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# A Statistical Framework for the Analysis of Productivity and Sustainable Development

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**Abstract**
To analyse the consequences of the changing economic structure of the UK, we need a set of statistics broken down by industry that are consistent with the whole economy measures available from the national accounts. The theory of growth accounting then provides a framework in which the contribution of each industry to the national economy can be measured and assessed. This paper identifies the obstacles currently facing a researcher trying to implement this approach. It makes a number of recommendations for the improvement of official statistics.

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# 1. Introduction

To analyse the consequences of the changing economic structure of the UK, we need a set of statistics broken down by industry that are consistent with the whole economy measures available from the national accounts. For each industry, we need at a minimum measures of output and of inputs. The theory of growth accounting then provides a framework in which the contribution of each industry to the national economy can be measured and assessed. Growth accounting also enables us to see how these contributions are evolving over time.

The pioneering growth accounting studies were at the whole economy level. Whole economy studies can be illuminating, but in practice policy makers frequently want to know what is going on at the sectoral and industry level. Through the work of Domar (1961), Hulten (1978) and Jorgenson *et al* (1987), the growth framework has been extended to the industry level. "Best practice" in this area is the Jorgensonian growth accounting framework, now enshrined in two OECD manuals (OECD (2001a) and (2001b)). Growth accounting analyses have been very influential in the ongoing debate about the US productivity acceleration of the 1990s (Oliner and Sichel (2000); Jorgenson and Stiroh (2000a) and (2000b)). They have also been employed to inform the UK policy debate (O'Mahony (1999)) and to analyse the failure of Europe or the UK to experience a similar productivity acceleration (Colecchia and Schreyer (2002); van Ark *et al* (2002); O'Mahony and van Ark (2003); Basu *et al* (2003); European Commission (2003)).

To some, growth accounting, based as it is on the assumption of perfect competition, may seem simplistic. But if one lacks the statistical tools to do growth accounting then it is unlikely that one will be able to carry out supposedly more sophisticated analyses either. Also, the statistics required for growth accounting can be used as a basis for testing more complex hypotheses going beyond those required for growth accounting itself (as eg is done by Basu *et al* (2003)). Another advantage of the growth accounting framework is that implementing it imposes an important discipline: more tests are imposed on the consistency and coherence of the national accounts than is the case at present.

### Outline of the paper

To implement the growth accounting framework at the industry level, we need for each industry measures of both gross output and value added on the one hand and of all the inputs — capital, labour and intermediate — on the other. It turns out that at the moment this is quite a difficult task using official UK data. The first difficulty arises from the way in which the growth of output is measured by the ONS at the industry level, which is inconsistent conceptually with the way that the growth of GDP is measured. This difficulty, which is important even if we do not seek to do a full growth accounting analysis, is discussed in Section 2. Section 3 sets out the growth accounting framework in an informal manner, showing it to be an extension of, not a substitute for, the national accounts as they currently exist; Annex A provides a more formal treatment. Section 4 is a brief discussion of the concept of sustainability. It shows how one particular measure of sustainability, which I call Weitzman's Net Domestic Product, can be calculated within the same framework. Section 5 sets out the barriers which currently confront a researcher seeking to implement the growth accounting framework. These can be divided into mundane difficulties which could be fixed relatively easily, and deeper conceptual and measurement issues. The latter centre round (1) the measurement of output and prices in the private services industries (considered in more detail in Annex B); (2) the measurement of capital services; and (3) issues surrounding information and communications technology (ICT). Lest the reader feel overwhelmed by the difficulties, Section 6 considers how the US statistical agencies tackle parallel problems and shows how they have solved some (though not all) of them. Section 7 draws together the conclusions.

## 2. GDP and Industry Output: Ensuring Consistency

It is well known that GDP at current prices can be measured in three ways: from income, output or expenditure. In principle, the three estimates must yield the same answer, in the absence of errors and omissions. It is not so often appreciated that the growth of GDP in real terms can be measured in several ways too and that the different ways must also be consistent in principle. For example, the growth of aggregate output (GDP) can be thought of as an average of the growth rates of the industries that make up the national economy. Equally, it can be thought of as an average of the growth rates of the different forms of expenditure on final output. The growth of the national economy can also be thought of as an average of the growth rates of the regions, and the latter in turn can be thought of as averages of the growth of regional output or of regional expenditure.

In nominal terms GDP is either a sum of value added in each industry or it is a sum of final expenditures net of imports (final outputs) and these two sums are equal in principle. We can show that this equality must hold by definition of value added.[1] But in addition to the level of GDP in current prices, we are also interested in the growth rate of the volume of GDP (real GDP). We obviously want the growth rate of real GDP to be the same, whether we use the output or the expenditure approach. It would be very strange if expenditure-side GDP in current prices was always equal to output-side GDP, but the growth rate of the two measures differed. If this was the case, GDP would not be a very useful concept. It can readily be shown that (in the absence of errors, omissions or inconsistencies in the underlying statistics) the two measures of growth will yield the same answer. But for this to be the case, we must measure real value added in each industry by double deflation.[2] Double deflation means that an industry's gross output is to be deflated by the price of its output, while each input, whether domestic or imported, is to be deflated by its own price index. For example, if in addition to labour and capital, flour is required to make bread, then to measure real value added in bread-making, we must deflate the value of output by the price of bread and the value of the purchased input (flour) by the price of flour.

For any industry, the definition of value added in current basic prices is:

Value added = Gross output *minus* Intermediate input (domestic and imported)

= Gross operating surplus (profits) + Wage bill + Taxes on production

The sum of value added across industries is GDP at current basic prices.

There are two ways in which *real* GDP may be measured, from the output or from the expenditure sides. From the output side, an index of GDP growth (GDP(O)) is:

$$\text{Growth of GDP(O)} = \sum_{i=1}^{n} w_i \hat{V}_i, \qquad \sum_{i=1}^{n} w_i = 1$$

[1] For the moment we are neglecting the difference between basic prices, which are normally used to measure GDP(O), and market prices, normally used to measure GDP(E).

[2] This fact is well known to national income statisticians: see Commission of the European Communities – Eurostat *et al.* (1993).

Here $w_i$ is the share of nominal value added of industry $i$ in current price GDP, $V_i$ is real value added in the $i$th industry, a "hat" denotes a growth rate, and there are $n$ industries. Second, from the expenditure side (GDP(E)):

$$\text{Growth of GDP(E)} = \sum_{i=1}^{n} s_i \hat{E}_i, \qquad \sum_{i=1}^{n} s_i = 1$$

where $E_i$ is final expenditure on the products of industry $i$ and $s_i$ is the share of final expenditure on $i$ in current price GDP. We can readily show that these two measures of GDP growth are equal, in the absence of errors or omissions in the statistics.[3] But note that equality is only guaranteed in principle if the growth of real value added is measured by double deflation: see Annex A.

In practice, of course the two estimates of growth will differ. The reconciliation between them is a complicated process. First of all, there is the reconciliation between levels in current prices. In addition to the quarterly balancing process, there is a quite separate *annual* balancing process to reconcile the output and expenditure approaches, using the input-output supply and use tables.[4] Next, successive estimates of levels have to be converted into estimates of growth rates. The ONS takes the view that for measuring growth on an *annual* basis the expenditure side estimate is the most reliable. For *quarterly* data, the ONS considers that movements within the year are best measured by GDP(O), but growth over the whole year is constrained to match the expenditure measure.

*Concepts, Sources and Methods* states: "In the UK economic accounts, the expenditure approach is used to provide current price and volume measures of GDP." [paragraph 11.164]. The 1998 Blue Book (Office for National Statistics (1998b), pages 137-138) spells this out in more detail:

> "Constant price gross value added provides the lead indicator of economic change in the short term. However in the long term, constant price gross value added is required to follow reasonably closely the path indicated by the constant price expenditure measure of GDP. To achieve this, special additional balancing adjustments (or coherence factors) are sometimes required to be included within gross value added at constant basic prices, as explained below. These instances can occur particularly in periods of rapid change in economic activity. ... An examination of the constant price gross value added and

[3] This ignores the difference between market prices at which expenditure is usually measured and basic prices at which output is usually measured. But the argument can easily be extended to encompass this point.

[4] At the moment this is done only in current prices, though eventually it may be done in constant prices too (Ahmad (1999); Tuke and Aldin (2004)).

expenditure measures of GDP suggested that the growth in the measure of gross value added was over-stated by around half a per cent between 1988 and 1989."

This makes clear that, eventually, the annual constant price output side estimates are constrained to follow the expenditure ones. In the published figures, there is no discrepancy between the two annual estimates (unlike in the US National Income and Product Accounts: see below), but this is because the output side estimate is adjusted to conform to the expenditure side one. The reason for preferring the expenditure side estimate is threefold:

1. The output of some industries is less well measured than others, ether because of conceptual difficulties or because less statistical effort is devoted to them. There is as yet no counterpart in the private service industries to the Producer Price Index (PPI) programme that covers the production sector. Much of the hard-to-measure part of the economy is engaged in producing intermediate products (eg business services or wholesale banking) and these activities largely drop out of GDP measured from the expenditure side.[5] See Annex B for more on this.

2. More detail is available on the expenditure side and the price indices are more reliable. The Retail Prices Index programme is far more extensive than the PPI programme.

