which ran perfectly for many years without any maintenance (so that its production is costless) but then suddenly fell to pieces in a single day. The problem with these examples are that light-bulbs are not usually treated as capital assets and the one-hoss shay is entirely mythical. Obsolescence and wear and tear virtually guarantee some fall in income as the years go by. Although this first case is unrealistic, it is instructive to note that a <u>steady</u> income flow produces a <u>rising</u> pattern of capital consumption. Inspection of annex table 1.1 shows why this occurs. Capital consumption is identical to the present discounted value of the income earned in the last year of the asset's life; as this last year's income draws closer it is discounted one less time and capital consumption grows exponentially at the discount rate. Clearly, neither straight-line nor geometric depreciation can approximate a capital consumption pattern of this kind; for either to do so successfully income must be <u>declining</u> over time. The next four cases deal with situations of this kind.

17. In case (b), the first year's income of 100 falls by 7 units in each subsequent year. This implies an increasing reduction in percentage terms from 7 per cent in the second year to about 10 per cent in the sixth year. It seems reasonable to assume that repair costs and obsolescence could result in an increasing reduction of income as the asset ages. Capital consumption declines gradually over the period but the straight line assumption of 61 (i.e., 368/6) each year would still provide a close approximation.

18. In cases (c), (d) and (e), incomes fall at constant rates each year, which is perhaps less plausible than the rising rate implied by case (b). At a 5 per cent annual fall (case (c)), capital consumption is still rising though less rapidly than in case (a). Straight-line depreciation of 65 per year (i.e., 392/6) would overstate capital consumption in the first two years and understate it in the last two, but the approximation is still quite close. Case (d) assumes an 8 per cent annual fall in income; eight is the

whole-number percentage decline which comes closest, in this example, to a straight line pattern of depreciation - i.e., 62 per year (370/6).

19. Case (e) assumes that income falls at a rather high rate each year - 15 per cent - but this may not be unrealistic for assets subject to high obsolescence such as those producing or incorporating electronic components. Case (e) gives an age-consumption curve that is convex to the origin with capital consumption falling more rapidly in the early years. This conforms more closely to a pattern of geometric depreciation than any of the earlier cases but, using a 10 per cent cut off point, geometric depreciation would give capital consumption estimates that are far too large in the early years and far too low towards the end of the service life. The actual figures are:

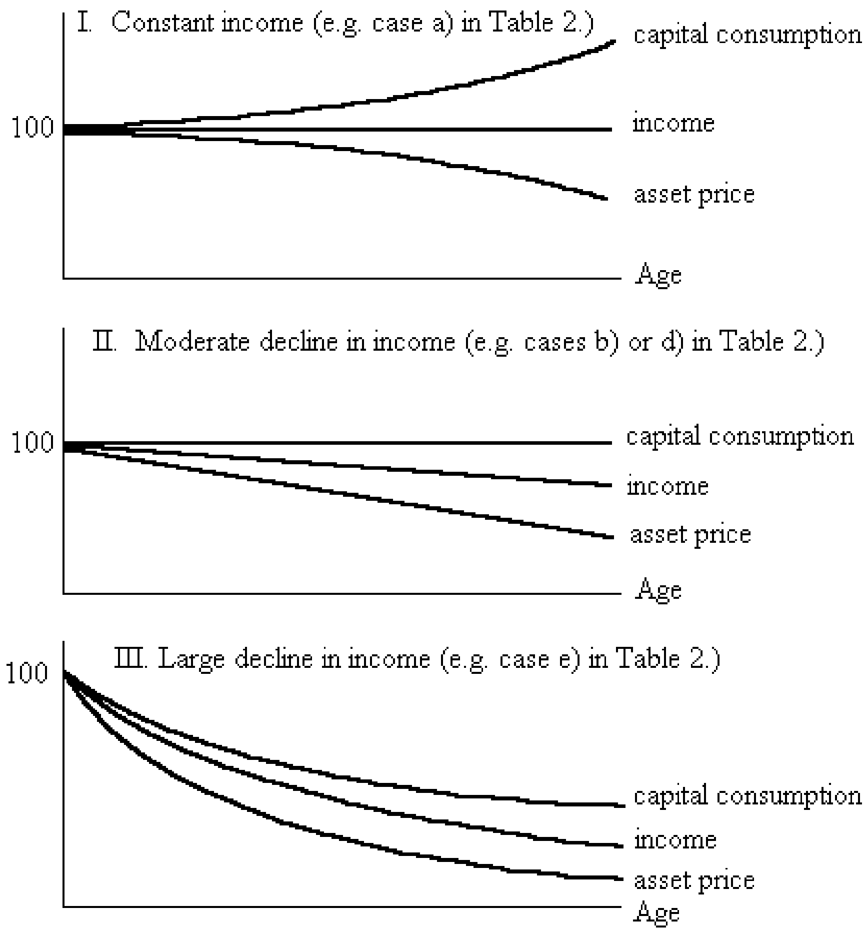
Year:	1	2	3	4	5	6
Capital consumption from Table 2 for case (e):	67	61	56	51	48	45
Capital consumption using geometric depreciation with a 10% cut-off point:	105	71	48	33	23	48*

