The OECD Productivity Manual: A Guide to the Measurement of Industry-Level and Aggregate Productivity

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Productivity growth forms the basis for improvements in real incomes and welfare. Slow productivity growth limits the rate at which real incomes can improve, and also increases the likelihood of conflicting demands concerning the distribution of income. Measures of productivity growth and of productivity levels therefore constitute important economic indicators.

Over a number of years, the Statistical Working Party of the OECD Industry Committee has dealt with different aspect of productivity measurement and analysis. The group noted that, despite a large body of literature, no recent systematic and accessible source of information exists to provide a guide to the different approaches, interpretations and statistical requirements of productivity measures at national or international level. At the OECD, the last product of this kind was published by the Productivity Measurement Advisory Service of the OECD in 1966. Consequently, the Working Party undertook a project to compile a manual on productivity measurement. The final draft of this manual was de-classified by the OECD Industry Committee in February 2001, and is available in electronic form as of April 2, 2001 on the OECD homepage (http://www.oecd.org/subject/growth/an_ec_gr.htm), to be followed by a paper publication later this year as well as a translation into French.

The main objectives of the 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 harmonisation: 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.
- 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.

Coverage of the Manual

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, 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 (SNA)*, in particular households' production. Within the SNA production boundary, emphasis is given to productivity measures of those industries that are characterised 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.[1] Reference is 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 so-called 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 singular, academic research projects.

Overview of Productivity Measures

There are many different measures of productivity growth. The choice between them depends on the purpose of productivity measurement and, in many instances, on the availability of data. Broadly, productivity measures can be classified as single factor productivity measures (relating a measure of output to a single measure of input) or multi-factor productivity measures (relating a measure of output to a bundle of inputs). Another distinction, of particular rele-

Table 1:
Overview of Main Productivity Measures

	Type of input measure			
Type of output measure:	Labour	Capital	Capital & labour	Capital, labour & intermediate inputs (energy, materials, services)
Gross output	Labour productivity (based on gross output)	Capital productivity (based on gross output)	Capital — labour MFP (based on gross output)	KLEMS multi-factor productivity
Value-added	Labour productivity (based on value-added)	Capital productivity (based on value-added)	Capital — labour MFP (based on value-added)	—
	Single factor productivity measures		Multi-factor productivity (MFP) measures	

vance at the industry or firm level, is between productivity measures that relate some measure of gross output to one or several inputs and those which use a value-added concept to capture movements of output.

Table 1 uses these criteria to enumerate the main productivity measures. The list is incomplete insofar as single productivity measures can also be defined over intermediate inputs and labour-capital multi-factor productivity can, in principle, be evaluated on the basis of gross output. However, in the interest of simplicity, Table 1 was restricted to the most frequently used productivity measures. These are measures of labour and capital productivity, and multi-factor productivity measures (MFP), either in the form of capital-labour MFP, based on a value-added concept of output, or in the form of capital-labour-energy-materials MFP (KLEMS), based on a concept of gross output. Among those measures, value-added based labour productivity is the single most frequently computed productivity statistic, followed by capital-labour MFP and KLEMS MFP.

These measures are not independent of each other. For example, it is possible to identify various driving forces behind labour productivity growth, one of which is the rate of MFP change. This and other links between productivity measures can be established with the help of the economic theory of production. The following pages will highlight some of the issues discussed in the Manual.

A Selection of Issues Raised in the *Manual*

The *Productivity Manual* covers a variety of issues and their repetition would clearly stretch beyond the scope of the present short survey. In what follows, some of these issues have been selected to give a flavour for the type of discussion that can be found in the manual. The issues presented here relate to the choice between gross output and value-added-based productivity measures, and to some of the questions associated with measuring labour and capital inputs.

Gross Output and Value-added Based Productivity Measures

Every productivity measure, implicitly or explicitly, relates to a specific producer unit: an establishment, a firm, an industry, a sector or an entire economy. The goods or services that are produced within a producer unit and that become available for use outside the unit are called (gross) output. Output is produced using primary inputs (labour and capital) and intermediate inputs. Gross output-based multi-factor productivity growth is positive when the rate of volume gross output rises faster than the rate of combined inputs. This is an intuitively plausible way of describing productivity change in a producer unit and can, with some simplifying assumptions, be interpreted as an empirical approximation to the rate of disembodied technical change, i.e., of advances in technology that are not embodied in new machinery and equipment.

