MEASURING PRODUCTIVITY

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INTRODUCTION

Productivity growth is 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 (Englander and Gurney, 1994). Measures of productivity growth and of productivity levels therefore constitute important economic indicators.

In principle, productivity is a rather straightforward indicator. It describes the relationship between output and the inputs that are required to generate that output. Despite its apparent simplicity, several problems arise when measuring productivity. These issues are particularly important for comparing productivity growth across countries, whether for the entire economy or for different industries, and for comparing productivity levels internationally. Some of these measurement difficulties are closely related to technological developments – currently of great interest. For example, assessing the role of information and communication technology (ICT) in productivity growth requires the construction of accurate price and quantity indices of ICT products that are internationally comparable. Other issues, such as the measurement of labour input, have been around for much longer, but remain important. The most important productivity measurement issues have recently been brought together in the OECD *Productivity Manual* (OECD, 2001*a*) and part of the discussion below draws on this manual.

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).[1] Another distinction, of particular relevance at the industry or firm level is between productivity measures that relate 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, the table was restricted to the most frequently used productivity measures. These

Table 1. **Overview of the main productivity measures**

Type of output measure:	Type of input measure: Labour	Capital	Capital and labour	Capital, labour and 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***	

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-services 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.

A full discussion of the entire set of productivity measures would go beyond the scope of this paper. The following pages will therefore highlight some key conceptual and measurement issues associated with comparisons of productivity growth and productivity levels over time and between countries. The sections on productivity growth and on the interpretation of productivity measures draw heavily on the OECD *Productivity Manual* (OECD, 2001*a*) to which the reader is referred for a more in-depth discussion. The paper primarily focuses on measurement and comparability issues, leaving the detailed analysis and interpretation of productivity to other papers in this issue of OECD *Economic Studies*. The next section explores measures of productivity growth and the theoretical foundations for these measures. The third section examines estimates of productivity levels, while the fourth section briefly discusses the interpretation of productivity growth and levels.

MEASURING PRODUCTIVITY GROWTH

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.[2] Output is produced using primary inputs (labour and capital) and intermediate inputs. This relation is normally presented as a production function H with gross output Q, labour input L, capital input K, intermediate inputs M and a parameter of technical change, A:

$$Q = H(A, K, L, M) \tag{1}$$

Technical change is called "Hicks-neutral" or "output augmenting" when it can be presented as an outward shift of the production function that affects all factors of production proportionately:

$$Q = H(A, K, L, M) = A \bullet F(K, L, M) \tag{2}$$

Differentiating this expression with respect to time and using a logarithmic rate of change, MFP growth (the rate of change of the variable A) is measured as the rate of change of volume output minus the weighted rates of change of inputs. For a cost-minimising producer, the weights attached to the rates of change of factor inputs correspond to the revenue share of each factor in total gross output:

$$\frac{d\ln A}{dt} = \frac{d\ln Q}{dt} - s_L \frac{d\ln L}{dt} - s_K \frac{d\ln K}{dt} - s_M \frac{d\ln M}{dt} \tag{3}$$

Here, MFP growth is positive when the rate of growth of the volume of gross output rises faster than the rate of growth of all combined inputs. When the assumption about factor-augmenting technical change holds, the so computed MFP measure can be interpreted as an index of disembodied technical change. This is the well-known Solow (1959) growth accounting model (Box 1; Box 2).

However, the gross output based approach provides few insights about the relative importance of a firm or an industry for productivity growth of a larger (parent) sector or of the entire economy, due to complications related to intra-industry deliveries. This is best explained by way of an example. Suppose that there are two industries: the leather industry, which only produces intermediate inputs for the shoe industry. By contrast, the shoe industry produces only final output. A productivity measure for the *aggregate shoe and leather industry* would need to address the following problem. Simple addition of the flows of outputs and inputs is not the right procedure for obtaining measures of output and input of the shoe and leather industry *as a whole*, since double counting of the intermediate flows between the leather and the shoe producer would result. These flows have to be netted out, such that 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 consequences for productivity measures. Take

Box 1. **Growth accounting and links between productivity measures**

The economic theory of productivity measurement goes back to the work of Jan Tinbergen (1942) and, independently, to Robert Solow (1957). They formulated productivity measures in a production function context and linked them to the analysis of economic growth. The field has developed considerably since and now offers a consistent approach that integrates the theory of the firm, index number theory and national accounts. Robert Solow's growth accounting approach identifies the contributions of different inputs to output growth. In its simplest form, where output Q is measured as deflated value-added and inputs are confined to primary inputs labour L and capital services K, the growth accounting equation can be stated as:

$$\frac{d\ln Q}{dt} = s_L \frac{d\ln L}{dt} + s_K \frac{d\ln K}{dt} + \frac{d\ln A}{dt}$$