3. In practice the ONS does not use double deflation to estimate real value added (except in electricity supply and agriculture); instead it uses real gross output as a proxy for real value added: see Office for National Statistics (1998), chapters 11 and 13, and Sharp (1998).[6] So even in the absence of errors and omissions, the output and expenditure side estimates would not be equal and the output side estimate would be wrong, unless in each industry real gross output and real intermediate input were growing at the same rate, which is clearly unlikely. The discrepancy between the output and expenditure side estimates is removed by adjusting output growth in the private service industries; output in the production sector (about a third of the economy) and in the government sector (about a fifth) is not adjusted.

5 Not completely, since some enter into international trade.
6 In most cases, real gross output is measured by sales deflated by an appropriate price index.

Even though the growth of the production sector is incorrect as a measure of its contribution to GDP growth (since the Index of Production uses single deflation), it is left unadjusted.[7] So the whole burden of errors and omissions, together with the error caused by the use of single rather than double deflation, is thrown onto the estimates of growth in the private services industries. The size of the adjustment needed to make GDP(O) conform to GDP(E) is not published. It is clearly very unfortunate that, at a time when the private service industries have been growing in importance, our understanding of their performance should be distorted in this way.

In fact, the ONS has the basic means available to implement double deflation, at least for recent years, using the Input-Output Supply and Use Tables, which are available on a fully consistent basis from 1992 onwards. These are in current price terms and play an essential role in the *current* price balancing process. The ONS has also had a programme, called the Constant Price Input Output (KPIO) programme, which has been investigating balancing in real terms, in effect double deflation (Ahmad (1999); Powell and Swatch (2002)). But so far double deflation has not been incorporated into the national accounts process. The First Report of this Review (Allsopp (2003), paragraph 6.10) recommended use of the output approach for estimating regional GDP. Adoption of double deflation would be consistent with this.

## 3. The Growth Accounting Framework[8]

The growth accounting framework is now more than fifty years old. Though it was first formalised by Solow (1957), the earliest empirical applications preceded his seminal paper (Hulten (2000)). Subsequently, the framework has been deepened by Jorgenson and his various collaborators (eg Domar (1961), Jorgenson and Griliches (1967), Hulten (1978), Jorgenson, Gollop and Fraumeni (1987), and Jorgenson (1989). This approach has now been codified in two OECD manuals (OECD (2001a) and (2001b)). Annex A sets out the approach more formally. Here we give an informal treatment.

7 The Review of Short Term Output Indicators suggested that the IoP too should bear a share of the adjustment (ONS (2000)).

8 See Annex A for a more formal derivation.

### 3.1 The aggregate framework

The starting point is the familiar aggregate growth accounting equation:

Growth of GDP = [Capital's share *times* growth of capital input]
*plus* [Labour's share *times* growth of labour input]
*plus* growth of TFP (1)

where GDP, capital and labour are all chain indices of their respective components. Thus labour input is a weighted average of the growth rates of the different types of labour, where the weights are the shares of each type in the aggregate wage bill; the shares are equal to the elasticities of output with respect to the inputs under the assumption of perfect competition. Capital input is defined as aggregate capital services, not capital stock. The treatment of capital is therefore exactly analogous to the treatment of labour, where each type of labour input is measured by the flow of labour services, ie hours worked.[9] Labour input grows *either* if hours worked increase *or* if the quality of labour increases; the latter occurs if the composition of the labour force shifts towards better paid workers (Burriel-Llombart and Jones (2004)). TFP growth is calculated as the residual.

This equation can be rearranged in per hour worked terms as

Growth of GDP per hour worked =
Capital deepening
*plus* Labour quality contribution
*plus* TFP growth (2)

where

Capital deepening = [Capital's share *times* growth of capital input per hour worked]
Labour quality contribution = [labour's share *times* growth of labour input per hour worked]

9 The important distinction between capital services and capital stock was introduced in Jorgenson and Griliches (1967) and set out theoretically in Jorgenson (1989). For further discussion, see Diewert and Lawrence (2000) and Oulton and Srinivasan (2003a).

**Building up from the industry level**

The next step is to build up the aggregate relationship of equations (1) or (2) from corresponding relationships at the industry level. Suppose we have data on the price and quantity of gross output and the prices and quantities of inputs and outputs for a set of industries covering the whole economy. These data can be used to measure the growth of TFP in each industry. For the *i*th industry:

Growth of TFP in industry *i* =
Growth of gross output of *i*
*minus* cost-share-weighted growth of capital services, labour and intermediate input (3)

We can also calculate TFP growth using prices rather than quantities, the so-called dual approach:

Growth of TFP in industry *i* =
*minus* [Growth of price of gross output of *i*
*minus* cost-share-weighted growth of prices of capital services, labour and intermediate input] (4)

Provided that the accounting system is consistent, the dual approach of (4) must yield exactly the same answer as the primal one using quantities, equation (3).[10]

The crucial link between the industry TFP rates and the aggregate TFP growth rate is provided by the concept of *Domar aggregation* (Domar (1961)):

Aggregate TFP growth rate = Domar-weighted sum of industry TFP growth rates (5)

where the *Domar weight* for industry *i* is

$$\frac{\text{Nominal gross output of industry } i}{\text{Nominal GDP}}$$

[10] At the aggregate level there is a dual analogue to equation (1) as well.

Note that the Domar weights sum to more than 1; this reflects the fact that each industry makes a double contribution to aggregate TFP, once in its own right and once through reducing the costs of industries that buy from it. Equation (5) can be shown to hold exactly if any given input (eg university-educated female workers aged 30-34) is paid the same wage in all industries. If this is not the case, then the equation for aggregate TFP growth also contains terms reflecting the reallocation of capital and labour towards or away from higher value uses (Jorgenson *et al* (1987)). But the Domar-weighted sum of equation (5) can still be regarded as the best measure of underlying productivity growth at the aggregate level. Equation (5) enables us to trace the sources of aggregate TFP growth rate to its industries of origin. Changes in aggregate TFP can be assigned either to changes in the underlying industry rates or to structural change (changes in the Domar weights).

## 4. Sustainability

Sustainability is a contentious concept that can no doubt be defined in more than one way. But the central notion behind the concept is the level of consumption that can be maintained indefinitely, without running down or using up stocks of resources, whether natural or man-made. This notion has a long history in economics. It is related to the concept of "permanent income" familiar to macroeconomists and to the concept of "real income" suggested by Hicks (1940). The modern formulation is due to Weitzman (1976), elaborated in Weitzman (1997) and (2003). It turns out that the statistical framework required for the analysis of productivity, namely growth accounting, can also be an important building block for the analysis of sustainability.

Weitzman's net domestic product, denoted by WNDP, is defined as net domestic product (NDP),[11] *measured in consumption units.* Alternatively, it is current price NDP deflated by the price index for consumption. In symbols,

$$\begin{aligned} WNDP_t &= [P_{Ct}C_t + \sum_{i=1}^{n} P_{it}\Delta K_{it}]/P_{Ct} \\ &= C_t + \sum_{i=1}^{n} p_{it}\Delta K_{it} \end{aligned} \qquad (6)$$

[11] Net national product is Weitzman's term, though net national *income* might be more appropriate. I use the term 'net domestic product' to retain the link with the national accounts and because I am neglecting net income from abroad. See Sefton and Weale (1996) for estimates of WNDP for the United Kingdom.

where $C_t$ is real consumption; $\Delta K_{it}$ is the growth of the $i$th capital stock ($i$ = 1,…,$n$) or equivalently real *net* investment in the $i$th stock; $P_{Ct}$ is the nominal price of consumption goods; $P_{it}$ is the nominal price of the $i$th type of capital; and $p_{it}$ is the relative price of the $i$th type of capital in terms of consumption goods $[= P_{it} / P_{Ct}]$.

Weitzman shows that WNDP can be considered a monetary measure of social welfare. The intuition behind WNDP is that only consumption matters for welfare. So the current level of consumption must obviously be part of the measure. In addition, net investment increases future consumption. The second term on the right hand side in equation (6) above can be interpreted as the present value of the future stream of consumption that is generated by adding to capital stocks. Alternatively, it can be interpreted as the additional amount of consumption (over and above actual current consumption) which could be enjoyed on a permanent basis, if capital stocks were just maintained rather than augmented.

Weitzman (1976) gave a more formal justification. He showed that WNDP is proportional to the yield on wealth (assuming perfect competition and no externalities). That is, it is equivalent to permanent income. Consider an economy which behaves as if it is governed by a social planner who seeks to maximise wealth, defined as the present value of the stream of real consumption, subject to technological constraints and to given initial capital stocks. Along the optimal path, Weitzman showed that WNDP is the yield on wealth, ie it is equivalent to permanent income. WNDP can therefore be considered a cardinal measure of welfare. This is important because WNDP is directly observable: only current prices and quantities enter into WNDP, while measuring wealth directly would require forecasting an infinite stream of future consumption.