(*capital consumption for year 6 includes the 10% remaining value of the asset.)

Straight-line depreciation - 55 per year in this case - provides a better, though not very good, approximation than geometric depreciation.

20. In order to visualise the relationship between income flows, capital consumption and asset prices, Figure 1 gives stylised graphs showing how three different patterns of income affect patterns of depreciation and asset prices. The three variables are set to 100 in the first year. Example II conforms broadly to straight-line depreciation; example III to geometric depreciation.

Figure 1. Impact of different income flows on capital consumption and asset prices



D. Empirical evidence

21. The only empirical evidence I have located on depreciation patterns refers to the United States. In a 1969 study Taubman and Rasche examined capital consumption of office buildings in the United States using information on sales of existing buildings. They found "an age-price pattern in which the price declines very little in the early years of asset life and accelerates rapidly toward the end. This pattern is consistent with the conventional view that the relative efficiency of buildings declines very little with age; that is, physical depreciation acts like the "one-horse shay" (Hulten and Wykoff (1980)). This age/price pattern implies that depreciation rises over time as depicted in example I of Figure 1. A decade later, Hulten and Wykoff (1980) used a similar approach but based on a larger set of data which covered four kinds of buildings - retail trade, office buildings, factories and warehouses. They obtained quite different results from Taubman and Rasche and found that prices of all four types of buildings decline most rapidly in value in the early years. This implies a geometric type pattern of capital consumption similar to that shown in example III of Figure 1. Their results are shown in Annex 2.

22. Several years later, Hulten, et al. (1988) studied second-hand prices for five types of construction equipment - two types of tractors, a motor grader, a rubber-tyre loader and a back-hoe - and four types of machine tools - a turret lathe, a milling machine, a grinder and a press. Annex Tables 3.1 to 3.9 shows the age-price profiles for these nine different kinds of assets. (Separate curves are shown for machines produced before 1974 and after 1973 because the authors were examining the effect of the oil shock on asset prices, but this distinction has no relevance for this note.) The age-price curve for milling machines broadly conforms to example III in Figure 1, but the other three types of machines have age-price curves more like pattern II (implying straight-line depreciation). The age-price profiles

for construction equipment are consistent with examples II and III in Figure 1.

23. Second-hand prices refer, by definition, to assets that have changed hands at least once during their lifetimes. Some critics have questioned whether these prices are applicable to the much larger population of assets that are retained by their original purchaser throughout their service lives. In particular, it is suggested that a "lemon-factor" is at play here; lemons - assets which disappoint their purchasers because of poor reliability - have the highest chance of being sold off. This might account in part for the sharp declines in price for relatively young assets. Another criticism is that many assets that enter the second-hand market do so as a result of bankruptcies and that they may be sold off at unrepresentative "fire-sale" prices. This latter criticism is rejected by Professor Hulten who notes that the market for second hand assets is large and well organised; there is no reason for dealers to dispose of assets at prices that are below market values.

E. Conclusions and questions

24. Some conclusions and some questions:

i) Economic depreciation as required for the 1993 SNA cannot usually be measured directly because neither asset owners nor statistical offices know the market prices of assets in the capital stock.

ii) Depreciation almost always has to be approximated by a modeling procedure in which the purchase prices of assets are reduced in some systematic way over their expected lifetimes.

iii) Two models are used by national accountants - straight-line depreciation, which reduces asset prices by the same amount each year, and geometric depreciation, which reduces asset prices by the same rate each year.

iv) One disadvantage of geometric depreciation is that an arbitrary cut-off point must be selected (e.g., 10 per cent of the initial asset price) since otherwise total depreciation would never equal the original cost of the asset.