However, the gross output based approach tells one very little about the relative importance of a firm or an industry for productivity growth of a larger (parent) sector or of the entire economy. The reason lies in the existence of intra-industry deliveries. This is best explained by way of an example: suppose that there are two firms and let firm 1 (a leather factory) only produce intermediate inputs for firm 2 (a shoe producer). Firm 2 itself produces only final output. Now assume that a productivity measure for the *aggregate shoe and leather industry* should be formed. Simple addition of the flows of outputs and inputs implies is still possible but not the right procedure to obtain measures of output and input of the shoe and leather industry *as a whole*. There is double counting of outputs and inputs because of the intermediate flows between the leather and the shoe producer and these flows have to be netted out. In line with the above definition of output, the output of the integrated shoe and leather industry would consist only of the shoes produced, and integrated intermediate inputs consist only of the purchases of the leather industry and non-leather purchases of the shoe industry. This has important consequence for productivity measures. Take the example where both the shoe and the leather producers' gross output-based MFP growth is 1 per cent. The simple (weighted) average of the shoe and leather producers' MFP growth will be 1 per cent. However, productivity growth of the integrated shoe and leather industry will be more than 1 per cent, because the shoe producer's productivity gains cumulate with those of the leather producer as the former buys inputs from the latter. In other words, it is difficult to compare gross output based MFP growth across different levels of aggregation, as aggregate MFP growth is not a simple weighted average of its component measures.

This is not the case with value-added based MFP growth. Here, productivity is measured as the ratio of deflated (volume) value-added divided by a ratio of combined primary (labour and capital) inputs. Value-added, which takes the role of the output measure, is gross output corrected for purchases of intermediate inputs.

Value-added based MFP growth will be positive if volume value-added grows faster than combined primary inputs. The advantage of the value-added measure is that aggregate value-added growth is a simple weighted average of value added growth in individual industries, and so, is value-added-based MFP growth. To stay with the above example, value-added (at current prices) of the integrated shoe and leather industry is simply the sum of value-added in the shoe and the leather industry. A 1 per cent growth of value-added-based MFP in both the shoe and leather industry translates into a 1 per cent productivity growth of the shoe and leather industry

Table 2:

Value-added and Gross Output-based Productivity Measures: an Example

Machinery and Equipment Industry, Finland

Averages of annual percentage rates of change

	1990-98	1990-94	1994-98
Gross output (deflated)	10.1	4.2	16.0
Value added (deflated)	9.5	3.3	15.8
Labour input (total hours)	1.6	-3.7	6.9
Capital input (gross capital stock)	3.0	1.5	4.5
Intermediate inputs (deflated expenditure)	10.4	4.8	16.1
Share of value-added in gross output (current prices)	37.0	38.9	33.4
Gross output-based productivity (KLEMS MFP)	2.7	2.1	3.3
Value-added based productivity (Capital-labour MFP)	7.8	5.7	9.8

Source: OECD, based on STAN database.

as a whole. This makes value-added-based productivity measures comparable across different levels of aggregation and turns them into meaningful indicators for an industry's contribution to economy-wide productivity growth. Value-added is, however, not an immediately plausible measure of output: contrary to gross output, there is no physical quantity that corresponds to a volume measure of value-added. Also, if the production model based on gross output is the 'true' model of technical change, the value-added-based calculation will overstate the rate of technical change.

Empirically, the choice of concepts matters as the example from the Finnish machinery and equipment industry in Table 2 demonstrates. The rate of change of the gross output-based MFP measure is 2.7 per cent over the 1990-98 period, compared with a 7.8 per cent rise in the value-added-based measure. Moreover, the two measures show quite different pictures in terms of the *acceleration* or *deceleration* of productivity growth between two periods, an indicator that is of significant importance to analysts as has been seen in the discussion about the 'productivity slowdown' in the years after 1973 or the 'productivity acceleration' in the United States in the late 1990s. In the Finnish example, the gross output-based measure rises from 2.1 per cent to 3.3 per cent per year between the first and the second half of the 1990s, or by 1.2 percentage points. The value-added measure rises from 5.7 per cent to 9.8 per cent — which is by 4.1 percentage points and significantly faster than the gross output measure.