It might seem at first sight that measuring WNDP is easier than measuring GDP, since the only price we need to know is the price of consumption. But this would be incorrect. WNDP requires us to measure capital stocks and to do this properly, we need to know the prices of investment goods (correctly adjusted for quality) and also depreciation rates. We could estimate WNDP at the aggregate level only. But just as in practice policy-makers and analysts are interested in tracing the sources of GDP growth, so it is likely that they would want to do the same for WNDP, if it became customary to calculate it. It can be shown that a similar kind of growth accounting decomposition, requiring the same statistical materials as for GDP, is possible for WNDP too (Oulton (2002b)).

The extent to which we can regard WNDP in practice as a satisfactory welfare measure depends on (a) the extent to which actual market prices correspond to true social values and

(b) whether or not all relevant capital stocks have been included. Under (a), we may note that the measurement of GDP also relies on market prices reflecting social values. Under (b), apart from land environmental assets are not currently included in the SNA.[12] Nevertheless, Weitzman's analysis shows us the relationship between GDP, a measure of output derived from the national accounts as currently constituted, and WNDP, a measure of sustainability, and indicates what would be required statistically in moving from one measure to the other.[13]

Despite its theoretical importance, Weitzman's NDP is not generally calculated by statistical agencies since it is not formally part of the 1993 System of National Accounts (SNA93), nor of the latter's European formulation (ESA95). In the United Kingdom for example, it is possible to derive net domestic product at 2000 basic prices from published series.[14] And the ONS publishes 'net national disposable income at 2000 market prices'. This concept equals GDP at 2000 market prices adjusted for fixed capital consumption, net income from abroad, and for gains or losses on the terms of trade. But in both these cases, investment, imports and government expenditure are valued in their own base year prices, not in consumption units. However, whether or not the ONS itself chose to publish estimates of WNDP, implementation of the growth accounting framework would enable anyone who wanted to to do so.

## 5. Barriers to Implementing the Growth Accounting Framework

Any researcher currently seeking to implement the growth accounting framework using official data runs into a number of difficulties, ranging from the mundane to deeper conceptual and measurement issues. These can be illustrated by reference to the Bank of England Industry Dataset (BEID) that did attempt to implement the framework: see Oulton and Srinivasan (2003b). The first issue is the number of industries that it is possible to distinguish, 34 in the case of the BEID. Of these, 18 fall in the production sector (including 11 in manufacturing), 3 in public services, but only 13 in private services which now accounts for half of GDP. It would have been possible to distinguish more industries in

[12] ESA95 recognised "mineral oil exploration" as a type of gross investment but depletion of oil fields is not counted as a form of depreciation.
[13] See Crafts (2002) for a discussion of some of the wider issues, including changes in life expectancy, involved in measuring real national income.
[14] This is 'gross value added at 2000 basic prices' [ABMM] *minus* 'fixed capital consumption at 2000 prices' [YBFX].

manufacturing, which accounts for less than a fifth of GDP, but not in private services. This statistical imbalance between the production and services sectors was noted in the First Report of this Review (Allsopp (2003), chapter 9).

### 5.1 Mundane difficulties

1. For analytical purposes we need long runs of data, eg 20-30 years. But these are hard to put together in practice because

- The SIC is changed at roughly 10 year intervals and earlier series are not always revised to the new basis. For example, for the Bank of England Industry Dataset (BEID), which covered the period 1979-2000, it was necessary to bridge across the 1968, 1980 and 1992 SICs.
- Some basic official series do not go back very far. For example, the official series for current price value added in communications (ONS code: QTPP) goes back only to 1985, while that for construction (ONS code: EWSX) goes back only to 1989. The official series for whole economy total weekly hours worked (ONS code: YBUS) goes back only to 1992Q2.

2. Some basic economic series are not produced by the ONS and have to be constructed out of a variety of sources. For example, hours worked is not published at the industry level. So for the BEID it was put together from unpublished data on employees by industry (from the AES/ABI surveys), grossed up for self-employment (from the Labour Force Survey), and multiplied by weekly hours worked per worker (from the New Earnings Survey).

3. There are inconsistencies between the levels of aggregation at which different series are published. For example, nominal data on sales and purchases are published in the input-output tables (also in the supply and use tables) for nowadays 123 industries. But the corresponding price indices are not published at this level, though price indices are in fact available at a much more detailed level.

4. The asset breakdown for the ONS's series for investment in fixed assets is poor. Only four types of asset are distinguished: buildings, "other machinery and equipment", vehicles, and intangibles. Software investment is included but, bafflingly, is divided half and half between intangibles and "other machinery and equipment". A much more detailed breakdown is available from the supply and use tables, but on a consistent basis only from

1992 and only in current prices. Lack of asset detail would not matter much if asset prices all rose at about the same rate, but we know this is far from being the case (see below on ICT).

### 5.2 Deeper issues

#### Output and prices in the service sector

It is widely believed that measuring output and prices in services is harder than in goods. This issue is discussed in detail in Annex B. The main problem is not the inherent difficulty of measuring service output (though for some industries there are genuine conceptual problems) but the absence of true price indices for an important part of service output. There is no equivalent for the service sector of the PPI programme for the production sector, though Corporate Services Price Indices are under development. When true price indices are absent, real output has to be measured either by deflating nominal gross output by an inappropriate price index such as RPIX (called "rough deflation" in Annex B) or by using an input indicator such as employment as a proxy for output (usually adjusted by a guesstimate of productivity growth derived from another industry group in which productivity growth is easier to measure). Use of RPIX to deflate an industry's output implies that labour productivity is assumed to be growing at the same rate as in the sectors to which RPIX properly applies (consumer goods and services). Whether input indicators or rough deflation is employed, either way the productivity growth rate is being assumed, not measured.

How large then is the proportion of GDP where productivity growth rate is assumed, not measured? For the public sector, this amounted to about 18% of GDP prior to the changes introduced in the 1998 Blue Book (the partial adoption of ESA95). For 1986 onwards, this figure is now reduced to about 9% of GDP, the remainder being covered by output indicators. (Output measurement in the public sector is to be covered by a separate inquiry (the Atkinson Review)). For private services, the proportion where productivity growth is assumed not measured comes almost entirely from sections J (Financial intermediation) and K (Real estate, renting and business activities) of the 1992 SIC and amounts to about 13% of GDP.

The contribution of an industry to GDP growth is the growth of industry output multiplied by the share of that industry in nominal GDP. For finance and insurance, even these shares are problematic. The contribution of the financial sector to GDP growth is about half what it otherwise would be, because of a negative item called the "Adjustment for financial services". This arises because profits in the rest of the economy are measured gross of interest payments to financial firms, while the profits of financial firms include their interest receipts. To avoid double counting, the "Adjustment for financial services" is required. Under ESA95, profits in the non-financial sector are reduced by the amount that firms pay for the services of financial intermediation, so the non-financial sector's weight in the economy will be somewhat lower and the financial sector's weight will be considerably higher (Begg *et al* (1996)). However, this part of ESA95 has not as yet been implemented in the UK. In insurance, the weight is measured by premiums net of claims as a proportion of GDP and this can be negative. It was in fact negative for non-life insurance in 1990 and this meant that while 1990 weights were being used, any growth in the non-life insurance industry had the effect of reducing GDP.

**Capital**

In most countries, including the UK, capital stocks are estimated by the Perpetual Inventory Model (PIM). That is to say, for each type of asset the stock is estimated by cumulating flows of gross investment, then subtracting retirements at the end of what is believed to be the service life, and finally (in the case of so-called "net stock" estimates) allowing for depreciation on older but still surviving assets. Empirically, estimates of capital stocks are bedevilled by two major areas of uncertainty. The first relates to the service lives of assets. Second, there is the choice of the appropriate pattern of depreciation: should we use for example geometric, hyperbolic, "light bulb" (also called "one-hoss shay"), or straight-line (the ONS uses the last of these)? [15]

Little is known about the service life of assets in the United Kingdom. Till 1983, the official estimates of the capital stock were based on the work of Redfern (1955) and Dean (1964); see also Griffin (1976). Their estimates of services lives were in turn based on the life lengths used by the Inland Revenue for tax purposes, from a period before the tax system encouraged business firms to depreciate assets more rapidly in their accounts than would be justified by true economic lives (Inland Revenue (1953)). In 1983, the Central Statistical Office (the predecessor of the ONS) revised the service lives downwards, citing (unpublished) "discussions with manufacturers" as its authority (Central Statistical Office (1985), page 201).

[15] Estimates of capital stocks are needed for balance sheet analysis but for measuring productivity we need estimates of capital *services*: the distinction between these two concepts of capital is extensively discussed in OECD (2001b) and in Oulton and Srinivasan (2003a). At the moment, the ONS publishes only stock estimates as official statistics. But the empirical requirements for estimating stocks and services are very similar, so I do not labour the distinction here.

Following a report commissioned from the National Institute of Economic and Social Research (Mayes and Young (1994)), this reduction was reversed. But at the same time two other changes were introduced. First, a new category of asset, "numerically-controlled machinery", was introduced into the ONS's Perpetual Inventory Model (PIM) of the capital stock. This type of asset is assumed to have only 40% of the service life of other types of plant and machinery (Vaze *et al* (2003)). Second, some plant and machinery is assumed to be scrapped prematurely; the rate of scrapping is assumed to be related to the corporate insolvency rate, which has been on a rising trend since the 1970s.