v) When the two methods are evaluated as approximations to economic depreciation for five different patterns of income flow, straight-line scores better than geometric depreciation. Income flows would need to fall at a rather high exponential rate in order for the geometric model to fit better than straight line depreciation.

vi) Studies of second hand asset prices undertaken in the United States suggest that prices of buildings and some kinds of machinery decline at a higher rate in the early years compared to the end of their lives. This implies that geometric would be more appropriate than straight-line depreciation. However, a rate of geometric depreciation designed to arrive at cut-off points between 5 to 15 per cent of the original asset price in the last year of its service life, may well give a worse approximation to economic depreciation than straight-line methods. (See para. 20.)

vii) Questions:

- Have empirical studies of market prices of assets been made in countries other than the United States?

- Which countries use only straightline, only geometric and both methods for estimating depreciation?

- Am I correct in assuming that countries that use geometric methods do in fact use rates defined as $(1/C)^{1/L}$ (see para. 10)?

Annex 1: Five patterns of income flows and their implications for capital consumption and asset prices

Annex Table 1.1 Market prices and capital consumption assuming that the annual income earned by the asset remains constant

Year	Annual income earned by asset (Y)	Present value of Y at the beginning of each year over the life of the asset, with 10% discount rate:					
		1	2	3	4	5	6
1	100.0	90.9	-	-	-	-	-
2	100.0	82.6	90.9	-	-	-	-
3	100.0	75.1	82.6	90.9	-	-	-
4	100.0	68.3	75.1	82.6	90.9	-	-
5	100.0	62.1	68.3	75.1	82.6	90.9	-
6	100.0	56.4	62.1	68.3	75.1	82.6	90.9
Market price of asset at the beginning of each year:		435.4	379.0	316.9	248.6	173.5	90.9
Capital consumption during the year:		56.4	62.1	68.3	75.1	82.6	90.9

Annex Table 1.2 Market price and capital consumption assuming that the annual income earned by the asset declines by 7 units each year

Year	Annual income earned by asset (Y)	Present value of Y at the beginning of each year over the life of the asset, with 10% discount rate:					
		1	2	3	4	5	6
1	100.0	90.9	-	-	-	-	-
2	93.0	76.9	84.5	-	-	-	-
3	86.0	64.6	71.1	78.2	-	-	-
4	79.0	54.0	59.4	65.3	71.8	-	-
5	72.0	44.7	49.2	54.1	59.5	65.5	-
6	65.0	36.7	40.4	44.4	48.8	53.7	59.1
Market price of asset at the beginning of each year:		367.8	304.6	242.0	180.1	119.2	59.1
Capital consumption during the year:		63.2	62.6	61.9	60.9	60.1	59.1

Annex Table 1.3 Market price and consumption of fixed capital assuming that the annual income earned by the asset declines by 5 per cent per year

Year	Annual income earned by asset	Present value of Y at the beginning of each year over the life of the asset, with 10% discount rate:					
	(Y)	1	2	3	4	5	6
1	100.0	90.9	-	-	-	-	-
2	95.2	78.7	86.5	-	-	-	-
3	90.7	68.1	75.0	82.5	-	-	-
4	86.4	59.0	64.9	71.4	78.5	-	-
5	82.3	51.1	56.2	61.8	68.0	74.8	-
6	78.4	44.3	48.7	53.5	58.9	64.8	71.3
Market price of asset at the beginning of each year:		392.2	331.3	269.2	205.4	139.6	71.3
Capital consumption during the year:		60.8	62.1	63.8	65.8	68.3	71.3

Annex Table 1.4 Market price and consumption of fixed capital assuming that the annual income earned by the asset declines by 8 per cent per year

Year	Annual income earned by asset	Present value of Y at the beginning of each year over the life of the asset, with 10% discount rate:					
	(Y)	1	2	3	4	5	6
1	100.0	90.9	-	-	-	-	-
2	92.6	76.5	84.2	-	-	-	-
3	85.7	64.4	70.8	77.9	-	-	-
4	79.4	54.2	59.7	65.6	72.2	-	-
5	73.5	45.6	50.2	55.2	60.7	66.8	-
6	68.1	38.4	42.3	46.5	51.2	56.3	61.9
Market price of asset at the beginning of each year:		370.0	307.1	245.3	184.1	123.1	61.9
Capital consumption during the year:		62.9	61.8	61.2	61.0	61.2	61.9