In a closed economy, the difference between the two measures becomes smaller with a rising level of aggregation; and at the level of the entire economy, the gross output-based productivity measure equals the value-added based MFP measure. In an open economy, with imports from abroad, this is not the case, and the two measures will continue to produce different results even at the macro-economic level.

Different interpretations have also to be invoked with respect to gross output and value-added-based measures of *labour productivity*. Both are widely-used productivity indices. In the first case, labour productivity is presented as the ratio between gross output and labour input, in the second case; value added supplies the numerator. Value-added-based labour productivity depends on shifts in capital intensity (the amount of capital available per unit of labour) and on MFP growth. When measured as *gross* output per unit of labour input, labour productivity growth also depends on how the ratio of intermediate inputs to labour changes. A process of outsourcing, for example, implies substitution of primary factors of production, including labour, for intermediate inputs. Everything else equal, gross output-based labour productivity rises as a consequence of outsourcing and falls when in-house production replaces purchases of intermediate inputs. As such, this does not reflect a change in the individual characteristics of the workforce, nor does it necessarily reflect a shift in technology or efficiency. In comparison with labour productivity based on gross output, the growth rate of value-added productivity is less dependent on any change in the ratio between intermediate inputs and labour, or on the degree of vertical integration. When outsourcing takes place, labour is replaced by intermediate inputs. In itself, this would raise measured labour productivity. At the same time, however, value-added will fall, and this offsets some or the entire rise in measured productivity.

Overall, it would appear that gross output and value-added based productivity measures are useful complements. When technical progress affects all factors of production proportionally, the former is a better measure of technical change. Value-added-based productivity measures vary with the degree of outsourcing and provide an indication of the importance of the productivity improvement in an industry for the economy as a whole. They indicate how much extra delivery to final demand per unit of primary inputs an industry generates. When it comes to *labour productivity*, value-added based measures are less sensitive to changes in the degree of vertical integration than gross output-based measures. Practical aspects also come to play. Measures of value-added are often more easily available than measures of gross output although in principle, gross output measures are necessary to derive value-added data in the first place. Consistent sets of gross output measures require dealing with intra-industry flows of intermediate products which may be difficult empirically.

The Need for Independent Measures of Output and Input

Different methodologies to obtain quantity series of output can significantly shape the outcome of productivity measurement. Quantity indices of output are normally obtained by dividing a current-price series or index of output by an appropriate price index (deflation). Only in a minority of instances[2] are quantity measures derived by direct observation of volume output series. Measurement of volume output is therefore often tantamount to constructing price indices — a task whose fuller description far exceeds the scope of the present paper. Some of the more difficult issues associated with the deflation of output are nevertheless mentioned here.

An important point for the validity of productivity measures is that price and quantity indices of output should be constructed independently of price and quantity indices of inputs. Such dependence occurs, for example, when quantity indices of outputs are based on extrapolation of some input series. Extrapolation relates to applying quantity indicators to carry forward and backward real value-added series. Such quantity indicators are sometimes inputs to the industry under consideration, in particular observations on employment. Input-based extrapolation is more frequent and quantitatively more important for service industries than for other parts of the economy (see OECD 1996) and can lead to biased productivity measures.

In other instances, output-related measures are used to extrapolate real value-added. Though often imperfect, it is apparent that the implied bias for productivity measurement is less severe than in the case of input-based extrapolation. For example, Eldridge (1999) reports that, in the United States, the quantity indicator for auto insurance expenditure is the deflated value of premiums, where deflation itself is based on a component index of the CPI. In other instances, physical output data are used as the quantity indicator: the United States quantity indicator for brokerage charges is based primarily on BEA estimates of orders derived from volume data from the Security and Exchange Commission and trade sources.