Clearly then the empirical evidence for service lives in the United Kingdom is weak.[16] This judgment is confirmed by the OECD. In its capital stock manual (OECD (2001b), Appendix 3) it lists four countries (not including the United Kingdom) for which service lives "appear to be based on information that is generally more reliable than is usually available for other countries": the United States, Canada, the Czech Republic, and the Netherlands. It is noteworthy that in each of these countries service lives are lower than assumed in the United Kingdom for both buildings and plant and machinery (at least before the effects of premature scrapping are considered).

The empirical evidence for depreciation rates in the UK is even weaker that that for service lives. The most extensive research on depreciation has been done for the United States, though even here the evidence is patchy and much of it is out of date.[17] Consequently, most independent researchers apply the US rates to the UK, possibly adjusting for assumed differences in service lives between the two countries.

No international consensus has yet been reached on the appropriate assumption to make about depreciation (OECD (2001b)). In practice, a variety of approaches has been used. In the United States, the Bureau of Labor Statistics (BLS) produces estimates of the "productive capital stock", ie aggregate capital services, that assume a hyperbolic pattern of decay rates, arguing that these are more realistic than geometric decay. The Australian Bureau of Statistics follows a similar approach (Australian Bureau of Statistics (2001)). But this pattern is not based on any strong empirical evidence. Statistics Canada on the other hand uses geometric decay. The BEA does not estimate capital services but does produce wealth measures of the capital stock using geometric depreciation (Fraumeni (1997); Herman (2000)). Academic researchers have tended to assume geometric depreciation, eg Jorgenson

[16] Knowledge may be improved if the results of the ONS's capital stock survey are published (West and Clifton-Fearnside (1999)). However, the survey was mainly confined to manufacturing and has now been discontinued.

[17] The U.S. evidence is reviewed in Fraumeni (1997); see also Oulton and Srinivasan (2003a).

and his various collaborators in numerous studies (eg Jorgenson *et al* (1987); Jorgenson and Stiroh (2000a) and (2000b)). By contrast the ONS in common with many other national statistical agencies employs straight-line depreciation in their "net stock" estimates.

Recently, the ONS has revised the PIM so that the underlying data are now consistent with the national accounts and there are also some improvements in the model (Vaze *et al* (2003)). An experimental index of capital services has also been published (Vaze (2003)). But significant weaknesses remain. First, as just noted, the estimates are not based on firm empirical evidence about service lives or depreciation rates. Second, the underlying investment data are only disaggregated into a small number of asset types, currently nine:

1. Industrial and commercial buildings
2. Dwellings
3. Plant and machinery (excluding items 4 and 5)
4. Computer- and numerically-controlled plant
5. Computers
6. Vehicles
7. Artistic originals
8. Mineral exploration
9. Software

By contrast, the US capital stock estimates are based on more than 50 asset types (see below). Lack of disaggregation has a large impact on the estimates when the prices of assets are changing rapidly relative to the average (Oulton and Srinivasan (2003a)). This is the case of course with computers, so separating them out is a step in the right direction. But the effect of doing so is greatly reduced in the revised UK PIM since the same deflator is employed for computers as for plant and machinery as a whole. Computers are not the only example of assets with rapidly changing relative prices. Others are telecommunications equipment and numerous other hi-tech products where semiconductors are important components.

**ICT**

Whatever one thinks about the New Economy, the measurement of ICT outputs and inputs is likely to remain a crucial issue for many years. It seems likely that there are differences between Europe and the US in the way that the same methodology, the 1993 SNA, is being applied and even differences between European countries (Lequiller (2001)). However, there is no doubt that at the moment the US statistical agencies are considerably in advance of the ONS in the measurement of ICT, though to be fair the rest of the EU generally lags as far behind. It has been known for some while that the evolution of official price indices for computers differs widely across countries. Most observers have judged the differences to be much too great to be plausible reflections of genuine differences between countries, given that computers are widely traded internationally (Schreyer (2002)). Outside analysts invariably use the US price (adjusted for exchange rate changes), whichever country they are studying. Other countries' (including the UK's) domestic PPIs for computers have up to now not carried conviction.

The correct measurement of ICT is of critical importance to the analysis of productivity growth, since applying US methods and price indices to ICT raises the growth rate of the UK's GDP and also raises substantially the contribution of capital to economic growth, while reducing that of TFP; (Oulton (2001b) and (2002a); Oulton and Srinivasan (2003b); see also O'Mahony and van Ark (2003)).

One reason that the US is statistically in advance of the UK is simply that it started earlier. The officially-sponsored study which led to the incorporation of a hedonic price index for computers into the US NIPAs was Cole *et al* (1986). Ironically, this was preceded by a pioneering study by Stoneman (1976) for the UK. Stoneman's analysis suggested, again on the basis of hedonic analysis, that the UK's official PPI for computers was overstating price change by some 10 percentage points per annum. But this work was ignored and only recently has the ONS adopted hedonic methods for the PPI for computers (Ball and Allen (2003)).

Computer prices are important but they are far from the only issue. Concentration on computer prices may have masked more pressing problems in software. In the US software investment is much larger than investment in all types of computer. So it seems we should be at least as concerned with measuring the level and growth of software stocks as with those of computer stocks. But here we have a puzzle. In the UK the official series for current price software investment shows it to be much smaller than computer investment. In earlier work done at the Bank of England (Oulton (2001b)), I questioned this, arguing that the 1991 survey to which up to now the official series has been pegged yields quite a different conclusion. The UK also appears to be out of line with other European countries. Lequiller (2001) has compared France with the US. He finds that the ratio of software investment to IT equipment investment was about the same in the two countries in 1998 (his page 25 and chart 5). He also finds that the ratio of software investment to intermediate consumption of IT services is substantially lower in France than in the US (page 26-27). This ratio is exceptionally high in the US, but equally his chart 6 shows that it is exceptionally low in the UK. In fact, the reported UK ratio is substantially lower than in France, the Netherlands, Italy and Germany. These considerations led me to conclude that the level of software investment in the UK should be multiplied by a factor of at least three, adding about 1% to the level of GDP at the end of the century. There is now an opportunity to settle this issue since the results from the recent SERVCOM survey are now available, though not as yet fully published (Prestwood (2001)).

An even bigger gap in our statistical knowledge relates to software prices. There is no official price index for software in the UK and so far as I am aware no programme to create one. (The US has a price index for pre-packaged software, one third of the total, but as yet no price indices for the other two thirds, custom and own account software: see Parker and Grimm (2000)). In the UK national accounts, software investment is deflated by a price index based on computer programmers' wages, with a guesstimated allowance for programmers' productivity.

We also have no data for the UK on the average service lives of computers and software. A survey focused on ICT service lives, perhaps concentrated on the industries which are the heavy users (wholesale and retail trade; finance and business services), would seem to be a relatively straightforward way of making progress here.

**Other measurement issues**

1. Computer and software prices are not the only areas of concern even in ICT. It seems likely that measuring prices for many types of hi-tech equipment, such as telecoms and medical equipment, requires a similar approach. The matched models method commonly used by national statistical agencies, including the ONS, may yield systematically biased results, though the direction of bias is not necessarily upwards. In the US, it is expected that hedonic methods will be applied more and more widely (Moulton (2001)).
2. Technical progress in semiconductors appears to lie at the heart of technical progress in computers, telecommunications equipment, and many other types of machinery. The quality-adjusted prices of semiconductors have been falling extraordinarily rapidly; from 1995-2000,

the price of integrated circuits (microprocessors and memory chips) fell at between 36 and 56% per annum in the US; microprocessor prices fell at over 50% per annum (Aizcorbe *et al* (2000; Aizcorbe (2002)). Semiconductors are an intermediate good, so on the expenditure side they largely drop out, their effect showing up in the prices of the goods in which they are incorporated. But they still have some effect on GDP(E) unless the semiconductors trade balance is zero. Even a small trade balance can have a significant effect on GDP because of the extreme size of the price change. On the output side there is the potential for a much larger effect since the UK semiconductor industry is not negligible. So getting the semiconductor price right is important.

3. The 1993 SNA, from which ESA95 derives, treats expenditure on software as a form of investment for the first time. But strangely, it continues to regard R&D expenditure as a current expense (intermediate consumption). This makes little sense. It would be highly desirable for the ONS to produce estimates of R&D expenditure for each industry on the same basis as other types of investment; at the moment published R&D spending is only broken down into 11 industry groups (Morgan (2003), Table 8). Then researchers could estimate R&D stocks and if desired incorporate these into the growth accounting framework. There is no need to wait until some future revision of the SNA mandates that R&D be treated as an investment.

## 6. Economic Statistics in the United States

The feasibility of employing the growth accounting framework can be assessed in part by looking at what other statistical agencies do. Here I concentrate on practice in the United States.

The U.S. Bureau of Economic Analysis (BEA) publishes estimates of value added in current prices ("Gross Product Originating" or "GDP by industry") for 72 industries covering the whole economy; the sum of value added across industries, plus a statistical discrepancy, equals GDP. The BEA also estimates chained-volume indices of the growth of each industry's real value added; these are calculated by double deflation (Yuskavage (1996)). Like the ONS, the BEA believes the expenditure estimate of GDP, both in current prices and in chained volume terms, to be more reliable than the output one.[18] Its reasons were stated by Yuskavage (1996) as follows:

> "The amount of detailed expenditures data that are available for weighting the price indexes used in calculating GDP [ie, GDP(E)] is greater than that for gross outputs and intermediate inputs used in calculating GPO [ie, GDP(O)], and little information is collected annually on the composition of inputs or of non-manufacturing outputs."

