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Measuring Capital

OECD Manual

MEASUREMENT OF
CAPITAL STOCKS,
CONSUMPTION
OF FIXED CAPITAL AND
CAPITAL SERVICES

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CAPITAL STOCKS,
CONSUMPTION
OF FIXED CAPITAL AND
CAPITAL SERVICES**

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- à contribuer à une saine expansion économique dans les pays Membres, ainsi que les pays non membres, en voie de développement économique ;
- à contribuer à l'expansion du commerce mondial sur une base multilatérale et non discriminatoire conformément aux obligations internationales.

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FOREWORD

In 1995 the United Nations Statistical Commission requested a study into critical problems in economic statistics. The study identified many problems related to the measurement of capital stocks. *Measuring Capital: A Manual on the Measurement of Capital Stocks, Consumption of Fixed Capital and Capital Services* is an important initiative to overcome these problems. It is aimed at compilers in all countries, both developed and developing. While focusing mainly on compilation issues, the *Manual* also clarifies the conceptual issues associated with capital measurement. It is important that compilers of any statistic have a sound understanding of that statistic's conceptual base. This is particularly important though in the case capital statistics, which are more complex than most. The *Manual* should also be useful to users of capital stock and related statistics, by providing information on the way that the statistics are put together.

Capital statistics are an important component of the national accounts. In recognition of this, the *Manual* takes the 1993 System of National Accounts (SNA) as its starting point. The SNA framework and SNA concepts are used throughout the *Manual* and the statistics compiled in accordance with the practices described in the *Manual* can be used directly in the compilation of the national accounts. Another important feature of the *Manual* is its emphasis on consistency between the various measures of capital. In particular, it is important that the national accounts measures of capital are consistent with those used in productivity analysis. Through the *Manual's* discussion of this issue, it provides an important link between the SNA and productivity statistics. The theory and measurement of productivity statistics is described in detail in the *OECD Manual on Productivity Measurement: a Guide to the Measurement of Industry-Level and Aggregate Productivity Growth*. The two manuals are complementary.

A number of persons contributed directly to the preparation of the *Manual*. Foremost among these was Derek Blades of the OECD, who was the principal author. Others who made direct contributions were Peter Harper and Charles Aspden of the Australian Bureau of Statistics who provided the initial draft of Chapter 2, Mike Harper (US Bureau of Labor Statistics) and Barbara Fraumeni (US Bureau of Economic Analysis) who were closely involved in the preparation of Chapter 9, and Peter Hill, who provided the initial draft of Annex 4. Special mention should also be made of Rob Edwards (Australian Bureau of Statistics) who was instrumental in establishing and guiding the "Canberra Group on Capital Stock Statistics". The Group's work was essential to the development of the *Manual* and the participants in the Group's meetings are listed at the end of Chapter 1.

The *Manual* takes the measurement of capital a long way forward. However, there remain unresolved issues that require further investigation. These are discussed in Annex 4, which provides an agenda for future research on capital measurement. The issues are challenging, but with the base provided by the *Manual* and through the continued efforts of experts in the field the forward momentum already established can be maintained.

The work is published on the responsibility of the Secretary General of the OECD.

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CHAPTER 1 INTRODUCTION

Purpose

1.1 This *Manual* serves two complementary purposes:

- To clarify the conceptual issues concerning stocks and flows of fixed capital in the national accounts, and
- To provide practical guidelines for estimation.

1.2 The nature of capital and its contribution to production has long been a contentious issue for economists but there is now a good measure of agreement on the definitions of the *stock of fixed capital assets* and *consumption of fixed capital* in the context of the national accounts. The 1993 System of National Accounts (1993 SNA) includes capital stocks as an integral part of the accounting system and shows how the opening and closing stocks are reconciled by transactions in assets and other changes. The 1993 SNA also provides detailed definitions of fixed capital formation, stocks of fixed assets and consumption of fixed capital and these definitions underlie the guidelines contained in this *Manual*.

1.3 This *Manual* also deals with the definition and measurement of *capital services*. There is now wide agreement that the contribution of capital to production should be measured in terms of *the flow of services* produced by capital assets rather than by the *stock* of those assets. The *Manual* shows how a *volume index of capital services* can be constructed in a way that is consistent with the measurement of capital stocks and consumption of fixed capital.

What the Manual does not cover

1.4 This *Manual* does not deal with the measurement of fixed capital formation. The 1993 SNA enlarged the asset boundary by introducing a new class of intangible fixed assets, including mineral exploration, computer software and entertainment, literary and artistic originals. There are both practical problems and conceptual questions about the valuation of some of these new assets, but it was agreed that it would not be appropriate to deal with these issues here. This *Manual* is concerned with the measurement of capital stocks and assumes that fixed capital formation, including capital formation in these new assets, has been correctly measured and correctly valued.

1.5 Price indices for fixed capital assets are required for the measurement of capital stocks. Constructing price indices for fixed assets is particularly difficult because many capital goods are unique so that it is not possible to observe price changes from one period to the next. Another problem is that an important set of capital goods - communications and computing equipment - is subject to dramatic technological improvements which are difficult to capture by the conventional

techniques used to measure quality change. These issues are not dealt with in detail in this *Manual* because they are seen as general price index problems and are not specific to capital stock measurement.

Contents of the Manual

1.6 Chapter 2, *Concepts in Capital Measurement*, introduces the standard equation relating asset values to the rentals that an asset is expected to earn during its lifetime. This equation is central to the theoretical basis of the measurement of capital stocks and flows. The chapter shows how it can be used to derive both an *age-price* profile and an *age-efficiency* profile for an asset. The age-price profile is relevant to the measurement of the net capital stock and consumption of fixed capital, while the age-efficiency profile is relevant to the measurement of capital services. A final section explains how a *volume index of capital services* can be calculated using the age-efficiency profiles of each asset and the *user costs of capital* which are also derived from the standard equation for the value of an asset.

1.7 Chapter 3, *Coverage and Classification of Assets*, identifies the kinds of assets that are included in capital stocks and in the associated flow measures. Classifications of both assets and asset owners are given in the 1993 SNA and these are the starting points for the classification of capital stocks. It is, however, unlikely that any country will be able to apply the full detail of these classifications and suggestions are given for a more aggregated breakdown of assets and asset owners.

1.8 Chapter 4, *Capital Stocks and Related Flows; Concepts and Uses*, starts by explaining the valuation principles and gives numerical examples of how stocks are valued at historic cost and at current and constant costs. The chapter provides the basic definitions of the gross and net stocks, consumption of fixed capital and capital services and explains their uses.

1.9 Chapter 5, *Overview of Measurement Methods*, reviews the basic data sources that may be used to estimate capital stocks, consumption of fixed capital and capital services. The gross capital stock can be estimated either by surveys of enterprises or by the “perpetual inventory method” (PIM). Company accounts give estimates of both net stocks and consumption of fixed capital but these are not generally suitable for national accounts purposes; both of these need to be estimated by statistical agencies, usually starting with the gross capital stock. Capital services can be directly observed when assets are leased but most assets are owned by their users and capital services have to be estimated indirectly.

1.10 Chapter 6, *Perpetual Inventory Method*, describes the basic requirements for implementing the PIM, namely statistics on gross fixed capital formation, price indices for capital assets, and information on average service lives and on how retirements are distributed around these averages. This chapter describes first the conventional PIM, in which the gross capital stock is estimated, assumptions are made about consumption of fixed capital and the net capital stock is obtained by deducting accumulated consumption of fixed capital from the gross stock. It then describes an alternative application of the PIM in which the net stock is estimated directly using the price-age profiles that are implied by assumed age-efficiency profiles. Consumption of fixed capital is derived as the difference between successive net stock estimates.

1.11 Chapter 7, *Measuring Consumption of Fixed Capital*, identifies the depreciation methods that are most likely to reflect the ways in which assets lose their value over time. The first part of the chapter reviews the empirical evidence about *age-price profiles* i.e. about how assets lose their value during the course of their service lives. The next section shows that there are many *age-efficiency profiles* that will produce age-price profiles for assets that are consistent with this empirical evidence.

The third section describes three common depreciation methods and compares the age-price profiles implied by each method with the empirically-consistent age-price profiles identified in the previous section.

1.12 Chapter 8, *Surveys and Other Direct Measurement Methods*, considers other ways of estimating capital stocks that may avoid the uncertainties inherent in the Perpetual Inventory Method. These relate, in particular, to assumptions about service lives and mortality patterns. It concludes that there is a case for wider use of direct survey methods. The main impediment to the use of surveys is their high cost but this can be reduced by a “rolling benchmark” survey of the kind that has been introduced in the Netherlands. Another alternative to the PIM is the “balance of fixed asset” survey that is carried out in several transition economies.

1.13 Chapter 9, *Capital Services*, introduces a production function of the kind used in studies of multifactor productivity and argues that the capital variable in this function should be a flow rather than a stock. The appropriate measure is a *volume index of capital services*. The chapter explains how this is constructed by first converting assets to *standard efficiency units* and then combining them into an index with *user costs of capital* as weights.

1.14 There are four annexes to the *Manual* and a Bibliography:

- Annex 1. Glossary of terms used in the *Manual*
- Annex 2. Methods used in four countries to estimate capital stocks and flows using the perpetual inventory method.
- Annex 3. Service lives of assets used in four countries.
- Annex 4. Research agenda
- Bibliography.

How the Manual was written

1.15 With encouragement from the United Nations Statistical Commission, the Australian Bureau of Statistics (ABS) organised a meeting on capital stock statistics in Canberra in early 1997. The participants agreed that it would be useful to produce a manual dealing with conceptual and measurement aspects of capital stock statistics and a Steering Group was appointed to draw up an outline for such a manual. This shaped the agenda for the next meeting of the “Canberra Group on Capital Stock Statistics” which was organised by the ABS at the Organisation for Economic Co-operation and Development (OECD) in Paris in September 1998. The papers presented at these two meetings and the discussions they provoked provided the input for a first draft of a manual, which was written at the OECD during the first half of 1999. This draft was reviewed at a third meeting of the Canberra Group, which was co-hosted by the United States Bureau of Economic Analysis (BEA) and the Bureau of Labor Statistics (BLS) in Washington D.C. in November 1999. Following discussions at that meeting, a second draft was prepared at the OECD and circulated for comment in September 2000. The final version of the *Manual* was completed in February 2001.

1.16 Capital stock statisticians and users of capital data from twenty-five countries participated in one or more of the Canberra Group meetings. They came from national statistical offices, universities and research institutes. Representatives of several international agencies also took part. Below is a list of all those who participated in one or more meetings of the Canberra Group and who, by doing so, have contributed materially to this *Manual*. It should be emphasised, however, that not all the participants listed below agree entirely with the contents of this *Manual*. On some issues the *Manual* reflects a majority view rather than unanimous agreement.

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CHAPTER 2 CONCEPTS IN CAPITAL MEASUREMENT

Introduction

2.1 The capital stocks that are the subject of this *Manual* are produced assets used as inputs into the production process. While the national accounts are primarily concerned with the wealth aspects of capital – consumption of fixed capital and net capital stocks – these wealth aspects are not independent of capital's role in production. Indeed, it is the latter that influences the former, as capital assets only exist as wealth to the extent that the assets can be expected to be used in future production processes. The purpose of this chapter is to explain the links between capital assets as an input into the production process and capital assets as components of the net worth – or wealth – of their owners.

2.2 This *Manual* is primarily intended to provide practical guidelines for the measurement of capital stocks, consumption of fixed capital and capital services. The theoretical considerations presented in this first chapter will help readers to understand the conceptual framework underlying those guidelines. It also introduces many of the technical terms that are used in the *Manual*. The chapter is arranged as follows:

- **How asset values are determined.** This section introduces the standard equation relating asset values to the rentals that an asset is expected to earn during its lifetime. This equation is central to the theoretical basis of measuring capital stocks and flows.
- **Relationship between rentals and asset prices.** This section uses the standard equation for the value of an asset to show how the sequence of rentals generated by an asset determines the changes in the price of an asset over the course of its lifetime.
- **Age-efficiency and age-price profiles.** The standard equation for the value of an asset can be used to derive both an age-efficiency and an age-price profile for an asset. The age-efficiency profile is relevant to the measurement of capital services, while the age-price profile is relevant to the measurement of the net capital stock and consumption of fixed capital.
- **Consumption of fixed capital.** This section explains that consumption of fixed capital is the difference between successive market values of assets and can be obtained *indirectly* by using age-efficiency profiles to obtain the age-price profiles of assets and then subtracting successive values of the assets. More commonly consumption of fixed capital is estimated *directly* by applying depreciation functions to the gross value of assets.
- **Aggregating assets to obtain stocks.** This section introduces the two stock concepts covered in this *Manual* - the gross capital stock and the net capital stock. It explains how

the values of assets that have been acquired at different times must be converted to a common price basis before they are added up to obtain stocks of assets.

- **Volume index of capital services.** This index is used to represent the input of capital for studies involving the analysis of production such as the measurement of multifactor productivity. This section explains how it is calculated by first converting each type of asset into *standard efficiency units* using the age-efficiency profiles described earlier. The *user costs of capital* are then used as weights to derive an overall index of the volume of capital services provided by the many different type of capital assets.

How asset values are determined

2.3 The value of an asset depends primarily on the value of the **rentals** that it is expected to earn during its lifetime. Rentals are the incomes earned by an asset during each accounting period. They are equal to the quantity of **capital services** produced by the asset, such as tonne-kilometres in the case of a truck or cubic metres of storage space in the case of a warehouse, multiplied by the unit price of those services. The lifetime of an asset is the total period that it is in productive use from the moment that it is first installed or constructed. During its lifetime the asset may remain with the original purchaser or it may be traded, as a second-hand asset, between several producers. The lifetime of an asset is referred to in this *Manual* as its **service life**.

2.4 Because the rentals generated by an asset are received over several years, they have to be discounted in calculating the value of the asset at any point in time. The rentals expected in future periods are discounted using a **discount rate**, which is often taken as the interest rate on long-term bonds.

2.5 When an asset is **discarded**, or **scrapped**, at the end of its service life it will have a **scrap value**. This will usually be a positive amount corresponding to the value of any parts or waste materials that can be recuperated from the asset minus the cost of dismantling the asset or removing it from the site. In some cases these costs may be so high that the scrap value becomes negative. Nuclear power stations, for example, have very high decommissioning costs so that scrap values are usually large negative amounts.

2.6 These three variables – the rentals, the discount rate and the scrap value – *determine* the value of an asset both when it is new and at all the later stages of its service life. In what follows the scrap values are ignored because they are usually small in relation to the discounted values of the rentals and have a negligible effect on the asset value. Ignoring scrap values, the standard formula for the value of an asset can be written as follows:

$$V_t = \sum_{\tau=1}^T \frac{f_{t+\tau-1}}{(1+r)^\tau} \quad (1)$$

Where V_t is the real value of an asset at the beginning of year t ,

f is the real rental in each period,

T is the service life of the asset in years,

τ takes values of 1, 2, 3 T ,

and r is the discount rate used to reduce the future flow of rentals to their present values. The discount rate is in real terms i.e. it is a nominal rate of interest minus the rate of general inflation.

Equation (1) assumes that the rentals are received at the end of each year so that the first year's rental is fully discounted. It would be more realistic to assume that the rentals are received evenly through the year but this complicates the calculations without affecting the conclusions.

2.7 This is the central equation for understanding the conceptual framework of this *Manual*. As will be shown later it provides the link between stock measures and consumption of fixed capital on the one hand, and the measurement of capital services on the other. The equation also provides the **user costs of capital** that are needed to combine the capital services produced by individual assets to construct an overall index of the flow of capital services generated by a stock of assets.

2.8 Hitherto equation (1) has been described as the equation that determines the *value* of an asset. Value is to be understood as the *market price*, of an asset. In considering whether to purchase an asset, rational producers will first calculate the rentals they expect to receive from an asset and will then solve equation (1) for r . They will buy the asset only if the price at which it is offered implies a rate of return – as measured by r – which is at least as high as they can earn from alternative use of their funds. If an asset is offered for sale at a price that does not seem likely to generate a satisfactory rate of return, there will be no market for that asset. If an asset is offered at a price that seems likely to generate a very high rate of return, demand for the asset will rise and bid up the price until the rate of return falls to a “normal” level. In practice, manufacturers of capital goods will themselves calculate the rates of return that assets are likely to earn and will not produce assets that are unlikely to generate rates of return that are sufficiently high to ensure that there will be a market for them. Equation (1) can, therefore, be seen as a very plausible explanation of how asset prices are determined in a market economy.

Relationship between rentals and asset prices.

2.9 Table 1 shows how equation (1) can be used to calculate the price of an asset both when it is new and at every stage in its lifetime. In this example the asset is expected to have a service life of 8 years and the discount rate is 5%. As noted above, a simplifying assumption is made that the rentals are received on the last day of each year, so that the first year's rental is fully discounted.

Table 1. Relationship between Rentals and Asset Value (Discount Rate 5%)

Year (<i>t</i>)	Capital service	Price	Rental (<i>f</i>)	Value of Discounted Rentals at the Beginning of Year:									
				1	2	3	4	5	6	7	8		
1	5.0	2	10.0	9.5									
2	4.5	2	9.0	8.2	8.6								
3	4.0	2	8.0	6.9	7.3	7.6							
4	3.5	2	7.0	5.9	6.0	6.3	6.7						
5	3.0	2	6.0	4.7	4.9	5.2	5.4	5.7					
6	2.5	2	5.0	3.7	3.9	4.1	4.3	4.5	4.8				
7	2.0	2	4.0	2.8	3.0	3.1	3.3	3.5	3.6	3.8			
8	1.5	2	3.0	2.0	2.1	2.2	2.4	2.5	2.6	2.7	2.9		
Asset value (<i>V</i>)				43.7	35.8	28.6	22.1	16.2	11.0	6.5	2.9		

To understand Table 1:

- The rentals that the asset is expected to earn each year are shown in the fourth column. They are the quantity of capital services produced by the asset multiplied by the unit price of those services. In this example the capital services shown in the second column are assumed to decline by half a unit each year because the asset loses efficiency as it ages. The prices of the capital services shown in the third column are held constant with the result that both the rentals and the asset values derived from them are measured in constant prices.
- Because these rentals are generated in sequence and are not all available in the first year, their **present value** has to be obtained by discounting each year's rental by the (real, i.e. inflation-adjusted) discount factor $(1+r)$. This is 1.05 in this example. The discounted rentals are shown in the right-hand triangular portion of the table.
- The fifth column shows the value, at the start of year 1, of the rentals that are expected to be received in each of the 8 years of the asset's life. This example assumes that rentals are received at the end of each year and so the first year's rental of 10 is worth only $10/1.05 = 9.5$ at the beginning of year 1; the rental of 9 expected at the end of the second year is worth only $9/1.05^2 = 8.2$ at the beginning of year 1; the rental of 8 expected at the end of year 3 is worth only $8/1.05^3 = 6.9$; etc. The total of these discounted rentals gives the value of the asset at the beginning of year 1, i.e. 43.7.
- The sixth column shows the discounted values of the rentals generated by the asset in the second year. The first year's rental of 10 has been used up so the price of the asset will be lower for this reason, but this is partly offset by the fact that by the beginning of the second year all the rentals expected from year 2 through to year 8 are now one year nearer and so will be discounted one less time. The total of these discounted rentals gives the price of the asset at the beginning of year 2, i.e. 35.8.

2.10 Table 1 shows that for a given rate of interest, there is one and only one sequence of asset prices for a given sequence of rentals. The reverse relationship also holds. For a given sequence of

asset prices Table 1 can be used to work back to the sequence of rentals, provided that the discount rate is known. (This is done by first determining the diagonal values, starting at the bottom right-hand corner, and then discounting the values for the earlier years.)

Age-efficiency and age-price profiles.

2.11 Rentals are defined as the quantity of capital services generated by an asset multiplied by the price of those services. In general the *quantity* of services will decline during the service life of the asset because wear and tear reduce the efficiency of assets as they age. The *price* of the capital services, on the other hand, may move in either direction. For example, the price may rise in line with inflation or it may fall, either absolutely or relatively to the prices of competing capital services, because of **obsolescence**. Obsolescence reduces the prices of capital services as newer assets become available which produce better capital services or as tastes and fashions change so that the demand for particular types of capital services falls.

2.12 Rentals can be expressed in either current or constant prices. Table 1 showed the rentals at constant prices with the result that the pattern of rentals during the service life is identical to the pattern of the quantity of capital services. For simplicity, the presentation here is confined to this special case in which the service price is constant. This case, although special, is important because of its links with the concept of capital services, which is discussed in paragraphs 2.23 to 2.29.

2.13 The pattern of the quantity of capital services produced by an asset is described as the **age-efficiency profile** of an asset. As noted above, for any given pattern of rentals and a given discount rate there is one and only one pattern of asset prices. The pattern of asset prices over its service life is described as the **age-price profile** of an asset.

2.14 Table 2 shows the age-efficiency and age-price profiles derived from Table 1 both at their original values and as coefficients standardised to unity in the first year. Note that the two profiles are different. Age-efficiency declines linearly in this example, while the age-price profile falls by decreasing amounts. Age-efficiency and age-price profiles are always different except for assets whose age-efficiency profiles decline “geometrically” (at a constant rate) and which have an infinite life.

Table 2. Age-Efficiency and Age-Price Profiles

		Year	1	2	3	4	5	6	7	8
Age-efficiency	Capital service quantities		5.0	4.5	4.0	3.5	3.0	2.5	2.0	1.5
	Standardised		1.00	0.90	0.80	0.70	0.60	0.50	0.40	0.30
Age-price	At constant prices		43.7	35.8	28.6	22.1	16.2	11.0	6.5	2.9
	Standardised		1.00	0.82	0.66	0.51	0.37	0.25	0.15	0.07

2.15 A linear decline in the quantity of capital services is only one of many possible age-efficiency profiles. Others include a constant flow of services (the “one-hoss shay” case), decline at a constant rate (geometric), and “hyperbolic” decline, meaning that capital services fall by small amounts initially and by larger amounts as the asset ages. In calculating volume indices of capital services, the United States Bureau of Labor Statistics and the Australian Bureau of Statistics assume hyperbolic decline in age-efficiency, while Statistics Canada assumes geometric decline. The relationship between these various age-efficiency profiles and age-price profiles is examined in Chapter 7.

2.16 The age-efficiency profile is relevant for the calculation of **volume indices of capital services**. The age-price profile is relevant to the **net capital stock** and **consumption of fixed capital**.

Consumption of fixed capital

2.17 It was noted in paragraph 2.10 that for a given rate of interest, there is one and only one sequence of asset prices for a given sequence of rentals. Since **consumption of fixed capital**, in real terms, is the difference between successive real market values of an asset over its lifetime, real consumption of fixed capital is jointly determined together with real rentals and real asset values. Chapter 6 explains how consumption of fixed capital can be estimated *indirectly* by using age-efficiency profiles to obtain the age-price profiles for different types of assets and obtaining real consumption of fixed capital as the difference between successive real asset values. This procedure ensures strict consistency between age-efficiency profiles and consumption of fixed capital, both of which enter into the calculation of volume indices of capital services.

2.18 In practice, most countries do not proceed in this way. Instead they estimate consumption of fixed capital *directly* by applying a **depreciation function** to the gross value of assets. Several different depreciation functions are available and each implies a different age-efficiency profile. Clearly the depreciation function selected should be at least broadly consistent with the age-efficiency profile used in calculating volume indices of capital services. This point is developed further in Chapter 7.

Aggregating assets to obtain stocks

2.19 Two kinds of capital stocks are described in this *Manual*. These are the **gross capital stock** and the **net capital stock**. In the gross capital stock, assets are valued at their “as new” prices regardless of their actual age and condition. In the net capital stock, assets are valued at their market prices. These are lower than their “as new” prices by the amount of accumulated consumption of fixed capital. Chapter 4 provides more details on these two stock concepts.

2.20 The assets in use at any one time will have been acquired over a number of preceding years. Because prices are constantly changing in a market economy, the **acquisition prices** of assets purchased in different years cannot be used in aggregating assets of different ages to obtain the stock of assets. This is true whether the stock is expressed at current prices or at constant prices. If the stock is to be valued at **current prices**, assets acquired in years prior to the current year need to be converted to the prices of the current year. In the usual case where asset prices are rising, this will mean that the prices of assets acquired in earlier years must be raised up to current year price levels. If the stock is to be valued at the **constant prices** of a particular year, assets acquired in years other than that year need to be deflated or inflated to the price levels of the selected year.

2.21 The price indices that are used to convert assets to a consistent price basis must correctly decompose changes in the value of assets into their price and quantity components. When new models of assets are introduced, new features that enhance their efficiency in producing capital services must be treated as increases in the quantity of the assets and the prices of the new, improved models must be adjusted downwards when they are being compared with the prices of the older models. Constructing “constant quality” price indices for capital goods that correctly allow for technical improvements is a difficult task and it is identified as a subject for further study in the *Research Agenda* in Annex 4.

2.22 Note that conversion to a common price basis is required whether the capital stock estimates are derived using the **Perpetual Inventory Method (PIM)**, which is described in Chapter 6, or by **direct survey methods**, which are described in Chapter 8.

Volume indices of capital services.

2.23 In considering the contribution of a capital asset to the production process, it is now generally accepted that it is the value of the capital services produced by the asset that is relevant and not the value of the asset itself. The procedure recommended in this *Manual* involves the construction of an index that measures the volume of capital services produced each period by the capital stock. This approach is currently applied by statistical agencies in Australia, Canada and the United States.

2.24 Two steps are involved in compiling a **volume index of capital services**. The first step is to convert assets of a particular type into **standard efficiency units**.¹ This is done using the age-efficiency profile and is necessary because older assets are usually less efficient than newer ones due to wear and tear and so they will produce a smaller volume of capital services. The second step is to combine the standard efficiency units of different types of assets into an overall index. The **user costs of capital** relevant to the different types of assets are used as weights in compiling the index.

2.25 As an example of how assets are converted into standard efficiency units, consider a stock of trucks of a specified haulage capacity. The capital service produced by the trucks consists of *tonne-kilometres*. For a given amount of inputs – fuel, spare parts, repair services – new trucks can be expected to produce more *tonne-kilometres* than older vehicles. The older trucks are likely to need more frequent maintenance, use more fuel and experience longer periods of downtime while they are being repaired. Suppose, for example, that a truck lasts for 8 years and its age-efficiency profile is the one shown in Table 1. This means that its efficiency in terms of *tonne-kilometres* produced for a given quantity of inputs, declines linearly by one tenth each year. Its age-efficiency profile can then be expressed as the series of coefficients 1.0, 0.9, 0.8, . . . 0.3, showing that the truck's initial efficiency of 1.0 declines by one-tenth each year to 0.3 in the last year of its service life.

2.26 If there is a stock of 3 trucks with ages of 2, 4 and 5 years, the above coefficients can be used to calculate the stock of trucks in **standard efficiency units** as $0.9 + 0.7 + 0.6 = 2.2$. The three trucks together produce a flow of *tonne-kilometres* each year that could also be produced by 2.2 new trucks. In other words, 2.2 is a measure of the **capital services** that the three trucks provide now that they are no longer new.

2.27 In practice, statisticians work with reported values of gross fixed capital formation rather than with numbers of assets installed. These values are first expressed in constant prices before being written down by the age-efficiency coefficients to convert them into standard efficiency units. For example, if the price of a new truck in the base period is \$200,000, the constant price value of the stock of trucks in standard efficiency units is $2.2 \times \$200,000 = \$440,000$. Moving the example a step nearer to reality, the GFCF data will almost certainly refer not to specific types of trucks but to some much broader asset class such as “road freight vehicles” or even “transport equipment”.

2.28 Once the different asset types have been converted into standard efficiency units, the next step is to aggregate each type of asset to obtain an overall measure of capital services for an

1. The term *productive capital stock* is sometimes used to describe a group of assets that have been converted into standard efficiency units. The use of the word *stock* in this context may lead to confusion because it is a very different concept from the *net* and *gross stocks* of assets as these terms are usually understood. For that reason the term *productive capital stock* is avoided in this *Manual*.

institutional sector or kind of activity. This is done by weighting the different types of assets by their annual **rentals**. In this context the rentals are usually referred to as the **user costs of capital**. The overall measure so obtained is expressed as an index and is here referred to as a **volume index of capital services**.

2.29 Chapter 9 explains how user costs of capital are calculated in practice and gives the theoretical basis for using them to aggregate stocks of different types of assets after they have been converted into standard efficiency units. Here it is useful to note that there is a close parallel between the use of *user costs of capital* to aggregate these stocks of different types of assets in productivity analysis and the use of *compensation of employees* to aggregate different types of employees. For productivity analysis, labour services are (ideally) measured by first classifying workers into categories defined by the factors that determine their efficiency in production – education level, gender, experience etc. After standardising for hours worked, each separate category is then aggregated to obtain overall measures of labour inputs using the rate of employee compensation relevant to each category. Employee compensation is used for aggregation because it is deemed to reflect the relative *marginal product* of the different categories of workers. In exactly the same way, user costs of capital reflect the relative *marginal product* of different types of assets.