Annex Table 1.5 Market price and consumption of fixed capital assuming that the annual income earned by the asset declines by 15 per cent per year

Year	Annual income earned by asset	Present value of Y at the beginning of each year over the life of the asset, with 10% discount rate:					
	(Y)	1	2	3	4	5	6
1	100.0	90.9	-	-	-	-	-
2	87.0	71.9	79.1	-	-	-	-
3	75.6	56.8	62.5	68.7	-	-	-
4	65.8	44.9	49.4	54.4	59.8	-	-
5	57.2	35.5	39.1	43.0	47.3	52.0	-
6	49.7	28.1	30.9	33.9	37.3	41.1	45.2
Market price of asset at the beginning of each year:		328.1	260.9	200.0	144.4	93.1	45.2
Capital consumption during the year:		67.2	60.9	55.6	51.3	47.9	45.2

Annex 2. Age-Price profiles for four types of commercial buildings

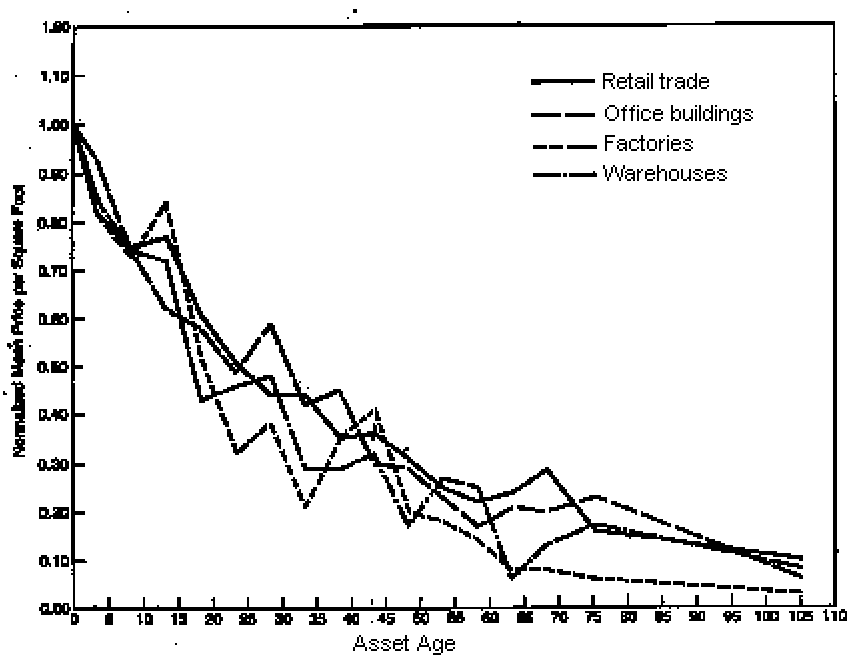
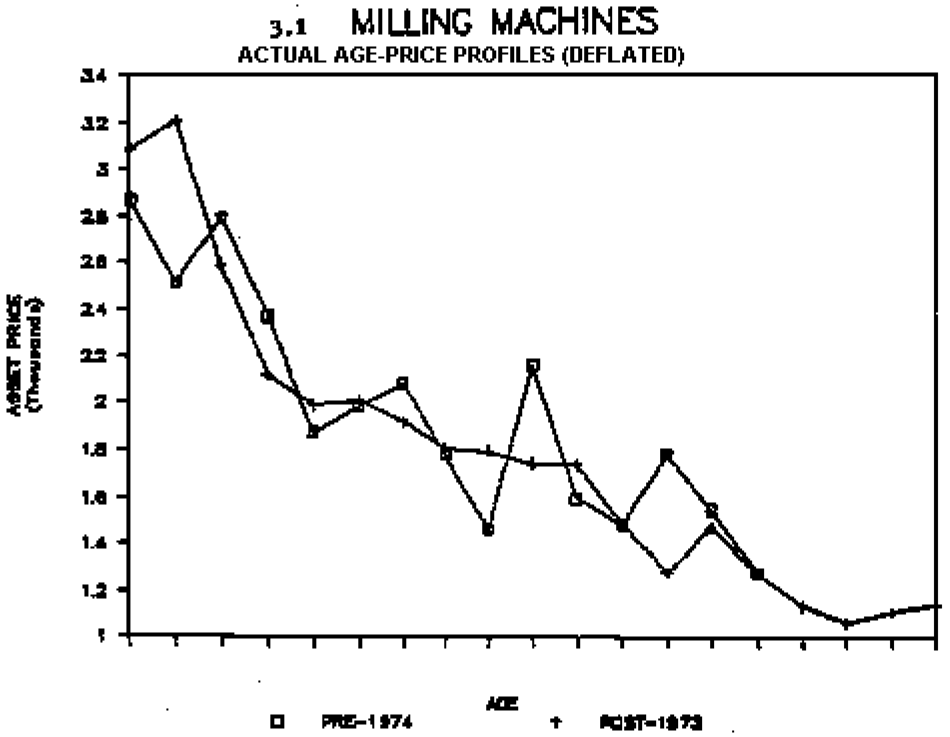
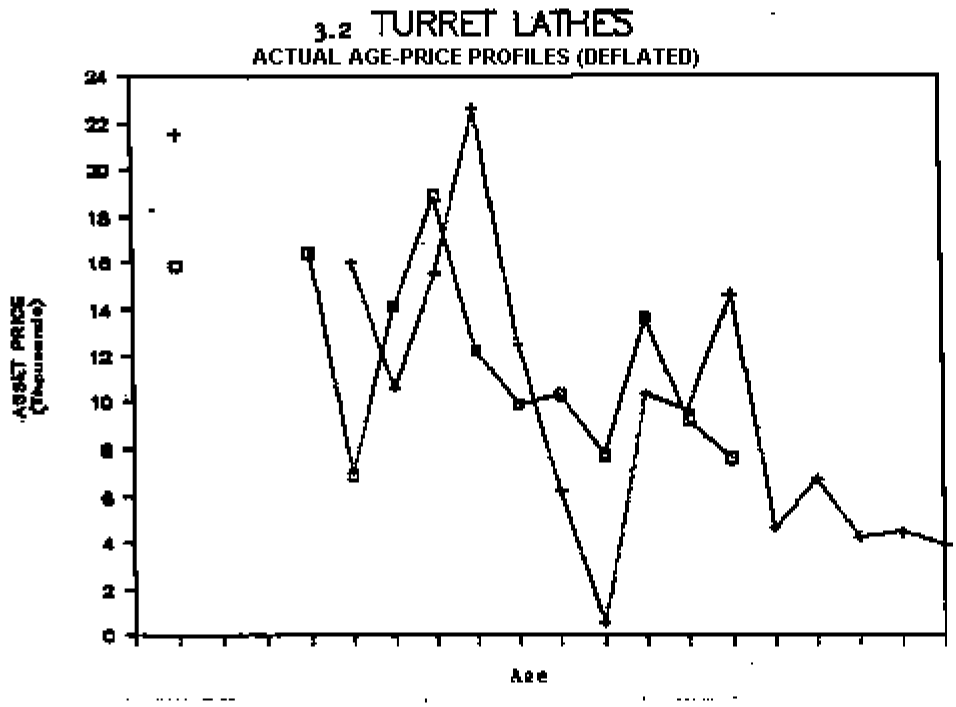