To make the two estimates of GDP agree, the BEA adds a statistical discrepancy to the output estimate. From 1995-2001 this has ranged between plus 0.4% and minus 1.4% of current price GDP(E), averaging about minus 0.3%. In growth rate terms, there is also a statistical discrepancy which averaged virtually zero over the period 1978-94, though ranging from –0.9 to +1.2 percentage points per annum in individual years (Yuskavage (1996), Table 2). The discrepancy is believed to be located in the private sector, not the government. Unlike the ONS, the BEA does not constrain the private sector growth rates of output so that the aggregate of private sector and government growth equals that of GDP(E), but instead is content to reconcile the two estimates of GDP growth by adding a statistical discrepancy.

The BEA also publishes estimates of the capital stock held by broad sectors (U.S. Department of Commerce (1999); Herman (2000)). These are calculated by the perpetual inventory method. In the private sector some 28 types of equipment are separately distinguished, plus 21 types of non-residential, and seven types of residential structures. For nearly all asset types depreciation is geometric with the rates deduced from studies of second hand asset prices (Fraumeni (1997); Oulton and Srinivasan (2003a)).

The U.S. Bureau of Labor Statistics (BLS) first published estimates of TFP growth in 1983, covering the period 1948-81. (The BLS uses the term multifactor productivity (MFP), but the concept is the same as TFP). Currently it publishes TFP growth estimates for broad aggregates like private business and manufacturing and also at a more detailed level, eg for 20 2-digit manufacturing industries and for 108 3-digit manufacturing industries. In addition, it publishes comparisons between US, German and French TPF growth. The more detailed estimates employ the so-called KLEMS approach: the growth of real gross output (not value added) is accounted for by the growth of capital (K), labour (L), energy (E), materials (M) and business services (S). Capital input is measured by aggregate capital services, not by the capital stock. The capital services estimate is built up from the same underlying data as the BEA's stock estimates, though the BLS assumes that the services of capital assets decay

[18] Confusingly, it calls the output side estimate the income estimate.

hyperbolically, not geometrically. Labour input is measured by hours worked, adjusted for qualifications, age and sex. Inputs of energy, materials and services are measured by deflated purchases, at a detailed level.

## 7. Conclusions: the Need for Joined-Up Statistics

Growth accounting provides, I would argue, a very fruitful way of looking at the changing structure of the economy, and assessing the contribution of each sector or industry to the whole. It also provides a very useful framework for the collection of economic statistics. This approach might be called "joined-up statistics". The advantages of this approach have long been recognised in the US, where the BEA and the BLS routinely supply the kind of productivity statistics for which I am arguing here.

At the moment, the ONS does not provide this service to users, nor does it supply the raw materials that would enable outsiders readily to create their own statistics. What of the future under current plans? The ONS does have a productivity programme, but so far it has concentrated on labour productivity and progress has been slow. The Corporate Services Prices programme promises one day to improve the measurement of prices and real output in services but again progress has been slow and the hardest sectors have yet to be covered. The ONS does have a programme for measuring real value added by double deflation, the Constant Price Input Output (KPIO) programme, but this has as yet not been incorporated into the national accounts process. The Capital Stocks Survey might have increased our knowledge of asset lives, but this has been discontinued with only part of manufacturing covered.

In my view, the ONS ought to adopt the growth accounting approach as the framework for their economic statistics. This is just an extension of the SNA which lies behind the national accounts and is now well sanctioned by international organisations, eg the OECD and the European Commission. As a part of this, the ONS should expand its input-output programme and integrate it with their ongoing PPI and CSPI programmes, ie reactivate their KPIO programme. This would enable them in due course to produce estimates of double deflated value added. The latter would in turn increase the coherence of the national accounts and greatly assist in the analysis of productivity.

In summary, the analysis above suggests the following action programme for the ONS in order to implement fully the growth accounting framework:

1. Improve the measurement of real output in the services sector by completing the Corporate Services Price Index programme, so that it covers the hard-to-measure industries like banking, insurance and business services (particularly legal, accounting and consultancy services).

2. Rebalance coverage of the national economy so as to allow greater disaggregation of private services. This might largely follow from success under point 1.

3. Introduce double deflation into the national accounts. That is, continue with and complete the "constant price input output" (KPIO) programme and make it an integral part of the national accounts process. The First Report of this Review (Allsopp (2003), paragraph 6.10) recommended use of the output (or production) approach for estimating regional GDP. Adoption of double deflation would be consistent with this.

4. Widen the use of hedonic methods for price measurement in hi-tech areas where such methods are likely to make a substantial difference, eg software, telecommunications, and semiconductors.

5. Commission or carry out research on the service lives of different types of capital and on their patterns of depreciation.

6. Commission or carry out research on the level of software investment, to establish whether the very large difference between the UK and the US is correct or an artefact.

7. Integrate statistics on employment (and better still, hours worked), output, prices, investment, and R&D so that all are published on a common industrial breakdown. Maintain the continuity of this breakdown even when the SIC is changed.

## Annex A: The Growth Accounting Framework

### A.1 Accounting relationships

We start by defining some accounting relationships at the industry level. For simplicity we assume a closed economy but the argument is easily extended to an open one. Value added in current prices in the $i$th industry is:

$$p_{iV}V_i = p_i Y_i - \sum_{j=1}^{n} p_j X_{ij}, \qquad i = 1,...,n \tag{A.1}$$

where $Y_i$ is real gross output, $X_{ij}$ is the real quantity of output supplied to industry $i$ by industry $j$, and $p_i$ is the price of industry $i$'s output. Here we have split up nominal value added conceptually into the product of the price of value added $(p_{iV})$ and the quantity $(V_i)$.

A Divisia index of the growth of real value added (Hulten (1973)) is then given by

$$\hat{V}_i = \left(\frac{p_i Y_i}{p_{iV} V_i}\right)\hat{Y}_i - \sum_j \left(\frac{p_j X_{ij}}{p_{iV} V_i}\right)\hat{X}_{ij}, \quad i = 1,...,n \tag{A.2}$$

Here a "hat" denotes a growth rate or more precisely a logarithmic derivative with respect to time, eg $\hat{V}_i = d\log V_i / dt$. Equation (A.2) gives the double deflated growth rate of value added.

Gross output can be sold either to final demand ($E_i$) or for intermediate use:

$$Y_i = E_i + \sum_j X_{ji}, \qquad i = 1,...,n \tag{A.3}$$

We define GDP from the output side, GDP(O), as aggregate nominal value added:

$$p_V V = \sum_{i=1}^{n} p_{iV} V_i \tag{A.4}$$

where $V$ is aggregate real value added and $p_V$ is the price of aggregate value added (ie the price of GDP).

Turing to the expenditure side, GDP(E) in current prices is

$$p_E E = \sum_{i=1}^{n} p_i E_i \qquad \text{(A.5)}$$

where $E$ is real GDP from the expenditure side and $p_E$ is the corresponding price index. The first task is to check that GDP(O) equals GDP(E) in current prices.[19] Solving (A.3) for $E_i$, multiplying by $p_i$ and summing:

$$\sum_i p_i E_i = \sum_i p_i Y_i - \sum_i p_i \sum_j X_{ij} = \sum_i p_i Y_i - \sum_i \sum_j p_j X_{ij}$$
$$= \sum_i \left[ p_i Y_i - \sum_j p_j X_{ij} \right] = \sum_i p_{iV} V_i \qquad \text{(A.6)}$$

Hence

$$p_V V = p_E E \qquad \text{(A.7)}$$

**A.2 The growth rate of real GDP**

In continuous time, the growth of nominal value added $(p_V V)$ is the growth of the price of value added plus the growth of the quantity of value added: $\hat{p}_V + \hat{V}$, and this must equal the growth rate of the right hand side of (A.4). By totally differentiating (A.4) with respect to time, and collecting terms, we can define Divisia price and quantity indices of value added as:

$$\hat{p}_V = \sum_{i=1}^{n} s_i \hat{p}_{iV}$$

$$\hat{V} = \sum_{i=1}^{n} s_i \hat{V}_i$$

where the $s_i$ are the (observable) shares of each industry in aggregate nominal value added:

[19] Typically, output is measured at basic prices and expenditure at purchasers' prices, but we are abstracting from taxes on expenditure here.

$$s_i = \frac{p_{iV} V_i}{p_V V}$$

The growth rates of real GDP and of the price of GDP from the expenditure side are given by

$$\hat{p}_E = \sum_{i=1}^{n} w_i \hat{p}_i$$
$$\hat{E} = \sum_{i=1}^{n} w_i \hat{E}_i \qquad \text{(A.8)}$$

where the $w_i$ are the shares of each type of final output in the total:

$$w_i = \frac{p_i E_i}{p_E E}$$

We now show that $\hat{E} = \hat{V}$ and consequently, from equation (A.7), that $\hat{p}_E = \hat{p}_V$. First note that the growth of any component of final demand can be written (by differentiating (A.3) logarithmically with respect to time) as:

$$\hat{E}_i = \left(\frac{Y_i}{E_i}\right)\hat{Y}_i - \sum_j \left(\frac{X_{ji}}{E_i}\right)\hat{X}_{ji}, \qquad i = 1,\ldots,n \qquad \text{(A.9)}$$