CHAPTER 3 COVERAGE AND CLASSIFICATION OF STOCKS AND FLOWS

Coverage

3.1 The stock and flow measures considered in this *Manual* relate to the “produced” objects that are included in gross fixed capital formation as defined in the 1993 SNA. Table 3 gives the full listing of non-financial assets recognised in that system, and those which form the subject of this *Manual* are printed in bold. They are tangible and intangible fixed assets (code AN 11) plus major improvements to tangible non-produced assets and costs associated with the transfer of ownership of non-produced assets (part of code AN 21).

Classifications

3.2 This chapter deals with the classifications used for publishing capital stock statistics. Three classifications contained in the 1993 SNA are relevant – the Classification of Assets, the Classification of Institutional Sectors, and the International Standard Classification of All Economic Activities (ISIC, Revision 3). These are used in different combinations for the gross and net capital stocks and the two flow measures covered in this *Manual* - consumption of fixed capital and the volume index of capital services.

3.3 The net capital stock and consumption of fixed capital appear as entries in the 1993 SNA and this determines the classifications to be used. Both are to be classified by the **institutional sector** that owns the assets. This is the appropriate classification for the net capital stock, which is needed for the Balance Sheets of the system and for the consumption of fixed capital, which appears in the Production Account, in the Distribution and Use of Income Accounts and in the Accumulation Accounts.

3.4 Capital stock statistics also serve a number of analytic uses, such as calculating capital-output ratios or rates of return on capital and studying capital and multifactor productivity. For these purposes, it is usually preferable to classify assets according to the **kind of activity** of the owner and **by type of asset**. This involves a cross-classification by the ISIC and by the Classification of Assets.

Table 3. SNA Classification of Non-Financial Assets

AN.1	Produced assets	AN.13	Valuables
AN.11	Fixed assets	AN.131	Precious metals and stones
AN.111	Tangible fixed assets	AN.132	Antiques and other art objects
AN.1111	Dwellings	AN.139	Other valuables
AN.1112	Other buildings and structures	AN.2	<u>Non-produced assets</u>
AN.11121	Non-residential buildings	AN.21	Tangible non-produced assets²
AN.11122	Other structures	AN.211	Land
AN.1113	Machinery and equipment	AN.2111	Land underlying buildings and structures
AN.11131	Transport equipment	AN.2112	Land under cultivation
AN.11132	Other machinery and equipment	AN.2113	Recreational land and associated surface water
AN.1114	Cultivated assets	AN.2119	Other land and associated surface water
AN.11141	Livestock for breeding, dairy, draught, etc.	AN.212	Subsoil assets
AN.11142	Vineyards, orchards and other plantations of trees yielding repeat products	AN.2121	Coal, oil and natural gas reserves
AN.112	Intangible fixed assets	AN.2122	Metallic mineral reserves
AN.1121	Mineral exploration	AN.2123	Non-metallic mineral reserves
AN.1122	Computer software	AN.213	Non-cultivated biological resources
AN.1123	Entertainment, literary or artistic originals	AN.214	Water resources
AN.1129	Other intangible fixed assets	AN.22	Intangible non-produced assets
AN.12	Inventories	AN.221	Patented entities
AN.121	Materials and supplies	AN.222	Leases and other transferable contracts
AN.122	Work-in-progress	AN.223	Purchased goodwill
AN.1221	Work-in-progress on cultivated assets	AN.229	Other intangible non-produced assets
AN.1222	Other work-in-progress		
AN.123	Finished goods		
AN.124	Goods for resale		

2. The capital stock does not include the value of non-produced assets as such but it does include two related items. These are *major improvements* to land, non-cultivated biological resources and water resources and costs associated with the *transfer of ownership* of non-produced assets. A detailed description of improvements to tangible non-produced assets is given in the 1993 SNA paragraphs 10.51-10.54, and of transfer of ownership in paragraphs 10.59-10.61.

Classification according to users or owners

3.5 For some purposes it may be useful to classify assets according to the kind of activity of the **user** of the asset rather than that of the **owner**. It should be noted, however, that when assets are classified by user, the statistics cannot be related to other flows in the national accounts because these are compiled on an ownership basis.

3.6 In particular, the distribution of value added among different kinds of activities depends on asset ownership rather than on asset use. If assets are rented on an operational lease³, the income generated by the asset appears in the value added of the owner and not that of the user. This is because the rental payment is deducted as intermediate consumption from the gross output of the user and appears in the gross output of the owner.

Classification by type of asset

3.7 The part of the 1993 SNA *Classification of Assets* covering non-financial assets is given in Table 3 above. Most countries that now compile capital stock statistics use an asset breakdown for publication purposes that is less detailed than this and the standard questionnaire that is used by the international organisations to collect annual statistics according to the 1993 SNA requires only a three-way breakdown – *machinery and equipment, buildings and structures* and *other assets*. In contrast, the United States Bureau of Economic Analysis (BEA) publishes capital stock statistics broken down into over 80 asset types.

3.8 The accuracy of capital stock statistics is determined to an important extent by the accuracy of the price indices used to revalue assets. In general, the greater the level of investment detail for which separate deflators are available, the more reliable will be the estimates of stocks and consumption of fixed capital; this is one of the reasons why BEA uses a very detailed asset classification. With the same consideration in mind, Eurostat suggests a minimum level of detail appropriate for the deflation of gross fixed capital formation in its handbook on price and volume measures in national accounts⁴; each group of assets in this classification is thought to be relatively homogeneous as regards price movements. Note that communications equipment and computers are separately distinguished because the behaviour of prices for these goods is so different from that of other assets:

Produced tangible fixed assets

Dwellings

Other buildings and structures

Non-residential buildings

Other structures

Major improvements to dwellings and other buildings and structures

Transport equipment

3. If assets are rented on a *financial lease* the user is considered to be the owner of the asset. It is only in the case of an operational lease that the user and owner are separate institutional units. In practice there are many types of leases and it is often difficult to decide whether a given leasing arrangement belongs in the operational or financial categories.

4. Eurostat, *Handbook on Price and Volume Measures in National Accounts*, Luxembourg 2001

- Aircraft
- Ships
- Railway trains and carriages
- Other transport equipment
- Other machinery and equipment
 - Machinery and equipment excluding communications equipment, office machinery and computers
 - Communications equipment
 - Office machinery
 - Computers
- Cultivated assets
- Produced intangible fixed assets*
 - Mineral exploration
 - Computer software
 - Entertainment, literary and artistic originals
- Non-produced tangible assets*
 - Major improvements to tangible non-produced assets
 - Costs associated with the transfer of ownership of non-produced assets.

Classification by institutional sector

3.9 The 1993 SNA identifies five institutional sectors:

- Non-financial corporations
- Financial corporations
- General government
- Households
- Non-profit institutions serving households

These five sectors are further broken down to give a total of 36 sub-sectors at the most detailed level.

3.10 The level of detail to be used for classifying the net capital stock and consumption of fixed capital depends on the degree of sector detail that is used in the balance sheets (for net stock) and in the non-financial accounts (for consumption of fixed capital). The few countries that compile balance sheets at the present time mostly classify stocks according to the five institutional sectors, but with some breakdown of *general government* by level - central, local, social security funds, for example. A similar breakdown is used by most countries for the non-financial accounts, although the *financial corporations* sector is sometimes broken down to distinguish between depository institutions and other financial institutions.

3.11 The annual 1993 SNA questionnaire used by the international organisations to collect national accounts statistics calls for the non-financial accounts to be sub-sectored as follows and this determines the institutional sector detail for classifying consumption of fixed capital:

Non-financial corporations

Financial corporations

Central government

State government

Local government

Social security funds

Households

Non-profit institutions serving households

In practice many countries cannot distinguish *non-profit institutions serving households* separately from the household sector. Some countries will also find the breakdown of government too ambitious and will only be able to provide estimates for general government as a whole.

Classification by kind of activity

3.12 For most kinds of analytic studies, capital stocks and flows will need to be classified by kind of activity. As a general rule, the more detailed the activity breakdown, the more useful will the statistics be for such purposes. However, practical considerations limit the amount of detail that can be shown. For example, if the PIM is used, the kind of activity breakdown cannot be more detailed than the kind of activity classification used for collecting statistics on gross fixed capital formation. If the latter is very detailed, transfers of used assets between producers in different kinds of activities will affect reliability and reduce the amount of detail that can reasonably be shown.

3.13 The annual 1993 SNA questionnaire calls for capital stock statistics to be broken down by 17 kinds of activities. These are the 17 *tabulation categories* of the ISIC (revision 3). It would be possible to make this list more useful by distinguishing the principal activities within manufacturing (which is a single tabulation category) and by grouping some of the categories covering service activities. A classification that may be useful for countries starting capital stock statistics is given in Table 4.

Table 4. Suggested activity classification for capital stock statistics

ISIC Tabulation Categories	Description
A + B	Agriculture, hunting, forestry and fishing
C	Mining and quarrying
D	Manufacturing (<i>with 4 or 5 important activities separately identified</i>).
E	Electricity, gas and water supply
F	Construction
G + H	Wholesale and retail trade, repair of vehicles and household goods, hotels and restaurants
I	Transport, storage and communications
J + K	Financial intermediation, real estate, renting and business activities
L	Public administration, defence and social security
M,N + O	Education, health and social work, other community, social and personal service activities

CHAPTER 4

CAPITAL STOCKS AND FLOWS: BASIC DEFINITIONS AND USES

4.1 This chapter gives the definitions and describes the main uses of the gross and net capital stocks and of two flow measures related to them, namely consumption of fixed capital and capital services. It starts by considering the three different ways in which stocks can be valued.

Valuing capital stocks

4.2 Capital assets can be valued at three kinds of prices:

- **historic prices**, which means that the assets are valued at the prices at which the assets were originally acquired. The term *acquisition prices* is used as a synonym for historic prices.
- **current prices**, which means that the assets are valued at the prices of the current year. Valuation at current prices is sometimes referred to as valuation at current “replacement” cost, but the qualifier “replacement” raises questions about what exactly is being replaced. For this reason the word “replacement” is not used in this *Manual*.
- **constant prices**, which means that the assets are valued at the prices of a selected year. As in the case of valuation at current prices, the qualifier “replacement” is sometimes used in referring to constant prices, but it is avoided here.

4.3 Note that price indices are required for valuation at **current prices** as well as valuation at **constant prices**. In the first case, assets acquired in earlier periods have to be revalued each year to bring them to the prices of the current year; in the second case, assets acquired in years other than the selected year have to be revalued to convert the prices actually paid to those of the selected year. It is only in the case of valuation at historic prices that no price indices are required because the prices at which the assets were originally acquired continue to be used in every year in which the assets remain in the capital stock.

4.4 Table 5 shows how the stock of a group of assets is valued at each of these three kinds of prices. The assets are assumed to each have a life of five years and to have been acquired in three successive years. In Table 5, the stocks of assets are valued “gross” *i.e.* before deducting consumption of fixed capital.

Table 5. Calculation of a capital stock at historic, current and constant prices

<i>Year</i>	<i>1</i>	<i>2</i>	<i>3</i>	<i>4</i>	<i>5</i>	<i>6</i>	<i>7</i>
Asset price	100.0	103.0	105.0	110.0	112.0	114.0	118.0
<i>Panel 1</i>	At actual prices paid i.e. at historic prices						
Assets purchased in year 1	10.0	10.0	10.0	10.0	10.0		
Assets purchased in year 2		20.0	20.0	20.0	20.0	20.0	
Assets purchased in year 3			5.0	5.0	5.0	5.0	5.0
Stock at historic prices	10.0	30.0	35.0	35.0	35.0	25.0	5.0
<i>Panel 2</i>	At prices of the current year						
Assets purchased in year 1	10.0	10.3	10.5	11.0	11.2		
Assets purchased in year 2		20.0	20.4	21.4	21.7	22.1	
Assets purchased in year 3			5.0	5.2	5.3	5.4	5.6
Stock at current prices	10.0	30.3	35.9	37.6	38.3	27.6	5.6
<i>Panel 3</i>	At constant prices of year 1						
Assets purchased in year 1	10.0	10.0	10.0	10.0	10.0		
Assets purchased in year 2		19.4	19.4	19.4	19.4	19.4	
Assets purchased in year 3			4.8	4.8	4.8	4.8	4.8
Stock at constant prices	10.0	29.4	34.2	34.2	34.2	24.2	4.8
Ratio of current to constant price stocks	100.0	103.0	105.0	110.0	112.0	114.0	118.0

4.5 The front line of Table 5 shows that the **asset price** has been rising over the period from 100 in year 1 to 118 in year 7. In order to obtain the value of the stock at **current prices** (Panel 2) the assets need to be re-valued in line with the rise in asset prices. Note that in year 2, the assets acquired in that year (to the value of 20) are already at the prices of year 2 and do not therefore need to be re-valued in that year. For subsequent years, however, they must be multiplied by $p_t/103$ where p_t is the asset price in year t . Similarly the assets, valued at 5, acquired in year 3 must be multiplied by $p_t/105$ for years 4 through 7.

4.6 In order to obtain the value of the stock at **constant prices** – in this example at the prices of year 1 – all assets acquired after year 1 must be deflated to bring them down to year 1 prices. Thus in Panel 3 the assets acquired in year 2 are multiplied by $100/103$ and those acquired in year 3 by $100/105$. The assets acquired in year 1 are, by definition, already at year 1 prices.

4.7 The last line of Table 5 shows the ratio of the asset stock at current prices to the stock at constant prices. It is of course identical to the asset prices given in the first line of the table. This means that the laborious procedure described above for calculating the capital stock at current prices can be avoided by first estimating the stock at constant prices and inflating with price indices. This is an important point to bear in mind when the capital stock is estimated using the *perpetual inventory method* (PIM).

4.8 Valuation at **historic, or acquisition, prices** is the usual procedure in company accounts. This is done because historic prices can be objectively verified by examining the invoices relating to asset purchases. Commercial accountants may also prefer historic prices because they give a conservative valuation of assets. These advantages, however, are offset by the fact that assets which

have been acquired at different dates are being valued at different prices so that when prices are rising/falling assets acquired more recently are implicitly given a higher/lower weight than those acquired in earlier periods. Capital stocks valued at historic prices cannot be compared with national accounting or other economic statistics that are expressed at either current or constant prices.

Gross fixed capital stock

4.9 The gross fixed capital stock is the value, at a point in time, of assets held by producers with each asset valued at “as new” prices – *i.e.* at the prices for new assets of the same type - regardless of the age and actual condition of the assets. The “as new” prices are obtained by revaluing assets acquired in earlier periods using price indices for the relevant types of assets. Provided that these price indices are properly adjusted for quality change, newer, more efficient, types of assets will be valued at higher prices than the older, less efficient, models which they are gradually replacing. The gross fixed capital stock is called *gross* because it has traditionally been thought of as the value of assets before deducting consumption of fixed capital. However, if asset price indices are correctly adjusted for quality change, the gross stock reflects the fall in the value of assets due to one component of consumption of fixed capital, namely obsolescence.

4.10 Two points should be noted about the coverage of the assets to be included in the gross capital stock.

- First, the assets included in the stock may be owned by the enterprises that use them in production or they may be rented out to producers by their owners. Certain types of assets, such as commercial and residential buildings, road vehicles and construction equipment are commonly rented in many countries.
- Second, not all the assets included in the gross stock may actually be in use to produce goods and services. Some assets may have been “moth-balled” or held in reserve to meet unexpected surges in demand. Others may be kept in reserve as insurance against the breakdown of critical pieces of equipment. Assets that are rented to producers may spend idle periods between customers. In order to be counted as part of the capital stock all that is required is that assets are present at production sites and capable of being used in production or that they are available for renting by their owners to producers.

4.11 The gross capital stock is not a part of the System of National Accounts but it is the conventional starting point for calculating consumption of fixed capital and the net capital stock. The gross capital stock also has several analytic uses in its own right.

- It is widely used as a broad indicator of the *productive capacity* of a country.
- The gross capital stock for a sector or the economy as a whole is often compared with value added to calculate *capital-output ratios*.

- The operating surplus, usually on a gross basis, is divided by the gross capital stock to give measures of profitability for a sector or the economy as a whole.
- Finally, although it is not recommended here for this purpose, the gross capital stock is sometimes used as a measure of *capital input* in studies of multifactor productivity. In this *Manual* it is recommended that capital inputs for this purpose should be measured by **volume indices of capital services** as described in Chapter 9.

Consumption of fixed capital

SNA definition

4.12 The general definition of consumption of fixed capital is given in the 1993 SNA, paragraph 6.179.

[Consumption of fixed capital] may be defined in general terms as the decline, during the course of the accounting period, in the current value of the stock of fixed assets owned and used by a producer as a result of physical deterioration (or wear and tear), normal obsolescence or normal accidental damage. It excludes the value of fixed assets destroyed by acts of war or exceptional events such as major natural disasters which occur very infrequently. Such losses are recorded in the System in the account for “Other changes in the volume of assets”.

4.13 Some clarifications are needed.

- First, “consumption of fixed capital must be measured with reference to a given set of prices, i.e. the average prices of the period. It may then be defined as the decline, between the beginning and the end of the accounting period in the value of the fixed assets owned by an enterprise...” (1993 SNA, paragraph 10.118). Changes in the value of fixed assets arising from changes in the general price level are recorded in the revaluation accounts and do not form part of consumption of fixed capital.
- Second, “used by a producer” must be interpreted to include situations where assets have been purchased by a producer but which for any reason have not yet been employed in a production process. This clarification is needed because consumption of fixed capital can occur in respect of assets which are available at the producer’s establishment for use in production but which are kept idle for some reason. For example, in some centrally planned economies it was customary for producers to hold a surplus stock of assets for use in the event of unexpected breakdown of working assets, as insurance against interruption in the future supply of particular kinds of assets, or to cannibalise for spare parts. Assets held by producers but which have not been, or may never be, employed for productive purposes may nevertheless fall in value, even in the absence of physical deterioration, because of obsolescence and these falls in value must be included in consumption of fixed capital.
- Third, “physical deterioration” refers to wear and tear that is not made good by repairs or by replacing worn components. Some assets may not suffer any physical deterioration because the asset owner makes good all wear and tear through careful maintenance. In such cases the fall in asset value over time measured by consumption of fixed capital will be due only to foreseen obsolescence or to normal accidental damage.

- Fourth, “normal accidental damage” refers to the kinds of accidents that are commonly insured against. Accidental damage includes cases where the asset has been so badly damaged that it has to be prematurely scrapped. Transport equipment is particularly vulnerable to damage of this kind and when service lives are estimated for such assets they must reflect the probability of premature scrapping through accidental losses.
- Fifth, the above definition implies, without explicitly stating so, that “abnormal” obsolescence is also excluded from consumption of fixed capital. Abnormal obsolescence here means unforeseen obsolescence and it may occur either because of unexpected technological breakthroughs or because of sudden changes in the relative prices of inputs. The introduction of electronic calculators in the 1960s is an example of an unforeseen technological development, which resulted in a sudden and sharp fall in the value of the existing stock of electromechanical calculators. The 1974 oil-shock is an example of a drastic shift in relative input prices, which may have led to premature replacement in some countries of inefficient oil-using equipment by more efficient models or by assets using other energy sources. Premature scrapping of assets, which arises from unforeseen obsolescence, is treated in the same way as losses of assets due to wars or natural calamities and is shown in the account for “Other changes in the volume of assets”.

4.14 The inclusion of foreseen obsolescence in consumption of fixed capital is a controversial issue for some authors. Consider a group of assets, which are strictly homogeneous but are of different ages. An example could be farm tractors of a particular make and model which were put into operation at different times. If the market prices of the different vintages are available from second-hand tractor dealers, they will show a declining age-price profile. But this decline in price clearly cannot be due to obsolescence. Since all the tractors are of the same make and model they must all be subject to exactly the same amount of obsolescence compared with newer, more efficient tractors, which have subsequently appeared on the market. The prices of older tractors are lower than those of newer tractors only because of physical deterioration. The consumption of fixed capital that occurs in this case can be described as a “cross-section” measure. For the national accounts, however, there is now broad agreement that a “time-series” measure which includes normal, or foreseen, obsolescence is required (see Box 1)

Consumption of fixed capital in the SNA

4.15 Consumption of fixed capital has three roles in the 1993 SNA:

- It is deducted from gross measures of product, income and saving to arrive at net measures of these aggregates. In recognition of the difficulties that many countries have in calculating consumption of fixed capital, the SNA provides for all balancing items in the Production Account and in the Distribution and Use of Income Accounts to be recorded on either a gross or net basis. However, SNA para. 6.203 indicates a preference for the net measures: “In general, the gross figure is obviously the easier to estimate and may, therefore, be more reliable, but the net figure is usually the one that is conceptually more appropriate and relevant for analytical purposes.” It may also be noted that as the terms are used in economics, *saving* and *income* (used without qualifiers) are almost always understood as being net of consumption of fixed capital.
- Consumption of fixed capital is one of the cost items required to estimate output and value-added of government and other non-market producers. Some countries at the

present time use consumption of fixed capital at historic prices taken from accounting records to estimate government output and value added. This is likely to produce very misleading estimates of value-added and gross output for non-market producers. For SNA purposes, consumption of fixed capital must be based on estimates of the capital stock at current and constant prices. This is all the more important because the 1993 SNA has considerably expanded the scope of consumption of fixed capital for government. Some durable military goods have been transferred from intermediate consumption to capital formation and the 1993 SNA also requires that consumption of fixed capital be calculated in respect of roads, dams, bridges and similar structures.

- Consumption of fixed capital is an entry in the Capital Account. Together with saving and net borrowing consumption of fixed capital provides the finance for gross fixed capital formation. Consumption of fixed capital is also one of the transactions that explain the differences between the opening and closing stocks of fixed assets.

Box 1. Obsolescence

Obsolescence occurs when an asset is retired before its physical capability is exhausted. Obsolescence can occur due to technical innovation. For example, a personal computer that is several years old may not be able to support the software that a new computer can, in which case the old computer may be withdrawn from use in production even though it may still be operational. Technical innovation is not the only cause of obsolescence. For example, all immovable assets at a mine site become obsolete when the mine is worked out, irrespective of their potential physical lives.

Note that obsolescence affects only the **prices** at which capital services can be sold. It does not affect the **quantities** of services - tonne-kilometres or warehouse storage space - that a capital asset is capable of producing. The quantities are affected only by wear and tear as the asset ages or, in the case of a group of assets, by losses of individual assets through accidental damage.

In considering obsolescence a distinction needs to be drawn between that which is foreseen and that which is not. If obsolescence is foreseen then the owner will factor it in when determining an asset's expected economic life and hence its consumption of fixed capital in future periods. As pointed out in the 1993 SNA paragraph 6.187 normal, or foreseen, obsolescence is included in consumption of fixed capital in the national accounts because it is an expected cost of production. Both the computer and mine asset examples given above are potentially cases of foreseen obsolescence. Unforeseen obsolescence, on the other hand, should not be included in consumption of fixed capital. Instead, it should be recorded in other changes in the volume of assets accounts (SNA93 paragraph 12.43).

Consumption of fixed capital and the age-efficiency profile.

4.16 The consumption of fixed capital measures the decline in the value of assets associated with ageing. This decline in market values can be described as the **age-price profile** of an asset. The age-price profile is related to, but different from, the decline in the **efficiency** of assets as they age. This decline is referred to as the **age-efficiency** profile.

4.17 The relationship between age-efficiency and age-price profiles has been explained in Chapter 2 and is explored further in Chapter 6. It is mentioned here for two reasons:

- Age-efficiency profiles determine the flows of **capital services**. The measurement of these capital services should be done in a way that is consistent with the measurement of

consumption of fixed capital and net capital stocks. This means that in selecting a procedure for calculating consumption of fixed capital, such as “straight-line” or “double declining balance”, it is important to remember that the method selected has implications for the shape of the age-price profile.

- The conventional way of measuring consumption of fixed capital is to do it **directly** by applying a depreciation formula to the capital stock. An alternative, however, is to use the age-efficiency profile to generate age-price profiles for assets and to then derive consumption of fixed capital **indirectly** as the difference between successive values of the net capital stock. This approach ensures strict consistency between the measurement of capital services, consumption of fixed capital and net capital stocks. At least one country, Australia, has already adopted an integrated approach of this kind. It clearly has merit for countries that wish to produce capital services as a regular part of their programme of capital stock statistics. The integrated approach is described in Chapter 6. Annex 2 explains how it is applied by the Australian Bureau of Statistics.

Net capital stock

Illustrative calculation

4.18 The net capital stock is the value at a point in time of assets at the prices for new assets of the same type less the cumulative value of consumption of fixed capital accrued up to that point. Table 6 shows how both consumption of fixed capital and the net capital stock can be derived from the gross capital stock. Consumption of fixed capital is here obtained using straight-line depreciation. (Note that Table 6 describes the conventional approach in which consumption of fixed capital is estimated directly from the gross capital stock. The newer, integrated approach starting from the age-efficiency profile uses a quite different set of calculations, which are explained in Chapter 6.)

4.19 In Table 6, the first and fourth panels showing the gross stock at current and constant prices respectively are taken directly from Table 5. Gross fixed capital formation is again assumed to be 10, 20 and 5 in years 1, 2 and 3, the asset has a service life of 5 years and the asset price rises as shown in the first line of the Table.

4.20 Annual consumption of fixed capital is obtained by dividing the gross capital formation series by five because the assets last for five years and straight-line depreciation is used in this example. For the calculations at current prices, consumption of fixed capital rises in line with the re-valued prices of the assets (Panel 2). When valued at constant prices, consumption of fixed capital is constant for each asset throughout its lifetime (Panel 5).

Table 6. Gross and net stocks and consumption of fixed capital at current and constant prices

<i>Year</i>	<i>1</i>	<i>2</i>	<i>3</i>	<i>4</i>	<i>5</i>	<i>6</i>	<i>7</i>
Asset price (year average)	100.0	103.0	105.0	110.0	112.0	114.0	118.0
<i>Panel 1</i>	Gross capital stock at prices of the current year						
Assets purchased in year 1	10.0	10.3	10.5	11.0	11.2		
Assets purchased in year 2		20.0	20.4	21.4	21.7	22.1	
Assets purchased in year 3			5.0	5.2	5.3	5.4	5.6
Gross capital stock at prices of the current year	10.0	30.3	35.9	37.6	38.3	27.6	5.6
<i>Panel 2</i>	Consumption of fixed capital at prices of current year						
CFC on assets purchased in year 1	2.0	2.1	2.1	2.2	2.2		
CFC on assets purchased in year 2		4.0	4.1	4.3	4.3	4.4	
CFC on assets purchased in year 3			1.0	1.0	1.1	1.1	1.1
Total CFC at prices of the current year	2.0	6.1	7.2	7.5	7.7	5.5	1.1
<i>Panel 3</i>	Net capital stock at prices of the current year						
Assets purchased in year 1	8.0	6.2	4.2	2.2	0.0		
Assets purchased in year 2		16.0	12.2	8.5	4.3	0.0	
Assets purchased in year 3			4.0	3.1	2.1	1.1	0.0
Net capital stock at prices of the current year	8.0	22.2	20.4	13.9	6.5	1.1	0.0
<i>Panel 4</i>	Gross capital stock at prices of year 1						
Assets purchased in year 1	10.0	10.0	10.0	10.0	10.0		
Assets purchased in year 2		19.4	19.4	19.4	19.4	19.4	
Assets purchased in year 3			4.8	4.8	4.8	4.8	4.8
Gross capital stock at prices of year 1	10.0	29.4	34.2	34.2	34.2	24.2	4.8
<i>Panel 5</i>	Consumption of fixed capital at prices of year 1						
CFC on assets purchased in year 1	2.0	2.0	2.0	2.0	2.0		
CFC on assets purchased in year 2		3.9	3.9	3.9	3.9	3.9	
CFC on assets purchased in year 3			1.0	1.0	1.0	1.0	1.0
Total CFC at prices of year 1	2.0	5.9	6.8	6.8	6.8	4.8	1.0
<i>Panel 6</i>	Net Capital stock at prices of year 1						
Assets purchased in year 1	8.0	6.0	4.0	2.0	0.0		
Assets purchased in year 2		15.5	11.7	7.8	3.9	0.0	
Assets purchased in year 3			3.8	2.9	1.9	1.0	0.0
Net capital stock at prices of year 1	8.0	21.5	19.5	12.6	5.8	1.0	0.0

4.21 The net capital stock is obtained from the gross capital stock as follows:

- The net stock at current prices for year 3 is shown in Panel 3 as 20.4. This is derived from the gross capital stock at current prices, i.e. 35.9, by deducting accumulated consumption of fixed capital on the assets purchased in year 1 (2.1×3), plus accumulated consumption of fixed capital on the assets purchased in year 2 (4.1×2) plus accumulated consumption of fixed capital on the assets purchased in year 3 (1.0×1). Observe that accumulated consumption of fixed capital at current prices is calculated using the prices of the year in question; it cannot be obtained by adding up the consumption of fixed capital calculated for earlier years because these amounts are valued at the prices of several different years.
- Exactly the same procedure is used to calculate the net capital stock at constant prices. For example, the net stock at constant prices for year 2 is shown in panel 6 as 21.5. This is obtained from the gross stock at constant prices, i.e. 29.4, by deducting accumulated consumption of fixed capital on the assets bought in year 1 (2.0×2) plus the accumulated consumption of fixed capital on assets bought in year 2 (3.9×1).