From the perspective of productivity measurement, the independence of statistics on inputs and outputs is key. Input-based indicators that are used to deflate output series generate an obvious bias in productivity measures: (labour) productivity growth will either be zero by construction or will reflect any assumption about productivity growth made by statisticians. Occurrences of input-based extrapolation are concentrated in activities where market output prices are difficult to observe.

Capturing Quality Change

The rapid development of information and communication technology products has brought to centre-stage two long-standing questions of price measurement: how to deal with quality changes of existing goods and how to account for new goods in price indices.[3] The distinction between these two issues is blurred because it is unclear where to draw the borderline between a 'truly' new good and a new variety of an existing good.

Typically, statistical agencies derive price indices for products by observing price changes of items in a representative sample. New products, quality change and new variants are common phenomena in the observation of price changes of items and statistical offices have well-established procedures to deal with them.[4] Unfortunately, these methods are not the same across countries and sometimes yield implausible large differences. The most widely quoted case is price indices for information and communication products such as computers. Their prices decline by between minus 30 per cent per year in the United States to about 5 per cent per year in a number of European countries. Given the homogeneity and international tradability of these products, it is likely that some of the differences are due to statistical methods rather than actual price developments. In the present context, the question arises: how much do these differences matter for comparisons of measures of output?

Empirically, the answer to this question depends largely on the level of aggregation at which analysis is conducted. As shown in Schreyer (2001), at the aggregate level the effects of a greater quality adjustment of ICT price measures tend to be comparatively small, and certainly not of a size to account for differences in measured productivity growth between countries. This is largely due to the fact that many ICT products are imported, and a different price measure not only affects measures of final consumption (and hence GDP) but also measures of imports, and some of the effects on measured GDP are offsetting. On the other hand, the effects on measured volume output are without doubt significant for individual industries such as the office equipment and computer industry.

Similarly, measures of individual demand components, in particular volume investment, may suffer from a lack of comparability unless similar methods are used between countries in their efforts to account for quality change in high-tech products. Volume investment measures are of direct importance for productivity analysis as they are important elements in the construction of capital stock series (see section on capital input below).

Choosing Between Different Measures of Employment

In the spirit of production theory, and disregarding quality differences for the moment, labour input for an industry is most appropriately measured as the number of hours actually worked. The simplest, though least recommended measure of labour input is a head count of employee jobs. Such a measure neither reflects changes in the average work time per employee nor changes in multiple job holdings and the role of self-employed persons nor changes in the quality of labour.

A first refinement to this measure is its extension to total employment, comprising both wage and salary earners, and the self-employed (including contributing family members). A second refinement is the conversion from simple job (or person) counts to estimates of total 'hours actually worked'. Rates of change of the number of persons employed differ from the rates of change of total hours worked when the number of average hours worked per person shifts over time. Such shifts may be due to a move towards more paid vacations, shorter 'normal' hours for full-time workers and greater use of part-time work. These developments have taken place in many OECD countries and underline the importance of choosing 'hours actually worked' as the variable for labour input in productivity measurement because it bears a closer relation to the amount of productive services provided by workers than simple head counts.

An example of the impact on labour productivity measures of choosing different measures for employment is given in Figure 1. For France, for the period 1987-1998, labour productivity indices were calculated using total hours, the number of full-time equivalent persons, the number of employed persons (head counts) and the number of employees (head counts). Results are presented for industry (comprising mining, manufacturing and construction) and for market services. Not surprisingly, the productivity measures based on total hours rise significantly faster than those based on other employment measures. In industry, correcting for part-time employment hardly changes the productivity series. This is quite different for the service sector where part-time employment plays a more important role. Even more pronounced are the effects of including or excluding the self-employed in the service sector, as reflected by the differences in productivity estimates based on total employment and based on the number of employees only.

Full-time equivalent jobs (or persons) are another variable sometimes used for measuring labour input. By definition, full-time equivalent employment is the number of total hours worked divided by average annual hours actually worked in full-time jobs. Conceptually, then, in full-time equivalent measures part-time employed persons are counted with a smaller weight than persons working full-time are. Consequently, the full-time equivalent measure should avoid the bias arising from a shifting share of part-time employment in the work force but will not adjust for changes in the number of hours which constitutes a full-time job, e.g., as a consequence of changes in legislation or collective agreements. In addition, methodologies underlying the construction of full-time equivalent persons (or jobs) are not always transparent and may vary internationally. For example, crude estimates are sometimes made whereby the number of part-time jobs (often defined as all jobs with less than normal working hours) is simply counted as half a full-time job.