Fig. C2.2 Mean asset price by age interval, transformed/deflated.

Source: Hulten and Wykoff (1980) p. 117.

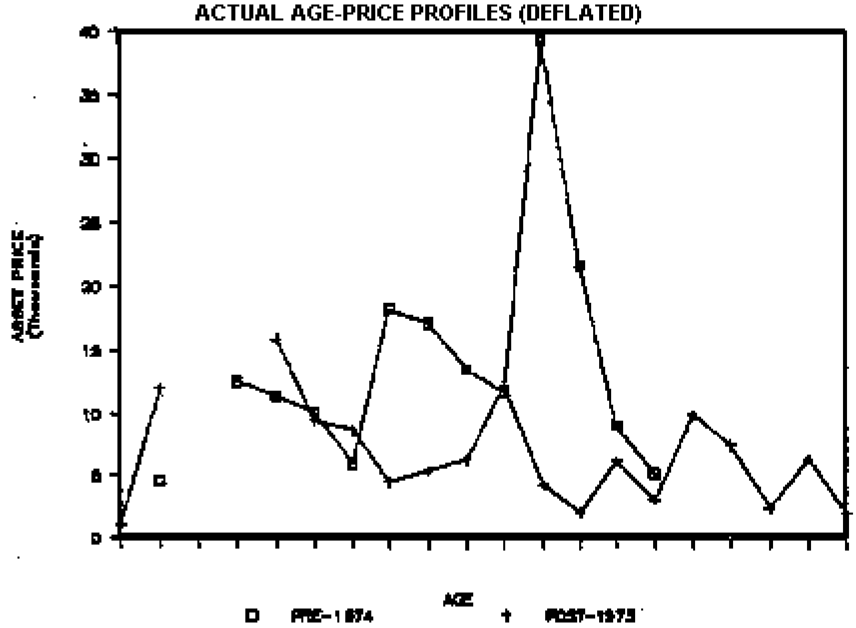
Annex 3. Age-Price profiles for nine types of machinery





