Measuring Productivity: The Response of National Statistical Institutes to the OECD's Productivity and Capital Manuals

Nicholas Oulton
London School of Economics[1]

Abstract

In 2001, the Organization for Economic Cooperation and Development issued its Productivity Manual, alongside its Capital Manual (the latter was updated in 2009). These Manuals set out a detailed guide for National Statistical Institutes (NSIs) on how to expand their national accounts to incorporate a production account using the KLEMS methodology. In many cases full acceptance of these proposals might well require changes to national accounts methodology, for instance the adoption of double deflation, and also a considerable statistical effort, such as incorporating data on wages and employment into the national accounts in a consistent way. This article summarizes the response of some leading NSIs to this challenge and assesses how far they have succeeded in meeting it.

In 2001, the Organization for Economic Cooperation and Development (OECD) issued its Productivity Manual whose full title is "Measuring Productivity – Productivity Manual: Measurement of Aggregate and Industry-Level Productivity Growth" (OECD, 2001).[2] In addition to much else, this contained a chapter devoted to the measurement of capital input. This chapter was later enlarged into a second manual devoted entirely to capital, now in its second edition: "Measuring Capital: OECD Manual 2009" (OECD, 2009). Though not credited on the title pages, the principle author of both manuals was Paul Schreyer. The two manuals will be considered together in what follows.

Given the nature of the OECD as an

---

1 Nicholas Oulton is an associate at the Centre for Macroeconomics at the London School of Economics, a fellow of the National Institute of Economic Social Research, and a research associate at the Economic Statistics Centre of Excellence. He would like to acknowledge helpful comments from four anonymous referees and the editors, Bart van Ark and Andrew Sharpe. Email: n.oulton@lse.ac.uk.

2 The Productivity Manual is summarized in Schreyer(2001).

organization, these manuals do not have the force of law. Their publication did not commit the member states to implementing the recommendations contained in them. So they have less force than the prescriptions of the System of National Accounts (SNA). And they have even less force than the rules laid down by Eurostat for implementing the System of National Accounts in the European Union, the European System of Accounts (Eurostat, 2013), which are legally binding on member states unless derogations are negotiated. Nonetheless the OECD's recommendations in the productivity area carry considerable weight since they were arrived at by a consensual process involving many experts, both from National Statistical Institutes (NSIs) and from academia, and are generally agreed to represent best practice. The purpose of this article is firstly to summarise and critically review the OECD's approach to productivity measurement and secondly to assess how much progress National Statistical Institutes have made in implementing the OECD's recommendations.

In the next section I first discuss the general framework adopted in the Manuals for productivity measurement which is frequently called the KLEMS approach. Here I summarize what seem to me to be the principle recommendations. Then in section 2 I sketch out the KLEMS approach in algebraic terms before turning in section 3 to what the OECD sees as the main measurement issues to be addressed before the framework can be implemented. Section 4 considers some limitations and omissions in the OECD approach. In section 5 I examine the response of selected National Statistical Institutes (NSIs) in their own productivity statistics. How close are they to fulfilling the "vision" of the Manuals? This entails examining first an NSI's own productivity handbook (where one exists) to check compatibility with the OECD's recommended methods and secondly seeing how closely its published productivity statistics conform to the OECD's standards. Section 6 concludes.

The OECD's Approach and Recommendations

The Productivity Manual sets out its objectives as follows:

"1.1. Objectives 1. The main objectives of this manual are to:

- Provide an accessible guide to productivity measurement for those involved in constructing and interpreting productivity measures, in particular statistical offices, other relevant government agencies and productivity researchers.
- Improve international harmonization: *although there is no strong prescriptive element in the manual*, it contains indications about desirable properties of productivity measures. Hence, when countries have a choice in constructing new measures or developing a system of indicators, the manual may provide guidance. [Emphasis added]
- Identify desirable characteristics of productivity measures by reference to a coherent framework that links economic theory and index number theory. Desirable properties have to be assessed against the reality of data availability or the costs of producing statistics. Broad trends can often be discerned with tools that do not live up to full theoretical standards as long as they are interpreted with the necessary

caution. However, the user has to be aware of simplifications that occur in the practice of productivity measurement."

These objectives are expanded on in the next subsection:

"2. The manual is focused in four ways:

- First, the manual focuses on measures of productivity growth rather than on the international comparison of productivity levels. Although there may be few conceptual differences between growth and level comparisons (the former compares different points in time, the latter different points in space), there are practical differences between the two. In particular, productivity level comparisons between industries have to address the tricky issue of currency conversion. … Productivity growth measurement avoids this question and constitutes a useful starting point, given its frequent use in analysis and policy formulation.

- Second, the manual focuses on the measurement of productivity at the industry level. This is a natural choice given that much of the underlying methodology relies on the theory of production and on the assumption that there are similar production activities across units of observation (firms or establishments). Because industries are defined as "a group of establishments engaged in the same, or similar, kinds of activity" (Commission of the European Communities, OECD, IMF, United Nations, World Bank, 1993, *System of National Accounts 1993*, paragraph 5.40 – SNA 93), the industry level is an appropriate level of analysis. At the same time, an important part of the manual is also devoted to issues of aggregation across industries and the link to economy-wide or sector-wide measures of productivity growth.

- Third, the manual does not cover productivity measures of production activities beyond the production boundary of the System of National Accounts, in particular households' production. Within the SNA production boundary, emphasis is given to productivity measures of those industries that are characterized by a large share of market producers, leaving aside those activities where non-market producers dominate in many OECD countries. These activities pose specific problems of productivity measurement, due to the difficulty or impossibility of observing and/or defining market prices or output. Reference will be made when appropriate but an in-depth treatment of the output measurement in each of these industries would go beyond the scope of the present manual.

- Fourth, the manual focuses on non-parametric methods of productivity measurement. This choice has been made because the manual's primary audience is statistical offices and other, regular producers of productivity series. Econometric methods, as opposed to non-parametric approaches to productivity measurement are a tool that is much more frequently used in the context of individual, academic research projects." I interpret these objectives as saying that productivity measures should be consistent with the SNA, which

3 The revised Capital Manual is consistent with the 2008 SNA where, for the first time, the concept of capital services was officially recognized; indeed the revision was undertaken in order achieve consistency with the new SNA.

at the time was the 1993 version[3], and should start at the industry level. There is no explicit recommendation as to the number of industries into which the economy should be broken down, though the implication is the more the better (provided quality can be maintained). Consistency with the SNA means that household production (unpaid cooking, cleaning, child-care, and house maintenance and repair undertaken by householders) will not be included since there is no household production industry, these activities being outside the production boundary. There is no such barrier to including the public sector, in particular health, education, social security, law enforcement and defence, since these activities form part of GDP even when done on a non-profit basis and when the outputs are not sold in the market, as is predominantly the case in OECD countries. But the Manual recognizes that international comparisons of productivity growth rates in the public sector are vitiated by the varying degree to which real output is measured appropriately; obviously, an "output equals inputs" approach which has been widespread in the past in the public sector and is still common today makes measured productivity growth meaningless (Atkinson, 2005).

The Productivity Manual also identified a number of "challenges for statisticians:

"17. From the perspective of productivity measurement, there are at least four areas with a specific need for further research and development of data and statistics:

- *Price indices for output measures* by industry, in particular for high-technology industries and difficult-to-measure but economically important services such as the financial sector, health care and education.
- Measurement of hours worked by industry, as labour is the single most important factor of production. Currently, there are many problems associated with the accurate measurement of hours worked, in particular when disaggregated by industry. Specific challenges in this context include successfully combining information from the two main statistical sources, enterprise and household surveys, and measuring labour input and compensation of self-employed persons. A cross-classification of hours worked by productivity-relevant characteristics of the workforce (education, experience, skills, etc.) would also be highly desirable.
- The quality of existing measures of capital input typically suffers from an insufficient empirical basis. For example, there are too few and often outdated empirical studies to determine the service lives of assets and their age-efficiency and age-price profile. More generally, capital measures for productivity analysis (capital services) should be set up consistently with capital measures for asset balance sheets (wealth stocks), and consumption of fixed capital in the national accounts.
- *Input-output tables* are sometimes missing or dated, and not always integrated with national accounts. The development of a consistent set of supply, use and industry-by-industry tables and their full integration with national accounts at current and constant prices is an important element in deriving reliable productivity measures."

Many of these issues still resonate today. A full evaluation of progress in these areas is beyond the scope of this paper.