Plugging this into the definition of the growth rate of GDP(E), equation (A.8):

$$\hat{E} = \sum_i \left( \frac{p_i E_i}{p_E E} \right) \hat{E}_i = \sum_i \left( \frac{p_i E_i}{p_V V} \right) \hat{E}_i \qquad \text{(using (A.7))}$$

$$= \sum_i \left( \frac{p_i Y_i}{p_V V} \right) \hat{Y}_i - \left( \frac{1}{p_V V} \right) \sum_i p_i E_i \sum_j \left( \frac{X_{ji}}{E_i} \right) \hat{X}_{ji} \qquad \text{(using (A.9))}$$

$$= \sum_i \left( \frac{p_i Y_i}{p_V V} \right) \hat{Y}_i - \left( \frac{1}{p_V V} \right) \sum_i \sum_j p_i X_{ji} \hat{X}_{ji}$$

$$= \sum_i \left( \frac{p_i Y_i}{p_V V} \right) \hat{Y}_i - \left( \frac{1}{p_V V} \right) \sum_j \sum_i p_j X_{ij} \hat{X}_{ij} \qquad \text{(interchanging summation indices)}$$

$$= \sum_i \left( \frac{p_{iV} V_i}{p_V V} \right) \left( \frac{p_i Y_i}{p_{iV} V_i} \right) \hat{Y}_i - \left( \frac{1}{p_V V} \right) \sum_i \sum_j p_j X_{ij} \hat{X}_{ij} \qquad \text{(interchanging order of summation)}$$

$$= \sum_i \left( \frac{p_{iV} V_i}{p_V V} \right) \left( \frac{p_i Y_i}{p_{iV} V_i} \right) \hat{Y}_i - \sum_i \left( \frac{p_{iV} V_i}{p_V V} \right) \sum_j \left( \frac{p_j X_{ij}}{p_{iV} V_i} \right) \hat{X}_{ij}$$

$$= \sum_i \left( \frac{p_{iV} V_i}{p_V V} \right) \left[ \left( \frac{p_i Y_i}{p_{iV} V_i} \right) \hat{Y}_i - \sum_j \left( \frac{p_j X_{ij}}{p_{iV} V_i} \right) \hat{X}_{ij} \right]$$

$$= \sum_i \left( \frac{p_{iV} V_i}{p_V V} \right) \hat{V}_i \qquad \text{(using (A.2))}$$

$$= \hat{V}$$

Hence also from (A.7)

$$\hat{p}_E = \hat{p}_V$$

We can therefore pick a common reference period in which we set $p_V = p_E = 1$. Hence in the reference period $V = E$, from (A.7). But since the growth rates are equal, it follows that $p_V = p_E$ and $V = E$ in all periods, not just the reference period.

The usual alternative to using double deflated value added is to proxy it by real gross output, with the growth of GDP(O) still being estimated using value added weights ("single deflation"). It is clear from equation (A.2) that this will not in general yield the same answer; in fact it will only do so if real gross output is growing at the same rate as real intermediate input. So when single deflation is employed the growth of GDP(O) will not in general equal that of GDP(E).

**A.3 The growth of TFP**

The production function for industry $i$ is:

$$Y_i = f^i(K_i, L_i, X_{i1}, X_{i2}, \ldots, X_{in}, t)$$

where $K_i$ is capital and $L_i$ is labour used by the $i$th industry. Here we assume just one type of capital and one type of labour but there is no difficulty in extending the argument to many types. TFP growth ($m_i$) is defined as the rate at which the frontier is shifting outwards, i.e. the rate at which output is growing with inputs held constant:

$$m_i = \partial \log Y_i / \partial t$$

As is well known, under the assumptions of perfect competition and constant returns to scale, we can measure TFP growth in the $i$th industry by

$$m_i = \hat{Y}_i - \left(\frac{p_K K_i}{p_i Y_i}\right)\hat{K}_i - \left(\frac{p_L L_i}{p_i Y_i}\right)\hat{L}_i - \sum_j \left(\frac{p_j X_{ij}}{p_i Y_i}\right)\hat{X}_{ij}, \qquad i = 1, \ldots, n \quad \text{(A.10)}$$

Here $p_K$ is the rental price of capital and $p_L$ is the wage rate of labour. We also have the accounting identity that the value of output equals returns to the inputs (including profit):

$$p_i Y_i = p_L L_i + p_K K_i + \sum_j p_j X_{ij}, \qquad i = 1, \ldots, n$$

Differentiating both sides of this identity and using (A.10),

$$m_i = -\left[ \hat{p}_i - \left( \frac{p_K K_i}{p_i Y_i} \right) \hat{p}_K - \left( \frac{p_L L_i}{p_i Y_i} \right) \hat{p}_L - \sum_j \left( \frac{p_j X_{ij}}{p_i Y_i} \right) \hat{p}_j \right], \qquad i = 1, ..., n \qquad \text{(A.11)}$$

Equation (A.11) shows the dual method of estimating TFP growth, employing prices instead of quantities. In principle, it yields exactly the same answer as the primal method of equation (A.10) provided that the statistics of prices and quantities are consistent with each other, ie that the accounting identity is satisfied.

At the aggregate level, TFP growth (the Solow residual) is defined by

$$m = \hat{V} - \left( \frac{p_K K}{p_V V} \right) \hat{K} - \left( \frac{p_L L}{p_V V} \right) \hat{L} \qquad \text{(A.12)}$$

where $K = \sum_i K_i$ and $L = \sum_i L_i$. Under the assumptions of perfect competition and constant returns to scale, the Solow residual measures the rate at which the aggregate production possibility frontier is shifting out (Hulten (1978)). The relationship between the industry and the aggregate TFP growth rate is given by:

$$m = \sum_i \left( \frac{p_i Y_i}{p_V V} \right) m_i \qquad \text{(A.13)}$$

*Proof.* Substitute from (A.10) into (A.13) and use (A.2).

Here $p_i Y_i / p_V V$ is the Domar weight for industry *i*. This result assumes that a given input is paid the same price whichever industry it is employed in. If this is not the case, then the relationship between the aggregate TFP growth rate and the industry ones is more complex, involving reallocation effects (Jorgenson *et al* (1987)).[20]

Finally, the Divisia index numbers derived above assume continuous time. In practice, index numbers must be estimated in discrete time, where chain indices are the empirical counterpart to Divisia ones. This means that the attractive duality between index numbers for prices and for quantities may have to be given up. For example, if both price and quantity indices are chained Laspeyres, then the accounting identities will not be satisfied. The

[20] See Oulton (2001b) for further discussion and also on the relationship between industry-level TFP on a value added basis as opposed to (as here) on a gross output one.

accounting identities can always be satisfied if price indices are defined as implicit deflators, but then the price indices may lack some desirable properties.[21]

## Annex B: The Measurement of Output and Prices in the Service Sector

### B.1 Introduction

The purpose of this Annex is to describe the methods currently used by the Office for National Statistics for measuring real gross output in services and to give some indication of their accuracy, insofar as this is possible.[22]

Measuring output and prices in services is widely believed to be more difficult than in goods. As the share of services in output is rising, there is a risk that the quality of the national income statistics could fall (Griliches (1994)). The Office for National Statistics measures output in constant prices in a large number of industries as part of its programme for constructing an estimate of GDP in constant prices from the output side. Table 1 lists the ten sections of the 1992 Standard Industrial Classification (SIC92) which cover the service sector. Of these ten, three fall largely within the public sector (L, M and N). These accounted for 18% of GDP in 1995. The other seven sections (G-K, O and P) may be broadly described as market services and accounted for 52% of 1995 GDP.[23] So services in total accounted for 70% of GDP.

The measurement of real output is of course intimately linked to that of prices. The ONS has two large price gathering programmes covering retail prices (the RPI) and producer prices (the PPI). Wherever possible, the ONS tends to use current price gross output deflated by an appropriate price index to measure real output. But one of the difficulties it faces is that for many services no price data are currently collected or even exist. For example, for most services provided by the government, no price is charged. But in addition, the PPI only cover goods and very few prices are collected covering corporate services (services provided by one set of businesses to another set). This sector now accounts for nearly a quarter of

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21 Eurostat has decided that volumes should be measured by chain-weighted Laspeyres indices, so the corresponding implicit deflator is chain-weighted Paasche. The US NIPAs employ Fisher quantity indices, which means that the corresponding implicit deflator is also Fisher.

22 See OECD (1987) for a general survey of methods.

23 The utilities (electricity, gas and water) are classified to the production sector, although in the RPI their products are counted as services.

GDP. A third major programme of price collection, which will lead eventually to a Corporate Services Price Index, is now underway but is currently far from complete (Skipper (1998); Palmer (2000)).

The next section discusses the different ways in which real output is measured in practice. Then section 3 considers the effect of some current or forthcoming methodological improvements. Section 4 looks at some conceptual problems which affect the measurement of service sector output, including single deflation bias which is discussed more fully in the Appendix. Section 5 considers the likely size of any errors of measurement and section 6 concludes.