4.22 As noted earlier, current price estimates of consumption of fixed capital and the net capital stock can more easily be obtained by first calculating them at constant prices and inflating to current year prices using the relevant price indices. This is the usual procedure in practice.

4.23 The net capital stock at prices of the current year was calculated in Table 6 using the **year average** prices of the asset. In the SNA balance sheets however, the net capital stock must be valued at **year-end** prices because all entries in the balance sheets refer to the market values of assets and liabilities at the end of each year. The net capital stock at current prices shown in Table 6 must therefore be multiplied by the ratio of end-year to year average prices. End-year prices are not usually calculated directly but are obtained by averaging December/January or fourth/first quarter prices if these are available or by averaging year-average prices for adjacent years.

4.24 Note that year-average prices are the correct ones to use for valuing consumption of fixed capital, both at current and constant prices. Consumption of fixed capital is a flow that occurs regularly throughout the year. Ideally it would be valued at the prices prevailing each moment that it occurs, but as this is not practical, the average of prices throughout the year – or failing that mid-year prices – are an acceptable approximation.

Net capital stocks in the SNA

4.25 The net stock, at current prices, appears in the opening and closing balance sheets of the 1993 SNA. Table 7 shows the connection between these opening and closing balances in the system.

Table 7. Links between opening and closing stocks of fixed assets

<p>The net value of the stock of the asset at its current price at the beginning of the period</p> <p><i>plus</i> gross fixed capital formation, <i>i.e.</i>, acquisitions <i>less</i> disposals of the asset in transactions with other units</p> <p><i>minus</i> consumption of fixed capital incurred during the period</p> <p><i>plus</i> the total value of <i>other</i> positive or negative changes in the quantity of the asset : <i>i.e.</i>, changes which are not attributable to the use of the asset in production or to transactions with other units (<i>e.g.</i> the physical destruction of an asset as a result of a natural disaster or the premature scrapping of assets because of unforeseen obsolescence),</p> <p><i>plus</i> the total value of the positive or negative holding gains accruing during the period as a result of changes in the price of the asset,</p> <p><i>equals</i> the <i>net</i> value of the stock of the asset at its current price at the end of the period.</p>
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4.26 The net stock is the market value of fixed assets owned by the different institutional sectors and the nation as a whole. As such, it is a measure of wealth and it is usually the largest part of national net worth in industrialised countries.

Capital services

4.27 For any given type of asset there is a flow of productive services from the cumulative stock of past investments. This flow of productive services can be measured by constructing a **volume index of capital services**. This is done by first converting each type of asset into **standard efficiency units** and then weighting each one by its **user cost of capital** to obtain an overall index. Assets are converted to standard efficiency units using coefficients derived from the age-efficiency profiles appropriate for each type of asset. These coefficients represent an asset's declining ability to produce capital services as it gets older. User costs of capital are the sum of depreciation and the net return on the asset less the nominal capital gain (or loss) from holding the asset for each accounting period.

4.28 Chapter 2 gave a simple example of how assets are converted into standard efficiency units and a short explanation of why they are weighted by their user costs to obtain the overall index. A fuller explanation is given in Chapter 9.

4.29 The volume index of capital services does not appear in the national accounts. It is not part of the 1993 SNA nor of any country's own national system of accounts. It is included in this *Manual* because there is now general agreement that a volume index of capital services is a better way to represent the input of capital into the production process than the gross or net capital stocks which have usually been used for this purpose in the past.

CHAPTER 5 OVERVIEW OF MEASUREMENT METHODS

5.1 This chapter reviews the methods that are available for measuring gross and net capital stocks, consumption of fixed capital and capital services.

Gross capital stock

5.2 The **gross capital stock** can be estimated in at least three ways. By far the commonest is the **perpetual inventory method** (PIM) which involves accumulating past capital formation and deducting the value of assets that have reached the end of their service lives. Both capital formation and discards of assets (“scrapping”) are revalued either to the prices of the current year (current prices) or to the prices of a single year (constant prices).

5.3 Survey methods can also be used. Enterprises are asked to report the historic or acquisition values of all assets still in use and the dates when they were installed or constructed. The assets are then revalued to current or constant prices either by the statistical agency or by the respondents themselves using revaluation coefficients supplied by the statistical agency.

5.4 A method that lies between the PIM and survey methods is the “balance of fixed assets”. In many centrally planned economies, enterprises were required to keep a running inventory of their fixed capital assets, tracking outflows as well as inflows. The results of these calculations were reported regularly to the central statistical agency which obtained the total capital stock by simple addition. Although they have moved away from central planning, several of these countries have continued to calculate the balance of fixed assets. Correctly applied, this method can be seen as an ideal form of the PIM; ideal because it substitutes actual retirements for the assumed retirements used in the conventional PIM.

5.5 Finally, the gross stocks of certain kinds of assets can be estimated using administrative records on the numbers of assets together with price information obtained by the statistical agency. Assets for which administrative records are often available include road vehicles, maritime shipping, commercial aircraft, dwellings and commercial buildings. Dwellings and other buildings usually account for the largest part of the capital stock. If stock estimates for dwellings and other buildings can be based on administrative records, the margin of error for the total stock estimates will be considerably reduced.

Net capital stock

5.6 The net capital stock is a concept familiar to commercial accountants and company balance sheets invariably record the value of assets on a net basis. Unfortunately company accounts use a number of conventions in calculating net asset values which render them unsuitable for national accounts purposes. The main problem is the use of historic valuation, which means that the stock of assets is valued at a mixture of prices.

5.7 For use in national accounts, the net stock is usually derived from the gross stock (obtained from one of the sources described above) by deducting accumulated consumption of fixed capital. Consumption of fixed capital is obtained using a depreciation function such as straight-line, geometric or sum-of-the-year's-digits. The net stock can also be derived by first estimating age-efficiency profiles for assets and using a discount rate to obtain the corresponding age-price profiles. The age-price profiles provide a direct estimate of the net stock without first having to calculate consumption of fixed capital.

5.8 There are two other possible sources for net stock estimates. First, insurance companies record the current values of commercial properties insured against damage by fire or other catastrophes. However, properties are sometimes under-insured so that insurance values will understate the net stock. Under-insurance is less likely to happen with assets exposed to a high risk of loss, such as road vehicles and ships. Insurance values for assets of this kind may provide a realistic estimate of net stocks and could be used as a cross-check on net asset stocks estimated by other methods.

5.9 Second, an estimate of the market values of a company can be obtained by multiplying the number of shares outstanding by the share price. To obtain the net value of the tangible fixed assets owned by the company, both the value of financial assets (less liabilities) and the market value of land, valuables and non-produced intangible assets must be deducted. This method is only applicable for companies with publicly quoted shares and such companies may cover only a small part of the capital stock in some countries. Another problem is that share prices can be heavily influenced by future profit expectations. For these reasons, this is not likely to be a very useful approach.

5.10 Note that while the gross capital stock may be derived from a survey, survey methods are not suitable for obtaining the net capital stock. This is because a consistent method must be used to estimate consumption of fixed capital, but companies' accounts may use a variety of depreciation methods.

Consumption of fixed capital

5.11 As noted, company accounts routinely report **consumption of fixed capital**, or **depreciation** as it is usually called by commercial accountants. Unfortunately, in most countries it is calculated by reference to the historic cost of assets and so is effectively calculated using a mixture of prices. When there is inflation, use of historic prices will lead to substantial understatement of depreciation. Another problem is that most countries allow companies to use a variety of depreciation methods so stocks reported by different companies cannot be added up to obtain the total stock. Companies will often select depreciation methods that minimise their tax liabilities regardless of whether the depreciation method used for tax purposes is a good measure of economic depreciation. Finally many governments have used "accelerated depreciation" schemes as a means of encouraging investment, with the result that reported depreciation bears no relation to the actual declines in asset values. Despite these problems, several countries use depreciation reported by companies in their national accounts. Such estimates cannot even be justified as crude approximations to consumption of fixed capital as defined in the SNA. They are misleading statistics and have no place in the accounting system.

5.12 For the national accounts, consumption of fixed capital can be obtained either directly by applying depreciation factors to the estimated gross values of assets (see Chapter 7) or indirectly as the difference between successive values of the net stock derived from age-price profiles (see Chapter 6).

Capital services

5.13 Capital services are the contribution of capital to production. Transactions in capital services occur when assets are leased by their owners to other producers. (Capital service transactions occur only in the case of “operational leasing”. In the case of a “financial lease” the asset is treated as being owned by the user and the payments involved are considered to be loan repayments.) Operational leasing is quite common for certain kinds of assets – road vehicles, aircraft, buildings and many types of construction equipment are examples. The price of a lease will include other costs in addition to the pure price of the capital service, such as insurance and the cost of storing equipment in a convenient location and transporting the assets to and from the producer’s site. These costs could of course be estimated so that, in principle, capital services for several types of assets could be obtained by direct observation. In practice, national statistical offices have not used this approach. As explained in Chapter 2, capital services are measured by first converting each type of asset into standard efficiency units and constructing a volume index of capital services with user costs of capital as weights. This is further developed in Chapter 9.

CHAPTER 6 PERPETUAL INVENTORY METHOD

Two ways of applying the Perpetual Inventory Method

6.1 The Perpetual Inventory Method (PIM) generates an estimate of the capital stock by accumulating past purchases of assets over their estimated service lives. The standard, or traditional, procedure is to use the PIM to estimate the gross capital stock, to apply a depreciation function to calculate consumption of fixed capital and to obtain the net capital stock by subtracting accumulated capital consumption from the gross capital stock. The first part of this chapter describes the standard application of the PIM. There is however, an alternative way of applying the PIM. This method has been pioneered by the United States Bureau of Labor Statistics (BLS) and is now also applied by the Australian Bureau of Statistics (ABS)⁵. It is described in the last section of this chapter.

6.2 The traditional application of the PIM requires the direct estimation of depreciation from which the net capital stock is obtained indirectly. The alternative approach is to start by estimating age-efficiency profiles for each type of asset which are then used to generate age-price profiles for the assets. The age-price profiles are used to directly estimate the net capital stock from which depreciation is obtained indirectly.

6.3 This alternative method has the important advantage that all stock and flow data are necessarily consistent with each other. This is because the age-efficiency profiles (used to estimate capital services) determine the age-price profiles (used to estimate the net capital stock and depreciation). All three measures, capital services, the net stock and consumption of fixed capital are thus based on identical assumptions - namely the age-efficiency profile and the discount rate. Because it generates measures of capital services at the same time as the stock estimates and consumption of fixed capital, it can be described as an *integrated approach*.

6.4 Annex 2 describes the PIM methods used by four countries – Singapore, France, the United States (Bureau of Economic Analysis - BEA) and Australia. The first three use the traditional approach, although there are several differences in how it is applied. In particular, the BEA methodology does not derive the gross capital stock as an intermediate step in calculating consumption of fixed capital and net capital stock. Australia uses the alternative, integrated approach.

5. The BLS uses the alternative approach only to calculate an index of capital services. The Australian Bureau of Statistics uses it to calculate capital stocks and consumption of fixed capital as well as the index of capital services

Standard application of the PIM

Gross capital stock

6.5 The basic requirements to apply the PIM to estimate the Gross Capital Stock are:

- An initial benchmark estimate of the capital stock.
- Statistics on gross fixed capital formation extending back to the bench-mark, or, if no bench-mark is available, back over the life of the longest-lived asset.
- Asset price indices.
- Information on the average service lives of different assets.
- Information on how assets are retired around the average service life (mortality functions).

Initial estimate of the capital stock

6.6 Provided the capital stock series go back as many years as the longest-lived asset, it is possible to estimate the capital stock without having an initial benchmark estimate. However, as the longest lived assets, usually structures, may have service lives in excess of 100 years, most countries need to start their PIM estimates with a bench-mark estimate, at least for assets with long lives. Possible sources for benchmark estimates include:

- Population censuses.
- Fire insurance records.
- Company accounts.
- Administrative property records.
- Share valuations.

None of these sources will give an accurate estimate of precisely what is required – namely the “as new” values of assets in place at a point in time.

6.7 **Population census** records usually provide information on the numbers of dwellings of different types. Estimated values will have to be assigned to the various types of dwellings identified in the Census records. **Fire insurance** records normally give the net values of assets at current prices and will have to be adjusted to gross valuation. They are incomplete because small companies may not insure their assets at all and very large enterprises and government bodies often prefer to bear the risks themselves and so will also be excluded from fire insurance records. **Company accounts** give asset values at depreciated historic costs and will need adjusting both to bring them up to current or constant prices and to “as new” values. An additional problem is that they are only available for the corporate sector. **Administrative property records** typically record residential and commercial buildings at values which purport to be current market prices but which are usually historic prices that are revalued

to current prices at irregular intervals. The **share valuation** of a company's fixed assets can be obtained by multiplying the number of shares issued by a company by the share price and subtracting financial assets net of liabilities. The resulting values should reflect the current market values of the company's fixed capital assets but the valuation will also be affected by various unquantifiable factors such as "good-will", differences in entrepreneurial skill and the general business climate. In addition, this approach can only be used in countries with active stock markets and then will only provide valuations for corporate enterprises whose shares are quoted on stock exchanges.

6.8 It is clear that a bench-mark estimate based on any of these sources will be highly approximate but the importance of errors introduced into the stock figures will diminish over time as the base period is left further behind.

Gross fixed capital formation

6.9 Gross fixed capital formation is defined as the acquisition, less disposals, of tangible and intangible fixed assets plus major improvements to, and transfer costs on, land and other non-produced assets. These are the assets denoted in bold in Table 3 of the Chapter 3. The assets acquired may be new or they may be used assets that are traded on second-hand markets. The assets disposed of may be sold for continued use by another producer, they may be simply abandoned by the owner or they may be sold as scrap and be broken down into reusable components, recoverable materials, or waste products.

6.10 Assets acquired are valued at prices, which include installation costs and transfer fees. Disposals are valued at the amounts received by the sellers before deducting any costs born by the sellers to dismantle the equipment or remove it from their property. (These latter costs are treated as negative capital formation and not as current production expenses.)

6.11 The fact that GFCF involves transactions in used assets, which are valued at less than the prices of new assets, causes problems for PIM estimates of the gross capital stock. Suppose, for example, that enterprise A sells a used asset to enterprise B. Enterprise A will report the sale of the asset at its current market value and not at the "as new" price which is required for valuation of the gross capital stock. This means that the GFCF reported by Enterprise A (its acquisitions less disposals of assets) will be too large for use in the PIM because its disposals are valued at (low) market prices instead of at (high) "as new" prices. At the same time, Enterprise B will report its acquisition of the used asset from A at the current market price which is lower than the "as new" price required for the gross capital stock. B's reported GFCF (its acquisitions less disposals) will be too small for use in the PIM.

6.12 The errors caused by the way that A and B report transactions in a used asset will cancel out if the records for the two enterprises are consolidated because the overstatement of A's reported GFCF is exactly matched by the understatement in B's reported GFCF. There are, however, circumstances in which there will be no compensating errors of this kind:

- Capital stock statistics need to be classified by institutional sector and by kind of activity. If transactions in used assets occur between units that are classified to different institutional sectors or kinds of activities, errors will be introduced into the sector or activity distribution of the capital stock.
- Second, used assets may move into and out of the domestic economy via imports and exports. If a used asset is imported, the acquisition will be recorded at the current market

value of the asset and GFCF will be understated for PIM purposes. If a used asset is exported, the disposal will be valued at current market value and GFCF will be overstated for PIM purposes. In neither case are there any offsetting errors because the other partners to the transactions are outside the domestic economy.

- Finally, used assets may move from productive to non-productive uses. In particular, they may move between the government or corporate sectors and the household sector. Perhaps the commonest example is the sale of used vehicles by car-hire companies to households. In this case there is no offsetting entry to the overstatement of GFCF by the car-hire companies because the purchase of the used cars by households does not count as capital formation.

6.13 How important are the errors that may be introduced into the gross stock estimates because of transactions in used assets? And what can be done about them?

6.14 As regards errors in the distribution of the stock by sector and activity, the size of the problem depends partly on the degree of detail in the sector or activity breakdowns that are used. This suggests that countries should be modest in the amount of activity detail given in their stock estimates, at least in the initial stages of developing these statistics. The importance of the problem also depends on the extent to which assets can be used in different industries. Most plant and machinery is industry-specific but buildings may often move between sectors and activities. A shop may become a bank, a factory may be used for different types of manufacturing or a railway station may become a museum. In order to make corrections for movements of assets between sectors and activities it is necessary to identify transactions in used assets separately from transactions in new assets.

6.15 Imports and exports of used assets may be quite significant for some countries but they do not cause problems additional to those mentioned above. Whether a producer sells a used asset to another domestic producer or to abroad, all that is required is to identify the sale as that of a used asset and make whatever upward adjustment is required to the disposal value. Similarly, if a producer purchases a used asset from abroad, exactly the same kind of adjustment is required as when the asset is acquired from a domestic source.

6.16 As regards movement of assets from producers to households, it seems likely that in most countries, the only significant transactions are in used vehicles sold by producers to households. A reasonable assumption that could be made here is that all sales of used passenger cars by producers are to households. Provided that sales of used cars can be identified in the records of producers it is possible to adjust disposal values to “as new” prices and eliminate this source of error.

Asset price indices

6.17 The problems of separating value changes into price and volume components are generally agreed to be more difficult for capital goods than for other goods and services because many capital goods are unique. This is the case, for example, with most buildings, construction work, special purpose industrial plant, aircraft and ships. The errors that may be introduced into capital stock estimates through incorrect price deflators may be as large as errors caused by the use of incorrect service lives and mortality functions. (Note, too, that direct survey methods are equally affected by errors in price deflators because these have to be used to move from historic to current and constant prices.)

6.18 For unique capital goods, such as ships, aircraft, and most structures a promising method of calculating price indices is through *model pricing*. This involves asking manufacturers and construction firms to estimate the selling price, in successive periods, of a standard model - such as a closely specified ship, car park, aircraft or building. Model pricing is a good method provided the models are representative and are regularly updated to reflect changes in technology. An inferior method is to use a cost approach in which the change in price of the finished asset is calculated from price changes of labour and material inputs. Problems with asset price indices are not confined to unique goods. A particular difficulty concerns the calculation of price indices for goods subject to rapid technological changes, notably computers and related equipment. For these goods increasing use is being made of *hedonic* techniques to measure the purchasers' evaluation of quality changes in new models.

Service lives of assets

6.19 The accuracy of capital stock estimates derived from a PIM is crucially dependent on **service lives** – *i.e.* on the length of time that assets are retained in the capital stock, whether in the stock of the original purchaser or in the stocks of producers who purchase them as second hand assets. The first section below looks at the sources that are available to estimate service lives, the next section considers evidence that service lives may be changing over time, and a final section looks at how errors in service life assumptions may affect reliability of capital stock estimates. Annex 3 shows the service lives used by four countries that have investigated service lives with particular care. These are the United States, Canada, the Netherlands and the Czech Republic.

Sources for estimating service lives

6.20 The main sources for estimating service lives are asset lives prescribed by tax authorities, company accounts, statistical surveys, administrative records, expert advice and other countries' estimates.

- Tax-lives

6.21 In most countries, the tax authorities specify the number of years over which the depreciation of various types of assets may be deducted from profits before calculating tax liabilities. Many countries – including Australia and Germany for example – make some use of them, either to estimate the service lives of assets for which no other source is available, or to provide a general credibility check on service life estimates obtained by other methods.

6.22 The interesting question is what sources are used to estimate tax-lives in the first place. In general, it appears that tax-lives are based on a variety of sources of differing reliability including expert opinion, ad hoc surveys of particular assets in particular industries and advice from trade organisations. In general, the accuracy of tax-lives will depend on the extent to which they are actually applied in tax calculations. Some governments use various systems of accelerated depreciation to encourage investment with the result that tax-lives become irrelevant to the calculation of tax liabilities, and neither tax collectors nor tax payers have any incentive to see that they are accurate and kept up-to-date. In several countries, however, tax-lives are based on periodic investigations by the tax authorities and can be assumed to be realistic.

6.23 In some cases, the statisticians have concluded that the pattern of tax lives across industries or asset types are fairly realistic but that there is a tendency for an overall bias in one direction or the other. They therefore apply an upward or downward correction factor before using them for their PIM estimates.

- Company accounts

6.24 Company accounts often include information on the service lives that they are using to depreciate assets. Singapore and Australia have both made use of service lives reported in company accounts. The International Accounting Standards Committee has for some years been encouraging member countries to adopt common standards for company accounting and the Committee's rules require companies to report asset service lives used to calculate depreciation in their accounts. Company accounts could, therefore, become a better source of information in the future.

6.25 Company accounts almost always record stocks of assets at historic (or "acquisition") values, and while this is a disadvantage for many purposes, it does not necessarily prevent them from being used to estimate asset lives. Current price estimates of GFCF are, by definition, also valued at acquisition prices and are therefore consistent with stock estimates in company accounts. If the latter can be converted to a gross basis by adding back depreciation (which is also recorded at historic prices in company accounts) service lives can be estimated by comparing the gross stock in each year with the sum of investments during a varying number of previous years until finding how many years' cumulated investments most nearly equal each year's capital stock. This technique has been used in France, Italy and the United States.

- Statistical surveys

6.26 Two kinds of surveys are relevant to the estimation of asset service lives – those which ask producers about **discards of assets** during some previous accounting period and those which ask respondents to give the purchase dates and **expected remaining lives** of assets currently in use. The Netherlands has been carrying out a discards survey for some years and the Czech Republic has recently added questions about discards to its annual capital expenditure survey. The United Kingdom, on the other hand, recently investigated the feasibility of a discards survey but concluded that very few respondents would be able to provide reliable information about assets that had already been discarded from the stock.

6.27 The results of the Netherlands discards survey have been used directly to estimate asset service lives, but Statistics Netherlands now prefers to use an indirect approach. The value, at "as new" prices, of reported discards of a given type of asset installed in a given year are divided by each year's gross stock of assets each year of that same asset and same vintage. This gives an estimate of the "hazard rate" defined as the probability that an asset of that particular type and year of installation (vintage) will be discarded in each year following its installation. The hazard rates are then used to estimate the parameters of a Weibull probability function which has been found to give a good approximation to the way in which a group of assets installed in a given year are discarded. The average service life of the assets is determined from the estimated Weibull parameters.

6.28 Several countries carry out surveys of the second kind – *i.e.* those asking respondents about expected lifetimes. Korea and Japan have carried out large-scale investigations of capital stocks and asset service lives covering most kinds of activities. Canada, Italy and Spain have added questions about expected service lives to ongoing surveys of capital investment or industrial production. The

United States carried out a number of industry-specific surveys in the 1970s with a view to updating the service lives used for tax purposes. A recent survey carried out in New Zealand on behalf of the tax authorities concentrated on 250 specified types of plant, machinery, transport and other types of equipment. For each asset type, a target group of producers was identified which could be expected to use that particular type of equipment and respondents were asked to report the year of purchase and expected remaining life of one individual asset of that type. By confining the investigation to a single asset the survey achieved a good response rate.

6.29 Producers of capital goods need to know the age structure of the asset stock in order to forecast future demand. For this reason, trade associations and publishers of technical journals sometimes carry out surveys, which may provide information on service lives. Information from these sources does not seem to have been widely used by statistical agencies but it may well be that information on particular kinds of assets is available from trade and technical publications in some countries.

- Administrative records

6.30 For some assets, government agencies maintain administrative records that can be used to estimate service lives. In almost all countries registers are kept of construction and demolition of dwellings and commercial buildings and vehicle registration records track the service lives of road vehicles. Aircraft and ships are often subject to similar controls. Regulatory bodies in power industries, railways and telecommunications are also a possible source of information.

- Expert advice

6.31 Most countries appear to base at least some of their asset lives on “expert advice”. This may involve seeking advice from a panel of production engineers familiar with conditions in a representative cross-section of industries, or asking firms that produce capital assets for the normal service lives of different sorts of equipment. As already noted, producers of capital equipment need to have realistic estimates of the usual working lives of the assets they produce because sales to replace existing assets are a significant part of their total market. Asset-producers are therefore a potential source of reliable information on service lives.

- Other countries’ estimates

6.32 Most countries periodically review estimates used by other countries to ensure that their own estimates are not too far out of line with those of neighbouring or similar countries. Certainly, when countries first estimate capital stocks, they usually search the literature or contact other statistical offices to find out the service lives used elsewhere. There is a danger here that if countries systematically copy other countries service lives, an impression is created that there is a well-based consensus on the matter when in fact few, if any countries, have actually investigated service lives in their own countries. It should also be noted that asset service lives must be strongly influenced by country-specific factors such as the relative prices of capital and labour, interest rates, climate and government investment policies. Other countries' estimates may provide a broad credibility check but should not be adopted without question.

Changes in service lives

6.33 Estimates of service lives are rarely updated in most countries. The “fixity” of service lives has been criticised because it is alleged that service lives are tending to fall over time. Two main reasons are given for this:

- It is argued that “product cycles” are becoming shorter. Consumer tastes in many countries may be changing more rapidly than in the past so that manufacturers are forced to introduce new versions and models more quickly and to bring new products onto the market more often than before. This could require producers to retool their production lines more frequently.
- It is also argued that many capital goods face much higher rates of obsolescence than in the past. This is particularly the case with computers and related equipment and may also be true for the increasing range of assets that incorporate computer technology; numerically-controlled machine-tools, communications equipment, and robotised production systems are examples.

6.34 As against this, some assets are certainly becoming more durable. Road vehicles and commercial aircraft are two examples. In addition, there has been considerable progress in recent year in the development of “flexible” production systems, which allow manufacturers to rapidly switch between alternative models without the need to retool. Shorter production cycles do not, therefore, necessarily imply shorter asset lives.

6.35 There have been few empirical studies relevant to the question of changes in asset lives. In Germany the Federal Ministry of Finance first began to publish tables of service lives to be used for tax purposes in 1957 and they have been regularly updated since then. The German *Statistisches Bundesamt* notes that officials of the Ministry of Finance are in regular contact with firms about changes in asset lives. The information obtained by the officials may be impressionistic rather than scientifically-based, but the *Statistisches Bundesamt* considers that it is nevertheless sufficiently well-founded to detect the direction of changes in service lives and the approximate size of such changes. A number of changes to tax lives are reported in these tables and, with the exception of commercial aircraft, all are reductions. Examples include farm-buildings (from 50 to 25 years), wood-working machinery (reduced by one or two years), machines in the precision industries (reduced from 10 to 8 years), and machines in the optical industries (reduced from 8 to 7 years).

6.36 Most countries appear to keep asset lives fixed for their PIM estimates, but there are some exceptions. In the capital stock estimates of the United Kingdom, the lives of most assets are assumed to have been gradually declining since the 1950’s and service lives of most types of long-life assets are reduced by just over 1% each year. The German *Statistisches Bundesamt* uses falling service lives for housing, farm buildings, motor vehicles and certain types of industrial equipment. Finland assumes that service lives for machinery and equipment were falling by 0.8% to 1% per year from 1960 to 1989 and at about half that rate since 1990.

6.37 Some of these reductions in asset lives are introduced not because the statisticians believe that service lives of particular kinds of assets are falling but rather that the asset **groups** identified in their PIM models are thought to contain increasing shares of shorter-lived assets. In particular, assets containing computerised components are generally assumed to have shorter lives than other types of equipment and the share of such assets in some asset groups is almost certainly rising in all countries. Thus, even in the absence of information about asset lives of **specific** assets, it may be right to assume

declining service lives for **groups** of assets. Clearly the importance of this composition effect will depend on the degree of detail in the asset classification that is being used.

6.38 The United States uses a rather detailed asset classification for stock estimates and certain changes in the service lives of specific assets lives are incorporated in its current PIM model. For example the Bureau of Economic Analysis assumes that the service lives of main frame computers have fallen from 8 years prior to 1970 to 7 years between 1970 and 1979 and to 5 years since 1980. Computer terminals were assumed to last 9 years prior to 1981, for 8 years up to 1985 and for only 6 years since then. Similar reductions are assumed for other computer related equipment. (The changes are discrete, rather than continuous as in the examples given above.)

6.39 There are fewer examples of increasing service lives. In Germany the service lives of commercial aircraft are assumed to have been between 5 and 8 years prior to 1976 and 12 years for aircraft purchased since then. In the United States electric light and power equipment was assigned a service life of 40 years before 1946 and 45 years for all later years. Commercial aircraft are also assigned longer lives in later years – 12 or 16 years prior to 1960 and 15 or 20 years since then. Australia cites evidence from vehicle registration records that the service lives of road vehicles are increasing and this may be a fairly widespread phenomenon.

Effect of errors in service life estimates

6.40 Ideally, what is required for accurate implementation of the PIM is a set of service lives for narrowly-defined asset groups that are used in different sectors and kinds of activity. Moreover, this set of service lives should be updated regularly to reflect cyclical or longer-term changes in the lengths of time that assets remain in the stock. From the review of the sources above it is clear that the information actually available falls far short of this ideal. Service life estimates are generally available only for broad asset groups, there is limited information available on differences in lives of asset groups between sectors and kinds of activity and service lives are updated at rare intervals in most countries. This section considers how errors in service lives may affect levels and growth rates of capital stocks derived from the PIM.