The KLEMS methodology

The theoretical basis for the OECD's approach rests ultimately on the fundamental contribution of Solow (1957) who pioneered growth accounting by estimating labour-augmenting technical progress for the aggregate US economy. Labour-augmenting technical progress is closely related to the growth of total factor productivity (TFP) at it came to be called, also known as multifactor productivity (MFP). This growth accounting methodology was greatly enriched by Griliches and Jorgenson (1967). The crucial distinction between capital services and capital stocks is due to Jorgenson (1963) and its extension to incorporate tax considerations is due to Hall and Jorgenson (1967). The framework for building up aggregate productivity from productivity at the industry level is set out in Jorgenson *et al.*. (1987), following Domar (1961) and Hulten (1978), and extended in Jorgenson *et al.*. (2005), (2016) and (2018). The OECD's approach is also influenced by developments in index number theory due to Diewert (1976) and (1978). This approach is commonly known by the acronym KLEMS (capital, labour, energy, materials, and services) referring to the expanded list of inputs that are taken into account.

Since the KLEMS approach will be familiar to most readers I will summarize it briefly in algebraic terms. The formulation is in continuous time using Divisia indices since this not only simplifies the algebra but leads to important results holding exactly as opposed to only approximately. For each industry gross output is assumed to be determined by a production function with Hicks-neutral technical progress:

$$Y_j(t) = A_j(t)F\left(K_j(t), L_j(t), M_j(t)\right) \qquad j = 1, \ldots, N \tag{1}$$

Here Y is gross output, A is the level of TFP (or MFP), K is capital services, L is labour services and M is intermediate input, all considered to be functions of time (t). By totally differentiating with respect to time and assuming perfect competition, we derive the basic growth accounting equation for the jth industry:

$$\hat{Y}_j(t) = \hat{A}_j(t) + v_j^K \hat{K}_j(t) + v_j^L \hat{L}_j(t) + v_j^M \hat{M}_j(t) \tag{2}$$

Here a hat ($\hat{}$) denotes a logarithmic growth rate and the shares of each input in the value of gross output (v) are denoted by:

$$\begin{aligned} v_j^K &= \frac{P_j^K K_j}{P_j Y_j} \\ v_j^L &= \frac{P_j^L L_j}{P_j Y_j} \\ v_j^M &= \frac{P_j^M M_j}{P_j Y_j} \end{aligned} \tag{3}$$

Here P_j^K, P_j^L, P_j^M are the prices of (respectively) capital services, labour services and intermediate input to the jth industry and P_j is the price of gross output. Under the assumption of perfect competition these shares can be interpreted as the elasticity of output with respect to each input. From equation (2) we can calculate the growth of TFP in the jth industry as a residual, all other terms being in principle observable.

The basic accounting identity for each industry is that the value of output equals the value of inputs:

$$P_j Y_j = P_j^K K_j + P_j^L L_j + P_j^M M_j \qquad (4)$$

Or, defining value added in nominal terms as output minus intermediate input:

$$P_j Y_j = P_j^V V_j + P_j^M M_j \qquad (5)$$

where P_j^V is the price and V_j is the quantity of value added (real value added). From this accounting relationship we can derive a Divisia index of the growth of real value added:

$$\hat{V}_j = \frac{1}{v_j^V} \left[\hat{Y}_j - \left(1 - v_j^V\right) \hat{M}_j \right] \qquad (6)$$

where v_j^V is the share of nominal value added in nominal gross output. Equation (6) is the definition of double-deflated real value added in continuous time. The price of value added P_j^V can now be derived as the implicit deflator: nominal value added divided by the quantity of value added.

Let us now simply define TFP growth in the *value added sense*, $\hat{A}_j^V$, as:[4]

$$\hat{A}_j^V = \hat{V}_j - v_j^{VK} \hat{K}_j - v_j^{VL} \hat{L}_j \qquad (7)$$

where $v_j^V K$ and $v_j^V L$ are the shares of capital and labour in value added:

$$v_j^{VK} = \frac{P_j^K K_j}{P_j^V V_j}$$
$$v_j^{VL} = \frac{P_j^L L_j}{P_j^V V_j} \qquad (8)$$

The relationship between TFP growth in the gross output sense and TFP growth in the value added sense can then be seen to be:

$$\hat{A}_j^V = \frac{\hat{A}_j}{v_j^V} \qquad (9)$$

So far we have been setting out the framework as if there were only a single capital input, a single labour input and a single intermediate input. But this is not necessary. Each of these inputs can be considered as an aggregate of as many types as we like (or can obtain data for). These aggregates can also be defined by Divisia indices:

$$\hat{K}_j = \sum_{k=1}^{N_K} w_{jk}^K \hat{K}_{jk}$$
$$\hat{L}_j = \sum_{l=1}^{N_L} w_{jl}^L \hat{L}_{jl} \qquad (10)$$
$$\hat{M}_j = \sum_{m=1}^{N_M} w_{jm}^M \hat{M}_{jm}$$

Here K_{jk}, L_{jl}, and M_{jm} are the inputs respectively of the kth type of capital ($k = 1, \ldots, N_K$), the lth type of labour ($l = 1, \ldots, N_L$), and the mth type of in-

4 Alternatively, we could assume the existence of a value added function for each industry. But this requires some restrictive assumptions. However, even in the absence of such a function nothing stops us from calculating TFP growth in the value added sense from equation (7). The fundamental assumption of the KLEMS approach is the existence of the gross output production function for each industry, equation (2).

termediate input ($m = 1, \ldots, N_M$) into the jth industry. The shares of these inputs in respectively the total compensation of capital, of labour and of intermediate input in the jth industry are:

$$\hat{K}_j = \sum_{k=1}^{N_K} w_{jk}^K \hat{K}_{jk}$$
$$\hat{L}_j = \sum_{l=1}^{N_L} w_{jl}^L \hat{L}_{jl} \qquad (11)$$
$$\hat{M}_j = \sum_{m=1}^{N_M} w_{jm}^M \hat{M}_{jm}$$

For the economy as a whole we can define the growth rates of aggregate capital services and aggregate labour services as:

$$\hat{K}_j = \sum_{k=1}^{N_K} w_{jk}^K \hat{K}_{jk}$$
$$\hat{L}_j = \sum_{l=1}^{N_L} w_{jl}^L \hat{L}_{jl} \qquad (12)$$
$$\hat{M}_j = \sum_{m=1}^{N_M} w_{jm}^M \hat{M}_{jm}$$

Let V be aggregate real value added or real GDP, given by:

$$\hat{V} = \sum_{j=1}^{N} v_j \hat{V}_j \qquad (13)$$

with the shares v_j of each industry in nominal GDP defined as:

$$v_j = \frac{P_j^V V_j}{\sum_{j=1}^{N} P_j^V V_j} \qquad (14)$$

The aggregate TFP growth rate is defined as:

$$\hat{A} = \hat{V} - v^K \hat{K}_j - v^L \hat{L} \qquad (15)$$

Here the aggregate capital and labour shares, the shares of capital and labour in the value of final output (nominal GDP), v^K , v^L are defined as:

$$v^K = \frac{P^K K}{P^V V}$$
$$v^L = \frac{P^L L}{P^V V} \qquad (16)$$

The aggregate TFP growth rate can be related to *the social production possibility frontier* of the economy. This shows the maximum feasible level of output of any single industry which can be produced given the outputs of all other industries and given the stocks of primary inputs and the level of technology. The latter concept can be written as:

$$G\left(V_1, \ldots, V_N, K, L, t\right) = 0 \qquad (17)$$

Where time t indexes technology. It has been shown by Hulten (1978) (see also Gabaix, 2011: Appendix B), that the aggregate TFP growth rate of equation (15) can be interpreted as the rate at which the social production possibility frontier is shifting out over time, provided that perfect competition prevails.

What is the relationship between the industry-level TFP growth rates and the aggregate TFP growth rate? The answer is:

$$\hat{A} = \sum_{j=1}^{N} \left(\frac{P_j Y_j}{P^V V} \right) \hat{A}_j \quad (18)$$

This result is known as Domar aggregation (Domar, 1961; Hulten, 1978), also as Hulten's Theorem. Note that the weights here typically exceed 1, so this is a weighted sum not a weighted average. In view of (9), equation (18) can written alternatively as:

$$\hat{A} = \sum_{j=1}^{N} \left(\frac{P_j^V V_j}{P^V V} \right) \hat{A}_j^V \quad (19)$$

So aggregate TFP growth is also a weighted average of industry-level TFP growth rates in the value added sense.