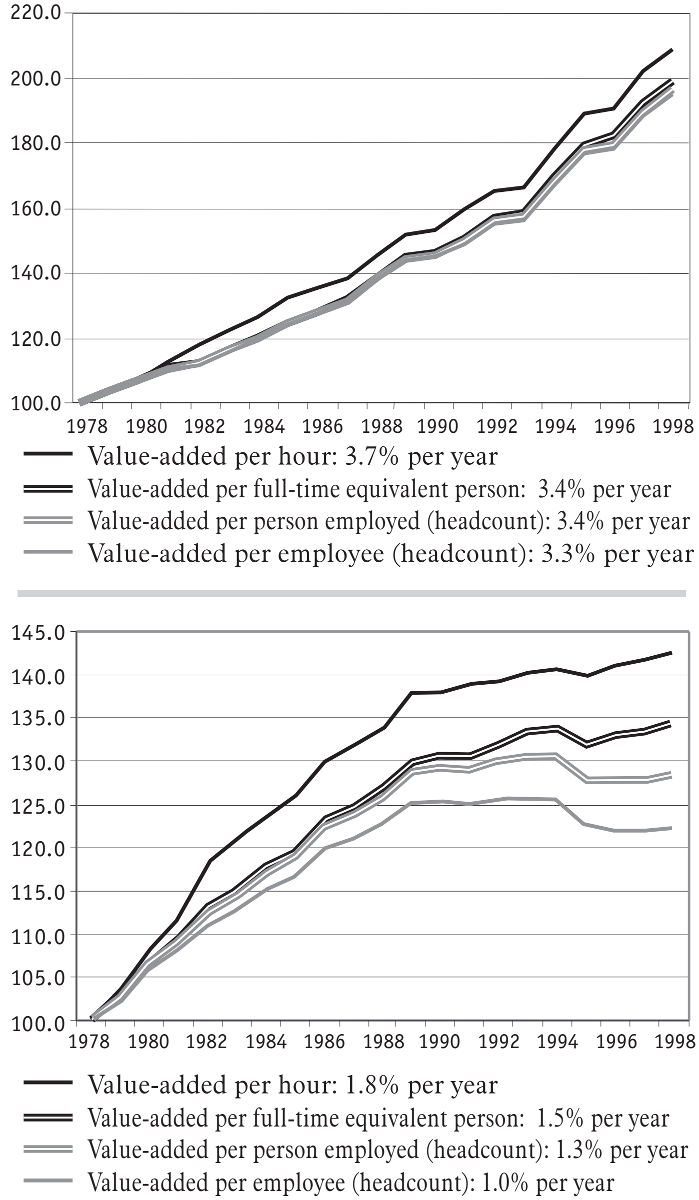
Capturing the Skill Composition of Labour

Labour input reflects the time, effort and skills of the work force. While data on hours worked captures the time dimension, it does not reflect the skill dimension. When total hours worked are the simple sum of all hours of all workers, no account is taken of the heterogeneity of labour. In the context of productivity measurement, Jorgenson et al. (1987), Denison (1985) and the U.S. Bureau of Labor Statistics (BLS, 1993) have tackled this issue.

For the estimation of productivity changes, the question is whether, over time, the composition of the labour force changes, *i.e.*, whether there is an increase or decrease in the average quality of labour input. By most measures, there has been a steady increase in the quality of labour (OECD 1998). An increase in the average quality of labour implies that a quality-adjusted measure of labour input would rise faster than an unadjusted measure of labour input. Successful quality-adjustment is tantamount to measuring labour in constant-quality units. Measuring constant-quality labour input is interesting from several perspectives.

