DEVELOPMENT OF ESTIMATES OF THE STOCK OF FIXED CAPITAL IN THE UNITED KINGDOM*

BY J. HIBBERT, T. J. GRIFFIN AND R. L. WALKER

Central Statistical Office, London

The historical background and present methodology used in compiling the U.K. official estimates of the stock of fixed capital are described. Mention is made of the possibility that with the development of commercial accounting direct estimates of capital stock may be derived from enterprise accounts at some future time. For the present, however, an indirect perpetual inventory approach is followed. Some of the deficiencies of the present estimates are discussed including the effects of possible biases in the life-length assumptions, price indices and the treatment of secondhand assets. Estimates of gross capital stock are given analysed by industry group of ownership and by type of asset.

Some conceptual issues are discussed in relation to user requirements, including the distinction between the stock of capital and the flow of services from it.

The authors conclude that little can be done to improve the perpetual inventory estimate of fixed capital in the U.K. without devoting more resources to the collection and analysis of new information, particularly on the service lives of fixed assets, the extent of leasing and the transfer of assets between industries.

1. INTRODUCTION

Work by government statisticians on the estimation of capital stock and capital consumption for the United Kingdom has been very uneven over the post-war years. The early pioneering work of Redfern and its later modification by Dean, which are described briefly in the next section, were substantive pieces of work involving considerable research and estimation. Partly because of other demands upon available resources, very little further progress has been made except for the mechanization of the calculations which are now so much more easily carried out by means of a fully computerized system. An additional explanation for the fact that no further developments have so far been carried out is, however, that the main problems to be tackled appear to be both difficult to solve and costly in terms of data requirements.

If further development work is to be undertaken decisions are required about the areas to which the major effort should be directed. These decisions are difficult to take for several reasons., First, there is little experience or information on which to base an assessment of the probable success to be achieved by pursuing a particular course of action. Given the nature of the work in question this is to be expected and some experimentation will be necessary. Secondly, however, the collection of additional data involves costs which it is impossible to justify unless the expected benefits are sufficiently great. Thus although there may be considerable uncertainty about the likely benefits to be derived from better capital stock

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It is essentially the text of a papcr presented to the 14th general conference of the IARIW in 1975. A more recent article (T. J. Griffin, "The Stock of Fixed Assets in the UK: How to Make Best Use of the Statistics," Economic Trends October 1976) provides some more up-to-date information especially on asset lines.

estimates, it is nevertheless necessary to attempt to assess them, at least qualitatively, in order to decide whether to incur the costs involved. Finally, there still remain questions about the appropriate definition, classification or concept to be followed for any given purpose which, as far as possible, should be resolved unambiguously before the task of measurement is undertaken.

Although there are at present no specific plans for devoting substantive resources to the development of our capital stock estimates, we discuss in this paper the main issues which would arise if such a programme of work were to be undertaken. There is some scope for development of the existing perpetual inventory model including more extensive use of the available data at a greater level of disaggregation. That work can go ahead with existing resources and without the collection of additional data, but we do not believe it is likely to lead to any substantial improvement in our estimates. This can come only from more reliable information about the service lives of assets, better data on the industries using particular types of asset (as distinct from the industries owning them) and improved methods of revaluing fixed investment expenditure at constant prices. At the same time some further clarification of the concepts underlying the measurement of capital stock and capital consumption may be needed in order that the estimates resulting from our work should be of greater value to potential users.

The discussion which follows takes as given current commercial accounting practices. If the published accounts of trading enterprises were to be prepared along the lines suggested in a recent Report [11], then it might well be possible to derive estimates of capital stock by reference to the balance sheet values of fixed assets.

2. History

The earliest estimates of capital stock in England of which we still have a record are in the nine hundred year old Domesday Book. Domesday, which can still be seen at the Public Records Office in London, is based on a great census carried out in 1086 for William the Conqueror. The wealth of the country then was almost entirely in the rural estates and so the main categories of assets were farm land, livestock, woodlands, grazing land, fisheries, watermills and so on. Domesday was in fact more comprehensive than the present official estimates of capital stock in the U.K. in that it was not confined to reproducible fixed assets.

The origins of our present estimates of capital stock date from work in the CSO in the 1950s culminating in the publication of Redfern's RSS paper in 1955 [14]. Redfern, using a perpetual inventory method similar to that used by Goldsmith [9] in the U.S.A. in 1951, compiled estimates of capital consumption and stock for 1938 and for each year from 1947 to 1953 analysed by six industry groups and nine groups of assets. The official annual national accounts publication "National Income and Expenditure 1956" provided the first published estimates of capital consumption analysed by institutional sector.

Dean in an RSS paper in 1964 reporting his work in the CSO [3] revised some of Redfern's earlier estimates and further distinguished eight industry groups within manufacturing. Although the capital stock estimates derived by these methods were still regarded primarily as a means of estimating capital consumption for the national accounts, it was recognized that there existed considerable interest in the estimates of capital stock in their own right. Accordingly, the estimates based on Dean's revised assumptions were published in "National Income and Expenditure, 1964". Gross capital stock was given for seven selected years between 1948 and 1963 at 1958 prices, analysed by twenty-five industry groups and by five types of asset.