Hulten's Theorem (as it is known in the modern macro literature) requires full efficiency; that is, not just perfect competition in all industries but also an absence of distortions in input markets. A given input must be paid the same price whichever industry it is employed in. For example, in the case of labour a given type must be paid the same wage in every industry: $P_{jl}^L = P_{rl}^L$ all j,r,l. If this is not the case then aggregate productivity can be improved by reallocating inputs towards industries where they earn a higher return. Formulas for these reallocation effects were developed in Jorgenson *et al.* (1987).

Real value added measured by double deflation was defined above, equation (6). Double deflation is significant for two reasons. First, the relationship between TFP growth in the gross output and value added senses, equation (9), only holds when real value added is measured by double deflation. Second, consistency in the national accounts requires double deflation. Consistency requires that the growth of aggregate real value added equals the growth of aggregate real final expenditure:

$$\sum_{j=1}^{N} v_j \hat{V}_j = \sum_{i=1}^{M} e_i \hat{E}_i \quad (20)$$

Here there are M categories of final expenditure, E_j , with corresponding shares in nominal GDP, e_j.[5] Equation (20) is the counterpart in real terms of the basic national income accounting identity that output must equal expenditure (and income) in nominal terms.

The relationships sketched out here justify the Productivity Manual's stress on the following points (which it does not always justify in detail):

- Productivity accounts should be integrated into and be consistent with the national accounts.
- Supply and use tables should be employed to ensure consistency in the national accounts.
- Real value added should be measured by double deflation.

The OECD Manuals are intended to be practical guides so they do not for the most part employ Divisia indices. But the formulas above can be translated into discrete terms by using some superlative index. Törnqvist indices are one possibility and are used in the Manuals. They have been employed for example by the Bureau

5 For this to hold, both final expenditure and value added must be measured on a common price basis, e.g. at basic prices.

of Economic Analysis (BEA) in the US; See the BEA/BLS joint productivity Program discussed in Section 6. They have also been employed by the Office for National Statistics (ONS) in the United Kingdom in their own productivity publications even though neither the ONS nor the BEA use the Törnqvist in the rest of their national accounts. The Törnqvist is also used by the US Bureau of Labor Statistics (BLS) in its own productivity publications: see below, section 5.

Measurement Issues

Output and Intermediate input

The Productivity Manual devotes a chapter each to the measurement of output, labour input, capital input and intermediate input.

The Manual is committed to a gross output approach[6] to measuring productivity, since "gross output-based productivity measures capture disembodied technical change", though it also argues that "value-added-based-productivity is meaningful in its own right". Many users are interested in labour productivity, for which real value added per hour worked is the preferred measure.

This emphasizes the issue of how real value added should be measured. The Manual recommends that real value added should be estimated by double deflation. But the Manual also adds that there may be a problem if Laspeyres quantity indices are employed for inputs and outputs, since there is then the possibility of negative real value added. This problem also arises for Fisher indices since a Fisher index is the geometric mean of a Paasche and a Laspeyres index. It does not arise for a Törnqvist index.[7] Double deflation requires an input-output approach, or, more precisely a supply-use table. These are commonly used for balancing the national accounts in nominal terms. But for double deflation they need to be balanced in real terms too. The Manual does not go into detail on how to do this. Subsequently, there has been much work on this in the world of official statistics, culminating in a new UN manual on supply, use and input-output tables (United Nations, 2018, see particularly Chapter 9).

There are issues here that are yet to be fully explored. Having started with consistency in the supply use tables in nominal terms, there is then the problem of maintaining consistency when the tables are revalued in real terms. This issue arises because the prices appropriate for deflating industry outputs, e.g. producer price

6 To avoid double counting, gross output at the industry level should exclude sales and purchases within the industry itself. The empirical importance of this point depends on how finely the industry is defined. The data necessary to make this adjustment should be available from the input-output tables. For a recent discussion, see Eldridge and Powers (2023): note that their term for gross output after the exclusion of intra-industry sales is "sectoral output".This adjustment is certainly made in US and Canadian productivity accounts. It is not clear which other NSIs also make it.

7 The Törnqvist index of real value added is defined as the difference between a weighted average of the growth rates of the outputs and a weighted average of the growth rates of the inputs. So it can never generate a negative *level* of real value added, provided that the level of nominal value added in the reference year is positive (a condition always fulfilled in practice with industry data.)

indices (PPIs), may not be consistent with the prices appropriate for deflating expenditures, e.g. consumer price indices. This is quite apart from the fact that CPI prices are inclusive of imports, transport and trade margins, and taxes on products less subsidies, while producer prices are not. A simple way to do double deflation is to start with a supply use table which is balanced in nominal terms and then deflate each industry's gross output by its own PPI (or the equivalent for service industries). For each industry, intermediate purchases from each of the other domestic industries can then be deflated by the latter's own PPI (adjusted to a purchasers' price basis). Imported inputs can be deflated by the appropriate import price. (Note that the supply use table has to be expanded from its standard form so that for each industry domestically-supplied inputs are distinguished from imported ones). This method will produce a supply use table which is balanced in real as well as in nominal terms.

The problem with this method is that the resulting estimates of real GDP may differ from those hitherto accepted, even in the absence of any changes in the underlying data or in other methodology. Most countries which have not adopted double deflation base their annual estimates of real GDP on the expenditure side. [8] This is because expenditure-side price indices such as the components of the CPI are considered more reliable than the corresponding PPIs. After all, NSIs make considerable efforts to ensure that the basket of goods and services in their CPI is up to date and to adjust for quality change (even if there is still scope for improvement).

Much less effort goes into the PPI and service industries prices programs. PPIs are widely believed to understate quality change even though in areas like ICT some countries have made large improvements.[9] The actual procedures used by NSIs to implement double deflation unfortunately remain somewhat opaque. In the United Kingdom case there is the following statement: "This balancing process [i.e. in real terms] draws heavily on the quality of the deflators used. Broadly speaking, this results in more emphasis given to the expenditure approach for balanced years – that is, the years for which the SUTs have been compiled. This is because it allows the volume estimates to draw more heavily upon the higher-quality Consumer Prices Index (CPI) deflators used within the expenditure approach." (Office for National Statistics 2022b, section2).

Labour Input

On labour input, the Manual states: "The quantity of labour input in production is best measured by hours worked

8 Prior to adopting double deflation in its 2021 national accounts, the United Kingdom estimated real GDP from the output side by assuming that the growth of real value added in each industry could be proxied by the growth of real gross output in that industry. This generated a discrepancy with the expenditure-side estimates of annual growth in real GDP which were believed superior. The discrepancy was eliminated (at first totally and then within a small margin) by adjusting the growth rate of private services industries (e.g. banking and business services) but leaving the growth rates in the public and production sectors unchanged (Lee, 2011).

9 These issues are discussed in more depth in Oulton *et al.*(2018). They suggest a method of implementing double deflation which is consistent with previous expenditure-side estimates of real GDP.

and its price by average compensation per hour". It notes that labour input includes the self-employed. Therefore part of the latter's income, called "mixed income" in the national accounts, must be allocated to labour. Finally, the labour chapter recommends disaggregating labour into skill types. In practice carrying out this recommendation entails integrating statistics on wages and labour into the national accounts, a non-trivial undertaking.

It is often useful to distinguish between labour input in the crude sense of hours worked and hours worked after adjustment for the age-sex-skill mix of the labour force. So labour input can be thought of as hours worked multiplied by an index of labour quality or, more neutrally, of labour composition.

Capital Input

The Capital Manual sets out the now familiar distinction between capital *services* and capital *stocks*. Capital stocks are to be estimated using the Perpetual Inventory Method (PIM), i.e. by cumulating flows of gross investment with allowance for *decay*, the decline in the ability of an asset to produce services as it ages, and retirement. The decay rate may vary with an asset's age but does not vary with the date of installation: i.e. the rate at which a 5-year-old asset of a given type decays this year is the same as the rate at which a 5-year-old asset of the same type 10 years ago was decaying then. Hence for each asset type there is an age-efficiency profile. Distinct in principle from the age-efficiency profile is the age-*price* profile which shows how, at a point in time, the price of an asset varies with its age. If the efficiency of an asset declines geometrically then it turns out that the second-hand price declines at the same geometric rate, i.e. the depreciation rate equals the decay rate. In constructing aggregate capital services the flow of services is assumed proportional to the stock of each type and the different types of services are to be aggregated using user costs as weights; for aggregating capital stocks asset prices are to be employed.