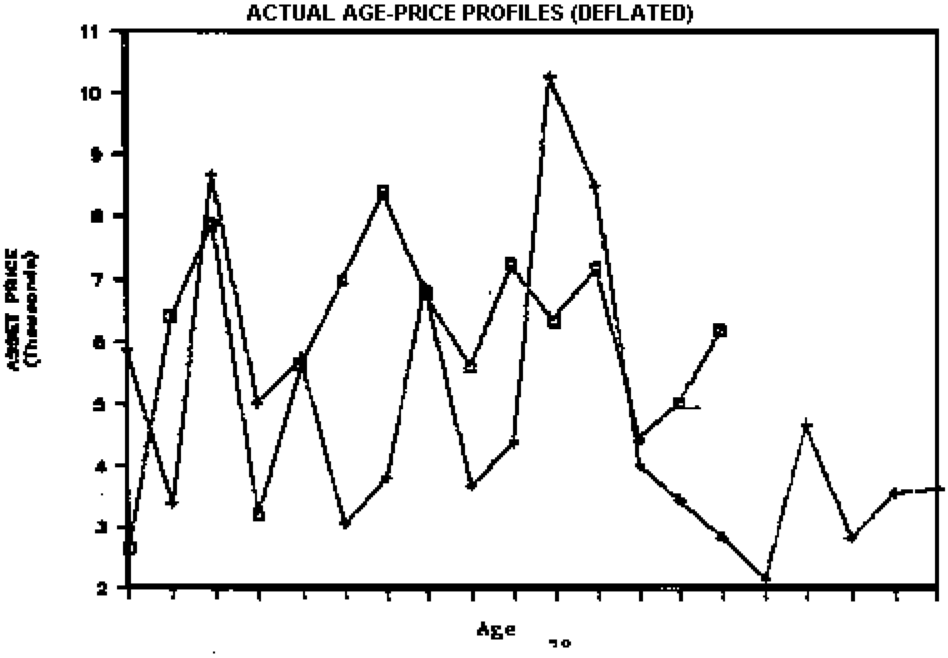
3.3 PRESSES

ACTUAL AGE-PRICE PROFILES (DEFLATED)



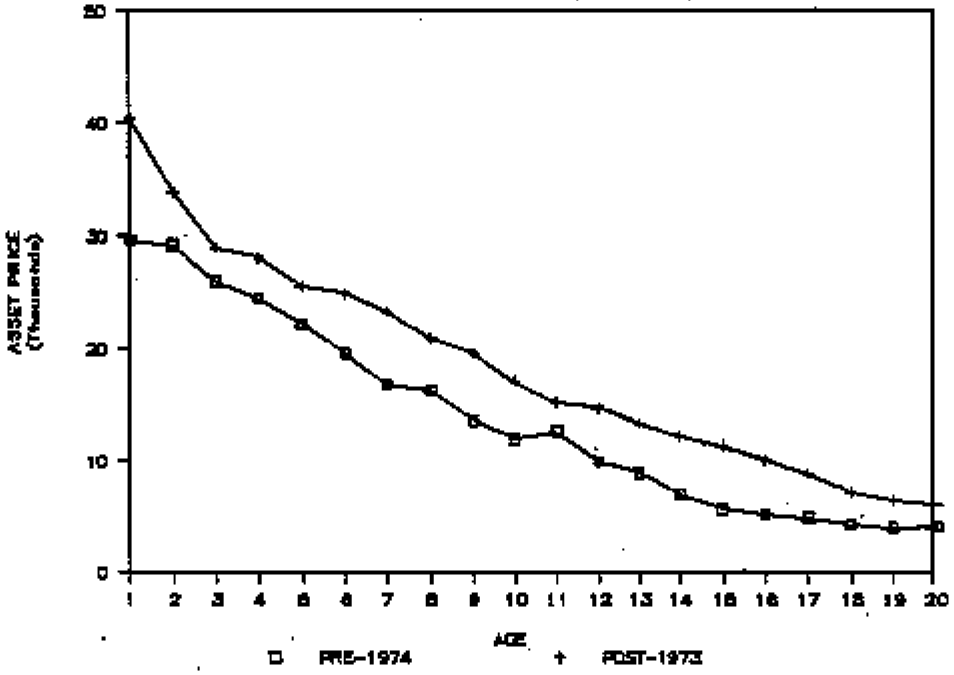
3.4 GRINDERS

ACTUAL AGE-PRICE PROFILES (DEFLATED)