6.41 The effect of errors in the average service lives used in the PIM can be gauged through “sensitivity studies” by running the PIM model with alternative estimates of service lives. Results of recent sensitivity studies for Canada and the Netherlands are described below.

6.42 Statistics Canada has estimated the **gross capital stock** in manufacturing with its standard PIM model but using service lives that increased from 0.5T to 1.5T, with T the average service life presently being used in Canada. The tests were run for the period 1950 to 1998. Predictably, changing service lives changes the level of the capital stock in the same direction. Using the shortest lives (0.5T) reduced the level of the stocks by up to 50% and using the longest lives (1.5T) increased the level by up to 40%. With less extreme changes – 0.9T and 1.1T – the size of the stock is reduced by about 8% and raised by about 7%. Assuming that service lives used for PIM estimates are not usually wrong by more than 10%, the Canadian study therefore suggests that stock levels may have error margins of +/-8%.

6.43 Analytic studies often focus on growth rates rather than stock levels. The effect of changing service lives has an unpredictable effect on growth rates because service lives act like weights. An upward revision to the service life of a particular asset increases the share of that asset in the total stock. An upward revision to a faster (slower) growing component of the stock will raise (lower) the growth rate of the capital stock as a whole. In the Canadian study, reducing service lives generally

increased capital stock growth rates during the period 1950 to 1970 but decreased them from 1971 to 1998.

6.44 The study carried out by Statistics Netherlands focused on stocks of machinery in the chemical industry and covered the period 1978 to 1995. Five different service lives were used – 10, 15, 20, and 25 years (the average service life actually used is 19 years). While the Canadian study deals only with estimates of the gross capital stock, the Netherlands study looked at the effects on both gross and net stocks and on consumption of fixed capital.

6.45 The level of the **gross stock** again changes in the same direction as the changes to service lives. **Consumption of fixed capital**, however, generally changed in the opposite direction; that is, increasing the service lives reduced the amount of consumption of fixed capital. This happened because, with longer service lives, each asset is written off over a longer period and this outweighs the increase due to the fact that longer service lives mean that there are more assets in the stock. In some years, however, the increase in the number of assets in the stock due to the use of longer service lives outweighed the reduction in the amounts of consumption of fixed capital charged to each asset and total consumption of fixed capital increased with longer service lives.

6.46 Net capital stock is obtained by deducting accumulated consumption of fixed capital from the gross stock. Since longer service lives will always increase the gross capital stock and will usually decrease consumption of fixed capital, the **net capital stock** will tend to increase when longer service lives are used. Moreover, the increase in net capital stock as service lives are lengthened will be relatively larger than in the case of the gross capital stock.

6.47 A final conclusion from the Netherlands study is that growth rates of gross and net stocks and of consumption of fixed capital become less volatile as service lives are lengthened. With longer service lives any lumpiness in investment flows into and out of the stock tends to be dampened by the larger size of the stock.

6.48 To summarise the results of these two sensitivity studies:

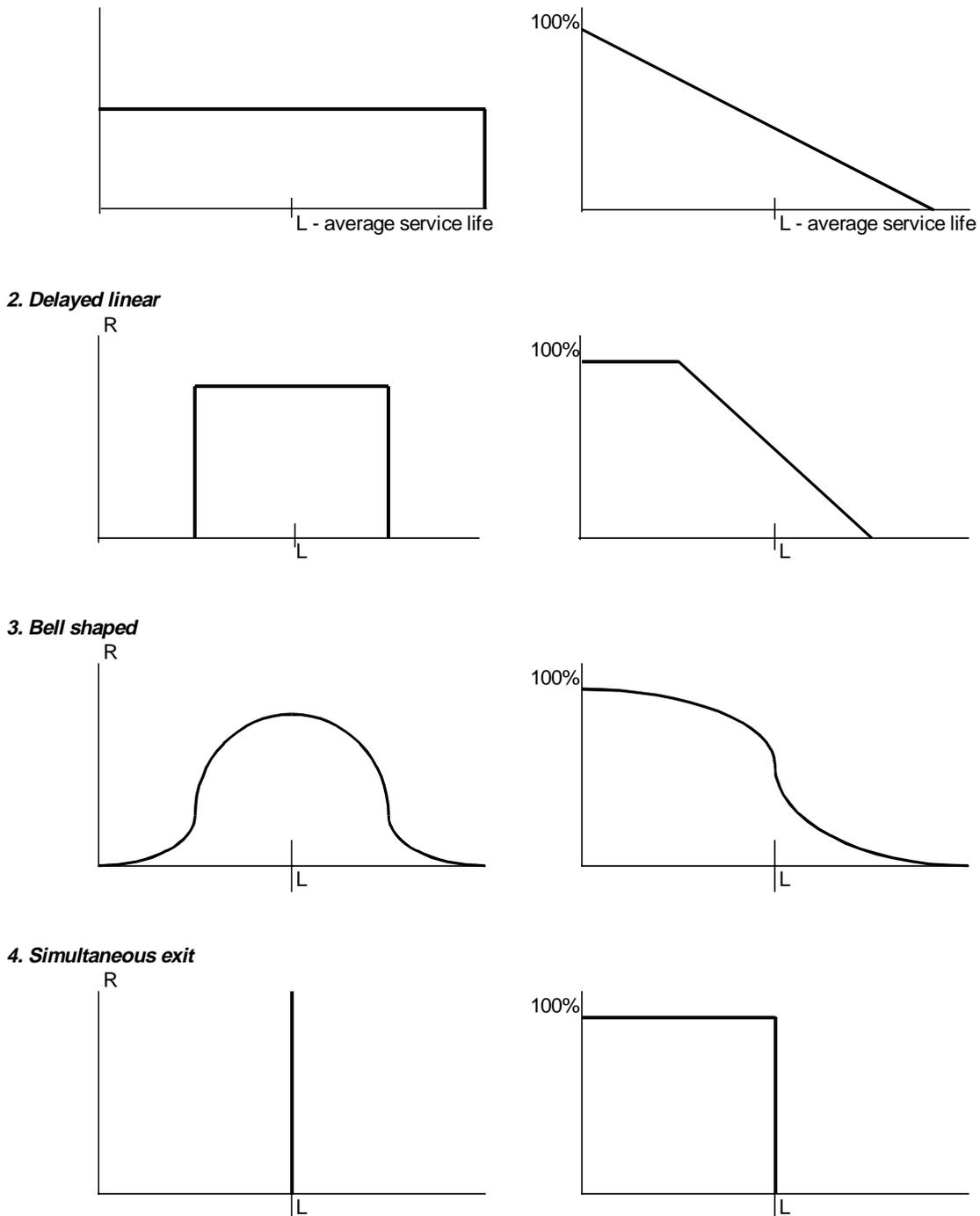
- Longer service lives always increase the size of the gross capital stock.
- Longer service lives usually reduce consumption of fixed capital.
- Longer service lives usually increase the size of the net capital stock and by relatively more than in the case of the gross capital stock.
- Longer service lives have an unpredictable effect on growth rates.
- Longer service lives reduce the volatility over time in the growth of stocks and capital consumption.

Mortality patterns

6.49 This section looks at the assumptions made about the distribution of retirements around the average service life. “Retirements” and “discards” are here used interchangeably to mean the removal of an asset from the capital stock, with the asset being exported, sold for scrap, dismantled, pulled down or simply abandoned. As used here retirements and discards are distinguished from “disposals” which also includes sales of assets as second-hand goods for continued use in production.

6.50 Four types of mortality patterns are discussed – simultaneous exit, linear, delayed linear, and bell-shaped. The mortality functions and survival functions corresponding to these four patterns are displayed in Figure 1. The mortality functions (first column) show rates of retirement over the lifetimes of the longest-lived member of a group of assets of a particular type that were installed in a given year. They are probability density functions with the area under each curve equal to unity. The survival functions (in the second column) show what proportion of the original members of the group of assets are still in service at each point during the lifetime of the longest-lived member of the group.

Figure 1. Four Mortality and Survival Functions



Simultaneous exit

6.51 The simultaneous exit mortality function assumes that all assets are retired from the capital stock at the moment when they reach the average service life for the type of asset concerned. The survival function therefore shows that all assets of a given type and vintage (i.e. year of installation) remain in the stock until time T , at which point they are all retired together. This retirement pattern is sometimes referred to as “sudden exit” but this term is ambiguous. Whatever mortality pattern is used, individual assets are always retired suddenly; the distinguishing feature of this mortality function is that all assets of a given type and vintage are retired **simultaneously**.

Linear

6.52 With a linear retirement pattern, assets are assumed to be discarded at the same rate each year from the time of installation until twice the average service life. The mortality function is a rectangle whose height – the rate of retirement – equals $1/2T$ where T is the average service life. The survival function shows that the surviving assets are reduced by a constant amount each year, equal to $50/T\%$ of the original group of assets.

Delayed linear

6.53 A linear retirement pattern assumes that retirements start immediately after they are installed and this is generally regarded as an unrealistic assumption. A delayed linear retirement pattern makes the more realistic assumption that discards occur over some period shorter than $2T$. Retirements start later and finish sooner than in the simple linear case. Suppose for example that it is assumed that the assets are retired over the period from 80% to 120% of their average service life. The rate of retirement in the mortality function is then equal to $1/T (1.2-0.8)$ or $250/T\%$ per year during the period when the retirements are assumed to occur.

Bell-shaped

6.54 With a bell-shaped mortality pattern, retirements start gradually some time after the year of installation, build up to a peak around the average service life and then taper off in a similar gradual fashion some years after the average. Various mathematical functions are available to produce bell-shaped retirement patterns and most provide considerable flexibility as regards skewness and peakedness (or *kurtosis*). They include gamma, quadratic, Weibull, Winfrey and lognormal functions. The last three are probably most widely used in PIM models and are described here.

- Winfrey curves

6.55 Winfrey curves are named after Robley Winfrey, a research engineer who worked at the Iowa Engineering Experimentation Station during the 1930s. Winfrey collected information on dates of installation and retirement of 176 groups of industrial assets and calculated 18 “type” curves that gave good approximations to their observed retirement patterns (see Box 2). The 18 Winfrey curves give a range of options for skewness and kurtosis. They are used in PIM models by several countries.

6.56 The Winfrey symmetrical curves are written as:

$$y_x = y_o \left(1 - \frac{x^2}{a^2} \right)^m \quad (1)$$

where y_x is the ordinate of the frequency curve at age x , y_o is the ordinate of the frequency curve at its mode, and a and m are parameters ranging from, respectively, 10 to 7 and 0.7 to 40.0, which determine the peakedness (kurtosis) of each curve.

Two widely used Winfrey curves are the symmetrical S2 and S3 curves; the S2 curve is flatter than the S3. For these curves the parameters are as follows:

S2: $y_o = 11.911$; $a = 10$; $m = 3.700$

S3: $y_o = 15.610$; $a = 10$; $m = 6.902$

Box 2. Winfrey Mortality Functions

During the 1920s and 1930s, Robley Winfrey assembled information on retirements of 176 different kinds of assets. Data were “accumulated from many sources, representing the following industries: gas, electric light and power, railway, telephone, telegraph, water supply, agricultural implement, motor vehicle and street pavement” (Statistical Analyses of Industrial Property Retirements, Robley Winfrey, page 59). His data sources included many of the major companies of the time -- the *American Telephone and Telegraph Company*, the *Atchison, Topeka and the Santa Fe Railway* and the *Pacific Gas and Electric Company*. He also used information from the *Chicago Water Works System* and other municipal enterprises and he examined Iowa State vehicle registration records covering a wide range of “motor trucks” and “motor cars” -- the latter including over 6 000 Model-T Fords and 5 000 cars of other makes.

His interest was in the ways in which a group of assets -- e.g. creosoted cross-ties (sleepers), motor cars, waterworks boilers, asphalt pavements -- that had been installed or constructed in a given year were retired over their total life-span. Winfrey plotted the 176 individual mortality functions showing when each member of each “cohort” (group of assets installed in a given year) was retired from the capital stock and concluded that they could be grouped into 18 “type” curves which he denoted by L, S and R for left-modal, symmetrical and right-modal and by the numbers 0 through 6 for the flattest to the most peaked curves. The 176 different kinds of assets were fairly evenly spread between the L, S and R curves but slightly more assets were assigned to the left-modal group -- i.e. mode to the left of the mean. Over half of them had rather peaked mortality functions (numbers 3 to 6) indicating that most retirements happen within a short space of each other

6.57 When mortality functions are used in a PIM model, the usual procedure is to calculate the percentage of assets of a given vintage that are discarded at different ages measured in percentages of the average service life. Table 8 shows how the Winfrey S-3 curve can be applied. Discards start at 45% of the average age and continue to 155% of the average, by which time all the assets of a given vintage have been discarded.

Table 8. Application of the Winfrey S3 mortality function

For GFCF of \$8700 with an average service life of 12 years

Per cent of average service life	Winfrey probability of discard at a given percent of average life	Amount of an investment of \$8700 discarded after a given percent of average life (8700 * col 2)	Actual service life for that part of the \$8700 investment shown in col 3 (col 1/100 * 12)
<i>column 1</i>	<i>column 2</i>	<i>column 3</i>	<i>column 4</i>
45	0.012	104.4	5.4
50	0.012	104.4	6.0
55	0.017	147.9	6.6
60	0.024	208.8	7.2
65	0.032	278.4	7.8
70	0.040	348.0	8.4
75	0.050	435.0	9.0
80	0.059	513.3	9.6
85	0.066	574.2	10.2
90	0.072	626.4	10.8
95	0.077	669.9	11.4
100	0.078	678.6	12.0
105	0.077	669.9	12.6
110	0.072	626.4	13.2
115	0.066	574.2	13.8
120	0.059	513.3	14.4
125	0.050	435.0	15.0
130	0.040	348.0	15.6
135	0.032	278.4	16.2
140	0.024	208.8	16.8
145	0.017	147.9	17.4
150	0.012	104.4	18.0
155	0.012	104.4	18.6

- Weibull distribution

6.58 The Weibull function has been widely used in studies of mortality in natural populations. It is a flexible function that can adopt shapes similar to those designed by Winfrey. It was devised by the Swedish mathematician Walled Weibull in 1951 and it is used by several countries for PIM estimates. The Weibull frequency function is written as:

$$f(x) = \alpha \lambda * (\lambda x)^{\alpha-1} * \exp(-(\lambda x)^\alpha) \tag{2}$$

where x is the number of years since the asset was installed, and λ and α are parameters which jointly determine kurtosis and skewness.

6.59 The frequency function at (2) can be used to calculate the percentage of assets of a given vintage that are discarded at different ages as shown in Table 8 above for the Winfrey mortality pattern.

6.60 Statistics Netherlands has used data from surveys of discards to estimate Weibull discard patterns for a wide range of assets. They report values of λ ranging from 0.015 to 0.033. The α parameter can be interpreted as a measure of changes in the risk of an asset being discarded.

$0 < \alpha < 1$ indicates that the risk of discard decreases over time,

$\alpha = 1$ indicates that the risk of discard remains constant through the lifetime of the asset,

$1 < \alpha < 2$ indicates that the risk of discard increases with age but at a decreasing rate,

$\alpha = 2$ indicates a linearly increasing risk of discard, and

$\alpha > 2$ indicates a progressively increasing risk of discard.

6.61 Most of the α values reported by Statistics Netherlands lie between 1 and 2 except for computers where values just over 2 were reported. The older the computer, the higher the risk that it will be obsolete and have a high risk of being discarded.

- Lognormal distribution

6.62 The *normal* distribution is widely used in many branches of statistics. The normal frequency distribution is symmetrical and has the useful property that 95% of the probabilities lie within two standard deviations around the mean. The *lognormal* distribution has this same property and is widely used as a mortality distribution for the PIM. The lognormal distribution is left-skewed and gives zero probability of discard in the first year of an asset's life. The right-hand tail of the distribution, however, approaches but never reaches zero and must be arbitrarily set to zero when the probabilities become small.

The normal frequency distribution is:

$$f_x = \frac{1}{\sqrt{2\pi} * s} * \exp\left(-\frac{(x - m)^2}{2s^2}\right) \quad (3)$$

x are years $1, 2, 3, \dots, T$,

m is the mean of the distribution,

s is the standard distribution.

The lognormal frequency distribution is:

$$f_x = \frac{1}{\sqrt{2\pi} * \sigma} * \frac{1}{x} * \exp\left(-\frac{(\ln x - \mu)^2}{2\sigma^2}\right) \quad (4)$$

x are years $1, 2, 3, \dots, T$

σ is the standard deviation of the lognormal distribution. It uses m and s from the normal distribution and is calculated as:

$$\sigma = \sqrt{\ln\left(1 + \frac{1}{(m/s)^2}\right)} \quad (5)$$

μ is the mean of the lognormal distribution. It uses m from the normal distribution and is calculated as:

$$\mu = \ln m - 0.5\sigma^2 \quad (6)$$

6.63 The lognormal frequency distribution is used in an ongoing study of capital stocks in the European Union. With m as the estimated average service life, the standard deviation s is set to between $m/2$ to $m/4$ to give more and less peaked distributions of retirements.

Which mortality pattern is the best?

6.64 Of the four discard patterns considered above, the first two – simultaneous exit and linear decline – are clearly unrealistic. It is simply not plausible to assume that all assets of a given vintage will all be withdrawn from the stock at the precise moment when they reach the average service life for that asset type. Like people, some assets will be discarded before they reach the average age of death because they are overworked, poorly maintained or fall victim to accidents, while others will continue to provide good service several years beyond their average life expectancy. **Simultaneous exit** must be regarded as an inappropriate retirement pattern.

6.65 It is equally implausible to assume that a constant proportion of assets of a given vintage are discarded each year beginning in the first year that they are installed. Assets are by definition expected to remain in use for several years and discards in the years immediately after installation are likely to be rare for most assets. **Linear retirement** also fails the test of plausibility.

6.66 The remaining discard patterns – delayed linear and bell-shaped – are clearly more realistic models. **Delayed linear** assumes that once retirements begin, equal parts are discarded until the entire vintage has disappeared and this is probably less plausible than the assumption of a gradual build-up of discards in the early years and a gradual slowdown in later years, which is implied by **bell shaped distributions**.

6.67 Winfrey curves were specifically developed to reflect the way that assets are discarded and they are used by several countries in their PIM models. Both Weibull and lognormal mortality patterns have some empirical support. Statistics Netherlands and the French INSEE respectively, have shown that they can satisfactorily replicate observed discard patterns.

Consumption of fixed capital

6.68 Consumption of fixed capital is not generally observable and is usually estimated on the assumption that asset prices decline in a systematic way over the course of the asset's service lives. Note that consumption of fixed capital almost always has to be estimated in this way whether the capital stock is obtained by the PIM or by some kind of survey method.

6.69 Business accountants have devised several methods for calculating consumption of fixed capital, which are also used for national accounting and these are explained in the Chapter 7. The

commonest of these are “straight-line depreciation”, “geometric depreciation” and “sum of the year’s digits depreciation”.

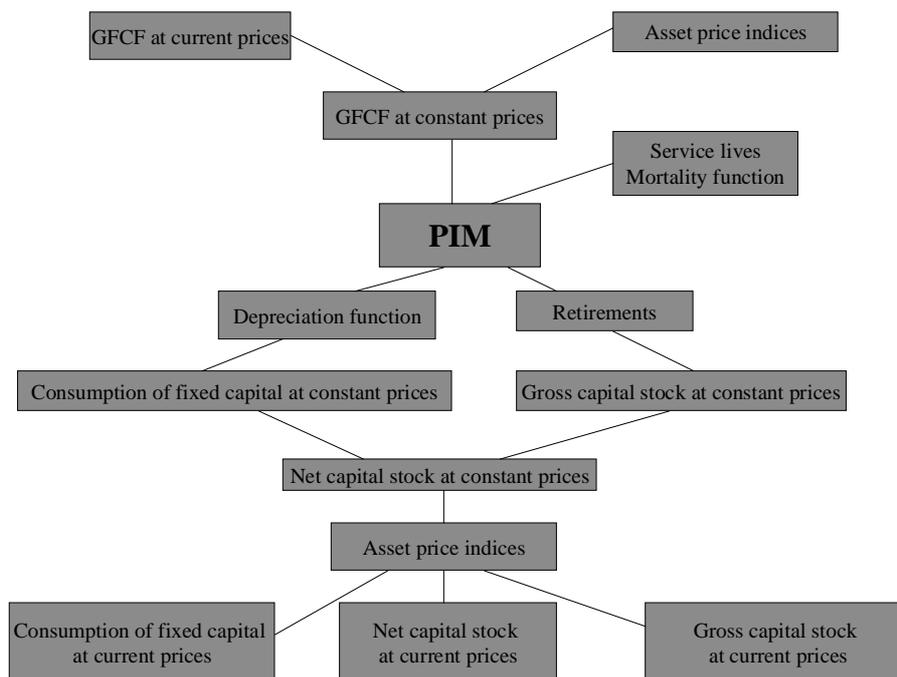
Net capital stock

6.70 The net capital stock is defined as the value of fixed assets at their market prices. Market prices are lower than the “as new” prices used for the gross capital stock because of consumption of fixed capital. These market values are estimated by deducting accumulated consumption of fixed capital from the gross capital stock. Chapter 4 contains an illustrative calculation showing how this is done.

Practical application of the Perpetual Inventory Model

6.71 Figure 2 presents a schematic view of how the PIM is usually applied in practice. Note that the first step is to convert GFCF at current prices to constant prices using the most detailed asset price indices available. The entire PIM is applied using constant price data to obtain consumption of fixed capital and the net and gross stocks in constant prices. It is only at the final stage that price indices are applied to reflate the estimates to current prices.

Figure 2. Application of the PIM in Practice



Alternative application of the PIM

6.72 The alternative way of applying the PIM that is described here exploits the relationship between age-efficiency and age-price profiles. Age-efficiency profiles are estimated for each service

life for each type of asset and, together with an assumption about the discount rate, these profiles generate the age-price profiles that are used to estimate the net capital stock.

6.73 It will be recalled from Chapter 2 that under competitive market conditions, the market price of an asset is related to the rentals that the asset is expected to earn through the following equation. (As in Chapter 2, the scrap value is ignored).

$$V_t = \sum_{\tau=1}^T \frac{f_{t+\tau-1}}{(1+r)^\tau} \quad (7)$$

Where V_t is the real market value of an asset at the beginning of year t ,

f is the real rental earned in each period,

T is the service life of the asset in years,

τ takes values of 1,2,3.... T ,

and r is the discount rate.

6.74 In Chapter 2, it was shown how equation (7) can be used to derive age-price profiles corresponding to any given age-efficiency profile. In the example in Chapter 2, a linear fall in efficiency was used as the age-efficiency profile. Table 9 shows three additional age-efficiency profiles. These are the one-hoss shay (no loss in efficiency), geometric decline (efficiency falls at a constant rate) and hyperbolic decline (efficiency falls at an increasing rate with age). The discount rate has been set at 5%.

Table 9. Four age-efficiency and age-price profiles

		Discount rate 5%							
Year		1	2	3	4	5	6	7	8
Linear (falls by the same amount each year)	Age-efficiency profile	1.00	0.90	0.80	0.70	0.60	0.50	0.40	0.30
	Age-price profile	1.00	0.82	0.66	0.51	0.37	0.25	0.15	0.07
One-hoss shay (constant efficiency)	Age-efficiency profile	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Age-price profile	1.00	0.89	0.80	0.68	0.56	0.43	0.29	0.15
Geometric (falls by 10% per year)	Age-efficiency profile	1.00	0.90	0.81	0.73	0.66	0.59	0.53	0.48
	Age-price profile	1.00	0.84	0.69	0.55	0.43	0.31	0.20	0.10
Hyperbolic ($\beta = 0.5$)	Age-efficiency profile	1.00	0.93	0.86	0.77	0.67	0.55	0.40	0.22
	Age-price profile	1.00	0.83	0.67	0.51	0.37	0.24	0.13	0.05

6.75 The last age-efficiency profile shown in Table 9 - the hyperbolic - is used by the ABS for calculating stocks, consumption of fixed capital and an index of capital services. The BLS also uses this profile for its capital service index. In Table 9 the hyperbolic profile has been calculated by a function of the form:

$$V_t = V_o(T - (t-1))/(T - \beta(t-1)) \quad (2)$$

t are the years $1, 2, \dots, T$,

and β is the slope-coefficient which has been set at 0.5 in this example. (Both ABS and the BLS use this value of β for most types of machinery and equipment.)

6.76 The hyperbolic age-efficiency and age-price profiles shown in Table 9 are then used to calculate the stock of an asset in *standard efficiency units* and *at constant market values* as shown in Table 10.

Table 10. Calculation of stocks in standard efficiency units and at market values

Hyperbolic decline in efficiency: 5% discount rate.

Year	GFCF at constant prices	Age-efficiency coefficient	Converted to standard efficiency units	Age-price coefficients	Value at constant market prices
1	100	0.22	22.0	0.05	5.0
2	90	0.40	36.0	0.13	11.7
3	120	0.55	66.0	0.24	28.8
4	60	0.67	40.2	0.37	22.2
5	80	0.77	61.6	0.51	40.8
6	120	0.86	103.2	0.67	80.4
7	100	0.93	93.0	0.83	83.0
8	80	1.00	80.00	1.00	80.0
		Stock at beginning of year 8 in standard efficiency units:	502.0	Net stock at beginning of year 8:	351.9

6.77 To understand the table:

- The second column shows gross fixed capital formation in a specified type of asset which has a service life of 8 years. The GFCF series have been converted to constant prices.
- The third column gives the age-efficiency coefficients for an asset whose efficiency declines hyperbolically over an 8-year service life as shown in Table 9
- The fourth column shows each year's constant price GFCF converted to standard efficiency units. For example, the GFCF of 100 that occurred in year one is multiplied by the age-efficiency coefficient 0.22, which measures its ability to produce capital services now that it has been in use for 7 years.

- The fifth column gives the age-price profile corresponding to an asset that lasts 8 years, whose age-efficiency declines hyperbolically and when the discount rate is 5%.
- The last column shows the net value, at the beginning of year 8, of the assets remaining from GFCF in earlier years. It is obtained by multiplying each year's GFCF by the corresponding age-price coefficient. For example, the GFCF of 90 that occurred in year 2 has declined to only 0.13 of its original value by the beginning of year 8.
- Finally, the stock of this particular asset at the beginning of year 8 is obtained by addition. The total of column 4 gives the stock in standard efficiency units (502.0) and the total of column 6 gives the net stock in constant prices (351.9).

6.78 If the same calculations are performed in year 9 the change in the two capital stock measures can be calculated. The proportionate change in the stocks expressed in standard efficiency units represents the real proportionate change in capital services produced by this particular type of asset during the period. The change in real net capital stocks can be decomposed into two elements – the increase attributable to gross fixed capital formation during the year and the decrease due to consumption of fixed capital. The latter can then be revalued using the price index in order to derive a current price estimate of consumption of fixed capital during period 8 for inclusion in the national accounts.

6.79 This method of applying the PIM has the advantage that the standard efficiency units of each type of asset are measured in a way that is strictly consistent with the net capital stock and consumption of fixed capital. The standard efficiency units are used to calculate the **volume index of capital services** as explained in Chapter 9. This index is the recommended measure of capital inputs for productivity analysis.

6.80 Note that capital consumption is here being derived indirectly from the changes in the net stock (after deducting gross fixed capital formation during the year). The method does not therefore require any assumptions about the form of the depreciation function which are needed when the PIM is applied in the standard way described in the previous section. Instead the alternative method requires assumptions about the form of the age-efficiency profiles appropriate to each type of asset and about the discount rate.

6.81 The two agencies that currently use this alternative PIM method (the Australian Bureau of Statistics and the US Bureau of Labor Statistics) use hyperbolic functions for almost all types of assets. The slope-coefficient is set at 0.5 for machinery and equipment and at 0.75 for buildings and structures. The higher value of β used for buildings and structures implies that they lose their efficiency more slowly than in the case of machinery and equipment. With β set at 1.0, the hyperbolic function gives a constant, or “one-hoss shay” age-efficiency profile. The ABS uses this value of β for mineral exploration because it believes that there is no efficiency decline in the knowledge acquired through exploring for minerals.

CHAPTER 7 MEASURING CONSUMPTION OF FIXED CAPITAL

Introduction

7.1 In the previous chapters the term *consumption of fixed capital* has been used in line with the terminology of the 1993 System of National Accounts. This rather clumsy expression has been traditionally used in the national accounts in order to distinguish it from *depreciation* as shown in company accounts. Depreciation in company accounts is almost always calculated using historic costs so that it is a very different measure from consumption of fixed capital. However, as it is defined in the 1993 SNA, consumption of fixed capital is in fact identical with depreciation as this term is widely used in economic literature. In this chapter the two terms are used interchangeably with the understanding that depreciation is the concept understood by economists and not depreciation as measured by commercial accountants.

Direct versus indirect measurement of depreciation

7.2 The traditional application of the PIM involves estimation of the gross capital stock, application of a depreciation function and a mortality function to obtain annual depreciation and, finally, estimation of the net capital stock by subtracting accumulated depreciation from the gross capital stock. This application of the PIM requires the **direct** estimation of depreciation, which is used to obtain the net capital stock indirectly. The alternative, integrated approach described in Chapter 6, is to start by estimating age-efficiency profiles for each type of asset which are then used to generate age-price profiles. The age-price profiles are used to directly estimate the net capital stock from which depreciation is obtained **indirectly**. This chapter considers the depreciation functions that are commonly used when depreciation is being **directly** estimated.