User costs are conceptually identical to what were called the prices of capital services in the previous section. Here I give a brief outline of user costs since the Capital Manual, though very comprehensive, makes quite difficulty reading in places.

The user cost of capital in year t, i.e. the cost of holding a new example of an asset of a particular type for (say) one year, can be thought of as the interest cost plus the capital loss (or minus the capital gain) from holding it for one year:

$$P_t^K = r_t P_{t,0}^A + \left(P_{t,0}^A - P_{t+1,1}^A\right) \tag{21}$$

Here r_t is the interest rate or required rate of return in year t. The capital loss (gain) term captures the change in value from all sources: inflation, wear and tear, and obsolescence. This is now a *discrete* formulation so I have added a time subscript to the user cost P_t^K (asset type and industry subscripts have been omitted for clarity). The asset price in year t of this type of capital when new is $P_{t,0}^A$; here there is a double subscript, the first to indicate the year (t) and the second to indicate the asset's age (0 in this case). (The user cost is also affected by tax *considerations* but is ignored here.) The user cost can be expressed in a more economically meaningful way. Define the rate of depreciation in the "cross-section" sense as δ so that:

$$P^A_{t,1} = (1-\delta)P^A_{t,0} \tag{22}$$

And let asset price inflation, i.e. the growth in the price of a new asset, be defined as:

$$\pi_t \equiv \frac{P^A_{t+1,0} - P^A_{t,0}}{P^A_{t,0}} \tag{23}$$

Then after a bit of manipulation the user cost of capital becomes:

$$P^K_t = \left[r_t + \delta\left(1+\pi_t\right) - \pi_t\right] P^A_{t,0} \tag{24}$$

The second term in square brackets, $\delta\left(1+\pi_t\right)$, captures depreciation in the "cross-section" sense. The third term, π_t , captures inflation (or deflation). In my view, this should be interpreted as the expected rate of inflation since investment decisions are necessarily forward-looking and made without full knowledge of the future.

The Capital Manual recommends that capital stocks and capital services should be estimated in a consistent way. This means for instance that the types of capital recognized in the SNA should also be included in productivity statistics. And the assumptions used about decay in measuring capital services should be consistent with those used to estimate depreciation in capital stocks and capital consumption in the national accounts. It is also clear that asset prices should be adjusted for quality.

The second edition of the Capital Manual goes further than the first edition in recommending the use of geometric patterns for depreciation. Apart from simplicity and convenience, the main justification is that what is needed is the depreciation rate for a *cohort* of assets of a given type, not just for a single example. So even in the case of the legendary "one-hoss-shay"[10], the depreciation rate for a *cohort* of one-hoss-shays may be geometric if they disintegrate after a lifetime of random length. Hence the geometric assumption may be a good approximation empirically.

There is an extensive discussion of how to estimate the required rate of return r. Under the endogenous approach, given the depreciation rates and data on asset prices, one solves for r using the condition that total returns to capital must add up to Gross Operating Surplus (including the capital part of mixed income). Under the exogenous approach financial data are used to select some market interest rate. The endogenous approach has the advantage that, by definition, total returns to all types of capital must add up to Gross Operating Surplus. This then makes Gross Operating Surplus exactly analogous in the national accounts to labour compensation which is the total of payments to all types of labour. On the whole the Manual favours the endogenous approach, though it notes that there must be no missing types of capital. This condition may be hard to satisfy in

10 Namely a capital asset that delivers the same flow of services throughout its lifetime before failing with zero scrap value. The subject of a poem by Oliver Wendell Holmes Sr.

practice since land, inventories, and environmental assets (important in some industries) are often excluded.[11]

The Capital Manual recommends the use of something similar to equation (24) for the user cost of capital, partly because it is consistent with the practice of NSIs in estimating wealth stocks in the national accounts. But it expresses some doubts about the third term in the formula, expected inflation. One reason is that if actual inflation is used to estimate expected inflation then in turbulent periods user costs can become negative which makes no sense economically.

The Capital Manual recognizes that the user cost formula should take account of taxes and subsidies affecting the profitability of investment, along the lines of Hall and Jorgenson (1967), but is reluctant to make this a formal recommendation because of the considerable effort involved in doing so. It relies on empirical studies suggesting that the effect of including taxes and subsidies on the magnitude of user costs is fairly small.

Limitations and omissions in the OECD approach

The OECD manuals do a good job of pointing out their own limitations and omissions (see above). But the following six points should perhaps be noted in addition:

First, the Manuals have very little discussion of comparing productivity levels across countries, whether at the whole economy or the industry level. As they point out, all international comparisons at the industry level require industry-level currency conversion factors. The fundamental (and well-known) difficulty here is that the International Comparison Program (ICP) constructs Purchasing Power Parities (PPPs) from the expenditure side of the national accounts. So the bulk of these are consumer prices; these are inclusive of taxes on products less subsidies (sales taxes and non-refundable VAT), and transport and wholesale and retail margins, and they include the prices of imported goods and services alongside those of domestic industries. Also they only cover intermediate inputs insofar as these also form part of final expenditure.

Efforts have been made by researchers to overcome these difficulties by utilizing the input-output tables to estimate industry-level basic prices from PPPs (e.g. Inklaar and Timmer *et al.*, 2007). The EU KLEMS project drew on this approach (O'Mahony and Timmer, 2009). But I am not aware of any work by NSIs in this area. The main use made by NSIs of PPPs is for international comparisons of living standards at the whole economy level, e.g. GDP per capita or household consumption per capita. But if one is interested in understanding why one country's productivity level is lower than another's, then knowledge of growth rates in both countries is

11 Some would argue that they are important in all industries. This may well be true from a welfare point of view. But the point here is that only natural assets which are owned by some economic agent influence investment decisions. Improvement or deterioration in environmental assets can still influence TFP; e.g. excessive heat may reduce TFP by requiring more expenditure on air conditioning.

not enough: levels are needed too.

Second, the manuals do not discuss productivity at the sub-national or regional level, a subject of increasing interest today. The basic KLEMS approach could in principle be applied just as well to regions or even cities as to whole countries. The main difficulties would be empirical: disaggregating national data on industry-level outputs and inputs to the regional level and constructing regional level input-output tables (though Canada has already done this). Finding appropriate industry-level prices for each region would be challenging too.

Third, labour input, which is supposed to be hours actually worked, may in practice be measured differently in different countries, one of the "challenges for statisticians" noted above in the Productivity Manual. This has been confirmed by later work. OECD research has found that if hours worked were calculated in a different but more comparable way across countries, then Britain's labour productivity gap in the market sector with the United States would be reduced from 24 per cent to 16 percent (OECD, 2018 and ONS, 2019a). This does not necessarily mean that the true gap is 16 per cent, only that there is a large margin of uncertainty.

Fourth, depreciation is considered independent of expenditure on maintenance and repairs; the latter are counted as intermediate consumption in the SNA.[12] But at least for some types of depreciation this is unrealistic. The decline in market value of a car (or of a building) as it ages can surely be reduced to some extent by spending more on maintenance and repairs. In fact, there is an economic calculation to be made here about the optimal level of maintenance expenditure (Feldstein and Rothschild, 1974). (Of course maintenance and repairs can do nothing to offset loss of value due to obsolescence).

Fifth, the manuals are founded on the assumption of perfect competition. Traditionally, this has been defended as quite appropriate for long run analysis. But nowadays productivity statistics are often quarterly and productivity analysis is applied over business cycle frequencies. And most macroeconomists now work within an imperfect competition framework. A great deal of empirical work (summarized in Basu, (2019)) is devoted to estimating the size of margins and whether they have been increasing or not. Hall (1988) was one of the first to consider the implications of imperfect competition for the measurement of productivity. One response is just to say that we should be using cost share weights rather than revenue weights in measuring the contribution of each input, i.e. we should subtract an estimate of monopoly profit from Gross Operating Surplus. This would reduce the relative weight attached to capital inputs while increasing that of labour inputs. But this is not enough in my view. If we take imperfect competition seriously, we should be looking for the cause of non-zero margins, e.g. increasing returns or proprietary knowledge.

12 However. major repairs and renovations that extend the life of an asset are treated as capital formation and their value is added to the value of the asset before the work was undertaken (2008 SNA 20.61).

Sixth, related to the previous point, in the presence of imperfect competition, some firms may be able to charge higher prices than their competitors in the same industry. This could be interpreted as these firms having higher productivity. If so, then a shift in resources to the high price firms is an additional source of aggregate productivity gains. But this source is not accounted for in the KLEMS framework. Also, if prices are not equal to marginal costs, then there is an additional distortion from the point of view of purchasing industries, again not accounted for in the KLEMS framework.