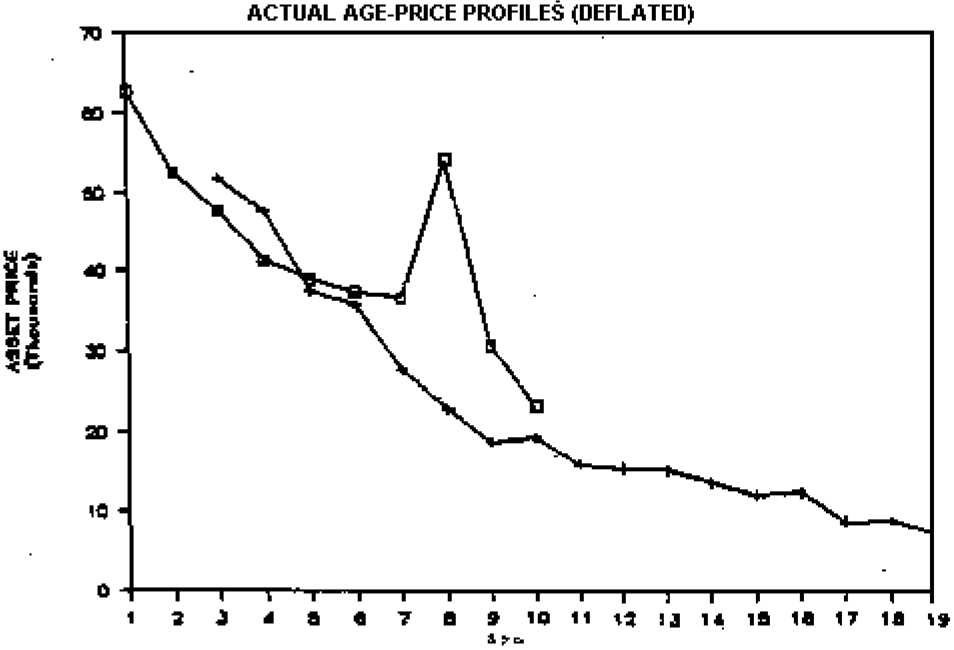
3.5 MOTOR GRADERS

ACTUAL AGE-PRICE PROFILES (DEFLATED)