**B.2 Methods of measuring gross output**

The ONS uses four methods to estimate output in constant prices (Sharp (1998)). These may be termed:

1. Input indicators
2. Rough deflation
3. Output indicators
4. Precise deflation

*1. Input indicators* Output is measured by input, eg numbers employed or the wage bill deflated by an index of earnings. The deflated wage bill is better since it allows for changes in the skill mix, but it is still only a measure of input, not output. Frequently, the input measure is adjusted by an assumed productivity growth rate.

An example of this method is Libraries, archives and museums (925). Here output is measured (mostly) by the number of local authority employees in these activities, adjusted for trends in local authority wages and salaries in constant prices. In this case, no allowance for productivity growth is made.

Private services industries where productivity-adjusted employment is used as the output measure accounted for 3% of GDP in 1990, down from 6% in 1980 (Sharp (1998)). But the productivity adjustment is also applied to industries where rough deflation is the method and these form a much larger proportion of GDP.

*2. Rough deflation* I call it rough deflation when turnover is deflated by a price index which is not appropriate to the industry. For example, in most of Section K (Real estate, renting and business activities) output is measured by turnover deflated partly by the RPIX and partly by the earnings index for this sector, the latter adjusted for assumed productivity growth. The reason is that no true price indices currently exist for most of this sector, so the implicit assumption is made either that prices rise at the same rate as the RPIX or that they rise at the same rate as the productivity-adjusted earnings index.

How is the assumed productivity growth rate derived? "The present method of assessing productivity change in the [private] service industries is to compare the output and employment series for all services industries where employment is NOT used as an output proxy. A productivity adjustment is calculated from this comparison which is then applied to those services industries where employment is used as an output proxy." (Sharp (1998), page 14, capitalisation in original). In other words, the ONS calculates productivity growth for services industries where it thinks that this can be done reasonably well (in practice, hotels and restaurants, and transport and communications) and applies the resulting estimate to sectors where productivity cannot be calculated, primarily to industries within finance and business services.[24] An overall cap of 4% p.a. is placed on the assumed rate.

*3. Output indicators* An output indicator is a quantity or volume measure which is assumed to be representative of (part of) an industry's output. Usually several are employed for a particular industry, weighted together by each indicator's share in costs or revenues. For example, the output of the postal service (6411) is a weighted average of 11 output indicators, of which the two with the largest weights are the numbers of 1st class and 2nd class letters.

*4. Precise deflation* I use this term when turnover has been deflated by an index which is fully appropriate to the industry. For example, the output of "Hairdressing and other beauty treatment" (9302) is turnover deflated by the RPI for hairdressing. I also use the term when turnover is deflated by the implicit deflator for the relevant category of consumers' expenditure or when deflated consumers' expenditure is the output measure. In the case of

[24] A complication is that the adjustment is also based on the relationship between that part of output in these sectors which the ONS considers can be measured and employment. For example, in banking part of output is deflated loans and deposits. This is then compared with the whole of employment in banking (since the ONS does not know what proportion of employment is related to this part of banking output). The productivity adjustment estimated in this way is then applied, amongst other industries, to the part of banking output represented by banking employment.

retail trade, the output measure is the volume of sales which is based on detailed deflation by components of the RPI. In all these cases, appropriate components of the RPI are being used as deflators. In the case of wholesale trade, the appropriate producer price index (PPI) is generally employed and this too is classed as precise deflation. Finally the small number of cases where the new Corporate Services Price Indices (see below) are used to deflate turnover are also classed as precise deflation (eg Freight transport by road, 6024).

"Precise deflation" does not mean that the output measure is necessarily accurate. That of course depends on the accuracy of the underlying price indices. Even if the indices are perfect, there may be conceptual problems in interpreting the meaning of the results (see below).

Frequently, several methods are used simultaneously in a given industry. For example, the output of banking (6511 & 6512/1) is measured using a combination of input indicators, output indicators, and rough deflation. The input indicator is a head count of employees in Great Britain, adjusted for assumed productivity growth, which receives a weight of 23%. The quantity indicators are the number (not the value) of clearings — credits and debits — with a weight of 13%. The third element is the stocks of loans and deposits, deflated mostly by the RPIX, with a weight of 64%. This last element is an example of rough deflation. Presumably, in addition to the ability to transmit and receive funds (measured by clearings), bank customers receive a flow of services proportional to the stock of loans or deposits but the price of such services is not measured. Hence the unknown price is assumed to rise at the same rate as the RPIX.

Precise deflation (ie deflation by true price indices) is usually argued to be theoretically the best method. But output indicators may be a reasonable, practical alternative when the product is fairly homogeneous and the indicators are comprehensive. This is the case with the postal service where the indicators correspond well with the main services provided, including as they do different qualities of service (eg 1st and 2nd class letter post). Similarly, with freight transport, tonne kilometres may be a reasonable measure, especially when broken down by type of commodity carried,[25] although obviously this will not capture dimensions like reliability, punctuality and frequency. Outside of services, quantity indicators are used to measure output in gas and water (section E) and in mining and quarrying (section C). In manufacturing, constant price output is measured in nearly all cases by nominal gross output deflated by the appropriate PPI.

[25] For rail transport, the ONS uses a breakdown into coal and coke, iron and steel, and "other".

**The relative importance of the different methods**

Table 1 shows the proportions of each service sector's output which were estimated by the four different methods, prior to the methodological changes made in the 1998 Blue Book. This table uses an earlier version of the ONS's methodological guide (Sharp (1998)), which has subsequently been revised in the light of the 1998 changes (Sharp (2003)).[26] In 1995 prices, services (excluding the utilities) accounted for 74% of GDP.[27] Overall, 44% of service output (30% of GDP) is estimated by precise deflation, 16% by rough deflation, 11% by output indicators and 29% by input indicators. But the shares of each method differ widely between the sectors.

In sections G-I, O and P, precise deflation is used to measure 70-100% of output. (The term "precise deflation" may give a misleading impression of accuracy in hotels and restaurants and in transport since use of the RPI is strictly only correct when households are the customers. Some of the output is in fact sold to business.) But precise deflation is not used at all in the public sector (sections L-N) and plays a much smaller role in finance and business services (J and K).

Output indicators play a small role overall but account for around a quarter of output in trade, transport and communications, and finance (sections G, I and J).

Input indicators are shown as dominating in the public sector (L-N) but the 1998 Blue Book introduced some important changes (see section 3 below). In health, education and social security, output indicators are now employed in their place. These changes affected about half of output in the public sector; this proportion has now risen to about 70%. But they have only been carried back to 1986, so the earlier methodology is still relevant.

45% of output in section K (Real estate, renting and business activities) is shown as precisely deflated. But this is rather misleading since nearly all of the precisely deflated part is rent arising from the letting of dwellings (counted as part of Division 70, Real estate activities). And most of this is the imputed rent of owner occupiers. "Business activities"

[26] The 2003 version became available too late to be employed here, but doing so would probably not change the picture much.

[27] This total is gross of the so-called "Adjustment for financial services", equal to 4.02% of GDP in 1995. Under the 1968 SNA, income earned by financial institutions from the difference between borrowing and lending rates is treated as intermediate consumption purchased by a fictitious industry. Since profits in other industries are gross of interest payments, this is necessary in order to avoid double counting. Under the 1993 SNA and ESA95, most though not all of the adjustment will be apportioned to and netted off each industry's value added in the non-financial sector. The remainder however, about 2% of GDP, which represents sales of intermediation services to final demand (households, government and net exports) will show as an increase in GDP when ESA95 is fully adopted by the UK (Begg *et al.* (1996)).

fall almost entirely into the rough deflation category. Business activities comprise the following divisions (with SIC92 code in brackets):

- Computer and related activities (72)
- Research and development (73)
- Other business activities (74)

The most important activities within the last category are legal services, accountancy, market research, advertising, management consultancy, architectural and engineering services, labour recruitment, and "other". Altogether, business activities have a weight of 8.6% in GDP. With the rent element excluded, section K as a whole accounts for 11.1% of GDP.

Perhaps the most important summary statistic is the proportion of GDP where the productivity growth rate is assumed, not measured. This is the proportion of GDP estimated either by rough deflation or by input indicators. For the public sector, this amounted to about 18% of GDP prior to the changes introduced in the 1998 Blue Book. For 1986 onwards, this figure is reduced to about 9% of GDP (see below). For private services, the proportion where productivity growth is assumed comes almost entirely from sections J and K and amounts to 12.5% of 1990 GDP (as can be calculated from Table 1).

### B.3 Methodological developments

#### Corporate Services Price Index (CSPI)

The development of this new set of indices is described in Skipper (1998) and Palmer (2000). The CSPI aims to do for corporate services what the PPI does for the production sector. Corporate services make up around 23% of GDP, a little more than manufacturing. They include parts of sections H, I, J, K and O of the 1992 SIC. Data collection for the new series began in 1992. 20 indices are currently published; two more are collected but not published for disclosure reasons. Another 24 are "under development" (Palmer (2000), Annex 1). Originally, it was planned that the published series should cover "most of the sector by early 2001". But at the moment finance and insurance are not covered at all and there is no target date for their inclusion.