Response of Selected NSIs and Other Organizations

In this section I look at how some selected NSIs and international organizations have responded to the OECD's manuals.

OECD

As well as producing the manuals the OECD also publishes productivity statistics. While their MFP measures are limited to the total economy, they cover a large number of countries (24 member states), they are timely (currently up to 2022), and they go back to 1985. Labour productivity series are also available at the industry level. [13]

Canada

Actually, Canada did not need to "respond" to the OECD manuals since it was already producing MFP statistics when the manuals first appeared. Canada's MFP statistics were in response to the same intellectual influences which also lay behind the manuals (section 3). After focusing initially on labour statistics the Canadian program was refocused on MFP in the mid-1980s. A comprehensive account of Canada's productivity statistics is the User Guide (Baldwin *et al.*, 2007).[14]

Statistics Canada publishes MFP at the industry-level, for the business sector and also for major sectors within the business sector. Törnqvist indices are used to estimate MFP from data on output and inputs. To quote the User Guide: "Statistics Canada's MFP programs provide data on chained-Fisher quantity indices and nominal values of output and intermediate inputs for the individual industries of the business sector. Output is valued at basic prices, while intermediate inputs are valued at purchaser prices. The output of the total business sector is measured as value-added, while the output at the industry level is measured as GDP (or value-added), sectoral output and gross output. The main source data for estimating output and intermediate inputs for the MFP programs are the annual input–output tables of Statistics Canada. The construction of output and intermediate inputs involves the aggregation of a large number of commodity outputs and intermediate inputs. For all of our aggregations, we use annually chained-Fisher indices." (page 18).

Real value added is measured by dou-

13 The relevant website is https://www.oecd.org/sdd/productivity-stats/.

14 See Baldwin and Gu (2013) for some updates on official Canadian methodology.

ble deflation using the input-output tables, but the User Guide does not state whether or how consistency is achieved between the expenditure and output measures of real GDP.

Capital: "The asset detail for capital services estimates in the MFP programs consists of 15 types of equipment, and 13 types of structures, and land and inventories for a total of 30 types of assets." (page 24). Note the inclusion of land and inventories. User costs employ endogenous rates of return, varying across industries. Negative user costs are eliminated by setting them equal to the average user cost across all industries and then adjusting for inter-industry differences in the user cost (page 25). Geometric depreciation is assumed (Table 9, page 42). Apart from land, no environmental assets are included. At that time, R&D, other intangible capital, and infrastructure capital are not included amongst assets. Since then the assets added by the 2008 SNA — R&D, software, and exploration — have been included (Baldwin and Gu, 2013).

Labour: labour composition includes age (7 groups), education (4 levels) and employment type (employee or self employed) but not industry or sex. Industry is excluded since unlike capital it does not change the measure very much. Sex is excluded since it is argued to reflect "workplace discrimination" rather than productivity (page 26).

The latest (18th April 2023) labour productivity and MFP estimates are for 41 industries in the business sector from 1961 to 2019.

United States

At the time that the Productivity Manual was published in 2001, the US productivity statistics were not fully consistent with the national accounts. One agency, the Bureau of Labor Statistics (BLS), produced the productivity statistics while another, the Bureau of Economic Analysis (BEA), produced the national accounts, including estimates of fixed asset stocks. As an example of inconsistency, the BLS assumed that decay was hyperbolic in its estimates of capital input while the BEA assumed depreciation was geometric for its estimates of asset stocks (Fraumeni, 1997).

This situation has now completely changed with the development of the BEA-BLS industry-level production account. The KLEMS methodology used and the data itself draw on many years of work by Jorgenson with his various collaborators, e.g. Jorgenson *et al.* (1987), (2005), (2016) and (2018). The data in this new production account include annual gross output, value added, intermediate input, capital input, labour input (all in both nominal and real terms), and MFP for 63 industries, classified by NAICS, covering the whole economy (including federal, state and local government). The period covered is currently 1987-2020.[15] Nominal value added in these 63 industries adds up to nominal GDP.

Real value added is double deflated,

15 Extending the data back to 1947 is possible. At the moment however that cannot be done on a fully consistent basis. In addition, the quality of the estimates for years prior to 1987 is lower (Eldridge *et al.*, 2020).

though unfortunately not much detail seems to be available on how this is done in practice. The growth of real labour input is the share-weighted growth of hours worked for approximately 170 different groups of workers cross-classified by sex, eight age groups, six education groups, and employment class (payrolled vs. self-employed). Nominal labour input is compensation of employees. The growth of capital input is the share-weighted growth rate of capital services based on about 100 types of capital including inventories and land. Nominal capital input is gross operating surplus plus the portion of mixed income assigned to capital. A full description of the BEA-BLS-industry-level production account is in Garner *et al.* (2020) and (2021). Further detail on methodology is available from Garner *et al.* (2018).[16]

Despite the considerable level of detail at which the estimates are constructed, the published data for the inputs are quite a bit more aggregated. Thus at the industry level, nominal compensation and real quantities for only two types of labour are published: college and non-college. Nominal compensation and real quantities for only 5 types of capital are published: Entertainment, Literary, and Artistic Originals; Research and Development; IT ; Other capital and Software.

Nominal expenditures on and quantities of three types of intermediate input are published: energy, materials and services.

For capital, more detail is available on an "experimental" basis. Capital is now disaggregated into 9 types: Communications equipment; Computer hardware ; Research and Development ; Software; Entertainment, Literary, and Artistic Originals; Instruments and other office equipment; Structures, land, and inventories; Transportation equipment; Other equipment.

The "IT" category has been disaggregated into two sub-categories (communications equipment and computer hardware), and the "other capital" category into four (instruments and other office equipment, structures, land and inventories, transportation equipment, and other equipment).

United Kingdom[17]

Labour Productivity

The Office for National Statistics (ONS) publishes data on labour productivity (output per hour worked) on an annual and quarterly basis for both the whole economy and for individual industries, using the 2007 Standard Industrial Classification (SIC);[18] the methodology is set out in ONS (2023). It also publishes data for the market sector. The market sector is defined by the institutional type of the establishments within it, not by the industry. So the mar-

16 The data for 1987-2020 can be downloaded from the BEA website (www.bea.gov) in the form of a spreadsheet named "BEA-BLS-industry-level-production-account-1987-2020.xlsx", available at https://www.bea.gov/data/special-topics/integrated-industry-level-production-account-klems. This spreadsheet was released on May 11 2022 and comprises the latest data available at the time this paper was begun.

17 An account of the current state of play in UK productivity measurement is Oulton (2020).

18 SIC 2007 corresponds exactly down to the 4 digit level to the EU classification system, NACE. The US and Canadian NAICS is somewhat different.

ket sector excludes establishments classified to the public sector or as Non-Profit Institutions Serving Households (NPISH). A drawback is that private researchers do not generally have access to establishment-level data so that it is impossible for them to replicate the ONS's series. Presumably this is one reason why the EU KLEMS project defined its "business sector" on an industry basis, by excluding industries which are predominantly (though not wholly) made up of public sector or NPISH establishments.

The whole economy annual labour productivity (output per hour worked) series goes back to 1971, on a chained volume basis, i.e. using a chained Laspeyres index. The ONS also publishes output per job (by industry) and output per worker (for whole economy and market sector only).

The disaggregated quarterly labour productivity data generally go back no further than 1997Q1. For all except the most recent quarters real value added since 1997 is double deflated, after an annual supply use table has been balanced in both nominal and real terms, i.e. at both current and previous year's prices.

The labour productivity series are available for 17 industries including public services (sections O-Q of the 2007 SIC combined) and real estate; the latter excludes the imputed rental of owner-occupied housing. The following aggregates are distinguished: whole economy (sections A-U of SIC 2007), production (B-E)[19], manufacturing (C) and services (G-U); Also, 10 Divisions within manufacturing and 11 within services. In addition, output per hour is available separately for 25 "bespoke" groups of Divisions; these Divisions, 98 in number, comprise the whole economy.

MFP

The ONS began publishing multifactor productivity (MFP) estimates in 2007,[20] characterized from then till now as "experimental", i.e. they do not meet the quality standards required for them to be classified as "national statistics", unlike the labour productivity estimates discussed above. There is no indication of what is required for them to be upgraded to "national statistics". But as the real value added and hours worked are the same for both MFP and labour productivity, presumably any problems are thought to lie in the capital and labour quality measures.