The methodology used by Redfern and Dean was used unchanged up to 1974. It is described in outline in "National Accounts Statistics Sources and Methods" [17]. The revised methodology in use since 1975 is described in "Economic Trends," October 1975 [10]. There have been only minor extensions to the coverage of the published estimates ince 1964.

Present Estimates

The basic data used in the estimation of capital stock are capital expenditure estimates collected from each industry together with estimates or assumptions about the average service lives of a wide range of types of asset. For example, in the aerospace industry 3 percent of expenditure on plant and machinery is assumed to survive for 16 years, 13 percent for 25 years, 69 percent for 34 years and 15 percent for 50 years. The Appendix lists the life lengths used for each asset within manufacturing industry. Until 1975 retirements (discards) were assumed to occur only in the final year of the expected life of each asset. The new retirement pattern which we have now adopted and the reasons for adopting it are discussed below. The depreciation method used in the calculation of consumption and hence net capital stock is the straight line method. A minor modification to the method of calculating consumption, introduced in 1975, is also mentioned later in the paper.

In recent years the calculations of capital stock and capital consumption have been fully automated in a flexible system which enables us to produce both regular and *ad hoc* analyses quickly. The most basic print out shows gross capital formation, retirements, gross stock, capital consumption, net capital formation and net stock, at current and at constant replacement prices, for a given type of asset in a given industry. The reference year for the constant price data can easily be varied and historic price estimates can also be produced. Aggregates by industry and asset type and analyses by institutional sector are produced in a similar way. Related programs can also produce analyses by age of asset and by the assumed lives of assets.

The industry and asset groups for which gross stock estimates are published are shown in Tables 1 and 2 taken from the latest annual national accounts publication [18]. We have not to date published *stock* estimates at any more disaggregated level for manufacturing industries, even though more detailed estimates of *fixed capital formation* are available from 1948 onwards.

Tables 1 and 2 were derived from the revised perpetual inventory model introduced in 1975 [10]. The examples given in Tables 3 and 4 employ the simpler model in use up to 1974. The results shown in Tables 3 and 4 would not be affected significantly if the revised model were used.

TABLE 1

GROSS CAPITAL STOCK AT 1970 REPLACEMENT COST BY INDUSTRY[1]

£ thousand million

	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Agriculture	2.6	2.7	2.8	2.9	3.1	3.2	3.3	3.4	3.5	3.7	3.9
Forestry and Fishing	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Mining and quarrying	2.1	2.1	2.2	2.2	2.3	2.3	2.3	2.4	2.4	2.5	2.8
Manufacturing:											
Food, drink and tobacco	3.4	3.6	3.8	4.0	4.2	4.3	4.5	4.7	4.9	5.2	5.4
Coal, petroleum products, chemicals and allied industries	5.3	5.6	5.9	6.2	6.6	6.9	7.3	7.7	8.0	8.1	8.4
Iron and steel	3.7	3.8	3.8	3.9	3.9	4.0	4.1	4.3	4.4	4.5	4.7
Other metals, engineering and allied industries	11.7	12.1	12.6	13.0	13.3	13.7	14.2	14.5	14.7	15.1	15.5
Bricks, pottery, glass, cement, etc.	1.2	1.3	1.4	1.4	1.5	1.6	1.7	1.7	1.8	1.9	1.9
Timber, furniture, etc.	0.5	0.5	0.5	0.5	0.6	0.6	0.6	0.6	0.7	0.7	0.7
Paper, printing and publishing	2.2	2.3	2.3	2.4	2.5	2.6	2.7	2.8	2.9	2.9	3.1
Textiles, leather, clothing and other manufacturing	4.4	4.5	4.7	4.9	5.0	5.3	5.4	5.6	5.7	5.9	6.1
Total	32.4	33.7	35.0	36.3	37.6	39.0	40.5	41.9	43.1	44.3	45.8