Layout

7.3 The aim of this chapter is to identify the depreciation methods that are most likely to reflect the ways in which assets lose their value over time. The chapter is divided into three sections:

- The first reviews the empirical evidence about how assets lose their value during the course of their service lives. This evidence comes from studies, mainly carried out in North America, on the prices of second-hand assets.
- The next section shows that there are several age-efficiency profiles that will produce age-price profiles for assets that are consistent with the empirical evidence drawn from the prices of second hand assets.
- The third section describes three common depreciation methods - straight-line, sum-of-the-digits and geometric – and compares the age-price profiles implied by each method with the empirically-consistent age-price profiles identified in the previous section.

7.4 It should be noted that in assessing the different depreciation functions in this chapter, it is assumed throughout that they are used in conjunction with a mortality function. This is the standard procedure used by countries that apply the PIM in the traditional way. However, the United States Bureau of Economic Analysis uses (infinite) geometric depreciation without applying a mortality function. The BEA notes that for a group of assets, straight-line depreciation together with a bell-shaped mortality function produces an age-price profile (for the group as a whole) that is quite similar to that obtained using geometric depreciation without a mortality function. Because BEA is applying the PIM in this way the assessment of the merits of different depreciation methods given in this chapter is not relevant to the BEA methodology. The BEA methodology is described in Annex 2.

Empirical evidence

7.5 If the price level is stable, depreciation is simply the change in the market value of an asset from one accounting period to the next. This change is referred to as the age-price profile. The prices of second-hand assets, after being adjusted to eliminate changes in price levels, can be used to establish age-price profiles for assets. For example they can be used to show how the market values of farm tractors of a particular model decline as they get older.

7.6 Virtually all studies of second hand asset prices have been made in the United States, perhaps because second-hand asset markets are more highly developed in that country. It is not certain that the age-price profiles identified for assets in the United States are also typical for other countries, although the few studies carried out elsewhere, in Canada, United Kingdom and Japan, for example, have found similar age-price profiles.

7.7 Ideally, these studies should use actual transaction prices. A few studies have done this by using auction prices. This is often the case in studies of farm equipment because auctions are a common way of disposing of assets when farms go out of business. Other studies have tried to obtain transaction prices from second-hand asset dealers through surveys. Most studies, however, have been based on “list prices”. These are the offer prices published by dealers and, because bargaining is common in asset markets, they may overstate actual transaction prices. In almost all cases, the first price in the age-price profile – the price of a new asset – is almost always a list price even when the subsequent observations are genuine transaction prices. Finally, at least one study has used insurance values. This was a study of fishing boats and because they run substantial risks of accidental loss, both owners and insurers have a shared interest in ensuring that insured values are realistic. This is not always the case for assets which face lower accident risks.

7.8 Questions have sometimes been raised whether assets traded on second-hand markets are representative of the entire asset stock, including the large majority of assets that remain in the possession of their original owners until they are scrapped. In particular, it has been suggested that assets are put on the second-hand market because they are defective in some way; this is sometimes referred to as the “lemons” theory. Even if most second hand assets are in fact not lemons (*i.e.* not defective), so long as some prospective buyers fear that there may be some defective ones among the assets on offer, prices will be depressed and the prices of assets traded on second-hand markets will understate the market values of assets not so traded. An additional point is that there may be an inverse relationship between the lemons effect and the age of an asset. If an asset is put on the market while it is still relatively new, prospective buyers may be more suspicious about possible defects than if an asset is traded towards the end of its normal service life. The opposite suggestion has also been made, namely that used assets are usually put on the market in order to raise finance and so firms will sell their best assets rather than their worst ones. Attempts to determine the validity of these and other

theories about the extent to which second-hand assets are representative of the total asset stock are inconclusive.

7.9 A significant source of bias, about which there is no dispute, arises from the fact that second-hand asset prices necessarily refer only to assets that have not yet been retired from the capital stock. Within the entire group of farm tractors of a given make, model and year of manufacture, there will be some whose second-hand prices are zero because they have been scrapped. A minority of studies has tried to correct for this bias by adding some (unobserved) zero prices to the set of prices that have been observed. It is usually assumed that the assets with zero prices were withdrawn from the stock following a bell-shaped mortality function such as the Winfrey “S3” curve.

7.10 Three main conclusions about age-price profiles can be drawn from these studies:

- First, different kinds of assets exhibit a very wide range of age-price profiles. If price is plotted on the vertical axis and age horizontally, studies have found age-price profiles that are concave to the origin, that are horizontal lines, that fall in a straight line and that are convex to the origin. The studies have covered a wide range of industrial, agricultural and construction machinery, commercial and industrial buildings and transport equipment and it is therefore no surprise that they have not identified a single, standard pattern for the age-price profile of assets.
- Second, notwithstanding the above, by far the commonest age-price profile is a line which falls over time with some convexity towards the origin. This is almost always the case for machinery and equipment and is generally the case for buildings.
- Third, the downward sloping convex curve, which is most often detected in these studies, does not follow any simple mathematical law. Some of the studies have tested whether their observed age-price profiles follow one of two simple models – geometric (*i.e.* asset prices falling by a constant rate each year) or straight-line (*i.e.* asset prices falling by a constant amount each year). Statistical tests almost invariably reject both of these simple models, although straight-line is usually rejected more firmly than the geometric model. Some studies have successfully fitted Box-Cox curves to the asset price data; these are flexible functions, which can take a range of forms including straight lines and geometric curves. The fact that Box-Cox curves may fit the data quite well is simply confirmation that age-price profiles follow complex paths. This is not a cause for surprise. It would be astonishing if the multitude of factors that may influence asset prices – shifts in demand, relative factor prices, technological developments to mention a few – combined to produce age-price profiles that follow some simple mathematical model.

Age-efficiency profiles, asset prices and depreciation

7.11 The standard equation relating the value of the rentals, or capital services, produced by an asset and the price of that asset was introduced in Chapter 2. In this section, that equation is used to show how the age-price profile of an asset will change from year 1 to T (the last year of its service life) under alternative assumptions about the age-efficiency profile of the asset over its lifetime. The purpose is to identify age-efficiency profiles which seem plausible on *a priori* grounds and which generate age-price profiles which are consistent with the empirical evidence discussed above – namely that age-price profiles are usually downward sloping and with some convexity towards the origin. The depreciation patterns implied by these age-efficiency profiles are then compared with those produced by three standard depreciation methods – straight-line, geometric and sum-of-the-years-digits.

7.12 Table 1 in Chapter 2 showed how equation (1) can be used to generate the value of an asset over its lifetime and how these are determined by the age-efficiency profile and the discount rate. The calculation explained in Chapter 2 is here repeated for five age-efficiency profiles as described below. First however, it will be useful to consider how the efficiency of assets may be expected to change as they get older.

- Most assets suffer from what can be termed **input decay** meaning that they require more labour or material inputs to maintain their performance. For, example a freight truck may use more oil as it ages or require more extensive maintenance work and therefore more inputs of labour. Input decay will result in a declining efficiency profile.
- Assets may also suffer from **output decay** as they age. This may take several forms. An older asset may produce more defective products which have to be rejected, or its productive capacity could be lowered because it needs to spend more time under repair and less time in production.
- Some assets may require a running-in period during which technical adjustments are made to maximise performance. Others may require the operators to learn new skills. In either situation the efficiency profile could be expected to rise during the early period of use. This could be described as **negative output decay**.

7.13 The five age-efficiency profiles used here are:

- *Constant age-efficiency*. This is also referred to as the “one-hoss shay” pattern after the mythical horse-drawn cart in “The Deacon’s Masterpiece”, a poem by Oliver Wendell Holmes (see Box 3). The deacon built his cart so well that it ran perfectly for a hundred years without need for repair, thus providing a constant stream of transport services until the day when it suffered catastrophic failure. During its service life neither input decay nor output decay reduced the quantity of services provided. There are probably rather few assets that maintain constant efficiency throughout their working lives. Light bulbs are sometimes cited as potential one-hoss shays, but light-bulbs are too short-lived to be classified as capital goods. More serious contenders might be bridges or dams. With a constant level of maintenance these structures may continue to provide constant rentals for very long periods. In general, however, few examples of the one-hoss shay have been identified in the real world.
- *Age-efficiency falls at a constant rate each year*. This is usually referred to as geometric decline. Note that geometric decline implies that the rentals generated by the asset fall by the largest absolute amount in the first year of service and by decreasing absolute amounts each subsequent year. Since both input and output decay can be expected to increase in absolute terms with age, the geometric profile is not applicable for assets that experience significant input or output decay.

Box 3. The Deacon's Masterpiece or the Wonderful "One-Hoss Shay"

Oliver Wendell Holmes' poem tells of a Deacon who decides to build a "shay" that would have no weak spots so that it would never break down. (Shay is a corruption of the French *chaise*, which is an old English abbreviation of "post-chaise" or stage-coach.)

*Now in building of chaises, I tell you what,
There is always somewhere a weakest spot,-
In hub, tire, felloe, in spring or thill,
In panel or cross-bar, or floor or sill,
In screw, bolt, thoroughbrace, - lurking still,
Find it somewhere you must and will.*

The Deacon assembles the hardest timbers, the finest steel, the toughest leather and the work begins.

*Seventeen hundred and fifty-five,
Georgius Secundus was then alive.-
Stuffy old drone from the German hive.
That was the year when Lisbon town
Saw the earth open up and gulp her down,....
It was on that terrible Earthquake day
That the Deacon finished the one-hoss shay.*

The shay outlives the Deacon:

*She was a wonder and nothing less,
Colts grew horses, beards turned gray
Deacon and deaconess dropped away,
Children and grandchildren - where were they?
But there stood the wonderful one-hoss shay
As fresh as on Lisbon Earthquake day!*

But still, nothing last for ever, and by its hundredth year:

*There are traces of age in the one-hoss shay,
A general flavour of mild decay,
But nothing local as one may say.
There couldn't be- for the Deacon's art
Had made it so like in every part
That there wasn't the chance for it to start.*

Finally, disaster:

*First of November fifty-five,
This morning the parson takes a drive....
The parson was working his Sunday's text,-
Had got to "fifthly", and stopped perplexed...
All at once the horse stood still.
Close by the meet'n'-house on the hill.
First a shiver and then a thrill,
Then something decidedly like a spill,-
And the parson was sitting upon a rock,
At half-past nine by the meet'n'-house clock,-
Just the hour of the Earthquake shock!*

Notice that while the one-hoss-shay suffered neither input decay nor output decay during its hundred year service life, this does not mean that it was immune to physical deterioration. It clearly did suffer wear and tear, which is why it suddenly fell apart. The physical deterioration took the form of metal fatigue and similar subtle changes in the molecular structure of the wood and leather. These changes were imperceptible to the naked eye and they in no way affected the ability of the shay to provide a steady flow of unchanged transport services. But the changes nevertheless guaranteed that, sooner or later, the shay would fall apart.

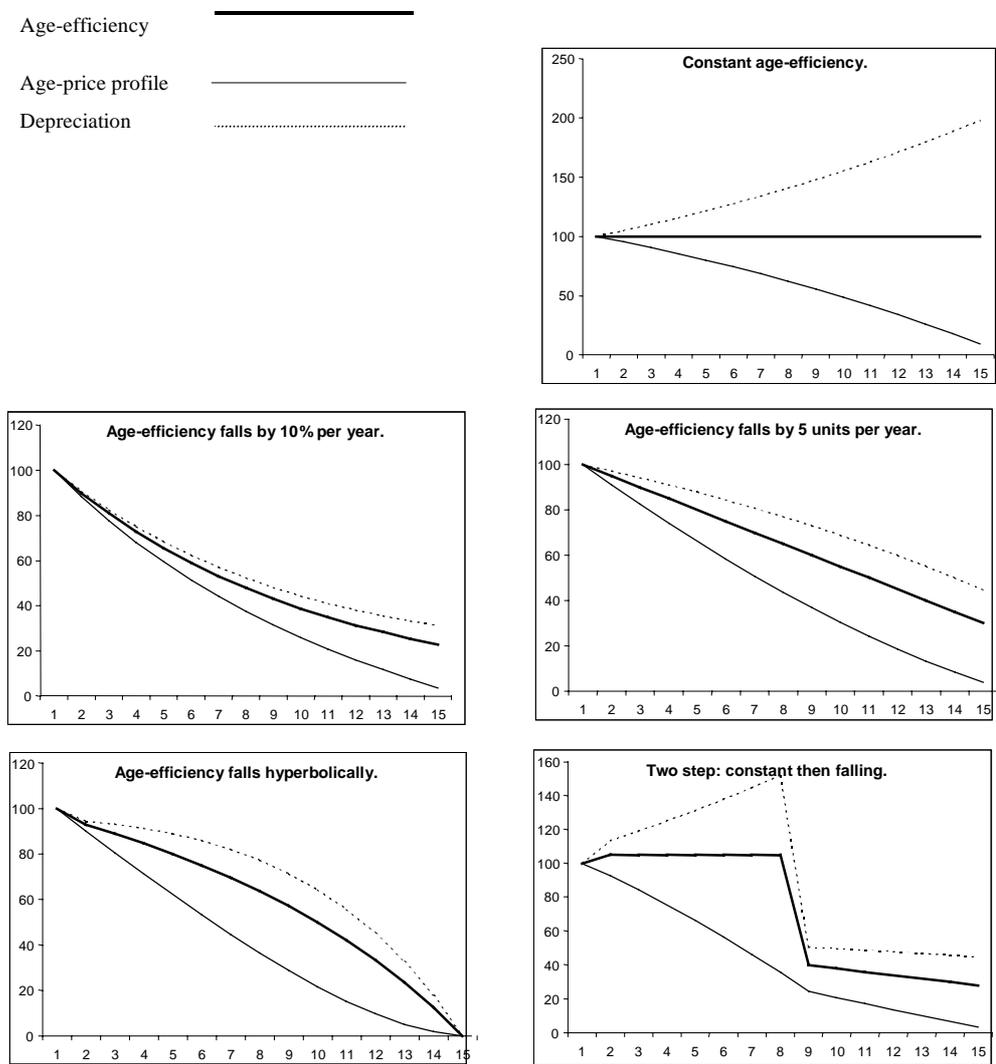
This point is not trivial because it is sometimes argued that one-hoss shays, such as light-bulbs, lose their value only because the failure point grows nearer as each year passes. From this it has been concluded that the **passage of time** is a cause of depreciation in itself, in addition to the causes identified in the SNA, namely physical deterioration (or wear and tear), obsolescence and accidental damage. This is a mistake. If the light-bulb is not suffering physical deterioration - through leakage of the inert gas or oxidisation of the filament, for example - it will go on working forever and the passage of time becomes irrelevant. Ageing, or *exhaustion* as it sometimes called, may be a useful rule of thumb for determining how much physical deterioration has occurred but is not, in itself, a **cause** of depreciation.

- *Age-efficiency falls fall by a constant amount each year.* The linear pattern means that efficiency falls at a faster rate as the asset ages. In the example below, the rental is assumed to fall each year by a constant amount equal to 5% of the initial value of the asset. A linear decline in efficiency can be seen as a compromise between the geometric profile and the hyperbolic profile described next.
- *Age-efficiency falls hyperbolically.* With this profile, efficiency declines slowly in the earlier period and at an increasing rate towards the end of the asset’s life. There is some evidence from the United States that this may be a common efficiency profile for many kinds of assets including both structures and plant and machinery. The hyperbolic function was explained in Chapter 6. Here β is set at 0.5, a commonly used value for age-efficiency profiles of machinery and equipment.
- *Two-step age-efficiency.* In many countries there is an increasing trend towards integrated production systems in manufacturing. There may be many separate pieces of equipment in such a system, each of which must operate without failure since the entire system will shut down if any single component malfunctions or produces defective outputs. Many of these systems are robotised, operating with little human intervention and they may be operated almost continuously rather than in shifts. Typically, the component machines in such a system will be expected to operate without failure for several years, at which point the investment manager will decide either to undertake necessary repair work in order to keep the machines in the integrated system or to remove them from the main production system. In the latter case they may either be sold to another producer or they may be assigned a less demanding role, such as developing prototypes or filling special orders. Assets incorporated into integrated production systems may be expected to have an age-efficiency profile that:
 - Increases in the first period as the system is run-in, *i.e.* negative output decay.
 - Remains constant during the several years in which it is a part of an integrated system, *i.e.* a one-hoss shay profile.
 - Declines abruptly when the machine is withdrawn from the integrated system.

In the “two-step” example given below, the real rental is assumed to rise by 5% in the first year, to remain steady for the next 7 years when it is operating in an integrated system, to fall abruptly when it is withdrawn from the system and then to decline linearly for the remainder of the asset’s service life. This “two-step” age-efficiency profile may be appropriate for an increasing proportion of plant and machinery in manufacturing industries.

7.14 The age-price and depreciation profiles for these five age-efficiency profiles are shown in Figure 3 with all three flows scaled to equal 100 in the first year. The service life is 15 years and a 5% discount rate is used.

Figure 3. Age-price and depreciation profiles given by five age-efficiency profiles



7.15 The empirical evidence on second hand assets that was reviewed in the first section of this chapter shows that asset values generally fall over time with some convexity towards the origin. The first age-efficiency profile in Figure 1 – one hoss shay – gives an age-price profile for the asset which is the opposite shape – *i.e.* it is concave to the origin. It can therefore be concluded that one-hoss shays are rare in the real world. The other four age-efficiency profiles, however, all produce age-price profiles that are consistent with the empirical evidence. The two-step profile gives a time profile for the asset value that has an inflection towards the origin rather than the smooth convexity produced by the other age-efficiency profiles but it is still broadly consistent with the empirical evidence.

7.16 As explained, the calculations underlying Figure 3 used a service life of 15 years and a discount rate of 5%. How far are these results sensitive to these two assumptions? It is a simple matter to repeat these calculations using different service lives and different discount rates. Calculations using service lives of 15 and 50 years and discount rates of 5% and 10% show that the overall shape of the age-price profiles is not affected by a longer service life or by a higher discount rate. The only

exception is with the hyperbolic profile where the asset price loses its convexity when the service life is extended to 50 years and the discount rate is set at 10%.

7.17 The conclusion of this section is that there are several age-efficiency profiles that are consistent with the empirical evidence based on studies of second hand asset prices. In reality, it is unlikely that any assets have age-efficiency profiles that correspond precisely with any of these patterns. It is much more likely that their age-efficiency profiles are combinations of these and other patterns during different parts of their life cycles. There will, therefore, be an infinite number of age-efficiency and depreciation profiles that are consistent with the empirical evidence on asset values.

Depreciation methods

7.18 In calculating depreciation, business accountants face the same problem as national accountants; except in the usually rare circumstance where they are buying or selling used assets, they do not know the market values of their company's asset stock. They have, therefore, devised a number of methods for estimating how asset values decline over their lifetimes. Some of these methods use information about the usage or performance of the asset; for example, depreciation may be assumed to be proportional to the hours of usage in the accounting period compared to the total hours that the asset was expected to be in use when it was originally purchased; another method essentially involves an annual updating of the present value of expected capital service flows over the remaining service life of the asset using the standard equation for the value of an asset. In the vast majority of cases, however, business accountants use one of the following three depreciation methods which all assume a systematic decline in the value of an asset over time and which depend only on the initial value of the asset and its expected lifetime:

- Straight-line depreciation.
- Sum-of-the-digits depreciation.
- Geometric depreciation.

7.19 With **straight-line** depreciation, the market value of an asset in constant prices is assumed to decline by the same amount each period. This amount is equal to $1/T$ th of the initial value of the asset, where T is the service life for that particular asset.

7.20 With the **sum-of-the-digits** method, the market value in constant prices is assumed to fall by an amount which declines linearly over the lifetime of the asset. Specifically, depreciation (D) in year t is calculated as:

- $D_t = V[T-t+1] / [T(T+1)/2]$, where V is the initial price of the asset, T is the service life and t takes values of $1, 2, \dots, T$
- For example, if the service life is 15 years, depreciation in the first year will be 15/120th of V , in the second year it will be 14/120th of V , etc. The denominator is the standard formula for the sum of an arithmetic progression – *i.e.* $15 + 14 + 13 + \dots + 1 = 120$. This gives the method its name and ensures that the total depreciation calculated over the lifetime of the asset fully exhausts its initial value.

7.21 With **geometric** depreciation, the market value in constant prices is assumed to decline at a constant rate in each period. The depreciation factor can be written as R/T where T is the service life and R is known as the “declining balance rate”. Depreciation for period t is obtained by multiplying the written down value of the asset in the period $t-1$ by the depreciation factor, R/T . There are several ways of calculating the declining balance rate (R):

- A method commonly used by commercial accountants is known as the “double declining balance” method. With this method, R is set at 2. The effect of this is that, in the first period, depreciation will be twice as large as depreciation calculated by the straight-line method. (It is for this reason that the method is referred to as “double-declining”.)
- Another approach is to set R at a value that ensures that the asset’s initial value will have been reduced to a predetermined percentage (g) of that value by the time it reaches the end of its expected service life. In other words, a value of R is required such that:

$$V(1 - R/T)^T = gV.$$

Dividing by V and solving for R gives:

$$R = T \left(1 - g^{\frac{1}{T}} \right)$$

7.22 With g set at 0.1 (*i.e.* 10% of the initial value remains at time T) a service life of 15 years gives $R = 2.135$ which implies slightly more rapid depreciation than the double-declining method; R increases as service lives get longer and for a 50 year service life, R rises to 2.250.

7.23 A third approach is to use evidence drawn from empirical studies of second-hand asset prices to determine the declining balance rate appropriate to each asset. This has been done in the United States where the Bureau of Economic Analysis (BEA) uses R values that range from 0.8892 for most office and commercial buildings to 2.2664 for federal government vehicles. An R value of 1.6500 is used for most types of industrial machinery and equipment and a value of 0.9100 is used for residential structures. (Annex 3 shows all the declining balance rates used by the BEA).

7.24 Geometric depreciation will never exhaust the full value of an asset because the depreciated value of the asset falls asymptotically, approaching, but never reaching, zero. This is a disadvantage for commercial accountants because accounting rules almost always require that, whatever system of depreciation is used, total depreciation calculated over the expected life of the asset must equal the initial price of the asset. It can also be seen as a disadvantage for national accountants because it is clearly not the case that a group of assets installed in a given year will continue contributing to production in all future periods. There are two common ways of dealing with this problem.

- One approach is to treat all the remaining value of the asset as depreciation in the last year of the asset’s service life. This is the standard approach of commercial accountants and is also used by some countries that use geometric depreciation for their PIM estimates. These countries also set the declining balance rate (R) so that a predetermined portion of the original asset value remains at the end of the service life. Ten percent – *i.e.* $g = 0.1$ – is usually selected as the share of the original asset value that is to remain at age T .

- The alternative is to arbitrarily adjust the rate of geometric depreciation so that the full initial value of the asset is exhausted when it reaches the end of its service life. Several adjustment techniques are available but what they all have in common is that they necessarily change the depreciation pattern so that it is no longer geometric. If it succeeds in fully exhausting the initial asset value, the adjusted depreciation pattern must be faster than geometric over at least some part of the asset's lifetime.

7.25 While the infinity problem is troublesome in applying geometric depreciation, it may be noted that geometric has a practical advantage over both straight-line and sum-of-the-digits depreciation in at least one situation. This is when there is a benchmark estimate of the net capital stock and data on GFCF for subsequent years but there are no historical series of GFCF. In this situation it is possible to update the net capital stock using geometric depreciation. Neither straight-line nor sum-of-the-digits depreciation can be used if there are no historical series of GFCF since they both require information on when the assets included in the benchmark estimates were purchased.

How well do depreciation methods perform in practice?

7.26 The left-hand part of Figure 4 shows the age-price profiles implied by the three depreciation methods for an asset that lasts for 15 years; a service life of around 15 years is commonly assumed for machinery and equipment. For geometric depreciation the double declining method is used; for an asset that lasts 15 years the double declining model gives virtually the same results as setting the depreciation factor so that 10% of the initial value remains at the end of the service life. The right hand panel shows the age-price profiles for assets with the same 15 year service life but with four different age-efficiency profiles. These age-efficiency profiles are those identified in the previous section as being consistent with the empirical evidence on age-price profiles from second-hand asset prices. They were obtained as explained for Figure 3 above.

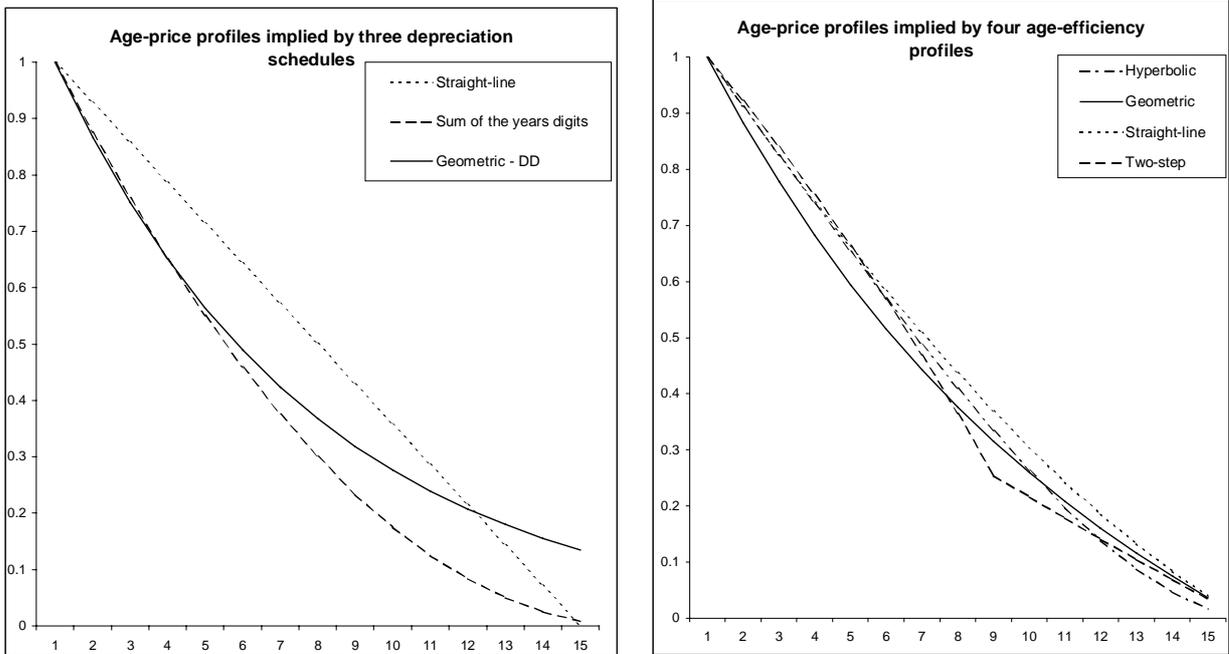
7.27 None of the three depreciation methods produce age-price profiles that are identical to any of the four age-price profiles shown in the right-hand panel. If the two graphs are superimposed, the age-price profiles generated using the four age-efficiency profiles lie between the age-price profiles implied by the straight-line and sum-of-the-years-digits depreciation methods. This suggests that either of these two methods will give a reasonable approximation to depreciation in practice.

7.28 There is, however, another consideration in choosing between the three depreciation methods, namely the shape of the *age-efficiency profiles* that each one implies.

- Geometric depreciation implies that the age-efficiency profile is also approximately geometric (and will be exactly geometric for assets with infinite service lives). Geometric depreciation is therefore appropriate for assets whose efficiency declines by the largest absolute amount in the first year of its service life. *Efficiency* here means the ability to produce capital services for a given quantity of inputs. Geometric depreciation will not therefore be appropriate for assets that require an increasing amount of maintenance as they get older or that consume more energy and other inputs with age.
- Sum-of-the-years-digits depreciation also implies that the largest efficiency losses occur at the beginning of the asset's service life. The main difference between geometric and sum-of-the-years-digits is that the latter has fully exhausted the initial outlay on the asset by the end of its service life.

- Straight-line depreciation, on the other hand, implies a linear decline in age-efficiency; efficiency falls by the same absolute amount in each period. This is closer than either geometric or sum-of-the-years-digits depreciation to the hyperbolic decline in efficiency that is assumed for most assets by both the United States BLS and the Australian Bureau of Statistics.

Figure 4. Comparing the Performance of Three Depreciation Schedules



CHAPTER 8

SURVEYS AND OTHER DIRECT MEASUREMENT METHODS

Introduction

8.1 Most countries estimate capital stocks and consumption of fixed capital by the *perpetual inventory method* (PIM), which was described in Chapter 6. The PIM is a cheap and convenient method, but it requires many assumptions and the estimates obtained are probably less reliable than most other official statistics. This chapter reviews other ways to estimate capital stocks that may be more reliable.

8.2 One way to proceed would be to make an inventory of all the objects considered to be capital assets through physical inspection by teams of enumerators. This was the main method used to compile the English "Domesday Book"⁶, but seems not to have been tried since then. Four possible data sources are reviewed in this chapter:

- Use of published company accounts.
- Enterprise surveys used in centrally planned economies to measure the “balance of fixed assets”.
- Statistical surveys carried out in market economies.
- Administrative records on the stocks of particular types of assets.