The ONS methodology broadly follows that of the OECD manuals, with an important exception noted below, and is set out in ONS (2007), summarized in ONS (2016). For MFP, ONS (2020a) provides an overview while for more detail on capital input see ONS (2019b) and (2020c), and for more detail on labour input (labour qual-

19 i.e. mining, construction and manufacturing

20 Prior to then the Bank of England Industry Dataset appeared in 2005. This produced KLEMS estimates for 34 industries covering the whole economy, of which 31 were in the market sector, over the period 1970-2000. Special attention was paid here to the role of ICT capital; US price indices instead of UK ones were used as deflators. See Oulton and Srinivasan (2005) for a full description. This dataset was superseded by the UK part of the EU KLEMS project (see below).

21 What was previously known as Quality-Adjusted Labour Input (QALI) has now (since November 2023) been rebranded as Compositionally Adjusted Labour Input (CALI). However, the methodology is the same.

Table 1: Asset Types Included in the UK Volume Index of Capital Services

1	Buildings other than dwellings
2	Other structures (e.g. chemical works, motorways)
3	Land improvements
4	Transport equipment
5	ICT equipment (excluding telecoms)
6	Telecoms equipment
7	Other machinery and equipment
8	Cultivated biological resources (e.g. cows)
9	Research and development
10	Mineral exploration and evaluation
11	Computer software and databases (Own-Account)
12	Computer software and databases (Purchased)
13	Entertainment, literary or artistic originals

Source: Source: ONS (2019c).

ity)[21] see ONS (2021).

The latest data release at the time of writing is in ONS (2022d). It gives value added, capital services, labour hours, labour composition (quality), labour share, and MFP of 16 industries plus the market sector as a whole; the annual data cover 1970-2020 and the quarterly data cover 1994Q1 to 2021Q2. The 16 industries are sections of the 2007 SIC and cover the whole economy but with non-market sector components (including the whole of sections O, P and Q) removed, so the total aggregates to the market sector. Gross output and intermediate input are not published though real value added is double deflated. Note that the MFP series employ the value added concept (equation (7). It is not possible to derive the gross output concept of MFP since neither nominal value added nor nominal gross output are published.[22] Market sector MFP growth is calculated as a Törnqvist index of the industry MFP rates.

Table 1 provides a list of the asset types that are currently distinguished in what the ONS calls the Volume Index of Capital Services (VICS).

Note that dwellings are excluded. The output of dwellings in national accounts terms is measured from the income side as the imputed rental on owner-occupied housing plus ordinary commercial rents. The latter accrues to the real estate sector while the former is part of the income of households. The difficulty lies with the imputed rental element since there is no industry corresponding to this. The activities of households in maintaining and managing their own properties are outside the production boundary of the national accounts. In other words the value of their labour in these activities is excluded from GDP and their expenditure on home improvement products and the like is counted as final not intermediate consumption. So though there is a case for including dwellings when measuring whole economy productivity, there is no industry in the industrial classification which corresponds to this stream of output and no corresponding measured labour input. So exclusion of

22 Though it may be possible to derive MFP on a gross output basis using equation (9) and employing data on nominal gross output and nominal value added from the supply use tables.

dwellings is quite appropriate for measuring MFP in the market sector.

However, what is less defensible is the exclusion of land and inventories from the UK VICS, contrary to the recommendations of the manuals. Also, the level of detail (the number of asset types and labour types) is considerably lower than in the United States or Canada. Note too that the assumptions underlying the VICS are not currently consistent with those underlying the assets included in the balance sheet estimates which form part of the national accounts.

Public Sector

As we have just seen, the ONS publishes a labour productivity series for the public sector. It also producers a separate publication on “Public Sector Productivity” (ONS, 2022a). The methodological basis is different from that of labour productivity. Public sector output is measured by gross output, not value added. Productivity is measured by the output index divided by the input index. Inputs here include labour, capital and intermediate index. So “productivity” here means MFP (or TFP). Real output is measured mostly by a cost-share-weighted index of activities, with allowance for quality change where possible.

In 2019, 41 per cent of output was measured using the “output = inputs” convention while 59 per cent is measured directly, i.e. by activities. The whole of police and defence output and large parts of local and central government are measured by inputs. In addition to this, quality adjustment is applied to some output estimates. In health this includes a host of indicators such as survival rates after some operations and waiting lists. In education, output is measured by the numbers of pupils passing through the various stages (primary, secondary, etc); quality adjustment is measured by attainment at the various stages (exam grades). The ONS adopted this approach to measuring public sector output following the influential Atkinson Review (Atkinson, 2005); there was earlier work in Sweden along similar lines. This approach only applies in full to the separately published public sector productivity estimates. In the national accounts, including the labour productivity statistics, there is a much more limited use of output measurement due to the need (until the United Kingdom exited from the EU) to conform to Eurostat rules imposing harmonization in GDP statistics across EU member states.[23]

Capital inputs are weighted together just by capital consumption with no allowance for the cost of capital (i.e. the rate of return on capital plus capital gains or losses). So only part of the private sector user cost of capital is included here. This reflects the treatment of public sector capital in the national accounts where only capital consumption is included. That is to say, value added in the public sector is defined under the 2008 SNA as payments to labour plus net taxes on production plus capital consumption, not profit.

23 Contribution by each member state to the EU budget is determined by its Gross Domestic Income. This still has some relevance to the UK even after Brexit because of continuing financial obligations under the withdrawal agreement.

The EU KLEMS Project

Much the most ambitious project to date designed to implement the KLEMS methodology, in the spirit of the OECD manuals, was the EU KLEMS project. This was led by two independent research organizations, the National Institute for Economic and Social Research in the United Kingdom and Groningen University in the Netherlands, working originally with a consortium of 24 research institutes and NSIs. It was funded by the European Commission's 6th Framework Program and ran from 2003 to 2008; the last of several later, smaller-scale updates to the original project appeared in October 2012.[24] It is discussed here because of its unique, semi-official character.

The consortium members provided detailed data, some of it unpublished, particularly on labour and gross fixed capital formation. The project published two datasets: first, a conventional one which reproduced each country's official series (as they stood at that time) and second a larger, analytical dataset which was as far as possible "harmonized" across countries. In the latter a common set of assumptions about depreciation and asset lives was employed. Depreciation rates were assumed to be geometric and constant over time, varying across asset types but not across countries. The rate of return was estimated endogenously, so varying across, countries, industries and time. The prices of ICT assets were made consistent across countries following the method suggested by Schreyer (2002), so they fell much more rapidly than in the typical country's own official series.[25]

Subsequent follow-up projects have carried the terminal date up to 2020[26]. The latest version also incorporates a much wider list of intangible assets following the lead of Corrado, Hulten and Sichel (2005) and (2009); for details consult Bontadini *et al.* (2023). These additional intangibles are not counted as investment in the 2008 SNA though that may change in future versions of the SNA. 27 EU countries plus the UK (now no longer an EU member state of course), the US and Japan are now covered. On the downside, the degree of disaggregation is now down to 55 industries. This latest version contains a statistical module which is compatible with Eurostat's official statistics. These accounts are published separately from the extended analytical module which includes non-national accounts intangibles. Note too that this latest version of the data now starts in 1995 and there has been no attempt to reconcile the earlier data for 1979-2007 with the more recent data for the period in which

24 The author was involved in this project but was not one of its leaders.

25 A full description of the resulting dataset is in O'Mahony and Timmer (2009); see also the project website https://www.rug.nl/ggdc/productivity/eu-klems/ where the data and more detailed explanations will be found. The analytical dataset covers 25 EU member states, plus Japan, the US and Australia. Data coverage began in 1970 (later for the former communist countries who had by then joined the EU) and in the original project concluded in what turned out to be a turning point for Western economies, 2007. The March 2011 update, also spanning 1970 to 2007, achieved a high level of disaggregation: 72 industries under ISIC Rev. 3. The last update, March 2012, switched to ISIC Rev. 4 and the data period was 1970-2011, but now for only 12 countries and 34 industries.

26 See the EUKLEMS website, https://www.rug.nl/ggdc/productivity/eu-klems

the two versions overlap.

In my view the original EU KLEMS project did everything which it set out to do and has been widely used by the research community. But it proved difficult to fund initially. The original application in 1998 under the EU's 5th Framework programe was rejected before a second application under the 6th succeeded in 2003. As just stated, the last update issued by the EU KLEMS consortium was in October 2012. Thereafter ownership passed to a series of research institutes (The Conference Board, the Vienna Iinstitate for International Economic Studies (WIIW) and currently the Luiss Lab of European Economics at Luiss University).