TABLE 1—*continued*

	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Construction	1.4	1.6	1.7	1.9	2.0	2.1	2.3	2.4	2.5	2.5	2.6
Gas	1.7	1.7	1.9	2.2	2.4	2.6	2.7	2.8	2.9	2.9	3.0
Electricity	8.3	9.0	9.8	10.5	11.0	11.4	11.7	12.0	12.2	12.4	12.5
Water	2.9	2.9	3.0	3.0	3.0	3.1	3.1	3.2	3.3	3.3	3.4
Railways	8.0	8.0	8.0	8.0	7.9	7.8	7.8	7.7	7.7	7.6	7.6
Road passenger transport	0.6	0.6	0.6	0.6	0.7	0.7	0.7	0.7	0.8	0.8	0.8
Road haulage and storage	0.8	0.9	0.9	1.0	1.1	1.2	1.2	1.3	1.4	1.4	1.5
Shipping	3.1	3.1	3.1	3.1	3.1	3.3	3.5	3.6	3.9	4.2	4.4
Harbours, docks and canals	1.5	1.5	1.5	1.5	1.6	1.6	1.6	1.6	1.6	1.7	1.6
Air transport	0.7	0.8	0.8	0.8	0.9	0.9	1.0	1.1	1.1	1.2	1.2
Postal, telephone and radio communications	3.5	3.6	3.8	4.1	4.4	4.7	5.1	5.5	5.8	6.3	6.7
Distributive trades and other service industries	12.9	13.8	14.7	15.5	16.5	17.6	18.8	20.0	21.4	22.9	24.3
Private dwellings	28.5	29.2	29.9	30.6	31.4	32.2	32.8	33.7	34.6	35.5	36.2
Public dwellings	13.7	14.4	15.1	16.0	16.9	17.8	18.6	19.3	20.0	20.8	21.6
Roads[2]	3.2	3.4	3.6	3.9	4.2	4.5	5.0	5.4	5.7	6.1	6.4
Other public services	12.7	13.3	13.9	14.7	15.5	16.3	17.2	18.1	19.2	20.2	21.1
Total gross capital stock	140.9	146.6	152.6	159.1	165.9	172.6	179.5	186.4	193.4	200.6	207.7

[1]For an account of the principles of valuation, see *National Accounts Statistics: Sources and Methods*, pages 383–387. Figures relate to end of year.
[2]Excluding the non-renewable element more than 75 years old.

TABLE 2

GROSS CAPITAL STOCK AT 1970 REPLACEMENT COST BY TYPE OF ASSET[1]

£ thousand million

	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Road vehicles	3.4	3.7	3.9	4.1	4.4	4.6	4.8	4.9	5.1	5.3	5.5
Railway rolling stock, ships and aircraft	6.3	6.2	6.2	6.1	6.2	6.2	6.4	6.6	6.9	7.1	7.2
Plant and machinery	39.8	42.0	44.5	47.1	49.6	52.0	54.7	57.2	59.5	62.1	64.8
Dwellings	42.2	43.6	45.0	46.7	48.3	50.0	51.4	53.0	54.6	56.3	57.8
Other buildings and works	49.2	51.1	53.0	55.1	57.4	59.8	62.2	64.7	67.3	69.8	72.4
Total gross capital stock	140.9	146.6	152.6	159.1	165.9	172.6	179.5	186.4	193.4	200.6	207.7

[1]For an account of the principles of valuation, see *National Accounts Statistics: Sources and Methods*, pages 383–387. Figures relate to end of year.

3. Some Deficiencies in the Present Estimates

Length of Life Assumptions

An important source of possible error in perpetual inventory estimates arises from the need to make assumptions about the average length of life of different categories of asset. The main difficulty is that there is virtually no hard information, either about the mean length of life of a particular type of asset or about its stability over time. Even the definition of an asset's life is not always unambiguous; whether or not an asset is worn out may be a matter of opinion.

The length of life assumptions for Redfern's estimates were based on lengths of life used for accounting purposes in some parts of the public sector, on lengths of life underlying Inland Revenue depreciation allowances for the major part of the private sector and on other miscellaneous data. The assumptions based on Inland Revenue depreciation allowances are of particular interest since they were used for the estimates relating to plant and machinery in some of the more important industries, including manufacturing.

The Board of Inland Revenue [2] did not publish explicitly the lengths of life on which depreciation allowances were based but gave annual percentages for different types of capital good to be applied in the reducing balance method of calculating depreciation. These percentages were reckoned to write down the value to one-tenth of the initial figure over the anticipated working life: hence the latter can be implied from the percentage. Redfern took these anticipated lengths of life to be average lengths of life for the relevant commodities. The percentages have not subsequently been revised and were based in the first place on custom and practice rather than any scientific study of longevity of assets. There is thus no firm basis for the assumption that they imply average lengths of life. It might be argued that if they implied excessive lengths of life industry would have made representations for the percentages to be increased and the fact that this has not been done can be taken to imply that the lengths were not excessive. There are two points to refute this argument. In the first place Inland Revenue defined the anticipated length of life as that obtained in the normal manner until unfit for further use. This would seem specifically to exclude early retirement due to accident or redundancy. Secondly, for many years now the percentages have been of declining importance in the calculation of allowable depreciation due to the presence of initial allowances and other investment incentives so there would be little return to industry for the effort of trying to get the percentages increased. The lengths of life implied by the Inland Revenue depreciation allowances and assumed to be averages by Redfern may have approximated to actual averages before World War II but it would not be reasonable to assume that these average lives should necessarily have persisted in the post-war period.

Soon after Redfern published his figures, however, Barna [1] published direct estimates of capital stock in manufacturing industries made from fire insurance valuations. When Dean came to make perpetual inventory estimates taking advantage of the estimates of capital formation and capital stock in the pre-war period made by Feinstein [7], he adopted the longer length of life assumptions implied by Feinstein's results and supported by those of Barna. These length of life assumptions have in the main been used in compiling the U.K. estimates ever since.