Published company accounts

8.3 In almost all countries enterprises are required to keep accounts for tax purposes and the accounts compiled by corporate enterprises normally include balance sheets showing the opening and closing stocks of their capital assets. Can these be used to estimate capital stocks for national accounts purposes?

8.4 A first problem is that accounts including balance sheets are usually only available for corporate enterprises. Unincorporated enterprises are not generally required to keep accounts for their capital assets and so even if company accounts can be used for the corporate sector it would be necessary to devise other methods to cover capital stocks of unincorporated enterprises.

6. The Domesday Book is a record of a survey carried out in 1086 by the servants of the French Conqueror, King William, to value the lands and other properties of his English vassals. There was no appeal against the valuations. The judgements were as final as those of Doomsday.

8.5 In general, capital assets are defined in company accounts as covering physical objects of the kind defined in the SNA as tangible fixed assets. There are some differences from SNA definitions, and between countries, in the treatment of capital repairs and transfer costs and in the capitalization of interest payments on loans used to purchase assets. These differences, however, are relatively minor and do not rule out the use of company accounts for direct estimates of capital stocks.

8.6 A more serious problem lies in the way that assets are valued. In virtually all countries the standard method of valuing assets is “depreciated historic cost”⁷. A few countries that have experienced long periods of high inflation specify that assets must be revalued to *current purchasing power* using the consumer price index or other general inflation measure. However, current purchasing power is a different concept from current prices as required for national accounts. Most countries also allow companies to revalue assets to current prices. Usually companies have considerable freedom to decide whether to revalue assets to current prices, but several place tight restrictions on this option and only allow revaluations after extended periods of high inflation, or as part of the restructuring of a company following a merger or bankruptcy.

8.7 Methods by which historic costs are depreciated in the accounts also vary. Most countries allow companies to use any method to depreciate fixed assets provided that it will exhaust the full value of the asset and will do it in a systematic way. In practice “straight-line”, “sum-of-the-digits” and “double-declining balance” are the commonest methods.

8.8 It is clear from the above that asset values reported in company accounts cannot simply be aggregated to obtain estimates of the capital stock. Historic costs are not suitable for national accounts purposes because assets are then being valued at a mixture of prices, and the use of different depreciation methods adds a further element of non-comparability from one company to another. The same problems also render depreciation reported in company accounts unsuitable for national accounts purposes.

8.9 The above comments refer to the **published** accounts of companies. Of course, companies keep many other records relating to the purchase and use of capital assets and these have been found, in several countries, to be suitable for capital stock estimates appropriate for national accounts purposes. As explained below, these records provide the essential basis for statistical survey methods.

Balance of fixed Assets

8.10 The “balance of fixed assets” is the term used to describe the annual enquiries traditionally carried out by the centrally planned economies of central and eastern Europe. They were comprehensive surveys of all fixed assets used in state enterprises. Such enterprises accounted for most production in these countries so that the total balance of fixed assets was virtually the same as the nation’s total capital stock. The main omission was assets used on private farms, where these were permitted. Several transition countries have continued these surveys.

8.11 To obtain the “balance of fixed assets”, enterprises were required to report the stock of fixed assets at the beginning of the year, the acquisitions during the year (including new assets), withdrawals (including liquidation) of fixed assets and the value of the stock of fixed assets at the end of the year. The balance is compiled at both full (non-depreciated) replacement value and remaining replacement value, *i.e.* after subtracting consumption of fixed capital. The full replacement value is defined as the

7. There are some exceptions. In France, for example, company accounts record capital stocks on a gross basis.

value of expenditures which is needed to acquire and put into operation new fixed assets in the present circumstances.

8.12 Until the changes which started in 1990s, the prices of domestically produced assets were “plan prices” which would reflect the “plan cost” of producing them. Imported assets were valued at the prices paid, which could be market prices if imported from market economies. Prior to transition, prices were relatively stable so that for many assets there was little difference between historic costs and current prices. In the early 1990s, however, most of these countries experienced rapid inflation and it became necessary to revalue assets each year to current replacement costs. The revaluations are carried out by the enterprises themselves either using coefficients supplied to them by the statistical agency or on the basis of information about the current market prices of the assets. The coefficients varied from one type of an asset to another but not from one enterprise to another. Thus, the gross value of an asset at the beginning of each would either be equal to its original price of acquisition multiplied by the cumulative product of all the revaluation coefficients applied up to that point of time or, alternatively, it would be equal to the estimated current market price of a replacement asset.

8.13 These countries used a definition of capital consumption that was narrower than the one required for national accounts. It covered only physical deterioration and excluded any fall in value due to obsolescence. Estimates of capital consumption obtained from these surveys is not, therefore, suitable for national accounts purposes but, provided revaluations were carried out regularly, the balance of fixed assets could, in principle, be used as an estimate of the gross capital stock.

8.14 In practice, there are at least three problems with these data:

- First, the coverage of the surveys has deteriorated with the growth of private sector enterprises. Some of these new enterprises are excluded from statistical surveys because they are not in the official business register. Others may be included in surveys but are unwilling or unable to supply detailed data on their asset stocks.
- Second, the very high rates of inflation in the early years of transition made it very difficult for the statistical agencies to provide realistic coefficients for revaluing assets. The current replacement costs at which the balance of fixed assets are supposed to be valued are highly suspect in many of the countries concerned. (The unreliability of asset price indices will affect PIM estimates in exactly the same way).
- Third, doubts have been raised about the true values of many of the assets held by state enterprises. Much of the older plant and equipment in heavy industries may no longer be used in production but is still being included in the balance of fixed assets at its revalued historic costs.

8.15 This said, even if these statistics are now of doubtful value, the balances of fixed assets which were calculated in the early 1990s before inflation became rampant could be used as benchmark estimates of the gross capital stock and could be updated by the PIM for the current period.

Statistical surveys in market economies

8.16 In addition to the centrally planned economies, two other countries, Japan and Korea, have traditionally carried out surveys of the capital stock. Both are described as “National Wealth Surveys” and are designed to provide estimates of the national balance sheet. In addition to fixed assets they also covered inventories and net foreign financial assets. Both surveys were carried out at

approximately 10-year intervals. The last Japanese survey was held in 1983 and there are no plans to repeat the survey; the Korean surveys are continuing and the latest was held in 1998.

8.17 The Korean survey covers all sectors, including general government, government business enterprises, incorporated and unincorporated enterprises and non-profit institutions serving households. Information is collected on the following asset classes: buildings, other structures, machinery and equipment, ships, vehicles and other transport equipment, tools and furniture, and construction work in progress. Almost 25 000 incorporated enterprises, and 60 000 unincorporated enterprises were sampled in the last survey, along with 5 000 households. A comprehensive survey of the government sector is conducted.

8.18 The Netherlands is the only other country that carries out capital stock surveys on a regular basis. There is an annual survey covering mining, quarrying and manufacturing. However the survey does not cover all mining, quarrying and manufacturing activities each year. Instead, different subsectors are covered each year in such a way that all activities within mining, quarrying and manufacturing are surveyed every five years. (This is described as a *rolling benchmark* method by Statistics Netherlands.) The survey covers only firms employing 100 or more employees and capital stocks for smaller firms are assumed to be proportional to employment.

8.19 Statistics Netherlands carries out two other annual surveys, one on capital formation and the other on disposals of assets. Results from these surveys are matched up, on a firm by firm basis, with the results of the stock survey to obtain stock estimates between the five-yearly surveys. This can be seen as a superior perpetual inventory approach - superior because it requires no assumptions about service lives or mortality functions⁸.

8.20 Statistics Netherlands also surveys capital assets held by a sample of firms in transport, storage and communications but the coverage is less complete than for mining, quarrying and manufacturing. The survey data are used in conjunction with registration data on road vehicles, aircraft and ships.

8.21 The Netherlands stock survey uses eight asset classes: purchase and sale of sites, industrial buildings, civil engineering, external means of transport, internal means of transport (e.g. assembly lines, cranes, pulleys), computers, other machinery and equipment, and other tangible fixed assets (e.g. furniture, silos).

8.22 Both the Korean and Netherlands surveys collect the following information:

- Type of asset.
- Original (historic) value.
- Year when the asset was installed or constructed.
- Whether the assets were purchased new or second hand.
- Whether the assets are owned or leased.

8. The Czech Statistical Office has recently begun a survey of disposals of assets. The results will be used in its perpetual inventory model to avoid the need for assumptions about service lives.

In both cases, revaluation to current and constant prices is done by the statistical agencies using asset price indices.

8.23 Like all statistical inquiries, the reliability of the results depends on the quality of the survey procedures and the ability of respondents to supply the information requested.

8.24 Both the Korean and Netherlands surveys involve visits by enumerators. Experience has shown that it is not usually possible to collect the necessary information by mail questionnaire. For the Korean survey, the work of enumeration is so great that it is divided up between several government agencies. In the Netherlands the high cost of on-site investigation by enumerators is the main reason that the five-year “rolling benchmark” method is used.

8.25 The ability of respondents to provide the information depends on the quality of their accounting records. The following problems have been encountered in the Netherlands:

- Companies do not always capitalize major alterations to assets.
- Most companies use value cut-off points in deciding whether expenditure is capital or current. In some cases these are so high that they exclude items that should be treated as capital assets according to the SNA.
- Company records do not always distinguish new from second-hand assets.
- Some companies pick arbitrary dates, such as the end of the Second World War, as installation dates for very old assets; others may report the year of a revaluation as the installation date for assets that were actually purchased before that date.
- Large installations consisting of several separate pieces of equipment, which were actually acquired at different times, may be assigned a single installation date.
- Replacement parts may be capitalized but the part it replaces may not be recorded as a discard.
- An asset may cease to be used in production but is not physically removed from the site and so is not recorded as a discard.

8.26 Some of these difficulties may be alleviated in the future by an interesting development reported in the United Kingdom. Most large companies now maintain computerized asset registers using standard software developed for this purpose. These records may improve the accuracy of the records and, equally important, may make it possible to measure capital stock without the need for on-site investigation by enumerators. The high cost of doing this is one of the main impediments to the wider use of surveys to measure capital stocks.

8.27 Finally, mention should be made of a survey procedure developed in Canada, called the “Fixed Asset Accounting Simulation Model” (FAASM). The essential feature of FAASM is that it uses enterprise records on asset stocks and gross fixed capital formation, both valued at historic values, to estimate service lives. These latter are the service lives that will reconcile past capital formation with the value of the stock of assets reported by the company. Gross capital formation is then revalued to current or constant prices and the gross capital stock is obtained by applying the estimated service lives to each year’s capital formation. The estimated service lives are also used to

calculate consumption of fixed capital and the net capital stock. FAASM has been tested in Canada and the results are said to be encouraging.

Administrative records

8.28 In most countries, administrative records are maintained on the stocks of certain types of assets. This may be done because ownership or use of the asset in question is taxed; examples are motor vehicles and residential buildings. Administrative record may also be kept on assets that represent health hazards or whose use is regulated for safety or environmental reasons; examples include nuclear fuel rods, passenger aircraft and fishing vessels. Most governments also keep detailed records of publicly-owned assets including roads, bridges and public buildings. Finally, there are international registers for maritime shipping and commercial aircraft.

8.29 These records usually give the numbers rather than values of the assets concerned, but if the records give additional information on their technical specifications they can be valued either at current values to obtain the net capital stock or at historic values updated to the current year to obtain the gross stock. Several countries use administrative sources where they are available and estimate other asset stocks by the PIM.

8.30 In some cases administrative records may be available only for selected years. For example, detailed information on the housing stock may be available only for population census years. In these cases the stock of assets in the inter-censal periods can be obtained by the PIM or by using records on new construction and demolitions. Using a combination of benchmark estimates and PIM estimates provides an opportunity to test the critical parameters of the PIM, notably service lives and mortality functions.

8.31 Administrative records are potentially an excellent source for estimates of the stocks of dwellings and commercial buildings. Both France and Denmark make extensive use of administrative records for these assets. Given the fact that buildings typically account for the largest part of the capital stock, the uncertainty surrounding capital stock estimates can be substantially reduced if the estimates for buildings are based on reliable administrative records.

Summary

8.32 There are a number of alternatives to the PIM for estimating capital stocks. The first method considered, use of **published company accounts**, is clearly an inferior method and is not recommended here. Although accounting practices vary between countries a common feature is that stocks and depreciation are calculated using historic costs. For national accounts purposes current or constant prices must be used. Several countries do in fact use data from company accounts, particularly for their estimates of consumption of fixed capital, but these will be crude approximations to what is required for the national accounts.

8.33 A survey method that is well-established in central and eastern Europe is the **balance of fixed assets**. Provided that prices are correctly revalued each year, this method can, in principle, provide suitable estimates of the gross capital stock. In practice, there are severe practical difficulties in applying this method at the present time; these include growing rates of non-response, difficulties in measuring asset prices under high inflation and the over-valuation of older assets. It may, of course, be possible to overcome these problems by redesigning the surveys and improving enumeration procedures and these surveys would then be a valid alternative to the PIM.

8.34 Korea and the Netherlands are the only two other countries that use **statistical surveys** at the present time. Both appear to be successful although the costs are high, particularly for the National Wealth Survey carried out in Korea. The success of survey methods depends crucially on the quality of the asset records maintained by companies. These vary so significantly from country to country that generalizations cannot be made about the potential of survey methods for any particular country.

8.35 There is no doubt that capital stock surveys can be expensive and it is probably not cost-effective to survey all sectors, for all asset types and for every time period. The most cost-effective strategy is likely to be using survey methods selectively and periodically. Estimates for non-survey years can be obtained either by the PIM or, as in the Netherlands, by collecting annual information on disposals as well as capital formation.

8.36 FAASM is an original approach but is still in the experimental stage. As with other surveys, much depends on the quality of the records maintained by enterprises. FAASM appears to be feasible in Canada but may not be exportable to other countries.

8.37 **Administrative records** are used in several countries to estimate stocks of certain types of assets, notably road vehicles, dwellings, aircraft, and nuclear fuel rods. The stocks of publicly owned assets, including roads, public buildings and other structures may also be calculated from government records. Such estimates are usually to be preferred to estimates based on the PIM.

CHAPTER 9 CAPITAL SERVICES

Introduction

9.1 Chapter 2 has already introduced the concept of **capital services** and outlined how these can be measured by a **volume index of capital services**. This chapter starts by considering the measurement of capital as an input into the production process and describes how the volume index of capital services is constructed in practice.

9.2 Studies of **multifactor** (or **total-factor**) productivity examine how much of the growth in output or value added is accounted for by increases in factor inputs and, in some cases, intermediate goods and services. The growth in output or value added that cannot be explained by the growth of factor or intermediate inputs is termed “multifactor” productivity. It is a measure of disembodied technological progress which makes an important contribution to raising living standards. Typically multifactor productivity studies use a production function, here denoted as H , which describes the amount of output (Q) which can be produced by various combinations of volumes of inputs:

$$Q = H(k_1, k_2, \dots, k_n; L, M, t) \quad (1)$$

9.3 The inputs include the different types of capital inputs (k_1, k_2, \dots, k_n), labour input (L), and intermediate input (M); the function can shift over time, t . Shifts in the function are generally associated with changes in technology. In many studies the dependent variable is value added rather than gross output, in which case intermediate inputs (M) are excluded from the right hand side.

9.4 In general, the function could be defined for sub-categories of each major type of input (labour and materials as well as capital). Ideally, the list would be sufficiently detailed so that each category described a homogeneous input. Data availability limits the number of sub-categories. This chapter will discuss only sub-categories of capital. The *OECD Manual on Productivity Measurement*⁹ discusses the measurement of the other variables in the production function.

9.5 The role of capital in production resembles the role of labour in that both capital assets and workers are used but not consumed. The relevant inputs of capital and labour are service flows just as materials and outputs are flows rather than stocks. Labour services are measured in hours worked, and the k_i refer to the service flows associated with various types of capital which may be thought of as machine hours or use of a building for a fixed period. These capital service flows are distinct from capital stocks. (See Box 4)

9.6 The production model involves three general assumptions. First, it is assumed that the producer always produces a unique quantity of output from any given set of inputs. Second, it is assumed that the production function is “smooth”, that is, inputs and outputs are related in a

9. *OECD Manual on Productivity Measurement: A Guide to the Measurement of Industry Level and Aggregate Productivity Growth*. OECD, Paris 2001.

continuous way. Third, it is assumed that aggregate behaviour reflects the behaviour of “representative competitive firms”. The assumptions are somewhat controversial but while they are not always precise representations of reality, the model-based approach represents a consistently grounded framework which, in turn, facilitates the exposition of complex issues.

Capacity utilisation

9.7 A practical problem in multifactor productivity studies is that the rates of utilisation of capital and labour vary over the production cycle. The rate of utilisation of capacity of a firm will vary over time because of changes in demand conditions, seasonal variations, interruptions in the supply of intermediate products or a breakdown of machinery. All these factors will lead to variations in the flow of capital services drawn from a stock of assets. There have been several attempts to deal with this problem, but a generally accepted solution has yet to crystallise. In practice, statistical offices make no attempt to adjust their capital input measures for changes in the rate of capital utilisation. The volume index of capital services described in this chapter measures the *potential* flow of capital services that could be provided by the capital stock in place during a given period. It does not attempt to measure the flow of capital services that were actually produced. As a result, swings in demand and output are picked up by the residual productivity measure. (See the *OECD Manual on Productivity Measurement* for a more extensive discussion of capacity utilisation)

Box 4. Stocks or flows

Many studies of multifactor productivity use the capital stock to represent the contribution of capital to production. The gross stock has generally been preferred to the net stock because it was believed that valuing assets at their “as new” prices was more likely to approximate their contribution to production than valuing them at (depreciated) market prices. However, the net capital stock has also been used, either alone or averaged with the gross capital stock. There are several problems with using the gross or net capital stocks for productivity studies.

The first problem in using **stocks**, whether net or gross, is that the other variables in the growth accounting model are all **flows**. These include labour inputs and intermediate consumption (where relevant) as independent variables and value added or gross output as dependent variables. The “dimensions “ of the variables are therefore inconsistent. In practice, almost all growth accounting models and productivity studies relate the **changes** in the independent variables – capital, labour and intermediate consumption – to **changes** in the dependent variable – value added or gross output. **Changes** in the capital stock can, of course, be regarded as **flows**; the change in the gross capital stock is gross fixed capital formation less discards and the change in the net capital stock is gross fixed capital less consumption of fixed capital (or “net capital formation” as it is usually termed). But the dimension problem remains because a first-order flow – namely a change in a stock - is now being used together with second-order flows, such as changes in the flow of labour inputs or the flow of value added.

A second problem with using the net or gross capital stock is that neither measure reflects the **productive efficiency** of capital assets. The gross capital stock values all assets in use as if they were still new, implying that older assets are just as productive as new ones; the net capital stock uses market prices to value older assets but these prices usually decline quite rapidly in the early years of their life even though the assets may be nearly as productive as when they were new.

Finally, in calculating the net or gross capital stock, each asset in the stock is weighted by its market value. This implies that two assets with the same market value are assumed to make an equal contribution to production. Suppose, however, that one of the assets is a truck with a life of seven years and the other is a structure with a fifty-year service life. It is clear that in order for the owners to recoup their investment, the shorter-lived asset must generate its contribution to production at a **faster rate** than the asset with the longer life. Weighting them both by their (identical) market values will understate the **annual** contribution of the truck into the production process and overstate that of the structure.

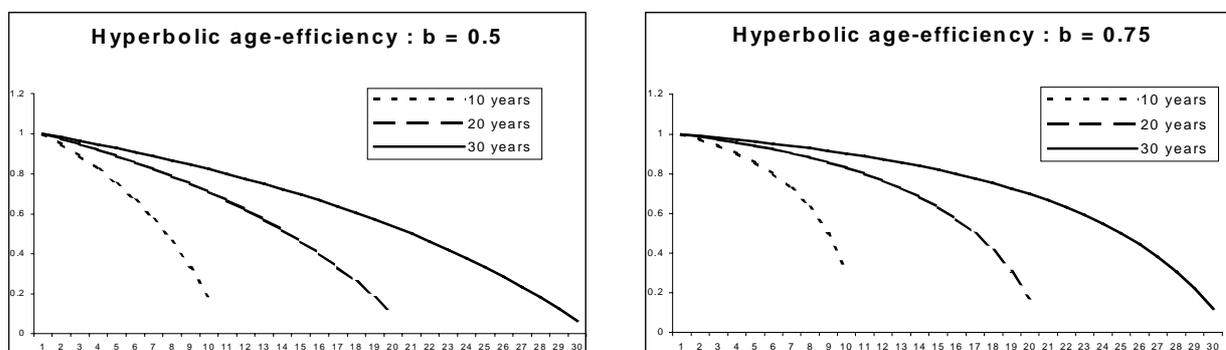
Volume index of capital services

Stocks of assets in standard efficiency units

9.8 Chapter 2 introduced the concept of a stock of a particular type of asset in standard efficiency units. A stock in standard efficiency units is obtained by converting the gross stock of the assets to constant prices and then applying age-efficiency coefficients to the different vintages to convert them into standard efficiency units. A worked example of the procedure was given in Chapter 6.

9.9 There is very little empirical evidence on the way in which different assets lose their productive efficiency with age. (There is evidence about how assets lose their *value* with age (the age-price profiles) but it was shown in Chapter 7 that this evidence is consistent with a number of quite different age-efficiency profiles.) Two age-efficiency profiles are in use at the present time - geometric and hyperbolic. The geometric profile (used by Canada) assumes that assets suffer their greatest absolute fall in efficiency in their first year of service and that efficiency losses become smaller in absolute terms thereafter. Hyperbolic efficiency loss (used by the United States (BLS) and Australia) assumes that assets lose their efficiency by small amounts at the beginning of their service lives and that efficiency losses increase with age.

9.10 The form of the hyperbolic function used by the United States Bureau of Labor Statistics and the Australian Bureau of Statistics is given in Chapter 6. It was there explained that both the BLS and the ABS set the slope coefficient (β) at 0.50 for most types of plant and equipment and at 0.75 for structures. Both values of β produce curves that are concave to the origin reflecting the way that their efficiency is assumed to decline with age. The higher β value for structures results in a slower fall than for plant and machinery. The charts below show how efficiency is assumed to decline using the hyperbolic function for different service lives and the two standard slope coefficients.



9.11 Stocks converted to standard efficiency units and valued at constant prices are calculated for each type of asset. This is done at the most detailed level of the asset classification. Because these stocks consist of standardised efficiency units they can be taken as measures of the capital services that the different types of assets contribute to the production process.

9.12 The next step is to aggregate these separate stocks to obtain overall measures of capital services for different kinds of activities, for institutional sectors or for the economy as a whole. This is done using the **user costs of capital** as weights. The user costs of capital are the prices of capital services and are assumed to measure the relative marginal productivity of different kinds of assets. In

exactly the same way, employee compensation is the price of labour services and is assumed to measure the relative marginal productivity of different kinds of labour.

User costs

9.13 The standard expression for the user cost of an asset, in *real terms*, is:

$$V_t(d_t + r_t) \quad (3)$$

In this expression, V_t designates the market value of a new asset at constant prices, d_t is the rate of depreciation on a new asset and r_t is some measure of the real cost of financial capital¹⁰. This expression is derived from the standard equation relating the value of an asset to the discounted real flows of rentals expected over its lifetime. (See Box 5)

9.14 For weighting stocks of specific asset types in standard efficiency units, user costs in *nominal*, rather than in real terms, are required. This parallels the procedure used for labour inputs which are weighted by the shares of each type of labour in the *nominal* wage bill. When (3) is converted to nominal terms it becomes:

$$V_t(d_t + r_t - \Delta p_t) \quad (4)$$

Here Δp_t is the change in the price of the asset from periods $t-1$ to t .

9.15 The user cost of capital measures the cost of financing the asset. It comprises $V_t r_t$ the nominal interest payment if a loan was taken out to acquire the asset or the opportunity cost of employing capital elsewhere than in production if the acquisition of the asset was financed from equity capital. To the interest cost has to be added $V_t d_t$ the nominal cost of depreciation or the loss in value of the asset as it ages. The third term $-\Delta p_t$ is the nominal gain from holding the asset for each accounting period. A positive gain reduces the user cost of holding the asset while a negative gain, *i.e.* a holding loss, increases the user cost. This nominal holding gain $-\Delta p_t$ is measured by the price index for the particular kind of asset concerned.

9.16 As noted above, the logic behind the use of user costs to weight asset stocks converted to standardised efficiency units is that, given the usual assumptions about competitive markets, they measure the relative marginal products of the different types of assets. Note that for two assets of the same original value but with different service lives, the shorter-lived asset will tend to have a higher user cost because it will depreciate more rapidly. Owners must recoup their investment in the shorter-lived asset over a shorter period than in the case of the longer-lived asset.

10. Some studies incorporate a tax variable into the formula for the user cost of capital in order to measure the after-tax user cost of capital. This chapter deals only with the conventional, *pre-tax*, measure of user costs.

Box 5. Derivation of User Cost from the Standard Equation for the Value of an Asset.

The value of an asset in its year of purchase - year t - can be written as:

$$V_t = \frac{f_t}{(1+r)} + \frac{f_{t+1}}{(1+r)^2} + \frac{f_{t+2}}{(1+r)^3} + \dots + \frac{f_{t+T-1}}{(1+r)^T} + \frac{S}{(1+r)^T} \quad (1)$$

Here V_t is the constant price value of the asset, f_t is the rental - *i.e.* quantity of capital services times price - measured at constant prices, r is the real discount rate and S is the scrap value of the asset, again measured in constant prices. T is the year when the asset is scrapped. For simplicity it is assumed that the rentals are received at the end of the year and that the asset is acquired at the beginning of the year.

The value of the asset in the next period is:

$$V_{t+1} = \frac{f_{t+1}}{(1+r)} + \frac{f_{t+2}}{(1+r)^2} + \dots + \frac{f_{t+T-1}}{(1+r)^{T-1}} + \frac{S}{(1+r)^{T-1}} \quad (2)$$

Dividing (2) by $(1+r)$ gives:

$$\frac{V_{t+1}}{(1+r)} = \frac{f_{t+1}}{(1+r)^2} + \frac{f_{t+2}}{(1+r)^3} + \dots + \frac{f_{t+T-1}}{(1+r)^T} + \frac{S}{(1+r)^T} \quad (3)$$

Subtracting (3) from (1) gives:

$$V_t - \frac{V_{t+1}}{(1+r)} = \frac{f_t}{(1+r)} \quad (4)$$

Multiplying each term in (4) by $(1+r)$ and then rearranging the terms gives:

$$f_t = V_t - V_{t+1} + rV_t \quad (5)$$

However, since:

$$V_t - V_{t+1} \equiv D_t, \quad (6)$$

where D_t is depreciation in year t , *i.e.* the fall in the real (constant price) value of the asset between the beginning and end of the year, equation (6) can be rewritten as:

$$f_t = V_t(d_t + r) \quad (7)$$

where d_t is the rate of depreciation in period t .

Interest rate (r)

9.17 There are essentially two approaches to the measurement of the interest rate. These are the use of national accounts statistics on operating surplus or the use of market interest rates. Both the BLS and the ABS use the first approach. The methodology is as follows.

- Net operating surplus is obtained from the production account by deducting compensation of employees from net value added. This operating surplus, Ψ_t , is assumed to be the total rent received from the various assets in each time period, t :

$$\Psi_t = \sum_i f_{i,t} K_{i,t} \quad (5)$$

Here $K_{i,t}$ is the stock, measured in standard efficiency units, of the i th asset and $f_{i,t}$ is its user cost.

- User cost was defined in (4) above. BLS solves (4) and (5) for the ex-post actual rate of return - r - by substituting user cost equations (4) for each type of asset i into the formula for the sources of property income, equation (5). This system of equations can be solved with the data on capital stocks expressed in standard efficiency units, $K_{i,t}$, and estimates of net operational surplus, Ψ_t .

9.18 The method used by the ABS and the BLS requires that the underlying production function exhibits constant returns to scale, that markets are competitive and that the expected (*ex-ante*) rate of return equals the realised (*ex-post*) rate of return. There is also a practical problem because net value added includes *mixed income* as well as *operating surplus* and *compensation of employees*. Mixed income includes the labour income attributable to the self-employed. Mixed income can be artificially divided into “compensation of employees” and “operating surplus” either by assuming that the self-employed receive similar rates of compensation as those earned by employees in similar jobs or by assuming that unincorporated enterprises earn similar rates of property income as those earned by corporate enterprises in similar activities. Both assumptions seem equally plausible but the two methods rarely produce a similar allocation of mixed income.

9.19 An alternative is to estimate r from market interest rates. The logic behind this is that interest rates play a key role in determining rates of return. First, the decision to purchase a capital assets is partially based on a comparison between the rate of return that the asset is expected to earn and the income that could be earned from alternative uses of the funds. These alternative uses include investment in financial assets. Second, investment in capital assets is often financed through borrowing and a producer will usually not borrow to buy an asset unless the expected rate of return exceeds the interest that has to be paid on the loan.