It might have been hoped that after the first project had achieved proof of concept it would be taken over by some official agency which could have kept the database up to date on a routinized basis. The natural body to do this would have been Eurostat. But this did not happen, whether from lack of interest or inadequate funding of Eurostat. This is particularly surprising given that the years since 2007 have been the period of the productivity puzzle, when virtually all European countries have seen a drastic fall in the growth rates of both labour productivity and of TFP. Furthermore since at least 2007 in most European countries productivity has been growing more slowly than in the United States, whose growth has itself fallen quite substantially. So certainly since 2007 Europe as a whole has ceased to converge with the United States.

Though the original EU consortium is no more, the KLEMS approach has been pursued more widely under the banner "World KLEMS", an initiative launched by the late Dale Jorgenson of Harvard (Jorgenson 2012). There is now an Asia KLEMS, an India KLEMS, and Latin America KLEMS amongst other similar developments in Japan, Korea and China.[27]

Though as their names imply these various projects draw inspiration from the KLEMS framework, they are not harmonized with each other. So in this sense they are less ambitious than the original EU KLEMS project. Nor do they enjoy the same degree of support from NSIs. For example, I am informed that China has no official productivity statistics . Within the realm of official statistics, the World KLEMS website reports that in addition to the countries already mentioned the following seven NSIs are producing multifactor productivity data using the KLEMS framework: Australia, Denmark, Finland, Italy, Mexico, Netherlands, and Sweden. All of these are in the OECD and only one is within the Global South.

Conclusions

The KLEMS approach now has a worldwide spread but outside of the OECD progress has been mostly unofficial. This matters because NSIs have access to much more detailed data (via their own surveys and administrative records) than do private researchers. Within the OECD, the level of support and take-up has been variable. In

27 See the website www.worldklems.net for more details.

North America support for the approach preceded the manuals and has continued after their appearance. In Canada and the United States the estimates of labour and capital inputs are built up from much more detailed data than seems to be available in Europe. In the EU and the United Kingdom, there has been progress but there is still some way to go. The promise of the EU KLEMS project has not been fully maintained. Productivity statistics are still not fully integrated into national accounts.

In the United Kingdom and Europe, there is only limited acceptance of the US approach to measuring ICT prices. For example, in the UK only the CPI uses a US-type price index for computers, while the PPI and the corresponding import price index do not. Software prices are poorly measured everywhere. This is worrying if we really are living in the age of AI which we are told is going to transform productivity.

The original purpose of the KLEMS approach was to study growth and productivity, rather than the business cycle. But it has also proved very useful in studying economic fluctuations. The idea here is that a relatively small shock in one industry can propagate through the economy via that industry's interconnections with others, so that the size of the original shock is greatly amplified (Gabaix, 2011). Baqaee and Farhi (2019) develop that idea, arguing that an industry's Domar weight may give a misleading impression of its role in propagating shocks since the Domar weight is only the first order effect and second order effects may be important. They estimate these effects using one of the Jorgenson datasets which underlie the official BEA/BLS dataset, finding that second order effects are indeed important.[28]

A final point relates to the KLEMS framework itself. As noted above, the framework assumes perfect competition while most macroeconomists believe in imperfect competition. How (if at all) should the framework be adapted to incorporate imperfect competition? Economists will have to reach a consensus on this before recommending any changes to NSIs.

References

Atkinson, T. (2005) *Atkinson Review: Final report: Measurement of Government Output and Productivity for the National Accounts,* Houndsmill: Palgrave Macmillan. http://www.ons.gov.uk/ons/about-ons/what-we-do/programmes---projects/completed-projects-and-reviews/atkinson-review/final-report/atkinson-review-final-report---download.pdf.

Baldwin, J. R., W, Gu and B. Yan (2007) "User Guide for Statistics Canada's Annual Multifactor Productivity Program," *Canadian Productivity Review,* Catalogue, No. 14. https://www150.statcan.gc.ca/n1/en/pub/15-206-x/15-206-x2007014-eng.pdf?st=AJ7WWkkOhttps://www150.statcan.gc.ca/n1/en/pub/15-206-x/15-206-x2007014-eng.pdf?st=AJ7WWkkO.

Baldwin, John R., and W. Gu (2013) "Multifactor Productivity Measurement at Statistics Canada". *The Canadian Productivity Review,* No. 31. https://www150.statcan.gc.ca/n1/en/pub/15-206-x/15-206-x2013031-eng.pdf?st=MQosJ75B.

Baqaee, D. R. and E. Farhi (2019) "The Macroeconomic Impact of Microeconomic Shocks: Beyond Hulten's Theorem," *Econometrica,* Vol . 87, pp. 1155-1203.

28 I believe that a growth accounting approach using chained indices allows one to estimate second order as well as first order effects. But over a given period one is estimating the impact of all shocks together and the effect of a shock to a single industry cannot be isolated. This point is addressed rather obliquely in footnote 45 of Baqaee and Farhi (2019).

Basu, S. (2019) "Are Price-cost Margins Rising in the United States? A Discussion of the Evidence," *Journal of Economic Perspectives*, Vol. 33, pp. 3-22.

Bontadini, F., C. Corrado, J. Haskel, M. Iommi and C. Jona-Lasinio (2023) "EUKLEMS & INTANProd: Industry Productivity Accounts with Intangibles: Sources of Growth and Productivity Trends: Methods and Main Measurement Challenges," Lab of European Economics. https://euklems-intanprod-llee.luiss.it/.

Corrado, C., C. Hulten and D. Sichel (2005) "Measuring Capital and Technology: an Expanded Framework," in *Measuring Capital in the New Economy*, pp. 11-46, (eds.) Carol Corrado, John Haltiwanger and Dan Sichel, Chicago: University of Chicago Press.

Diewert, W. E. (1976) "Exact and Superlative Index Numbers," *Journal of Econometrics,* Vol. 4, pp. 115-146.

Diewert, W. E. (1978) "Superlative Index Numbers and Consistency in Aggregation," *Econometrica,* Vol. 46, pp. 883–900.

Domar, E. (1961) "On the Measurement of Technical Change," *Economic Journal,* Vol. 71, pp. 710-729.

Eldridge, L. P., C. Garner, T. F. Howells, B. C. Moyer, M. Russell, J. D. Samuels, E. H. Strassner and D. B. Wasshausen (2020) "Technical Document: Toward a BEA-BLS Integrated Industry-level Production Account for 1947–2016," Bureau of Economic Analysis. https://www.bea.gov/system/files/2020-11/Technical-Document-Toward-a-BEA-BLS-Integrated-Industry-level-Production-Account-for-1947-2016.pdf.

Eldridge, L. P. and S. G. Powers (2023) "The Importance of Output Choice: Implications for Productivity Measurement," *Monthly Labour Review.* https://www.bls.gov/opub/mlr/2023/article/the-importance-of-output-choice.htm.

Eurostat (2013) "European System of Accounts: ESA 2010," Luxembourg. https://ec.europa.eu/eurostat/documents/3859598/5925693/KS-02-13-269-EN.PDF/44cd9d01-bc64-40e5-bd40-d17df0c69334.

Garner, C., J. Harper, T. Howells, M. Russell and J. Samuels (2018) "Backcasting the BEA/BLS Integrated Industry-level Production Account and the Sources of U.S. Economic Growth between 1987 and 2016," Working Paper, No. 6, Bureau of Economic Analysis.https://www.bea.gov/system/files/papers/WP2018-6.pdf.

Garner, C., J. Harper, M. Russell, and J. Samuels (2020) "Integrated Industry-level Production Account for the United States and the Sources of U.S. Economic Growth between 1987 and 2018," *Survey of Current Business*, Vol. 100, pp. 1-14.

Feldstein, M and M. Rothschild (1974) "Towards an Economic Theory of Replacement Investment," *Econometrica*, Vol. 42, pp. 393-424.

Fraumeni, Barbara M. (1997) "The Measurement of Depreciation in the U.S. National Income and Product Accounts," *Survey of Current Business*, (July), pp. 7-23.

Gabaix, Xavier. (2011) "The Granular Origins of Aggregate Fluctuations." *Econometrica*, vol. 79, No. 3 (May), pp. 733-772.