First, it provides a more accurate indication of the contribution of labour to production. One recalls that MFP measures the residual growth in output that cannot be explained by the rate of change in the services of labour, capital and intermediate inputs. When quality-adjusted measures of labour input are used in growth

Figure 1:
Labour productivity* based on different measures of employment in France



* Output is measured as a quantity index of value-added .
Source: OECD, based on INSEE.

accounting instead of unadjusted hours worked, a larger share of output growth will be attributed to the factor 'labour' instead of the residual factor 'productivity growth'. In other words, substituting quality-adjusted labour input measures for simple ones can shift the appreciation of the sources of growth from externalities or spillovers captured by the productivity residual to the effects of investment in human capital.

Second, a comparison of an adjusted and unadjusted measure of labour input yields a measure of the corresponding compositional or quality change of labour input. This can usefully be interpreted as one aspect in the formation of human capital. As such it is a step towards measuring one important aspect of the effects of 'intangible investment'.

The theory of the firm stipulates that, under certain conditions (the firm is a price-taker on labour markets and aims at minimising its total costs), labour of a certain type will be hired up to the point where the cost of an additional hour of labour is just equal to the additional revenue that using this labour generates. This equality implies that, for a measure of total labour input, the individual labour inputs of different quality can be weighted with the respective relative wage rate, or more specifically, with the share that each type of labour occupies in total labour compensation.

Note that even when only a simple trait such as occupation is chosen to differentiate labour input, information requirements are severe: data is needed that distributes the number of total hours worked across different occupations, by individual industry and by individual year. In addition, quantity measures of labour input (hours worked) have to be accompanied by price measures (relative average compensation) to construct weights for aggregation. Such rich data sets are normally both difficult and costly to collect and therefore not readily available in practice.[5]

In this case, implicit differentiation can provide one, though incomplete substitute. Implicit differentiation arises when labour input (simple hours worked) is measured by detailed industry without, however, distinguishing between different types of labour within each industry. When the rate of change in hours worked by industry are aggregated to the economy-wide level and when each industry's share in total labour compensation is the aggregation weight, these weights will be comparatively large for industries that pay above-average wages and relatively small for industries with below-average wages. Assuming that above-average wages reflect above-average skills of the work force, some of the quality change of labour input is taken into account. Such an approach of implicit differentiation is for example, present in Statistics Canada's industry-level productivity statistics.

Measuring Capital Input[6]

In a production process, labour, capital and intermediate inputs are combined to produce one or several outputs. Parallel to labour services that are measured as hours actually worked, capital measures should be captured by total machine hours. Conceptually, capital services reflect a quantity, or physical concept, not to be confused with the value, or price concept, of capital. Because flows of the quantity of capital services are not usually directly observable, they have to be approximated by assuming that service flows are in proportion to the stock of assets after each vintage has been converted into standard 'efficiency' units. The so computed stock is sometimes referred to as the 'productive stock' of a given type of asset. Thus, the importance of capital stock measures in productivity analysis derives from the fact that they offer a practical tool to estimate flows of capital services — were the latter directly observable, there would be no need to measure capital stocks.

By contrast, the net or wealth capital stock is the current market valuation of an industry's or a country's productive capital. One of the purposes of the wealth stock is measuring economic depreciation or the loss in value of an asset as it ages. Total depreciation across all vintages of an asset is exactly the amount by which the value of the net capital stock of an asset declines as an effect of ageing. However, the wealth stock is not the appropriate tool to capture the quantity side of capital services.

A third capital measure is frequently encountered in economic statistics, the 'gross capital stock'. It represents the cumulative flow of investments, corrected only for the retirement of capital goods but based on the assumption that an asset's productive capacity remains fully intact until the end of its service life (sometimes called 'one-hoss-shay'). For a single, homogenous asset, the gross capital stock can be considered a special case of the productive stock, where an asset loses nothing of its physical productive capacity until it is retired.

The price of capital services is measured as their rental price. If there were complete markets for capital services, rental prices could be directly observed. In the case of, say, office buildings or cars, rental prices do exist and are observable on the market. This is, however, not the case for many other capital goods that are owned by producers and for which rental prices have to be imputed. The implicit rent that capital good owners 'pay' themselves gives rise to the terminology 'user costs of capital'. Under competitive markets and equilibrium conditions, user costs reflect the marginal productivity of the different assets. User cost weights thus provide a means to effectively incorporate differences in the productive contribution of heterogeneous investments as the composition of investment and capital changes.