Sensitivity of the Estimates to Different Length of Life Assumptions

It has sometimes been suggested that our existing assumed average life lengths for particular industries are too high. It is a relatively simple matter to calculate the effects of alternative length of life assumptions on the U.K. estimates for the post-war years, and these are illustrated by the examples for manufacturing plant and machinery given in Table 3.

TABLE 3
ESTIMATED EFFECTS OF CHANGE IN ASSUMED AVERAGE LENGTHS OF LIFE ON GROSS AND NET STOCK AND CAPITAL CONSUMPTION FOR MANUFACTURING PLANT AND MACHINERY

Change in Assumed Average Life	Effect on Estimates at Constant Prices for:		
	Gross Stock	Net Stock	Capital Consumption
20 percent	13 percent	15 percent	10 percent
40 percent	25–30 percent	30–35 percent	20–25 percent

The effect of reducing the assumed life lengths on the estimates for this post-war period is to reduce gross and net capital stock whilst increasing capital consumption. The relationship between the change is assumed lengths of life and the changes in estimated stock and capital consumption is, of course, partly dependent upon the rate at which new capital formation is taking place (i.e., the rate at which the capital stock itself is changing). If capital formation were constant, and therefore capital stock were static, then a change in assumed life lengths would be matched by an exactly corresponding change in gross and net stock with no change in capital consumption. With increasing capital stock over time, a given percentage reduction in assumed life lengths leads to a relatively smaller percentage change in estimated stock and some increase in capital consumption (because capital consumption now represents a greater using up of more recently acquired assets).

Perhaps of potentially greater interest than the effects of alternative but fixed length of life assumptions is the sensitivity of the perpetual inventory to the assumption that average lengths of life are changing over time. The results of simulations carried out for plant and machinery in the chemicals and allied industries are given in Table 4. The proportions of investment in plant and machinery allocated to the five categories with different assumed lives in the existing perpetual inventory are given in Appendix 9. For the simulations it was assumed that the lengths of life should remain for investment in years up to 1947 but that over the next twenty five years the weighted average length of life should fall gradually from a little over 37 years to (A) around 30 years and (B) about 22 years. The distribution of investment between categories of asset with different lengths of life was extended to six categories for (A) and seven categories for (B), life lengths of 5 and 10 years being introduced in addition to those already included in the model.

TABLE 4

EFFECTS OF ASSUMING REDUCTION IN AVERAGE LENGTHS OF LIFE OVER THE PERIOD 1948 TO 1973 ON ESTIMATES FOR 1973: PLANT AND MACHINERY IN CHEMICAL AND ALLIED INDUSTRIES

		Gross Stock	Net Stock	Capital Consumption	Net Capital Formation*	Addition to Gross Stock
(A)	£ million	−128	−270	+26	−25	−14
	Percent	−2.7	−8.9	+19.5	−26.2	−7.3
(B)	£ million	−309	−585	+59	−57	−37
	Percent	−6.5	−19.2	+43.7	−59 6	−19.3

*Results averaged over years 1971–1973 as gross capital formation fluctuated significantly.

Whether the differences resulting from the use of these assumptions about changing average lives over time should be regarded as significant clearly depends upon (1) the plausibility of the changed assumptions and (2) the context in which it is intended that the results might be used. We believe that assumption (A) is by no means implausible and that assumption (B) could be regarded as within the range of possibilities for these industries. This judgement is, however, purely subjective and not based on any actual data. Furthermore, there are many contexts in which the differences resulting from these changed assumptions would surely be significant. This would be particularly true in any study of long-term changes of stock or capital consumption. Our conclusion is that the possible errors in our length of life assumptions cannot be regarded as relatively insignificant, and that the possibility that average lives are changing over time could lead to significant error even if the assumptions made for the early post-war years were substantially correct. The industries which are most likely to have experienced reduced asset lives are those in which the greatest rate of technological change has occurred in the last thirty years.

The Classification of Capital Stock by Industry

The industry classification of the capital stock estimates given in Tables 1 and 2 relates to the industry of ownership. The extent to which assets are owned by one industry and used by another is not known but it seems likely that the leasing of assets has grown rather than lessened in importance over the post-war years in the United Kingdom. Either of the two systems of classification may be appropriate for different purposes but at present we have only estimates classified by industry of ownership. Data on the leasing of capital goods will be collected in certain business inquiries in the future, and it is expected that this information will enable us to see more clearly the relative importance of this particular problem and the extent to which it may be growing.

The Treatment of Second-hand Assets

The estimates of gross capital formation from which the perpetual inventory is compiled represent net expenditure (i.e., purchases less sales) on plant, machinery and vehicles together with expenditure on new buildings and works. If a firm in industry A sells second-hand equipment to a firm in industry B, the net expenditure of industry A understates the value of new assets acquired by that industry and the net expenditure of industry B includes, as though it were new, the value of the second-hand assets acquired. Most plant and machinery may be too specialized for inter-industry transfer, but the lower the level of industry detail at which the calculations are made the greater is the likelihood that this is a potential source of error. It seems most likely to be of significance for road vehicles and machinery such as office equipment which can equally well be used in any industry. Probably a more serious source of error arises where second-hand assets are sold predominantly for scrap, export or to consumers. In particular, the failure to make special provision in the estimates for cars purchased new and sold one or two years later to consumers seems likely to be leading to error. We intend to correct this at an early date, along the lines already followed in the official estimates for the United States.