Garner, C., J. Harper, M. Russell, and J. Samuels (2021) "Integrated BEA/BLS Industry-level Production Account and the Sources of U.S. Economic Growth: New Statistics for 2019 and Updated Statistics for 1987-2018, Including Extended Capital Detail," *Survey of Current Business*, Vol. 101, pp. 1-7.

Hall, Robert E. and Dale W. Jorgenson (1967) "Tax Policy and Investment Behaviour," *American Economic Review*, Vol. 57.

Hall, Robert E. (1988) "The Relation Between Price and Marginal Cost in US industry,"*Journal of Political Economy*, Vol. 96, No.5, pp. 921–947.

Hulten, Charles R. (1978) "Growth Accounting with Intermediate Inputs,"*Review of Economic Studies*, pp. 511–518.

Griliches, Zvi and Dale W. Jorgenson (1967) "The Explanation of Productivity Change," *Review of Economic Studies*, Vol. 34, pp. 249-283.

Inklaar, R. and Timmer, M. P. (2007) "International Comparisons of Industry Output, Inputs and Productivity Levels: Methodology and New Results." *Economic Systems Research.* Vol. 19, No.3, pp. 343-363.

Jorgenson, Dale (1963) "Capital Theory and Investment Behaviour," *American Economic Review*, Vol. 53, pp. 247-259.

Jorgenson, Dale W., Frank M. Gollop, and Barbara M. Fraumeni (1987) "Productivity and U.S. Economic Growth," Cambridge, MA: Harvard University Press.

Jorgenson, Dale W., Mun S. Ho, and Kevin Stiroh (2005) "Productivity, Volume 3: Information Technology and the American Growth Resurgence," Cambridge, MA, MIT Press.

Jorgenson, Dale W. (2012) "The World KLEMS Initiative," *International Productivity Monitor*, Spring, Number 24, pp. 5-20 http://www.csls.ca/ipm/24/ipm-24-jorgenson.pdf.

Jorgenson, D. W., M.S. Ho and J. D. Samuels (2016) "U.S. Economic Growth — Retrospect and Prospect: Lessons from a Prototype Industry-level Production Account for the U.S.," in *The World Economy: Growth or Stagnation?*, edited by D. W. Jorgenson, K. Fukao, & M. P. Timmer, pp. 34–69, Cambridge: Cambridge University Press.

Jorgenson, D. W., M. S. Ho and J. D. Samuels (2018) "Educational Attainment and the Revival of US Economic Growth," in *Education, Skills, and Technical Change: Implications for Future US GDP Growth*, edited by C. R. Hulten & V. A. Ramey, Chicago: University of Chicago Press.

Lee, P. (2011) "UK National Accounts: A Short Guide," *Office for National Statistics.* http://www.ons.gov.uk/ons/rel/naa1-rd/national-accounts-concepts--sources-and-methods/august-2011/index.html.

Office for National Statistics (2007) *The ONS Productivity Handbook: A Statistical Overview and Guide*, Edited by Dawn Camus. https://www.ons.gov.uk/fileuri=/economy/economicoutputandproductivity/productivitymeasures/methodologies/productivityhandbook/onsproductivityhandbooktcm77187914.pdf.

Office for National Statistics (2016) "Productivity Handbook," https://www.ons.gov.uk/economy/economicoutputandproductivity/productivitymeasures/methodologies/productivityhandbook.

Office for National Statistics (2018a) "International Comparisons of UK Productivity (ICP), Final Estimates: 2016," https://www.ons.gov.uk/economy/economicoutputandproductivity/productivitymeasures/bulletins/internationalcomparisonsofproductivityfinalestimates/2016.

Office for National Statistics (2019a) "Improving estimates of labour productivity and international comparisons," .https://www.ons.gov.uk/economy/economicoutputandproductivity/productivitymeasures/articles/improvingestimatesoflabourproductivityandinternationalcomparisons/2019-01-09.

Office for National Statistics (2019b) "Capital Services Estimates (Experimental)," https://www.ons.gov.uk/economy/economicoutputandproductivity/output/datasets/capitalservicesestimates.

Office for National Statistics (2020a) "Multi-Factor Productivity (MFP) QMI," https://www.ons.gov.uk/economy/economicoutputandproductivity/productivitymeasures/methodologies/multifactorproductivityqmi.

Office for National Statistics (2020b) "Multi-factor Productivity Estimates, UK: July to September 2019," https://www.ons.gov.uk/economy/economicoutputandproductivity/productivitymeasures/articles/multifactorproductivityestimates/latest.

Office for National Statistics (2020c) "Volume Index of Capital Services (VICS) QMI," https://www.ons.gov.uk/economy/economicoutputandproductivity/productivitymeasures/methodologies/volumeindexofcapitalservicesvicsqmi.

Office for National Statistics (2021) "Quality-Adjusted Labour Input (QALI) QMI," https://www.ons.gov.uk/employmentandlabourmarket/peopleinwork/labourproductivity/methodologies/qualityadjustedlabourinputqaliqmi.

Office for National Statistics (2022a) "Sources and Methods for Public Service Productivity Estimates,"https://www.ons.gov.uk/economy/economicoutputandproductivity/publicservicesproductivity/methodologies/sourcesandmethodsforpublicserviceproductivityestimates.

Office for National Statistics (2022b) "Double Deflation and the Supply and Use Framework in the UK National Accounts," https://www.ons.gov.uk/economy/nationalaccounts/supplyandusetables/articles/doubledeflationandthesupplyanduseframeworkintheuknationalaccounts/2022-12-02.

Office for National Statistics (2022c) "Gross Domestic product (GDP) QMI,"https://www.ons.gov.uk/economy/grossdomesticproductgdp/methodologies/grossdomesticproductgdpqmi.

Office for National Statistics (2022d) "Multi-factor Productivity Estimates," https://www.ons.gov.uk/economy/economicoutputandproductivity/productivitymeasures/datasets/multifactorproductivityexperimentalestimatesreferencetables.

Office for National Statistics (2023) "Labour Productivity QMI," https://www.ons.gov.uk/employmentandlabourmarket/peopleinwork/labourproductivity/methodologies/labourproductivityqmi.

OECD (2001) "Measuring Productivity – Productivity Manual: Measurement of Aggregate and Industry-Level Productivity Growth," OECD Publishing, Paris.

OECD (2009) "Measuring Capital: OECD Manual," OECD Publishing, Paris.

OECD (2018) "International Productivity Gaps: Are Labour Input Measures Comparable?," SDD Working Paper, No. 99, OECD. www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=SDD/DOC(2018)12&docLanguage=En.

O'Mahony, M. and M. P. Timmer (2009) "Output, Input and Productivity Measures at the Industry Level: The EU KLEMS Database," *Economic Journal,* No. 119, pp. 374-403.

Oulton, N. and S. Srinivasan (2005) "Productivity Growth in UK Industries, 1970-2000: Structural Change and the Role of ICT," Working Paper, No. 259, Bank of England.http://www.bankofengland.co.uk/research/Pages/workingpapers/2005/wp259.aspx].

Oulton, N., A. Rincon-Aznar, L. Samek and S. Srinivasan (2018) "Double Deflation: Theory and Practice," Economic Statistics Centre of Excellence, ESCoE DP 2018-17.https://www.escoe.ac.uk/publications/double-deflation-theory-and-practice/.

Oulton, N. (2020) "Measuring Productivity: Theory and British Practice," Centre for Macroeconomics, Paper No. CFM-DP-2020-02, London School of Economics.http://www.centreformacroeconomics.ac.uk/Discussion-Papers/2020/CFMDP2020-02-Paper.pdf.

Schreyer, P. (2001) "The OECD Productivity Manual: A Guide to the Measurement of Industry-Level and Aggregate Productivity," *International Productivity Monitor*, No 2, Spring. http://www.csls.ca/ipm/2/schreyer-e.pdf.

Schreyer, P. (2002) "Computer Price Indices and International Growth and Productivity Comparisons," *Review of Income and Wealth,* Vol. 48, No. 1, pp. 15–31.

Solow, R. M. (1957) "Technical Change and the Aggregate Production Function," *Review of Economics and Statistics,* Vol. 38, No. 3, pp. 312-320.

Statistics Canada (2023) *Labour Productivity Measures – National (Quarterly) (LPM).* https://www23.statcan.gc.ca/imdb/p2SV.pl?Function=getSurvey&SDDS=5042.

United Nations (2018) "Handbook on Supply, Use and Input-Output Tables with Extensions and Applications," in *Studies in Methods: Handbook of National Accounting*, New York.