Because many different types of capital goods are used in production, an aggregate measure of the capital stock or of capital services must be constructed. For net (wealth) stocks this is a straightforward matter of summing estimates for different types of assets. In so doing, market prices serve as aggregation weights. The situation is different in productivity analysis. Typically, each type of asset is associated with a specific flow of capital services and strict proportionality is assumed between capital services and capital stocks at the level of individual assets. This ratio is not the same, however, for different kinds of assets, so that the aggregate stock and the flows covering different kinds of assets must diverge. A single measure cannot serve both purposes except when there is only one single homogenous capital good (Hill 1999).

Jorgenson (1963) and Jorgenson and Griliches (1967) were the first to develop aggregate capital service measures that take the heterogeneity of assets into account. They defined the flow of quantities of capital services individually for each type of asset, and then applied asset-specific user costs as weights to aggregate across services from the different types of assets.

Figure 2 shows an example for the differences in capital measures that arise from the two concepts. Over the period under consideration, the capital services measure in Australia grew at a significantly faster pace than the wealth measure in that same country. This feature can also be found in other countries, in particular the United States (Dean et al. 1996). It implies that the choice of the capital measure may have non-negligible impacts on measured productivity growth. For example, Australia's multi-factor productivity grew by an annual average rate of 2.0 per cent over the period 1995-99, when based on a capital services measure. This capital services indicator grew by 4.7 per cent per year over the same period, whereas the net (wealth) capital stock measure only showed a 3.1 per cent rise. The resulting 1.6 percentage point difference implies approximately a 0.5 percentage point adjustment to the MFP measure. Thus, based on the net stock rather than on a measure of capital services, Australia's MFP growth would have been evaluated at 2.5 per cent over the years 1995-99, and hence over-estimated: too large a share of output growth would have been attributed to a change in MFP rather than to an increased contribution of physical capital to output.

Interpretation of Productivity Measures

The *Manual* provides a short discussion of interpretation of productivity measures. There are indeed a number of possible pitfalls when using productivity measures for analysis and limits and assumptions have to be kept in mind. Nonetheless, the Manual takes a positive stance about the general usefulness of the various productivity measures. Some issues are mentioned below.

Labour productivity is a useful measure: it relates to the single most important factor of production, is intuitively appealing and relatively easy to measure. Also, labour productivity is a key determinant of living standards, measured as per capita income, and from this perspective is of significant policy relevance. However, it only partially reflects the productivity of labour in terms of the personal capacities of workers or the intensity of their efforts. Labour productivity reflects how efficiently labour is combined with other factors of production, how many of these other inputs are available per worker and how rapidly embodied and disembodied technical change proceed. This makes labour productivity a good starting point for the analysis of some of these factors. One way of carrying out further analysis is to turn to multi-factor productivity measures.

Multi-factor productivity measurement and growth accounting helps disentangle the direct growth contributions of labour, capital, intermediate inputs and technology. This is an important tool for reviewing past growth patterns and for assessing the potential for future economic growth.

However, one has to be aware that *not all technical change translates into MFP growth*. An important distinction concerns the difference between embodied and disembodied technological change. The former represents advances in the design and quality of new vintages of capital and intermediate inputs and its effects are attributed to the respective factor as long as the factor is remunerated accordingly. Disembodied technical change comes 'costless', for example in the form of general knowledge, blueprints, network effects or spill-overs from other factors of production including better management and organisational change. The distinction is important from a viewpoint of analysis and policy.