For buildings and works the transactions in existing land and buildings are not reflected in the capital formation estimates used to compile the perpetual inventory. This is because the value of land cannot generally be distinguished in these transactions and land does not, of course, form part of the perpetual inventory. As a result new buildings and works are included in the industry of first purchase throughout the whole of their assumed lives. To deal with this problem additional data would be required on transfers between industries, although this would not provide a basis for correcting the perpetual inventory estimates in respect of past transfer between industries. A special problem has arisen in recent years from the practice of selling factories and office buildings to property leasing companies which then lease the property back to the original owners. Where changes in the ownership or use of buildings and works are likely to be significant, it would seem that direct estimation will provide the only satisfactory basis on which to deal with the problem.

Revaluation at Constant Prices

Some aspects of the conceptual problems of defining real capital are touched upon in the next section of this paper. Even for a given theoretical concept, however, errors of estimation arise from inadequate data on prices. An assessment of the deficiencies of the existing perpetual inventory estimates arising from errors in price data would be difficult to undertake and we have not attempted one. Clearly, estimates of the levels of capital stock and capital consumption will not be greatly affected by the short-term timing errors in the measurement of price changes; these are of much more significance when measuring gross or net fixed capital formation at constant prices for a year or calendar quarter. But long-term errors in the measurement of price changes would lead to biases in the estimates of capital stock and capital consumption at constant prices. Any tendency to underestimate a rise in prices would have the effect of giving relatively too much weight to the newer vintages of capital, whilst a tendency to overestimate a rise in prices would have the opposite effect of giving too much relative weight to the older vintages. It can be seen, therefore, that the question of possible long-term biases in the measurement of price changes is inextricably linked with the conceptual issues of whether capital of different vintages should be given different weights in any aggregate measure of capital stock. It may well be that biases in the measurement of long-term price changes already lead to a relative weighting of vintages which is not neutral.

The Distribution of Retirements

One of the defects of the simple perpetual inventory model used up to 1974 in the U.K. is that the assumption of a fixed length of life (of n years) for any given category of asset may lead to the series for retirements in year t being implausibly high or low simply because it reflects too precisely the capital formation series for year $(t-n)$. Because of abnormally high investment in manufacturing plant and machinery in the early 1940s, in assets assumed to last for 34 years, use of the simple model would lead to erratically high retirements from 1974. This would be unsatisfactory and so for the estimates published in 1975 we introduced an assumption that retirements are distributed around the average expected life. The form of distribution adopted was a simple uniform distribution from mean life less 20 percent to mean life plus 20 percent. The revised model is described in detail in an article in Economic trends October 1975 [10].

The Pattern of Capital Consumption

In the U.K. perpetual inventory model in use up to 1974 capital consumption for year t was calculated from the gross stock at the end of year t. Thus capital formation of £x million in year t with an expected life of n years was deemed to contribute (£x/n) to capital consumption in year t. In other simple perpetual inventory models the assumption has sometimes been adopted that capital formation in year t contributes to capital consumption in years $t+1$ to $t+n$ (i.e., the capital consumption calculations are based on the gross capital stock at the beginning rather than at the end of a given year). We decided that capital formation in year t should be deemed to contribute to capital consumption in all the years t to $t+n$ instead, as at present, of contributing only in the years t to $(t+n-1)$. Capital consumption in the years of acquisition and retirement are now therefore taken as half the amount for each of the intervening years. This small modification of the model did not, of course, lead to any significant changes in the estimates of capital consumption except where an industry's investment increases or decreases very sharply.

4. User Requirements and Some Conceptual Issues

The United Kingdom capital stock estimates were originally regarded as little more than a potentially useful by-product of our national accounts estimates of capital consumption. Always conscious of the fragile character of our perpetual inventory estimates of capital stock, we nevertheless considered it worthwhile publishing them because there was some demand for them from economic researchers, even if they were to be regarded for the most part only as orders of magnitude.

The fields of study in which capital stock estimates might play a key role seem to comprise three main areas. They are (1) the study of the processes of economic growth, including the role of investment in these processes, the distribution of income between profits and wages, and the relationship between capital stock and output in the different industrial sectors (branches) of the economy; (2) methods of forecasting the future demand for capital goods involving study of the relationship between output, desired capital stock and investment (inclusive of replacement investment); and (3) study of the distribution of wealth between and within institutional sectors. Clearly, these areas of study are not independent of each other, nor do the problems of statistical measurement associated with each of these areas fall neatly into separate categories. Nevertheless, it is convenient to review the potential requirements of users, keeping these needs in mind.