9.20 The fact that both the interest that could be earned and the interest that would have to be paid seem equally relevant for investment decisions poses a problem. Which should be used for estimating the rate of return? One possibility is to use the average of these two rates as an estimate of the rate of return. This average can be seen as an estimate of the “pure” rate of interest, *i.e.* the compensation that

lenders demand for postponing consumption to a future period. The difference between this and the interest actually paid can be regarded as a service charge levied by financial intermediaries for arranging loans to borrowers and managing the accounts of lenders.

9.21 The BLS has investigated the different ways of estimating rates of return and their impact on user cost measures. They compared effects from using market interest rates with those based on the capital income identity and found significant differences in the resulting user costs. Overall, and based on several performance measures, such as the share of negative user costs and the volatility of measures, as well as on theoretical considerations, BLS has adopted the approach based on the income identity. However, no strong conclusion has been reached on the matter and much speaks for solutions that are governed by data availability. (See the *OECD Manual on Productivity Measurement* for a more extensive discussion of this issue.)

Index calculation

9.22 Once the users costs have been obtained as described above, the next step is to combine the stocks of each asset type to obtain *volume indices of capital services* for kinds of activities, institutional sectors or for the economy as a whole.

9.23 Production theory makes it clear that calculation of these indices should be carried out with a **superlative index number**. The rationale for a superlative index number such as the Tornqvist or Fisher index, derives from its property as an approximation to general functional forms of the production function.

9.24 Given estimates of the capital stock for different types of assets in standard efficiency units ($K_{i,t}$), and given a set of user cost weights ($f_{i,t}$), a Tornqvist index of total capital services is given by the expression below. This formulation is used in the capital service indices derived by the U.S. Bureau of Labor Statistics and the Australian Bureau of Statistics. With the same type of data, it is also possible to construct a Fisher index of aggregate capital services and experience has shown that results will be very similar.

$$\prod_i \left(\frac{K_{i,t}}{K_{i,t-1}} \right)^{\bar{v}_i} \quad (6)$$

where $\bar{v}_i = 0.5(v_{i,t} + v_{i,t-1})$ and $v_{i,t} = \frac{f_{i,t} K_{i,t}}{\sum_i f_{i,t} K_{i,t}}$.

Development of capital service measures.

9.25 This chapter explains why the contribution of capital to the production process should be measured in terms of the services that capital assets provide to their owners rather than in terms of the value of the assets themselves. At present, only three countries - the United States, Canada and Australia - publish capital service measures as part of their official programme of statistics, but measures of the kind described in this chapter have been calculated by researchers in several other countries. There is growing interest in studying the productive potential of the *new economy* and in

calculating the productivity benefits of *globalisation*. It is, therefore, highly probable that several other countries will soon start producing capital service measures on an official basis.

9.26 The Australian Bureau of Statistics uses what it describes as an *integrated* approach and derives its volume index of capital services as part of the same process that generates its estimates of gross and net capital stocks and consumption of fixed capital. This ensures strict consistency in the sense that their stock and depreciation estimates are derived from the same age-efficiency profiles that underlie the volume index of capital services. While there is an inherent appeal for many statisticians in an approach which guarantees a consistent data set, experience in the United States shows that analysts can work with data sets that are not strictly consistent provided that the assumptions on which they are based are transparent. In starting to produce volume indices of capital services, many countries may prefer to develop them independently from their regular stock estimates. The conceptual framework developed in Chapter 2 does, however, suggest that it is important to bear in mind that the assumptions underlying the construction of capital service measures should be broadly consistent with those on which net stocks and depreciation are based.

ANNEX 1
GLOSSARY OF TECHNICAL TERMS USED IN THE MANUAL

Abnormal obsolescence	<i>Abnormal obsolescence</i> is the loss in value on an asset due to a fall in demand for that type of asset that could not have been foreseen when the asset was acquired. Abnormal obsolescence may occur because of a new invention or discovery which destroys the market for the asset or because a shift in relative prices makes it uneconomical to continue using the asset. It is not included in consumption of fixed capital but in “other changes in non-financial asset n.e.c.” in the “Other changes in assets account”. Abnormal obsolescence is a synonym for “unforeseen obsolescence”.
Acquisition price	The <i>acquisition price</i> is the price that was actually paid for an asset when it was first acquired by a resident user. It is a synonym for “historic price”.
Age-efficiency profile	The <i>age-efficiency profile</i> of an asset describes the change (usually the decline) in the efficiency of an asset as it ages. Efficiency in this context refers to the asset's ability to produce a quantity of capital services for a given amount of inputs.
Age-price profile	The <i>age-price profile</i> of an asset describes the change (usually the decline) in the price of an asset as it ages.
Assets	<i>Assets</i> are entities that must be owned by some unit, or units, and from which economic benefits are derived by their owner(s) by holding or using them over a period of time.
Balance sheet	A <i>balance sheet</i> is a statement, drawn up at a particular point in time, of the values of assets owned by an institutional unit or sector and of the financial claims - liabilities - against the owner of those assets.
Capital services	<i>Capital services</i> are the productive inputs, per period, that flow to production from a capital asset. The value of capital services is the quantity of services provided by the asset multiplied by the price of those services.
Capital service price	The <i>capital service price</i> is the unit cost for the use of a capital asset for one period--that is, the price for employing or obtaining one unit of capital services. The service price is also referred to as the "rental price" of a capital good, or the “user cost of capital”.
Catastrophic losses	The volume changes recorded as <i>catastrophic losses</i> are unanticipated losses resulting from large scale, discrete, and recognisable events that may destroy assets within any of the categories of assets.

Constant prices	A stock of assets is expressed at <i>constant prices</i> when all members of the stock are valued at the prices of a single base period.
Consumption of fixed capital	<i>Consumption of fixed capital</i> represents the reduction in the value of the fixed assets used in production during the accounting period resulting from physical deterioration, normal obsolescence or normal accidental damage.
Current prices	A stock of assets is expressed at <i>current prices</i> when all members of the stock are valued at the prices of the year in question.
Decay	<i>Decay</i> is the loss in the physical efficiency of an asset as it ages. Efficiency in this context refers to the asset's ability to produce a quantity of capital services for a given of labour or materials.
Depreciation	<i>Depreciation</i> is used in this <i>Manual</i> as a synonym for <i>consumption of fixed capital</i>
Discards	Synonym for “retirements” or “scrapping”. An asset is discarded, retired or scrapped when it is withdrawn from the capital stock at the end of its service life.
Discount rate	The <i>discount rate</i> is an interest rate used to convert a future income stream to its present value.
Disposals	<i>Disposals</i> of assets occur when assets leave the capital stock of a producer, either to be scrapped or to be used in production by another producer.
Double-declining balance depreciation	<i>Double-declining balance</i> is a form of geometric depreciation in which the constant annual rate of capital consumption is set equal to $2 \cdot V/T$, where V is the value of the asset when new and T is the service life of the asset in years.
Expected obsolescence	<i>Expected obsolescence</i> is the loss in value on an asset through obsolescence that the purchaser was expecting to occur when the asset was acquired. It is a synonym for “foreseen” obsolescence and is included in consumption of fixed capital.
Fixed assets	<i>Fixed assets</i> are tangible or intangible assets produced as outputs from processes of production that are used repeatedly or continuously in other processes of production for more than one year.
Foreseen obsolescence	<i>Foreseen obsolescence</i> is the loss in value on an asset through obsolescence that the purchaser was expecting to occur when the asset was acquired. Foreseen obsolescence is included in consumption of fixed capital.
Geometric depreciation	<i>Geometric depreciation</i> is a depreciation profile based on a constant annual rate of capital consumption over the life of the asset.
Gross capital formation	<i>Gross capital formation</i> is measured by the total value of the gross fixed capital formation, changes in inventories and acquisitions less disposals of valuables for a unit or sector.

Gross capital stock	<i>Gross capital stock</i> is the value of all fixed assets still in use when a balance sheet is drawn up, at the actual or estimated current purchasers' prices for new assets of the same type, irrespective of the age of the assets.
Gross fixed capital formation	<i>Gross fixed capital formation</i> is measured by the total value of a producer's acquisitions, less disposals, of fixed assets during the accounting period plus certain additions to the value of non-produced assets (such as land or subsoil assets) realised by the productive activity of institutional units.
Historic cost accounting	<i>Historic cost accounting</i> is a valuation method which requires goods or assets used in production to be valued by the expenditures actually incurred to acquire those goods or assets, however far back in the past those expenditures took place.
Historic prices	The <i>historic price</i> is the price that was actually paid for an asset when it was first acquired by a resident user. It is a synonym for "acquisition price".
Input decay	<i>Input decay</i> is the loss in the physical efficiency of an asset because, over time, it requires a greater input of labour or materials to produce a given quantity of capital services.
Intangible fixed assets	<i>Intangible fixed assets</i> are non-financial produced fixed assets that consist of mineral exploration, computer software, entertainment, literary or artistic originals and other intangible fixed assets intended to be used for more than one year.
Lemons	<i>Lemons</i> is used in the literature on capital measurement to mean defective capital goods. It is sometimes alleged that prices of second hand assets are biased downwards because buyers assume that the sellers are disposing of their defective assets or "lemons".
Major renovations or enlargements	<i>Major renovations or enlargements</i> are activities which increase the performance or capacity of existing fixed assets or significantly extend their previously expected service lives; the decision to renovate, reconstruct or enlarge a fixed asset is a deliberate investment decision which may be undertaken at any time and is not dictated by the condition of the asset.
Net capital stock	The sum of the written-down values of all the fixed assets still in use when a balance sheet is drawn up is described as the <i>net capital stock</i>
Net fixed capital formation.	<i>Net fixed capital formation</i> consists of gross fixed capital formation less consumption of fixed capital.
Net value of a fixed asset	The <i>net</i> (or written-down) <i>value of a fixed asset</i> is equal to the actual or estimated current purchaser's price of a new asset of the same type less the cumulative value of the consumption of fixed capital accrued up to that point in time.

Net worth	<i>Net worth</i> is the value of all the non-financial and financial assets owned by an institutional unit or sector less the value of all its outstanding liabilities; it is a measure of the wealth of a unit or sector at a point in time.
Non-produced assets	<i>Non-produced assets</i> are non-financial assets that come into existence other than through processes of production.
Normal accidental damage	<i>Normal accidental damage</i> is the loss in value of assets from accidents that damage or destroy and that were known to be likely to occur when the assets were acquired. Transport equipment is frequently subject to accidents of this kind. Losses from normal accidental damage are included in consumption of fixed capital.
Normal obsolescence	<i>Normal obsolescence</i> is the loss in value of an asset through obsolescence that the purchaser was expecting to occur when the asset was acquired. It is a synonym for “foreseen” obsolescence and is included in consumption of fixed capital.
Obsolescence	<i>Obsolescence</i> is the loss in value of an old asset because a newly introduced asset of the same class contains improvements in productiveness or efficiency or suitability in production.
One-hoss shay	A one-hoss shay is a colourful term taken from the poem, “The Deacon's Masterpiece”, by Oliver Wendell Holmes (In nineteenth century American dialect, a “one hoss shay” is a cart drawn by a single horse.) “Shay” is a corruption of the French “chaise” or “post-chaise”. The term is used to designate a capital asset that exhibits neither input decay nor output decay during its lifetime.
Other changes in the volume of assets account	The <i>other changes in the volume of assets account</i> records the changes in assets, liabilities, and net worth between opening and closing balance sheets that are due neither to transactions between institutional units, as recorded in the capital and financial accounts, nor to holding gains and losses.
Output decay	<i>Output decay</i> is the loss in the physical efficiency of an asset because, over time, it produces a smaller quantity of capital services for a given input of labour or materials.
Perpetual inventory method (PIM)	The <i>perpetual inventory method (PIM)</i> produces an estimate of the stock of fixed assets in existence and in the hands of producers by estimating how many of the fixed assets installed as a result of gross fixed capital formation undertaken in previous years have survived to the current period.
Physical deterioration	<i>Physical deterioration</i> is the loss in the physical efficiency of an asset as it ages. Efficiency in this context refers to the asset's ability to produce a quantity of capital services for a given amount of inputs. It is a synonym for “wear and tear” or “decay”.
Produced assets	<i>Produced assets</i> are non-financial assets that have come into existence as outputs from processes that fall within the production boundary of the SNA.

Productive capital stock	The <i>productive capital stock</i> is the stock of a particular type of asset after assets of different ages have been converted into standard efficiency units. (This term is not used in the <i>Manual</i> .)
Rate of return	The <i>rate of return</i> is the income generated by an asset expressed as a percentage of the value of that asset. The rate of return may be measured <i>ex ante</i> (the return expected when the investment was made) or <i>ex post</i> (the return that was actually earned).
Rental price	The <i>rental price</i> of a capital asset is the unit cost for the use of the asset for one period--that is, the price for employing or obtaining one unit of capital services. The rental price is also referred to as the “capital service price” of a capital good, or the “user cost of capital”.
Retirements	<i>Retirements</i> occur when capital assets are withdrawn from the capital stock at the end of their service lives. Retirements are synonymous with “discards” and “scrapping”.
Scrapping	<i>Scrapping</i> occurs when capital assets are withdrawn from the capital stock at the end of their service lives. Scrapping is synonymous with “discards” and “retirements”.
Second hand asset	A <i>second-hand asset</i> is one which has already been acquired by at least one resident or non-resident user, or produced on own account. A second-hand asset will usually be exchanged at less than the price when it was first acquired. It is a synonym for "used asset".
Service life	The <i>service life</i> of an asset is the total period during which it remains in use, or ready to be used, in a productive process. During its service life an asset may have more than one owner.
Standard efficiency units	A stock of a particular type of asset is converted to <i>standard efficiency units</i> by adjusting the older assets in the stock to account for their reduced efficiency in producing capital services.
Straight-line depreciation	<i>Straight-line depreciation</i> is a depreciation profile based on a constant annual amount of capital consumption over the life of the asset.
Sum-of-the-years-digits depreciation	<i>Sum-of-the-years-digits depreciation</i> is a depreciation profile based on an amount of annual capital consumption that declines linearly over the life of the asset. The amount in any year is calculated as the number of years that the asset is expected to remain in the capital stock divided by the sum-of-the-digits of the service life of the asset when new.
Tangible fixed assets	<i>Tangible fixed assets</i> are non-financial produced assets that consist of dwellings; other buildings and structures; machinery and equipment and cultivated assets.

Unforeseen obsolescence	<i>Unforeseen obsolescence</i> is the loss in value on an asset due to a fall in demand for that type of asset that could not have been foreseen when the asset was acquired. Unforeseen obsolescence may occur because of a new invention or discovery which destroys the market for the asset or because a shift in relative prices makes it uneconomical to continue using the asset. It is not included in consumption of fixed capital but in “other changes in non-financial asset n.e.c.” in the “Other changes in assets account”. Unforeseen obsolescence is a synonym for " abnormal obsolescence".
Used asset	A <i>used asset</i> is one which has already been acquired by at least one resident or non-resident user, or produced on own account. A used asset will usually be exchanged at less than the price when it was first acquired. It is a synonym for “second-hand asset”.
User cost of capital	The <i>user cost of capital</i> is the unit cost for the use of a capital asset for one period--that is, the price for employing or obtaining one unit of capital services. The user cost of capital is also referred to as the “rental price” of a capital good, or the “capital service price”.
Volume index of capital services	A <i>volume index of capital services</i> measures the flow of services into the production process from the different types of assets included in the capital stock.
Wealth capital stock	The <i>wealth capital stock</i> is a synonym for the “net capital stock”. The term is widely used in North America but in this <i>Manual</i> the SNA term “net capital stock” is used.
Wear and tear	<i>Wear and tear</i> is a synonym for physical deterioration.
Written-down (net) value of a fixed asset	The <i>written-down (net) value of a fixed asset</i> is the actual or estimated current purchaser’s price of a new asset of the same type less the cumulative value of the consumption of fixed capital accrued up to that point in time.

ANNEX 2

ESTIMATES OF CAPITAL STOCKS AND FLOWS IN FOUR COUNTRIES

Introduction.

This annex summarises the methods used by four countries to estimate capital stocks. All four countries use some version of the Perpetual Inventory Model (PIM). The first country - Singapore - uses a rather simple model but one which could be easily applied by many countries that do not at present have any capital stock estimates. France uses what may be regarded as the standard method; most OECD countries estimate capital stocks using methods very similar to those used by France. The United States Bureau of Economic Analysis has developed a version of the PIM which has the merit of simplicity and which exploits empirical data on used asset prices. It has the drawbacks that it does not provide estimates of the gross capital stock and that it uses “infinite” geometric depreciation which assumes that assets last for ever. Australia uses an alternative version of the PIM which has the merit of providing measures of capital services for use in productivity studies, which are fully consistent with their capital stock and depreciation estimates.

A. Singapore Department of Statistics. (DOS)

The Singapore Department of Statistics (DOS) uses the Perpetual Inventory Method (PIM) to estimate Singapore’s capital stock of fixed assets at current and constant market prices. The PIM requires assumptions on retirement patterns, depreciation and average service lives. The assumptions used by DOS are:

- Simultaneous retirement pattern.
- Straight-line depreciation.
- Average service lives which are fixed over time.

In applying the PIM with the above assumptions, estimates of gross fixed capital formation (GFCF) for the seven broad asset groups shown in Table 1 are obtained from Singapore’s national accounts. Table 1 also shows the assumed average service lives for each of these asset groups. These service lives are arrived at through a consideration of the nature of these asset groups, service lives reported in company accounts, and a careful review of the average service lives used by other (mainly OECD) countries. The average service life for a given class of asset is assumed to be identical for all kinds of economic activities.

Table 1. Asset Classes and their Average Service Lives

Asset Class	Average Service Life (Years)
Residential Buildings	80
Non-residential Buildings	40
Other Construction and Works	40
Ships and Boats	20
Aircraft	15
Road Vehicles	10
Machinery and Equipment	15

The starting point for the computation of the capital stock series is 1946. It is assumed that the value of the capital stock in the economy prior to 1946 is zero. However, as official GFCF data from national accounts are available only from 1960, it is necessary to estimate GFCF for 1946 to 1959. In general, these estimates are arrived at by reference to the best available indicators. For example, estimates from a previous GFCF series together with statistics on retained imports provide some basis to estimate GFCF in buildings, and machinery and transport equipment. Nonetheless, the reliability of Singapore's capital stock estimates is not compromised due to the relatively low values of fixed assets during that time. Most, if not all, of these assets will have been withdrawn from the capital stock by now.

B. France - INSEE

Basic assumptions for the PIM

The PIM is used with the hypothesis that fixed assets are discarded according to a lognormal mortality function. Depreciation is assumed to be straight-line.

A lognormal mortality function is used since it has the advantage of being a bell-shaped unimodal curve that is easy to use and well adapted to reality. Indeed this law often fits appropriately to empirical distributions. The lognormal mortality function is also a simple way to account for the dispersion of service lives of a heterogeneous group of assets.

Assuming straight-line depreciation for each component with the same service life in groups of heterogeneous assets is also a simple and sensible way to construct net capital stock estimates.

Data on gross fixed capital formation

In the French national accounts, GFCF is estimated from company accounts as the difference between the closing and opening capital stocks in gross terms, even though the stocks are valued at historic costs. GFCF at current prices is estimated, by product and by industry at the detailed level (nomenclature with 40 positions¹¹), for each institutional sector¹².

Using prices of GFCF by product at the same detailed level, chain Laspeyres price indexes are compiled at the detailed level and are aggregated to obtain price indices for the following types of fixed assets: dwellings, non-residential buildings, other structures, transport equipment computers, other machinery and equipment, livestock for breeding, dairy, draught, etc., vineyards, orchards, and other plantations of trees yielding repeat products, mineral exploration, computer software, entertainment, literary or artistic originals.

Series of GFCF in constant price are then obtained by type of asset, for each institutional sector and by industry.

Gross and net capital stocks and depreciation

Coefficients of mortality and depreciation are calculated for each type of asset and each industry (since assets have different service lives depending on the industry they are used in). These coefficients are based on the hypotheses of a lognormal mortality function and straight-line depreciation.

For each type of asset, constant price estimates of gross capital stock, retirements, consumption of fixed capital and net capital stock are derived for each year by multiplying the appropriate coefficient vector with the corresponding vector of constant price estimates of GFCF.

For each type of asset, the constant price estimates of gross capital stock and net capital stock are multiplied by end-year price indexes with the same reference year, so as to get end-year current prices estimates.

C. United States Bureau of Economic Analysis

In 1997, the United States Bureau of Economic Analysis (BEA) published revised estimates of the net capital stock and consumption of fixed capital, which were based on a perpetual inventory model, but which omitted the first step of explicitly calculating the gross capital stock. This alternative approach goes directly to the calculation of consumption of fixed capital which is then cumulated and subtracted from the sum of past investments to obtain the net capital stock.

11. Some products in that nomenclature are not included in GFCF, and others (computers; software; architecture, engineering, accounting and juridical services) are found at a more detailed level of the nomenclature (nomenclature with 118 positions); for example, computers represent a part of the position FE3 'Industry of electric and electronic equipment'.

12. In France balance sheets are compiled for the following institutional sectors: non-financial corporations, financial corporations, general government and its sub-sectors (central government, local government, social security funds), households, non-profit institutions serving households.

In BEA's application of the PIM, the mortality function is not explicit; a mortality function is implicit in the estimates, however, because an adjustment for mortality was used in the empirical studies that were used to determine the depreciation rates. (see Chapter 7, paragraph 7.9). For most assets, consumption of fixed capital is assumed to be strictly geometric, though for a few assets other depreciation patterns are taken from empirical studies. BEA has found that for machinery and equipment this new method produces estimates of the net capital stock that are quite close to those obtained using their former approach which assumed straight-line depreciation and a bell-shaped mortality function whereas for buildings and structures, the new method produces substantially larger estimates of the net capital stock. BEA prefers its new approach because it makes use of the results of the many empirical studies of used asset prices that have been carried out in the United States.

Table 2 is a worksheet showing how this version of the PIM is implemented.

Table 2. Direct calculation of consumption of fixed capital and net capital stock without calculating gross capital stock

	<i>year</i>									
	<i>1</i>	<i>2</i>	<i>3</i>	<i>4</i>	<i>5</i>	<i>6</i>	<i>7</i>	<i>8</i>	<i>etc</i>	
Gross fixed capital formation at year 1 prices										
In year 1	10									
In year 2		20								
In year 3			5							
Depreciation factor for first year (1-d/2)	0.9184	0.9184	0.9184	0.9184	0.9184	0.918	0.9184	0.9184	0.9184	0.9184
Depreciation factor for other years (1-d)	0.8367	0.8367	0.8367	0.8367	0.8367	0.836	0.8367	0.8367	0.8367	0.8367
Net stock at the end of year for assets purchased in:										
Year 1	9.184	7.684	6.429	5.379	4.501	3.766	3.151	2.636		
Year 2		18.367	15.368	12.858	10.758	9.002	7.532	6.302		
Year 3			4.592	3.842	3.215	2.690	2.250	1.883		
Total:	9.184	26.051	26.388	22.079	18.474	15.45	12.933	10.821		
Consumption of fixed capital										
Year 1			10	minus	9.184	equals	0.817			
Year 2	9.184	plus	20	minus	26.051	equals	3.133			
Year 3	26.05	plus	5	minus	26.388	equals	4.662			
Year 4	26.38	plus	0	minus	22.079	equals	4.309			
Year 5	22.07	plus	0	minus	18.474	equals	3.606			
Year 6	18.47	plus	0	minus	15.457	equals	3.017			
Year 7	15.45	plus	0	minus	12.933	equals	2.524			
Year 8	12.93	plus	0	minus	10.821	equals	2.112			

To understand the worksheet:

- The worksheet shows expenditures on a particular type of asset in years 1, 2 and 3 amounting to 10, 5 and 20 respectively. The expenditures were converted to the constant prices of year 1 before being entered in the worksheet.
- The depreciation rate for this asset (construction tractors) is 0.1633. This was obtained by a modified version of the double declining balance method. The standard double declining balance method would calculate $d = 2 / T$ where (T) is the average service life of the asset. BEA uses a modified version of the double declining balance method in which 2 is replaced by numbers that are derived from empirical studies of second-hand asset prices; for assets for which estimates are unavailable, 2 is replaced by 1.65 for equipment and by 0.91 for structures. For this example of construction tractors, the service life, T, is 8 years and the declining balance rate is 1.3064.
- BEA assumes that new assets are placed in service at midyear, so that the depreciation on them in year 1 is equal to one-half the depreciation on existing assets. Therefore, the net stock remaining at the end of the first year of service $(1 - 0.1633/2)$ times the gross fixed capital formation.
- For subsequent years, the net stock at the end of the year for each vintage equals the stock at the beginning of the year times $(1 - 0.1633)$.
- The total net capital stock is obtained as the sum of the net capital stock across vintages of assets. For example, the net capital stock at the end of year 2 is the sum of the year-end net stock of assets purchased in year 1 (7.684) plus the year-end net stock of assets purchased in year 2 (18.367). (From year 4 onwards the total net stock of the asset is the sum across the stock purchased in the first 3 years because in this example there were no further purchases of this asset after year 3.)
- Consumption of fixed capital is calculated as the beginning-of-year stock, plus the gross fixed capital formation, minus the year-end stock.
- Note that the worksheet takes no explicit account of the average service life of the assets. A mortality function was used to determine the depreciation rates for various assets, so the mortality assumption is implicit rather than explicit. Even though the average service life of these assets is here assumed to be only 8 years, they continue to contribute to the consumption of fixed capital and to the net capital stock for all future periods. These contributions decline asymptotically and in this example they become negligible after a few years because the worksheet uses assets with a short service life. For buildings and other long-lived assets, however, contributions to capital consumption and the net capital stock may continue to be significant for many years after their average service lives.
- Finally, the price index for this asset is used to inflate capital consumption and net stocks to obtain estimates at current prices. Year-average values of the index are used to inflate estimates of capital consumption while year-end values of the index are used to inflate estimates of net stocks.

D. Australian Bureau of Statistics (ABS)

Capital stock and flow estimates are estimated by the ABS in the following steps:

1. *Basic data and assumptions for the PIM*

- Express GFCF in volume terms at the most detailed level practicable (most are constant price estimates but some are chain volume estimates).
- Determine mean asset lives and the associated mortality functions (Winfrey S3 for tangibles) at this detailed level.

2. *Estimates of capital services*

- At the detailed level, specify the age-efficiency function for each lifespan as determined by the mortality functions. Normalised hyperbolic functions are used to obtain the age-efficiency functions and a value is assigned to the efficiency reduction parameter for each asset type.
- At the detailed level, use the values of the mortality function to weight together the age-efficiency values for all possible lifespans to form a composite age-efficiency function. For assets whose lives are constant over time there is only one composite age-efficiency, but for those assets whose mean lives change over time separate composite age-efficiency functions are computed for every year.
- At the detailed level, volume estimates of productive capital stock are derived for each year by multiplying the appropriate age-efficiency vector with the corresponding vector of volume estimates of GFCF.
- At the detailed level, estimates of rental prices are derived (using the formula developed by Jorgenson and used by the BLS) for each asset type within each industry. These are then used to weight together indexes of productive capital stock to form indexes of capital services at an aggregate level. Alternatively, we could derive volume measures of capital services and use them to derive the aggregate capital services volume measures, but there is no point because the productive capital stock of an asset has the same growth rate as the volume of capital services it provides and it is volume growth rates that are used to derive the indexes.

3. *Estimates of the net capital stock*

- At the detailed level, the composite age-efficiency functions together with an annual 4% real discount rate are used to derive age-price functions. The age-price functions are normalised and adjusted to be centred on the mid-year so as to match GFCF centred on mid-year.
- At the detailed level, constant price estimates of net capital stock are derived for each year by multiplying the appropriate age-price vector with the corresponding vector of volume estimates of GFCF.

- At the detailed level, the constant price estimates of net capital stock are multiplied by end-year price indexes with the same reference year. The resulting end-year current price estimates are aggregated to the desired level.
- At the detailed level, the constant price estimates of net capital stock are expressed in the prices of the previous year and then aggregated to the desired level. Also, the detailed constant price estimates are inflated using average-year price indexes referenced to the average prices of the constant price base year to form average-year current price estimates. The aggregate average-year current price estimates are divided into the following year's aggregate estimates expressed in the prices of the previous year to form year-to-year Laspeyres volume indexes. These are then chained.

4. Estimates of the gross capital stock

- Current price and chain volume estimates of gross capital stock are derived in a similar fashion. These estimates are not published, but are available on request.

5. Consumption of fixed capital (COFC)

- At the detailed level, the normalised and adjusted values of each age-price function - as described above - are first differenced to obtain a vector of COFC rates. This vector is then multiplied by a vector of volume estimates of GFCF to obtain constant price estimates of COFC. Current price estimates of COFC are obtained by inflation using average-year price indexes. Chain Laspeyres volume estimates are derived in the usual way.

ANNEX 3

SERVICE LIVES OF ASSETS USED IN FOUR COUNTRIES

The service lives shown for these four countries – United States, Canada, Czech Republic and the Netherlands – appear to be based on information that is generally more reliable than is usually available in other countries.

United States

The table on the following pages shows the service lives and “declining balance rates” used by the US Bureau of Economic Analysis for its capital stock estimates. (This rate is set at 2 for the commonly used method of geometric depreciation known as “double declining” balance.)