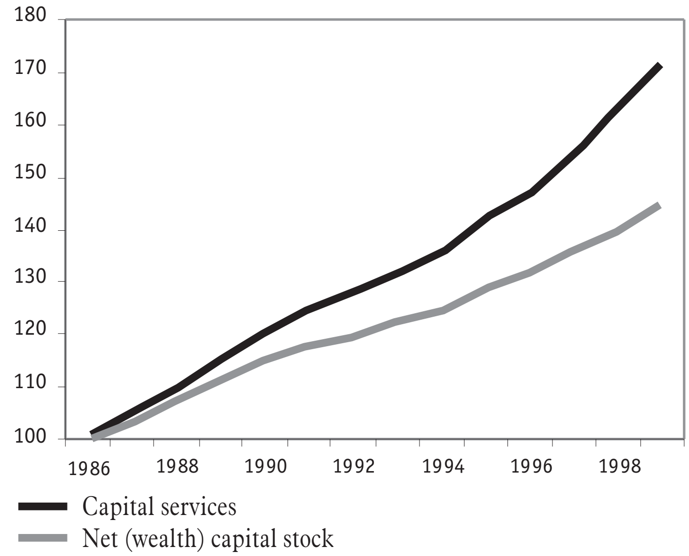
Further, in empirical studies, measured *MFP growth is not necessarily caused by technological change:* other non-technology factors will also be picked up by the residual. Such factors include adjustment costs, scale and cyclical effects, pure changes in efficiency and measurement errors.

MFP measures tend to understate the eventual importance of productivity change in stimulating the growth of output. In static models of production such as the one used in the *Manual*, capital is an exogenous input, given at the beginning of every accounting period. In a dynamic context, this is not the case and feedback effects exist between productivity change and capital: suppose that technical change allows more output to be produced per person. The static MFP residual measures just this effect of technical change. However, additional output per person may lead to additional savings and investment, and to a rise in the capital-labour ratio. Then, a traditional growth accounting measure would identify this induced effect as a growth contribution of capital, although it can be traced back to an initial shift in technology. Thus, the MFP residual correctly measures the shift in production possibilities but does not capture the induced effects of technology on growth (Rymes 1971, Hulten 2001.

MFP growth can also — and usefully — be interpreted in terms of costs. Productivity and growth accounting measures described in the manual are discussed with the help of production functions and quantity measures of inputs and outputs. There exists an equivalent, and intuitively appealing 'dual' approach to express advances in productivity as shifts of a cost function.[7] A cost function shows the minimum input cost of producing a certain level of output, given a set of input prices. Under relatively weak regularity conditions, cost functions can be derived from production functions, and vice versa — there is duality. It can be shown that the MFP productivity residual can be measured either as the residual growth rate of output not explained by the growth rate of inputs or as the residual growth rate of average costs not explained by change in input prices. Thus, without progress in multifactor productivity, average costs change in line with input prices. When MFP growth is positive, average costs rise by less than average input prices. A slightly different formulation of the same phenomenon is that productivity growth equals the diminution in total costs that is neither explained by a fall in output nor by substitution of inputs that have become relatively more expensive for those whose relative price has fallen.

This formulation of MFP in terms of average costs lends a richer interpretation to technological change. It is intuitively plausible that total and average costs can be reduced by many means including technological innovations in an engineering sense but also by organisational innovations, learning by doing, and managerial efforts.

Figure 2:
Capital services and net capital stock measures
Australia, 1986-99



Source: Australian Bureau of Statistics.

The cost approach also shows how average cost can decline as a consequence of embodied technological change only: suppose that one of the inputs (*e.g.*, computer services) exhibits falling prices (user costs) relative to other inputs as a consequence of (embodied) technical change. Most likely, a substitution process will take place where computer services replace other factors of production. The ensuing decrease in aggregate input prices leads to a fall in average costs, even if disembodied technology does not grow at all.

Accounting is not explaining the underlying causes of growth. Growth accounting and productivity measurement identifies the relative importance of different *proximate* sources of growth. At the same time, it has to be complemented by institutional, historical and case studies if one wants to explore the *underlying* causes of growth, innovation and productivity change.

Challenges for Statisticians

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 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.

Notes

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1 Practices of deflation of output and value-added of non-market activities are described in OECD (1996). A more recent discussion can be found in Eurostat (2001).

2 For a discussion regarding the United States, see Eldridge (1999).

3 See the *OECD* (2001a) and the *Eurostat* (2001).

4 For example, Lowe (1996) provides an overview of how quality change is handled in the Canadian National Accounts.

5 For empirical results see United States Bureau of Labor Statistics (1993), Fosgerau et al. (2000) and Scarpetta et al. (2000).

6 For specific information about the practical and conceptual issues regarding the construction of capital stock measures, see *OECD* (2001b).

7 For an overview, see Diewert (1992).

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