It is perhaps questionable, given the theoretical controversies about the role of capital, whether the economic statistician has a sufficiently well-defined concept of capital stock to undertake the task of measurement. Most of the conceptual issues have been very fully debated, however, and certain standard approaches to measurement have emerged even though complete agreement on these issues has not necessarily been reached. Furthermore, some of the uncertainties or ambiguities (such as the question of whether gross or net capital stock is the appropriate concept for a particular purpose) may not be of particular concern to the compiler of the estimates since it will often be possible to provide estimates for each of a number of different definitions. It seems to us, however, that the important distinction between the concept of stock and flow does not always receive the attention it deserves. Even though a stock variable may be regarded as the capitalization of future flows, and therefore the two concepts are clearly related, they are nevertheless different and should not be confused. Two questions to which it may be necessary to give special attention in the context of capital stock estimates for individual industries are the concept of "real capital" (a stock variable) to be followed, and the precise definition of capital input (a flow variable) when studying the role of capital as a factor of production.

Measurement of Real Capital

As Denison has suggested [6], many of the difficulties of reconciling apparently conflicting analyses of the role of capital and other factors of production have arisen from the use of different systems of classification. In its simplest terms the controversy over the definition of real capital—whether or not changes in the volume of real capital should simply reflect changes in capacity to contribute to output—can be regarded as coming down to the question of whether improvements in technology should be wholly reflected in the productivity changes for the industry producing an improved capital good or whether some part of this should be reflected in productivity changes for the industry using the capital good. Thus what would seem to be at issue is the particular system of classification to be adopted for the analysis of economic growth.

There are some aspects of the system of classification used by researchers into total factor productivity for a whole economy which appear to be worth closer examination if we are thinking in terms of analysis for particular industrial sectors in the economy. First, we should recall that statistical analyses of the relationship between factor inputs and output can proceed only on the basis of *measured* output. This important point is made in Chapters 14 and 21 of [4] and referred to in Chapter 20 of [5]. If our national accounts estimates of changes in the volume of output are constructed in such a way that the introduction of new and improved final products does not contribute to measured output, then the question arises as to the appropriate definition of inputs which contribute to output defined in this way. As Denison explains,[1] the treatment of quality changes in most countries' national accounts calculations leads to a situation where "... only those advances of knowledge that reduce the unit costs of end products *already in existence* contribute to measured growth". But as he also notes,[2] all improvements in the quality of capital goods eventually contribute to measured output (and thus to measured productivity) through the output of the industries which utilize those improved capital goods. We see, therefore, that *ultimately* even "costless" quality improvements in *capital* goods are reflected in measured output since they lead to increases in output and productivity in the industries using these goods. It is in fact only "costless" quality changes in goods and services produced for domestic consumers or for export which are liable never to be reflected in changes in the volume of measured output. (The extent to which this is true will, of course, depend upon the precise methods of contructing the volume estimates of private consumption and exports, but we agree with Denison that for most countries it would seem that the methods adopted will lead to the exclusion of costless quality changes from the estimates of changes in volume.)

If, then, all quality changes in capital goods are eventually reflected in measured output (either directly when they are produced[3] or indirectly when they are used) the question at issue is the point of time at which the contribution to the volume of output should be deemed to take place. By measuring real capital according to its capacity to contribute to output one would be including in measured output all quality changes in capital goods at the time those goods were produced instead of including the effects of costless quality changes only at the time the improved capital goods were used. It is here that the roots of the controversies over the measurement of real capital lie and our difficulty arises because ultimately capital goods are intermediate goods. Considered in terms of net product (output) after deducting capital consumption, the question is whether the costless quality improvement should be added to the existing capital stock (with correspondingly higher values of capital consumption when the asset is used), or whether it should contribute to net product at the time of use.

We favour the existing convention of regarding costless quality changes in capital goods as contributing to output only when the improved asset is used. This seems acceptable both in principle, since we do not value other intermediate goods in terms of their ultimate contribution to final goods, and in practice since it is usually difficult to value existing capital in terms of its currently expected contribution to future output.

[1][5] page 279.

[2][4] page 156, footnote 2.

[3]A quality change is counted as a change in the volume of output when it is matched by a change in the resource cost of producing the good in question (i.e., it is not a costless quality change).

One or two words of caution may nevertheless be necessary. First, the distinction between a costless quality change and one entailing a change in the use of real resources is not always clear. How it it intended, for example, that the research and development (R & D) efforts of firms producing capital goods should be reflected in the volume of output of these firms? R & D costs incurred in order to improve the methods of production of a firm will, to a varying degree depending upon the relative success of the R & D effort, be reflected in an increased volume of output for a given net set of inputs other than R & D. However, R & D costs incurred in order to improve the products of a firm may not be regarded as leading to an increased volume of output.[4] Secondly, even if the principle of measurement is clearly established, the divergences of the methods of revaluation at constant prices actually adopted, from those sought in principle, may vary significantly between industries. Thirdly, even if the problems of measurement error are not serious, it seems likely that there would be problems of interpretation of inter-industry differences in total factor productivity since these arise both from differences in the importance of costless quality changes in the capital goods used by each industry and from other factors which cannot be separately distinguished.