The development of the CSPI is hampered by some practical problems, many of them springing from the absence of anything like the old Census of Production in the services sector. This means that the ONS frequently does not have sufficiently detailed knowledge of the nominal value of sales of different services, due in part to the absence of a detailed product code for services. This means that even if prices are collected for a representative range of services, the weights necessary to aggregate them to the industry or sectoral level may be missing. So it will be difficult for the CSPI to match the depth of coverage of the PPI.

**Government sector**

The 1998 Blue Book introduced a revised treatment of part of the government sector, covering health, education, and social security. The new methodology is briefly explained in Caplan (1998); see also Pritchard (2002). Instead of input indicators, output indicators are used. The new methodology applies only to the figurers from 1986 onwards. It is estimated to have raised the growth rate of GDP between 1986 and 1997 by an average of 0.04% per annum.

In the case of health, the new indicators seem to be mostly activities, eg consultations, prescriptions, and sight tests, weighted together by cost shares. In social security, the indicator is claims: the number of claims under each of the 12 most important benefits, again weighted together by cost shares. In education, the indicator is number of pupils in the various educational stages.

Within education, an additional factor of 0.25% per annum has been added to the output of schools to take account of improvements in educational quality; the evidence cited to justify this is the rise in GCSE scores. On the other hand no such quality improvement is allowed in health. In fact it is not clear how different the new health measures are from input indicators. If a doctor sees the same number of patients a year, his output will be counted as constant, irrespective of the quality of the treatment he dispenses. Yet health is one area where there seems incontrovertible evidence of quality improvement. One well studied example is treatment for cataracts, which is nowadays a routine outpatient affair but which not so long ago involved an elaborate and expensive operation.

### B.4 Conceptual problems

There are some deep-seated conceptual problems of measurement in the services sector. Some of these, such as quality adjustment and the one-off nature of services like law and accountancy, apply widely. Though not necessarily unique to services they are perhaps more prevalent there. There follow some brief comments on conceptual problems in particular service industries.

**Banking**

Banks are multi-product firms. Some of their products, like the money transmission service, are relatively straightforward to measure, others ("financial intermediation") are more elusive. There is a long-standing debate on whether a gross or a net approach to output measurement should be employed. In banking, as Jack Triplett has said, there is no agreement on what constitutes "price times quantity", so there cannot be agreement on quantity or price separately.[28]

**Insurance**

Insurance is also a type of financial intermediation and there is a "price times quantity" issue here too. With the 1990 weights, non-life insurance made a negative contribution to constant price GDP since value added (the weight) is measured as premiums net of claims and this happened to be negative. (This does not stop the insurance industry being profitable since income earned on reserves fills the gap).

**Wholesale and retail trade**

Output in wholesale and retail trade is measured by the volume of sales. Though most of this sector's output is classified as precisely deflated, there is no attempt made to capture quality of service. So if supermarkets stay open more days a week or for longer hours, or have faster checkout procedures, or offer a greater variety of products, this will have no impact on their measured output.

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[28] See Berger and Humphrey (1992) and Fixler and Zieschang (1992) for alternative approaches to output measurement in banking.

There is one exception to this neglect of quality of service. In the RPI, prices are collected by shop type and any difference between shop types in the prices for the same item is ascribed to quality. So if consumers switch from less to more expensive shops, this will show up as an increase in retailing output, given the growth of the nominal value of turnover and the growth rates of prices in the two types of shop. However, since shops are divided only into "multiples" and "independents" in the RPI it is not clear how important this effect is in practice. The general point is that improvement or deterioration in quality of service within each shop type is not captured in the RPI.

The same point applies to hotels and restaurants where output is measured to a large extent by deflated expenditure on food, alcohol and tobacco. This procedure will not capture a general improvement or deterioration in level of service in a given type of establishment.

A similar point applies to the retailing aspects of banking. Neither the spread of ATMs nor the closure of branches has had any direct effect on the output estimates.

### B.5 Quantitative importance of measurement errors in service sector output

As discussed above, the ONS uses real gross output as a proxy for real value added. This induces an error in the estimate of GDP(O) growth. The growth rates of real value added in the private service industries are then adjusted to remove any discrepancy between the growth rates of GDP(E) and GDP(O), whether arising from the use of single rather than double deflation or from errors and omissions. Here we set that issue aside and deal only with the error in the real gross output proxy.

The Boskin Commission argued that the US CPI had a likely upward bias of 1.1 percentage points per annum, of which 0.6 p.p. per annum was due to underestimating the effects of quality change and new goods (Advisory Commission to Study the Consumer Price Index (1996)). If Boskin was right about the quality change/new goods bias in the US, then arguably a bias of similar magnitude exists for the UK (Crawford (1996); Oulton (1998)).

If this is the bias in an area where considerable resources are put into price collection, then the bias might be larger in areas which rely on cruder methods. This concern is reinforced when we recall that the finance and business services sectors in particular have seen a great deal of product innovation in recent years. But this argument has to be treated with caution since there is an important difference between these two sectors. In finance, the ONS relies much more heavily on output indicators which arguably might be subject to the quality change/new goods bias. In business services, as we have seen, the ONS uses mainly deflated turnover. The deflator is either RPIX or an earnings index, the latter adjusted for (assumed) productivity growth. If RPIX is used, this is probably similar to assuming that productivity rises in this sector at the same rate as in the rest of the economy. So all depends on whether the assumed productivity growth is realistic or not. In this case, there seems no way of assessing even the direction of any bias.

**B.6 Conclusions**

The main problem which the ONS faces in measuring service sector output is the absence of true price indices for much of the sector. This problem is acute for finance and business services. In these industries (sections J and K of the 1992 SIC), output is mainly measured by input with an adjustment for productivity growth. The productivity growth adjustment is an assumption rather than a measurement since it is mainly based on productivity growth in other industries. Private service industries where productivity growth is assumed rather than measured account for about 12.5% of GDP.

The current methodology is not able to capture changes in service quality which may be occurring in retailing, retail banking, hotels and restaurants. In transport, the output measures do not capture the dimensions of reliability, punctuality and frequency.

Until the 1998 Blue Book output in the public sector was measured entirely by input, with no adjustment for productivity growth. This has now changed and output indicators are employed instead for about half of the public sector; this proportion is likely to rise. However, the new methodology has been carried back only to 1986.

What of the future? The development of the Corporate Services Price Indices will gradually improve measurement in this sector. An improvement in measuring output in the public sector has already occurred due to the development of output indicators. This approach will no doubt be further extended. However, any changes to methodology are unlikely to be carried back to cover the whole run of past data on which econometric studies must rest. So there is a sense in which current limitations of the methodology will be with us forever.

**Table B.1**

**Proportion of real output in services measured by different methods, by SIC92 Section, in 1990 prices (pre-1998 Blue Book methodology)**

| | | | | *Method* | | | | |
|---|---|---|---|---|---|---|---|---|
| *SIC92 Section* | *Name* | *1995 weight in GDP* | *1990 weight in GDP* | *Input indic-ators* | *Rough deflation* | *Output indic-ators* | *Precise deflation* | *Total* |
| | | *%* | *%* | *%* | *%* | *%* | *%* | *%* |
| G | Wholesale and retail trade; repair of motor vehicles, etc. | *11.69* | *11.48* | 0.0 | 0.0 | 25.7 | 74.3 | 100.0 |
| H | Hotels and restaurants | *2.90* | *2.78* | 0.0 | 0.0 | 0.0 | 100.0 | 100.0 |
| I | Transport, storage and communication | *8.25* | *8.39* | 0.0 | 0.2 | 29.4 | 70.4 | 100.0 |
| J | Financial intermediation | *6.74* | *7.15* | 12.0 | 37.6 | 23.6 | 26.8 | 100.0 |
| K | Real estate, renting and business activities | *18.35* | *17.26* | 3.0 | 48.6 | 3.1 | 45.4 | 100.0 |
| L | Public administration and defence; compulsory social security | *6.12* | *6.61* | 100.0 | 0.0 | 0.0 | 0.0 | 100.0 |
| M | Education | *5.60* | *4.87* | 100.0 | 0.0 | 0.0 | 0.0 | 100.0 |
| N | Health and social work | *6.46* | *5.93* | 100.0 | 0.0 | 0.0 | 0.0 | 100.0 |
| O | Other community, social and personal service activities | *4.29*[a] | *3.34* | 27.5 | 0.0 | 0.0 | 72.5 | 100.0 |
| P | Private households with employed persons | *n.a.* | *0.39* | 0.0 | 0.0 | 0.0 | 100.0 | 100.0 |
| | Total services | *70.40* | *68.28* | 28.9 | 16.3 | 11.2 | 43.7 | 100.0 |

*Note* Total services are calculated before netting off the “Adjustment for financial services”, 5.13% of 1990 and 4.02% of 1995 GDP. Under SNA93 and ESA95, most though not all of the adjustment will be apportioned to and netted off each industry’s value added in the non-financial sector. The remainder, about 2% of GDP, will show as an increase in GDP (Begg *et al* 1996).

*Source* Calculated from Sharp (1998), Table 2. The treatment of the public sector changed in the 1998 Blue Book. See the text for further explanation.

a. Includes section P.

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