	Service life (years)	Declining- balance rates		Service life (years)	Declining- balance rates
Part (a) Private non-residential equipment and structures					
Private non-residential equipment			Construction machinery, except tractors	10	1.5498
Office, computing, and accounting machinery (1):			Mining and oil field machinery	11	1.6500
Years before 1978	8	2.1832	Service industry machinery:		
1978 and later years	7	2.1832	Wholesale and retail trade	10	1.6500
Communications equipment:			Other industries	11	1.6500
Business services	11	1.6500	Household appliances	10	1.6500
Other industries	15	1.6500	Other electrical equipment	9	1.6500
Instruments	12	1.6203	Other	11	1.6230
Photocopy and related equipment	9	1.6203	Private nonresidential structures		
Nuclear fuel (2)	4	..	Industrial buildings	31	0.9747
Other fabricated metal products	18	1.6500	Mobiles offices	16	0.8892
Steam engines and turbines	32	1.6500	Office buildings	36	0.8892
Internal combustion engines	8	1.6500	Commercial warehouses	40	0.8892
Metalworking machinery (3)	16	1.9600	Other commercial buildings	34	0.8892
Special industrial machinery, n.e.c	16	1.6500	Religious buildings	48	0.9024
General industrial, including materials handling equipment	16	1.7150	Educational buildings	48	0.9024
Electrical transmission, distribution, and industrial apparatus	33	1.6500	Hospital and institutional buildings	48	0.9024
Trucks, buses, and truck trailers:			Hotels and motels	32	0.8990
Local and interurban passenger transit	14	1.7252	Amusement and recreational buildings	30	0.8990
Trucking and warehousing; and auto repair, services, and parking	10	1.7252	All other nonfarm buildings	38	0.9480
Other industries	9	1.7252	Railroad replacement track	38	0.9480
Autos (4)	..	..	Other railroad structures	54	0.9480

	Service life (years)	Declining- balance rates		Service life (years)	Declining- balance rates
Part (a) Private non-residential equipment and structures (continued)					
Aircraft:			Telecommunications	40	0.9480
Transportation by air, Depository institutions, and business services			Electric light and power		
Years before 1960	16	1.6500	Years before 1946	40	0.9480
1960 and later years	20	1.6500	1946 and over	45	0.9480
Other industries			Gas	40	0.9480
Years before 1960	12	1.6500	Petroleum pipelines	40	0.9480
1960 and later years	15	1.6500	Farm	38	0.9100
Ships and boats	27	1.6500	Mining exploration, shafts, and wells:		
Railroad equipment	28	1.6500	Petroleum and natural gas:		
Household furniture and fixtures	12	1.6500	Years before 1973	16	0.9008
Other furniture	14	1.6500	1973 and later years	12	0.9008
Farm tractors	9	1.3064	Other	20	0.9008
Construction tractors	8	1.3064	Local transit	38	0.8990
Agricultural machinery, except tractors	14	1.6500	Other	40	0.8990
Part (b) Government non-residential equipment					
National defense:			Electronic equipment:		
Aircraft:			Computers and peripheral equipment (7)	..	..
Airframes:			Electronic countermeasures	7	1.6500
Bombers	25	1.6500	Other	10	1.6500
F-14 type	19	1.6500	Other equipment:		
Attack, F-15 and F-16 types	20	1.6500	Medical	9	1.6500
F-18 type	15	1.6500	Construction	10	1.5498
Electronic warfare	23	1.6500	Industrial	18	1.6500
Cargo and trainers	25	1.6500	Ammunition plant	19	1.6500
Helicopters	20	1.6500	Atomic energy	12	1.6500
Engines	6	1.6500	Weapons and fire control	12	1.6500
Other:			General	10	1.6500
Years before 1982	14	1.6500	Other	12	1.6500
1982 and later years	10	1.6500	Nondefense:		
Missiles: (5)			General government:		
Strategic	20	..	Computers and peripheral equipment (7)	..	..
Tactical	15	..	Aerospace equipment	15	1.6500
Torpedoes	15	..	Vehicles	5	2.2664
Fire control equipment	10	..	Others	10	1.6500
Space programs	20	..	Enterprises:		
Ships:			U.S. Postal Service:		
Surface ships	30	1.6500	Computers and peripheral equipment (7)	..	..
Submarines	25	1.6500	Vehicles	7	2.2664
Government furnished equipment:			Other	15	1.6500
Electrical	9	1.6500	Tennessee Valley Power Authority	33	1.6500

	Service life (years)	Declining- balance rates		Service life (years)	Declining- balance rates
Part (b) Government non-residential equipment (continued)					
Propulsion	20	1.6500	Bonneville Power Authority	33	1.6500
Hull, mechanical	25	1.6500	Other	25	1.6500
Ordnance	10	1.6500			
Other	10	1.6500	State and local:		
Vehicles:			Power tools, lawn and garden equipment	10	1.6500
Tanks, armored personnel carriers, and other combat vehicles	20	1.6500	Miscellaneous metal products	18	1.6500
Noncombat vehicles:			Agricultural machinery and equipment	9	1.6500
Trucks	6	1.7252	Construction machinery and equipment	10	1.6500
Autos (6)	..	..	Metalworking machinery and equipment	16	1.6500
Other	7	1.7252	General purpose machinery and equipment	11	1.6500
Motors, generators, motor generator sets	32	1.6500	Special industry machinery and equipment	11	1.6500
Switchgear and switchboard equipment	33	1.6500	Integrating and measuring instruments	12	1.6500
Electronic components and accessories	9	1.6500	Household appliances	11	1.6500
Miscellaneous electrical machinery	12	1.6500	Home electronic equipment	11	1.6500
Calculating and accounting machines	7	1.6500	Motor vehicles	10	1.6500
Typewriters	7	1.6500	Motorcycles	10	1.6500
Computers and peripheral equipment (7)	..	..	Aircraft	15	1.6500
Machine shop products	8	1.6500	Railroad equipment	28	1.6500
			Sporting and athletic goods	10	1.6500
			Photographic and photo- copying equipment	10	1.6500
Wood commercial furniture	14	1.6500	Mobile classrooms, mobile offices, etc.	10	1.6500
Metal commercial furniture	14	1.6500	Musical instruments	9	1.6500
			Other equipment	12	1.6500
Part (c) Government non-residential structures					
Federal, State and Local:			Nonbuildings:		
National defense:			Highways and streets	60	0.9100
Buildings:			Conservation and development	60	0.9100
Industrial	32	0.9100	Sewer systems	60	0.9100
Educational	50	0.9100	Water systems	60	0.9100
Hospital	50	0.9100	Other	60	0.9100
Other	50	0.9100			

	Service life (years)	Declining- balance rates		Service life (years)	Declining- balance rates
Part (d) Residential capital (private and government)					
1-to-4-unit structures-new	80	0.9100	Mobile homes	20	0.9100
1-to-4-unit structures-additions and alterations	40	0.9100	Other structures	40	0.9100
1-to-4-unit structures-major replacements	25	0.9100	Equipment	11	1.6500
5-or-more-unit structures-new	65	0.9100			
5-or-more-unit structures-additions and alterations	32	0.9100			
5-or-more-unit structures-major replacements	20	0.9100			

(1) Depreciation rates for these assets are taken from Oliner. See The Measurement of Depreciation in the U.S. National Income and Product Accounts, Barbara M. Fraumeni, Survey of Current Business, BEA, July 1997.

(2) The depreciation rates for nuclear fuel are based on a straight-line rate pattern and a Winfrey retirement pattern.

(3) The service life listed is the average for nonmanufacturing industries; the service lives used for manufacturing industries differ by industry.

(4) The depreciation rates for autos are derived from data on new and used auto prices.

(5) Depreciation rates for missiles are based on straight-line patterns of depreciation and Winfrey retirement patterns.

(6) Depreciation rates for government-owned autos are derived from data on autos that are privately owned.

(7) Depreciation rates for these assets are taken from Oliner. See The Measurement of Depreciation in the U.S. National Income and Product Accounts, Barbara M. Fraumeni, Survey of Current Business, BEA, July 1997.

Canada

This table shows the service lives used by Statistics Canada. The lives for the recent period are based on information regularly supplied by enterprises on the service lives of discarded assets. The lives for the earlier period were based on a number of less reliable sources. The **declines** in service lives over the period are based on assumption rather than observation.

Activity/Sector	Building construction		Engineering construction		Machinery and equipment	
	1961-65	1991-94	1961-65	1991-94	1961-65	1991-94
Agriculture, forestry and fishing						
Agriculture and related services	29	24	29	24	10	8
Fishing and trapping	25	25	25	25	12	11
Logging and forestry	19	19	17	12	9	8
Mining and quarrying						
Mining (metal, non-metal, coal, petroleum)	20	17	20	15	12	9
Quarry, sand-pit and service industries	28	35	20	15	12	8
Manufacturing:						
food and beverages	35	30	33	27	16	11
tobacco	35	30	31	24	12	11
rubber products	38	33	27	20	12	11
plastic products	37	32	28	21	13	12
leather	39	34	28	21	12	11
textiles	34	29	35	29	14	9
clothing	29	28	35	29	14	10
wood	25	22	20	14	15	12
furniture and fixtures	37	37			13	8
paper and allied products	31	25	31	24	19	18
primary metal industries	36	35	32	26	18	17
fabricated metal products	33	28	32	26	13	10
machinery industries	34	29	33	28	11	8
transport equipment	33	30	32	27	14	9
electrical and electronic products	31	28	27	21	12	8
non-metal mineral products	26	22	27	22	16	13
Refined petroleum and coal products	26	21	26	20	18	16
chemicals and chemical products	33	27	24	17	16	13
other manufacturing industries	34	34	23	18	10	9
Construction industries	25	25	30	30	10	10

Activity/Sector	Building construction		Engineering construction		Machinery and equipment	
	1961-65	1991-94	1961-65	1991-94	1961-65	1991-94
Transport and storage						
Air transport and related services	31	28	43	40	16	16
Rail transport and related services	38	33	53	52	21	18
Water transport and related services	36	31	40	37	23	18
Truck transport	39	33	45	39	9	8
Public passenger transit systems	37	32	32	26	11	10
Other transport and related systems	39	33	45	39	9	8
Pipeline transport	35	30	35	30	14	14
Grain elevator industry	36	28	..	..	19	15
Other storage and warehousing	38	33	..	..	12	7
Communications						
Broadcasting industries	37	32	18	13	11	9
Telecommunication carriers	39	35	37	31	17	14
Postal and courier services	42	38	45	39	8	6
Electricity, gas and water						
Electric power and gas distribution	49	48	49	47	32	31
Water systems	31	25	54	49	12	7
Wholesale trade and retail trade	33	27	25	18	11	8
Finance, insurance, real estate and business services						
Deposit accepting intermediary industries	45	43	..	..	19	7
Consumer and business financing	43	40	..	..	8	6
Insurance industry	45	43	..	..	10	7
Real estate and insurance agents	45	43	..	..	10	7
Business service industries	42	39	..	..	8	6
Government service industries						
Federal government	39	35	39	34	12	9
Provincial and territorial	39	34	39	33	11	8
Local government	39	35	39	33	13	10
Education and museums						
Elementary and secondary	44	42	..	..	13	10
Post secondary, non-university	44	42	..	..	13	10
Univer	53	53	..	..	13	10
Museums and archives	42	39	..	..	8	6
Health and social services						
Hospital	45	43	..	..	13	11
Other health and social services	43	40	..	..	16	14

Activity/Sector	Building construction		Engineering construction		Machinery and equipment	
	1961-65	1991-94	1961-65	1991-94	1961-65	1991-94
Accommodation, food and beverage services						
Accommodation services	42	39	..	..	8	6
Food and beverage services	42	39	..	..	8	6
Other	52	42	..	..	9	6
Amusement and recreation services	42	39	..	..	8	6
Membership organization industries	56	51	..	..	19	16

Czech Republic

These service lives are based on an annual survey of ages of assets when discarded.

Activity	Transport Equipment	Other Machinery and Equipment	of which Computers
Agriculture	13	15	9
Forestry	12	13	6
Mining – coal	19	15	9
– other	13	16	8
Manufacturing			
- Food, beverages, tobacco	13	16	7
- Textiles and clothing			
- Wooden products, paper and pulp	11	18	10
- Chemicals, rubber and plastic	15	16	10
- Metal products, including vehicles, office machinery, etc,	14	18	9
	11	18	11
Electricity, gas, water	12	18	11
Construction	11	15	9
Sale and repair of motor vehicles	11	15	9
Wholesale and retail trade	9	12	8
Hotels and restaurants	7	11	7
Air Transport	13	14	11
Post and telecommunications	11	16	16
Financial and insurance services	...	9	7
Public administration and defence	13	15	7
Education	13	15	12
Health and welfare services	12	15	8

Netherlands

These service lives, used in the Netherlands, are “best source” estimates. For mining and manufacturing they are mainly based on a survey of discards and on other indirect sources for other assets.

	Buildings	Other construction	External transport	Machinery	Computers	Other assets
Agriculture/forestry	45	35	12	15	5	10
Fishing	50	35	25	15	5	10
Mining and quarrying	40	35	10	20	12	25
Food and beverages	43	35	10	28	13	27
Textile/leather	47	35	10	28	15	40
Paper/paper products	55	35	10	29	10	36
Petroleum and products	46	35	10	37	10	38
Chemical industry	39	35	10	32	13	38
Basic metal and products	47	35	10	49	16	19
Other manufacturing	47	35	10	32	12	34
Public Utilities	47	35	10	32	12	34
Construction	47	35	10	20	12	34
Trade	60	35	8	15	5	10
Hotel, restaurants	60	35	8	15	5	10
Transport						
Water	60	35	25	15	5	10
Air	60	35	25	15	5	10
Rail	60	35	25	15	5	10
Other	60	35	10	15	5	10
Banking and insurance	60	35	8	15	5	10
Rented dwellings	75	35	8	15	5	10
Rented buildings	60	35	8	15	5	10
Commercial services	60	35	8	15	5	10
Government	60	35	8	15	5	10
Health care	60	35	8	15	5	10

ANNEX 4

THE RESEARCH AGENDA FOR CAPITAL STOCKS AND FLOWS

Introduction

Capital stocks, flows of capital services and depreciation are interdependent both conceptually and numerically. In common with other items in economic accounts, their measurement must be firmly grounded in economic theory. Until recently, estimates of capital stocks and their related flows have had to rely heavily on simple assumptions or conventions, because the underlying theory was not sufficiently developed. However, the situation has changed considerably in recent years as the underlying theory has been considerably strengthened and clarified. There is no longer any necessity to fall back on arbitrary rules of thumb when there is a much clearer perception of what the statistics ought to be measuring in principle. There remain some theoretical points that need to be further clarified, but at least in the case of tangible fixed assets, research needs to be directed towards obtaining more and better information rather than refining the underlying theory. However, in the case of intangible assets, the underlying theory is not so well developed and there remain some serious conceptual problems to be resolved, mainly with regard to scientific originals and research and development. The role of financial assets also requires some clarification. Another factor to be borne in mind is the extent to which the considerable amount of research which has been undertaken on the theory of the depletion of natural assets is applicable to, or has implications for, the depreciation of fixed assets.

Service values and depreciation

The value of a fixed asset is given by the present value of the flow of capital services that it contributes to production. The capital services have price and quantity components. The asset is eventually retired from production when either the price or the quantity of the service falls sufficiently. More information is needed about the behaviour of both prices and the quantities of services over the lives of different types of assets.

The price profile and obsolescence

The price of a new asset changes over time in proportion to the price of the service it provides. Two issues arise. The first is a conceptual issue. The question is how to treat a fall in the price of the service provided by an asset, and hence a fall in the price of the asset itself, that is foreseen at the time that the decision to invest in the asset is made. Such price falls are to be expected when assets are subject to obsolescence as result of technical progress or changing tastes. In economics, and both national and business accounting, the traditional view has always been to treat foreseen obsolescence as depreciation, but this view has been challenged in recent years it being argued that price falls, whether foreseen or not, should be treated as real holding losses and not as depreciation. Consensus needs to be reached on the treatment of foreseen obsolescence.

The second issue is more practical than theoretical: namely, how to obtain improved measures of changes in the prices of assets. The price indices used for purposes of capital stock measurement have to span extremely long periods of time while the assets themselves are complex products subject to continual changes in quality. The difficulty of making satisfactory adjustments for changes in quality is a familiar one for price statisticians. However, failure to allow for improved efficiency or quality can have very serious consequences for capital stock measurement because most assets are continually being improved or modified as a result of technical progress or changes in tastes. The problem of estimating price change satisfactorily is particularly acute for high technology assets subject to rapid technical progress, such as computers. Unless the price indices used in the PIM method make proper allowance for changes the quality of the assets, both the capital stock and the related flows may be subject to serious bias. The development of good price indices should remain a high priority for capital stock measurement.

The quantity, or efficiency, profile

There is still debate about the most appropriate functional form for age-efficiency profiles. It is generally agreed that efficiency profiles are non-increasing, except possibly over short periods at the start of an asset's life-age. The key question is whether the efficiency of an asset may be expected to decline at a constant, accelerating or decelerating rate over the life of the asset. This question must be clearly distinguished from the rate at which the value of an asset depreciates. The functional forms of the age-efficiency profiles for different types of assets are not likely to be the same, and it would be useful to establish which forms are most appropriate for particular types of asset. This is an area of particular concern for productivity measurement and analysis where most of the research on this issue may be expected to take place.

Service lives and repairs and maintenance

The age at which an asset is retired depends on the interaction of several factors, including the rate of technical progress, the relative costs of repairs and maintenance and labour, and also the physical characteristics of the asset. Many assets are retired on grounds of obsolescence even though they may be in good working order. Other assets are retired when they are worn out or breakdown, but this depends very much on the amount of repairs and maintenance they receive. Many assets, especially many buildings and structures, could have infinite service lives if properly maintained. Roads provide a good example. The optimal level of maintenance itself depends on various factors, in particular on the level of demand for the services of the assets and the relative costs of capital and labour. Some assets may appear to be retired because they are worn out, but their physical condition may actually be allowed to deteriorate by cutting back on ordinary repairs and maintenance, or even ceasing repairs and maintenance altogether, because the assets themselves are becoming obsolete. Many buildings and other structures only become dilapidated when the demand for their services has fallen. In such circumstances, assets that may appear to be retired on grounds of physical deterioration may actually be retired because of obsolescence.

The notion that assets have exogenous service lives that are determined entirely by their physical characteristics is an over simplification. Some may, but many may not. Even the notion that assets have exogenous efficiency profiles that depend only on their physical characteristics may only be valid for a minority of assets. Research needs to be directed towards the factors determining rates of repairs and maintenance and decisions to retire assets from production. Assets may be retired at different ages, depending on the economic environment in which they are used. The age at which an asset is retired may vary over time and may also vary significantly between countries.

The treatment of repairs and maintenance is a grey area for economic accounts in general and not only capital stock measurement. Whereas the lives of assets that are becoming obsolete may be deliberately shortened by neglecting repairs and maintenance, some major repairs or renovations may actually prolong the lives of the assets concerned beyond the lives expected when the assets were acquired. In this case the SNA reclassifies the expenditures from intermediate consumption to gross fixed capital formation, thereby affecting GDP. Similarly, expenditures that enhance the performance or capacity of the assets concerned are treated as gross fixed capital formation. As it is not easy to distinguish ordinary repairs and maintenance from improvements, renovations or enlargements, the distinction between the two may be interpreted differently by different compilers. It would be useful to shed more light on this grey area. First, it would be useful to know how different statistical agencies handle this problem. Second, more guidance might be provided on the theoretical and operational criteria that may be used to distinguish ordinary repairs and maintenance from expenditures that count as gross fixed capital formation.

Scrap values and decommissioning costs

The last receipt in the service value profile should be the scrap value of the asset after it is retired less any decommissioning or demolition costs. The costs of demolishing and dismantling certain types of assets may be very large, notably for nuclear reactors and off shore oil platforms. The possibility that the last item in the service value profile may be both large and negative raises conceptual problems. Certain fixed assets may, in fact, be substantial liabilities for their owners in the interval between the time the assets are retired and the time they are decommissioned or demolished. More attention needs to be paid to the implications of large decommissioning costs for the efficiency and price profiles and for the depreciation schedules derived from them.

Depreciation

The depreciation on a fixed asset is measured by the decline in its value over time. The value of an asset at any point of time should equal the present value of the remaining services that it is capable of providing to production. The rate of decline in the present value of the services in turn depends on the functional form of the service value profile. Thus, the rate of depreciation ultimately depends on the rate of decline in the price of services it provides due to obsolescence and the rate of decline in the quantities of services due to declining efficiency and ageing. It follows that the more that is known about the service price profile and the age-efficiency profile, the more reliable the estimate of depreciation should be.

If there are efficient markets in used assets, the relative prices of different vintages of assets on the market at the same time are capable of providing direct estimates of depreciation. This is an important area for empirical research. Such research has been carried out in the United States but seems to be relatively neglected elsewhere. This type of research should be given high priority.

The relationship between the depreciation schedules for individual assets and the corresponding schedules applicable to stocks of assets also requires clarification. The functional form of the aggregate schedule need not be the same as that for the individual assets. The same may apply for the service price and efficiency profiles. More attention needs to be paid to potential aggregation problems of this kind.

Financial Capital

The capital stock considered in this *Manual* is the stock of fixed assets held by an enterprise, sector or the economy as a whole. They are valued at their actual or estimated market prices that should equal the present values of the services they provide. The balance sheets of enterprises also record the funds used to finance the acquisition of their fixed assets, inventories, and natural assets. The funds appear as liabilities in the form of various kinds of debts, bonds, shares or other securities issued by the enterprises. These are recorded elsewhere as financial assets owned by other institutional units. It is necessary to clarify the role of financial capital in production and productivity analysis. The question has been raised as to whether a comprehensive measure of capital should be extended to include financial capital as well as fixed capital for certain analytical purposes.

The concept of ‘capital’ as a Fund out of which the acquisition of physical assets may be financed has a very long history. It is the original meaning of ‘capital’ in commercial accounting. This is the way it was understood by classical economists including Marx who coined the term ‘capitalism’. The concept of capital as the stock of the physical assets themselves rather than the funds out of which they are financed is more recent. Confusion between the two ways of viewing capital has been a fruitful source of controversy about the concept of ‘capital’. The relevance of financial assets and liabilities for the measurement of the capital stock as defined in this *Manual*, and as used in production functions and productivity analysis, needs to be clarified.

Intangible fixed assets

Further research is needed on the nature, classification and valuation of intangible assets. It is generally agreed that they play an increasingly important role in the economy. Further clarification of the concepts and definitions of different kinds of intangible assets may be needed, but the main problems relate to their valuation.

Valuation

As in the case of tangible fixed assets and natural assets, the value of an intangible is given by the present value of the future stream of the services it provides. This may be highly uncertain and speculative for some intangible assets such as film or music originals. The great majority of such assets may have extremely low present values while a few have very high values. The distribution of values is highly skewed. Moreover, the values may bear no close relationship to the costs of producing them. Valuation on the basis of production costs is not generally a satisfactory substitute for market valuation for the majority of intangible assets. In this respect, intangibles differ considerably from most tangible fixed assets. The fact that most intangibles have many of the characteristics of public goods also complicates their valuation. More guidance is needed about appropriate ways in which value assets such as the originals of films and music recordings. This is a difficult area for the SNA as a whole and not simply capital stock measurement.

Service lives, efficiency profiles, obsolescence and depreciation

Intangible assets highlight many of the problems discussed above in relation to tangible fixed assets. An intangible asset is capable of supplying an infinite stream of quantities of services so that the efficiency profile is presumably an infinite horizontal line. There is no need for repairs and

maintenance. The only reason for retiring intangible assets is that there is no longer any demand for their services. If they have only limited service life in practice, it must be due to obsolescence. It follows that their rates of depreciation must be entirely determined by obsolescence. In the case of artistic originals, the decline in demand will be due to changing tastes or fashion, but in the case of software it will be due to technical progress. Although software does not need to be maintained, it may need to be improved or enhanced if it is to continue to be used, the improvements counting as gross fixed capital formation.

Mineral exploration

Expenditures on exploration are treated as gross fixed capital formation leading to the creation of intangible fixed asset classified as 'mineral exploration'. The subsoil assets themselves are classified as non-produced assets. It is not clear that these classifications are mutually consistent. Some assets may be double counted. The treatment of exploration and subsoil assets needs to be reviewed and clarified.

Scientific originals, patents and research and development

Scientific and technological originals, which may be the most important category of intangible fixed asset, are not classified as such in the SNA because the activity that gives rise to them, research and development, is not classified as gross fixed capital formation. Patents, which are the legal documents demonstrating evidence of ownership of scientific originals, have to be treated as if they were themselves the assets whereas legal documents demonstrating evidence of ownership of fixed assets such as equipment and structures are not treated as assets. The SNA is quite inconsistent in this area and the treatment of scientific originals needs to be reviewed. Classifying scientific originals as intangible assets would have significant impact on the capital stock. Classifying research and development as gross fixed capital formation would also change GDP.

Miscellaneous topics

Land improvements

Improvements to land count as gross fixed capital formation in the SNA but no new fixed asset is created that is included in the capital stock. The value of the improvement is incorporated into the value of the land itself, which is classified as a non-produced asset. Gross fixed capital formation takes place without a new fixed asset being created. The situation is confusing and it would be desirable to try to find a better solution.

Costs of ownership transfer

Similar kinds of problems arise with respect to the costs of ownership transfer which are classified as gross fixed capital formation but which do not necessarily increase the values of the assets concerned or lead to new fixed assets. The problem is most evident in the case of the costs of ownership transfer on non-produced assets. The treatment of costs of ownership transfer needs to be reviewed to see whether it can be improved from the perspective of the capital stock.

Natural assets

The stock of fixed assets does not include natural assets. Nevertheless, there are many points of similarity between fixed assets and natural assets, mainly because both derive their value from the inputs they contribute to production. Both are valued by the present value of the inputs that they are expected to provide over their service lives. The decline in the value of the stock of a natural asset as it is used up in production, namely depletion, parallels the decline in the value of a fixed asset, namely depreciation. There is a substantial literature concerned with the methodology for measuring stocks of natural assets and their depletion. It would be desirable to take advantage of this literature to see how far research undertaken with the objective of improving methodology for natural assets may be directly relevant to, or have implications for, the stock of fixed assets.

Capital Inputs in the production account of the SNA

The volume index of capital services described in Chapter 9 measures the flow of capital services into production. The corresponding flow of services valued at current prices needs to be recognized explicitly in the SNA and recorded in parallel with the flow of labour services, or compensation of employees. For purposes of productivity analysis, however, it is necessary to go even further if all inputs into production are to be recorded. This would require a radical restructuring of the SNA production account, a topic that might figure prominently on the agenda for future research.

The production account in the 1993 SNA is not, in fact, a proper production account. It would be better described as a 'value added account'. The first step, therefore, would be to reintegrate the 1993 SNA 'value added account' with the generation of income account in order to reconstitute the more comprehensive production account of the 1968 SNA. The term 'production account' is to be understood here as referring to this more comprehensive account. (It can always be partitioned into two sub-accounts in order to show gross value added, and hence GDP, explicitly as a balancing item, if desired.)

Inputs of capital services can then be recorded in the production account alongside compensation of employees. The services may be valued by the actual or estimated pure rentals payable; that is, by the sum of depreciation and the capital, or interest, costs. While it would not be easy to estimate the value of capital services, it is no more difficult than estimating depreciation, or consumption of fixed capital.

Consistency then requires that inputs of natural assets should also be recorded. The equivalent flows to inputs of capital services in the case of deposits of minerals and fuels are the values of the quantities extracted and used in production. The depletion of natural assets is defined and measured in the same way as depreciation on fixed assets. The values of the quantities extracted are equal to the sum of depletion and the capital costs. Finally, inputs of land may be recorded on the basis of the actual or estimated rents payable. As depletion should be zero for land, the rent consists essentially of the capital charge.

Restructuring the production account along these lines would raise many complex issues that would require careful study. The balancing item on the revised production account would be very different from the existing net operating surplus, being much closer to the economic concept of pure profit. The consequences for the SNA as a whole, however, may not be as radical as they appear at first sight. Many of the changes involve moving items from the primary income account to the

production account without affecting the balance of primary income. Nevertheless, the exact nature of the required changes and their full ramifications are by no means clear and would require further consideration and investigation. The reconstruction of the production account of the SNA could be a fruitful area for further collaborative research between compilers of the accounts and economists interested in the measurement and analysis of productivity.

Summary

The following topics emerge as the main priorities for the research agenda on capital stock measurement:

- The treatment of intangible assets, their valuation and depreciation.
- The treatment of scientific originals and research and development.
- The development of improved price indices for fixed assets.
- The impact of repairs and maintenance on service lives.
- Market prices of used assets and depreciation.
- The role of obsolescence.
- Decommissioning and demolition costs.
- The role of financial capital.
- Links with the methodology used to measure stocks of natural assets.

Finally, in addition to the above list of topics concerned specifically with capital stock measurement, the reconstruction of the SNA production account to put it in a form in which it would be suitable for growth accounting and the measurement and analysis of productivity would be a major research project in its own right.

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