An Alternative Concept of Resource Cost

Before leaving the question of measuring real capital it may be worthwhile considering an alternative approach. If the creation of a capital good were to be regarded as consumption foregone then there might well be merit in using a deflator relating to consumption goods and services for the measurement of real capital. This suggestion was made by Hicks [12] only apparently to be rejected, but it is by no means certain that such an approach would not yield useful results. Clearly, real capital defined in this way would not reflect physical capital, and would not perhaps be of interest in the context of analyses of individual industries, but for the economy as a whole there may be a case for relating the volume of consumption goods foregone to the subsequent additions to consumption goods resulting from this saving.

Capital Inputs

One puzzle which may strike a newcomer to the field under discussion is why capital stock should be the variable of major interest when it would seem to be the *flow* of capital services which contributes to current output. Often it is not clear, when a particular researcher has chosen a given variable as that most suited to his purposes, whether this is on grounds of principle or whether it is simply because that variable is more easily computed than another and the difference is not considered to be of practical significance. Denison explains why he chooses gross capital stock but it seems that he reaches his conclusion only because the concept of output with which he is concerned is net product after deducting capital consumption.[5] If we are concerned with factors contributing to gross product, including the using up of capital assets, then the appropriate measure of capital

[4]This was Denison's conclusion for the United States in the late 1960s [4], pages 243–244.
[5]For a full explanation, see [4], Appendix D.

input would seem not to be gross capital stock but a measure of the flow of capital services, possibly derived in the way suggested by Johansen and Sorsveen [13]. Such methods take into account the different expected lifetimes of the various capital goods comprising the capital stock at a given point of time.

In terms of capacity to contribute to current output, it surely cannot be correct to give twice as much weight to one asset compared with another only because the former has an expected life at the time of construction twice that of the latter, the assets in other respects being equivalent. The question of determining the appropriate concept seems potentially important if, as suggested earlier in this paper, we may need to compile separate estimates by industry of ownership and industry of use. For the latter classification it may be only the flow of capital services which is of interest.

An indication of the possible significance of using a concept of capital services instead of capital stock is given in Table 5.

TABLE 5
VALUE OF CAPITAL PER YEAR EMBODIED IN AN ASSET PURCHASED FOR £1,000

Rate of discount	2%	5%	10%
Asset life			
10 years	110	129	159
12 years	94	111	143
16 years	73	91	125
20 years	61	79	116

The table shows the annual service charge in respect of an asset with a present value of £1,000, assuming service lives varying between 10 and 20 years and discount rates of 2, 5 and 10 per cent. The lower the rate of discount the greater the relative difference between the implied value of capital services for assets of different expected lives. For a zero rate of discount the value of capital services each year would be equal to capital consumption assuming straight line depreciation (£100 for the asset with an expected life of 10 years and £50 for the asset with an expected life of 20 years). Although estimates of this kind have not been made from the United Kingdom perpetual inventory, for any given rate of discount it would be relatively simple to do so from the tabulations of gross capital stock classified by original expected length of life.

A quite separate point is the question of whether the capital services provided by relatively new vintages of capital should be given greater weight than those provided by older vintages. The use of net capital stock rather than gross capital stock seems to be motivated by the idea that the newer vintages should be given greater weight. This is confusing since, in net stock, the newer capital represents a proportionally greater share of the total stock because it has a longer expected remaining life—not because it is technically more efficient or requires less maintenance for a given level of performance. Thus, although one can accept the logic of using net stock as a proxy for gross stock weighted by age, if this is in fact the reason for choosing net stock then it ought to be made clear.

The method of estimating capital services described in [13] and referred to above requires that a system of straight line depreciation of the asset should be appropriate. Although this may be a satisfactory assumption in some circumstances, if we are attempting to construct estimates for a particular industry it seems possible that divergences from straight line depreciation may assume some importance.

For any single capital good straight line depreciation will typically be inappropriate. One might expect, for example, that a major overhaul would be required at some time during the asset's life—possibly on more than one occasion—and that maintenance costs would be higher during the later years of the asset's life. In commercial accounts these factors could be taken into account either by charging a higher rate of depreciation in the early years, or by setting aside from revenue during the whole of the asset's life amounts sufficient to provide for the cost of overhaul and additional maintenance in the later years. Alternatively, it might be that the enterprise owned a set of machines, one or more of which fell due for overhaul each year so that straight line depreciation charges plus the annual cost of overhaul and maintenance provided a satisfactory approximation to the appropriate charge for use of assets to be set against current revenues.

When we are concerned with estimating the volume of capital services provided each year by the capital stock of a given industry, it may be reasonable to adopt the assumption that for the stock as a whole—even if not for any particular capital good—the services provided can be regarded as flowing at a constant rate over the lifetime of each part of the stock. But for rapidly growing or declining industries—which may well be those which are of particular interest— the assumption seems questionable. We might feel it necessary, therefore, to adopt some scheme of depreciation other than straight line. This, however, would greatly complicate the calculation of the flow of capital services.