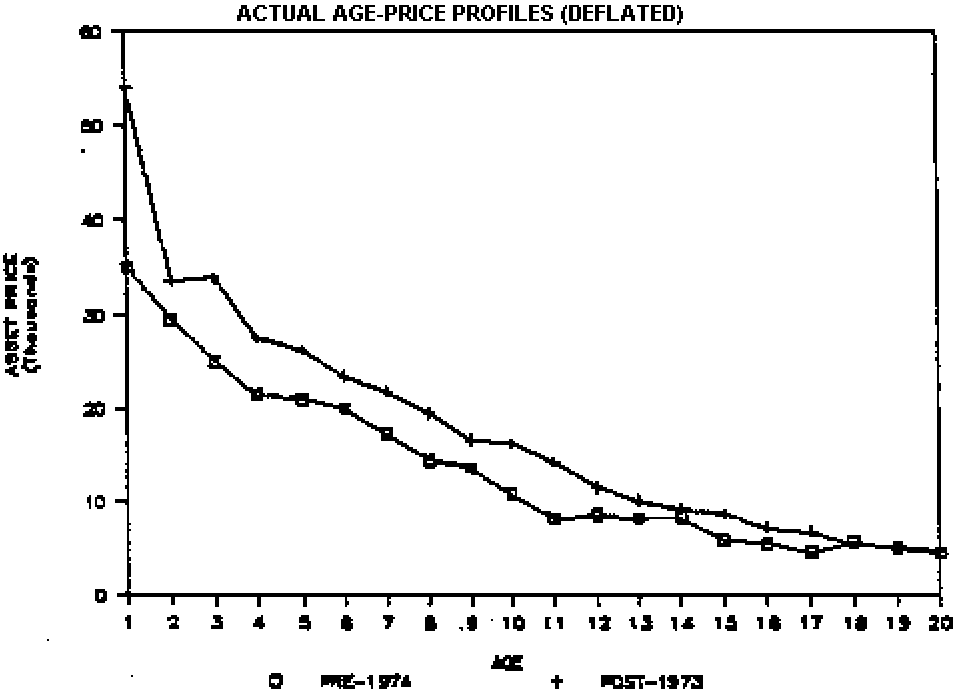


3.6 RUBBER TIRE LOADER

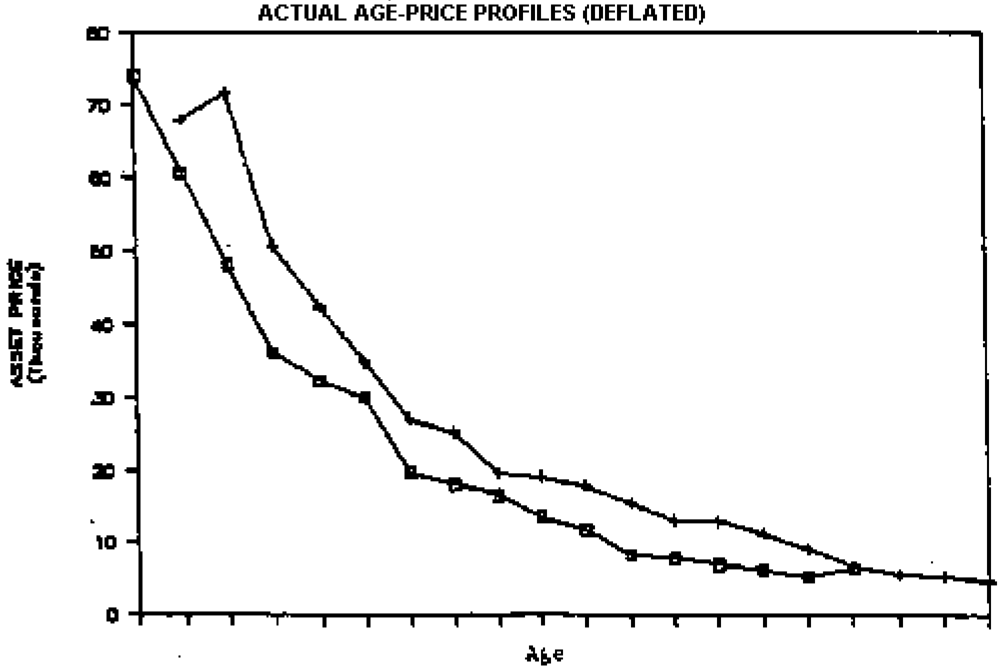
ACTUAL AGE-PRICE PROFILES (DEFLATED)



3.7 D–6 TRACTORS
ACTUAL AGE-PRICE PROFILES (DEFLATED)



3.8 D9 TRACTORS
ACTUAL AGE-PRICE PROFILES (DEFLATED)



Source: Hulten et al. 1988.

Notes and References:

i. See International Comparison of Tax Depreciation Practices, OECD, Paris 1975 for a description of the various tax regimes relating to depreciation in OECD countries, and T.P. Hill (1979), Profits and Rates of Return, OECD, Paris for a summary of commercial accounting practices.

ii. System of National Accounts, 1993, paragraphs 6.179 to 6.203.

iii. The System of National Accounts, 1993 notes in paragraph 6.195 that geometric depreciation can be approximated by calculating depreciation as a constant fraction, 200/L, of the written down value of the good at the start of each year. This is the "double declining balance" method. It should be noted, however, that the double declining balance method is only an alternative way of calculating geometric depreciation and cannot be regarded as a separate depreciation method in its own right.

Hulten, Charles R. and Frank C. Wykoff (1980) "Economic Depreciation and the Taxation of Structures in United States Manufacturing Industries: An Empirical Analysis" in Dan Usher (ed.) The Measurement of Capital, University of Chicago Press, Chicago and London, 1980.

Hulten, Charles R., James W. Robertson and Frank C. Wykoff, Energy, Obsolescence, and the Productivity Slowdown, BLS Working Paper 176, US Department of Labor, Washington, D.C., February 1988.