Role of Capital Stock Estimates in Forecasting

Some of the issues already discussed have a bearing upon the specification of the appropriate variables to be included in an investment function or other econometric approach to forecasting fixed investment. The concept of desired capital stock will usually play a key role in such work and a decision will need to be taken about the appropriate definition of this variable. If it is accepted that the investing enterprise is not strictly speaking concerned with desired capital stock but with the potential flow of capital services, then there is a possible complication arising from the fact that, as already mentioned, the same flow of capital services in a given period may be generated by different levels of capital stock because of the varying durability of assets.

Perhaps a more serious problem in work of this kind, however, appears to be that of defining and measuring replacement investment. In a recent paper [8] replacement investment is defined as the purchase of assets necessary to maintain output capacity lost through output decay[6] and scrapping. This may be a useful

[6]Output decay (the fall in the asset's yield as it ages) is distinguished from input decay (the absorption of more inputs for a given level of output).

distinction to draw in principle but there would not seem to be any way of directly measuring replacement investment so defined, unless enterprises providing data on fixed investment expenditure recognized the concept as one useful to them in the running of their affairs. A difficulty would appear to be that, although managers may think in these terms when planning future investment, ex post classification of actual expenditure in this way might still not be practicable. Feldstein and Rothschild quite properly in our view reject the assumption that replacement invesetment can be taken as a constant proportion of capital stock, the circumstances in which this assumption would be valid being regarded as too restrictive. If this view is accepted it leaves us with a major difficulty to be resolved if such an approach to forecasting fixed investment is to be attempted. The retirements of gross stock generated by a perpetual inventory model might be expected to provide one useful piece of information about replacement investment, of course, but the timing of retirements is not known with sufficient confidence for this to be of much help in short-term forecasting work. But for long-term studies the retirements generated by a perpetual inventory may be of greater potential value. The differences observed between retirements and any constant proportion of capital stock certainly support the view of Feldstein and Rothschild.

Capital Stock in Sector Balance Sheets

The system of classification to be used for stocks of reproducible tangible assets in sector balance sheets has received considerable attention from the international statistical agencies in recent years [20]. We would expect that estimates of capital stock compiled by means of a perpetual inventory could be used for this purpose, the appropriate concept generally being net capital stock at current replacement cost. In the light of the work of Revell [15] and Roe [16] however, there is no doubt that estimates for land and buildings will be constructed by other means since it is not practicable simply to add estimates for land to the perpetual inventory estimates for buildings.

More reliable estimates of land and buildings combined can generally be derived for the United Kingdom by making use of data on the rateable value of property in each sector. Some property (e.g., agricultural land and buildings) cannot be covered in this way, but there are alternative approaches available which provide reasonable approximations.

The perpetual inventory estimates of plant, machinery and vehicles can be expected to form the basis for the corresponding balance sheet estimates for these categories of reproducible tangible assets in each of the institutional sectors. Although the United Kingdom estimates are built up by industry rather than by institutional sector, these calculations provide a satisfactory basis for institutional sector estimates since any allocation to sectors within any particular industry does not usually present any serious problems.

5. Summary of Conclusions

We have discussed the present estimates of capital stock and capital consumption for the United Kingdom and pointed to a number of deficiencies, some of them already well-known. Although there is some scope for development of the existing perpetual inventory, in our view substantive improvement can come only from the collection of additional information and more reliable data. The principal gaps are:

1. Reliable information about the expected service lives of different categories of asset, in particular about the way in which average lives may have changed and be changing over time.
2. Data on leasing of capital goods.
3. Data on transfers of existing capital goods between industries.

There is also some uncertainty about the most useful form in which capital stock and capital consumption estimates might be compiled. The concepts to be followed for sector balance sheets, though perhaps difficult to apply in practice, do seem reasonably clear. In other contexts, however, it is less obvious how best to proceed. Probably only greater experience of actually using the estimates provides compilers of the data with the necessary understanding of what is required.

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Appendix

Length of Life Assumptions for Estimates of Capital Stock in Manufacturing Industry

Proportion of investment in plant and machinery[1] assumed to fall in each category

	Assumed Life Lengths (years)				
	16	19	25	34	50
Food, drink and tobacco	0.020	—	0.220	0.680	0.080
Coal and petroleum products	0.034	0.027	0.068	0.569	0.302
Chemicals and allied industries	0.034	0.027	0.068	0.569	0.302
Iron and steel	—	0.138	0.037	0.779	0.046
Other metals; Engineering; Metal goods (not elsewhere specified)	0.014	0.100	0.200	0.565	0.121
Vehicles[2]	0.030	—	0.130	0.690	0.150
Textiles			0.026	0.897	0.077
Bricks, pottery, glass, etc.	0.050	0.240	0.190	0.140	0.380
Rubber, leather, clothing, footwear			0.730	0.040	0.230
Paper, printing, publishing			0.045	0.545	0.410
Other manufacturing			0.730	0.040	0.230
Timber, furniture, etc.			0.760	0.050	0.190

[1]For all manufacturing industries the assumed life lengths for buildings are 80 years and for road vehicles 10 years.

[2]In the motor vehicle industry certain tools, representing about one third of total expenditure on plant and machinery but varying from year to year, are assumed to have a life of only five years.