In this expression, labour and capital each contribute to value-added growth and their contribution is measured as the rate of change of each input times its share in total costs. The change in value added that is not explained by these contributions is attributed to multi-factor productivity growth, captured by the variable A. Thus, the rate of change of A is measured residually, *i.e.* by subtracting the contributions of labour and capital from the rate of output growth. Another useful way of presenting the growth accounting equation is in terms of a decomposition of the rate of change of labour productivity. Labour productivity growth is measured as the difference between the rate of change of output growth and the rate of change of labour input growth, or as

$$\frac{d\ln Q}{dt} - \frac{d\ln L}{dt}.$$

Re-arranging the above expression gives a decomposition of the movement in labour productivity into two components. The first depicts the change in labour productivity due to capital deepening (labour productivity rises when more capital is used per worker) and the second shows the effects of MFP growth:

$$\frac{d\ln Q}{dt} - \frac{d\ln L}{dt} = (1 - s_L)\left(\frac{d\ln K}{dt} - \frac{d\ln L}{dt}\right) + \frac{d\ln A}{dt}$$

The following table presents this decomposition for the business sector of several OECD countries. It shows that capital deepening has played an important but not a dominant role in explaining value-added based labour productivity growth in the 1990s. This does not imply that investment has been unimportant in the process of growth. For instance, if output growth is driven both by capital and employment growth, capital intensity remains stable. Much depends also on the measurement of capital input (see discussion below). The present table is based on a measure of capital services, thereby reflecting the theoretically preferred approach towards the measurement of capital input.

Box 1. **Growth accounting and links between productivity measures** (*cont.*)

Productivity growth in the business sector

(annual percentage change)

		Labour productivity (Value-added per hour worked)	Of which: Capital deepening	Of which: MFP growth
Australia	1990-99	2.5	0.6	1.9
	1995-99	2.9	0.9	2.0
Canada	1990-99	1.5	0.2	1.3
	1995-99	1.3	0.2	1.1
France	1990-99	1.8	1.1	0.7
	1995-99	1.5	0.7	0.8
Germany	1990-99	2.4	1.2	1.2
	1995-99	1.7	0.9	0.8
Italy	1990-99	1.9	0.9	0.9
	1995-99	0.7	0.6	0.1
Japan	1990-99	2.0	1.5	0.6
	1995-99	1.7	1.1	0.5
United States	1990-99	1.5	0.7	0.8
	1995-99	2.3	1.0	1.3

Source: Colecchia and Schreyer (2001).

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 sum, 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.

Double counting does not arise with value-added-based MFP growth.[3] Here, productivity is measured as the ratio of value-added to an index of combined primary inputs (*i.e.* labour and capital), with both the numerator and denominator

Box 2. **The econometric approach to productivity measurement**

The econometric approach to productivity measurement is appealing for being based solely on observations of volume outputs and inputs. For example, it avoids postulating the relationships between production elasticities and income shares that are implied by cost minimisation but may not correspond to reality. Indeed, researchers are able to test these relationships. Further possibilities arise with econometric techniques: *i*) allowance can be made for adjustment cost (the possibility that changes in factor inputs are increasingly costly the faster they are implemented) and variations in capacity utilisation; *ii*) it is possible to investigate forms of technical change other than the Hicks-neutral formulation implied by the index number based approach; *iii*) there is no *a-priori* requirement to assume constant returns to scale of production functions. The literature about the econometric approach is large, and examples of integrated, general models can be found in Morrison (1986) or Nadiri and Prucha (2001).

All these possibilities come at a cost, however. These models raise complex econometric issues that sometimes put a question mark on the robustness of results. Often, researchers are constrained by modest sample sizes to revert to *a priori* restrictions (for example constant returns to scale) to increase the degrees of freedom for estimation. From the point of view of statistical offices responsible for the publication of regular productivity statistics, complex econometric approaches have little attractiveness because: *i*) updating involves full re-estimation of (systems of) equations; *ii*) methodologies are often difficult to communicate to a broad spectrum of users of productivity statistics; and *iii*) significant data requirements tend to reduce the timeliness of results.

Hulten (2001) points out that there is no reason why the econometric and the index number approach should be viewed as competitors and he quotes examples of synergies that proved particularly productive. Synergies arise in particular when econometric methods are used to further explain the productivity residual.

Overall, econometric approaches are a tool that is best suited for academically oriented, single studies of productivity growth. Their potential richness and testable set-up make them a valuable complement to the non-parametric, index number methods that are the normal tool for productivity statistics.

representing deflated (real) volumes. Value-added, which takes the role of the output measure, is gross output corrected for purchases of intermediate inputs. In terms of rates of change, real value-added can be defined[4] as

$$\frac{d\ln VA}{dt} \equiv \frac{1}{s_{VA}}\left(\frac{d\ln Q}{dt} - s_M \frac{d\ln M}{dt}\right).$$

Here, S_{VA} stands for the current price share of value-added in gross output. Using equation (3) to substitute for the expression in parenthesis yields:

$$\frac{d\ln VA}{dt} = \frac{1}{s_{VA}}\left(s_L \frac{d\ln L}{dt} + s_K \frac{d\ln K}{dt} + \frac{d\ln A}{dt} \right) \tag{4}$$

Value-added-based MFP measures, evaluated residually as the difference between the rate of change of real value-added and the weighted rates of change of primary inputs labour and capital, can then be expressed as in (5), where $s_L^{VA} = s_L / s_{VA}$ is the labour share in value-added and $s_L^{VA} = s_L / s_{VA}$ is the capital share.

$$\frac{d\ln A^{VA}}{dt} = \frac{d\ln VA}{dt} - s_L^{VA}\frac{d\ln L}{dt} - s_K^{VA}\frac{d\ln K}{dt} \tag{5}$$

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 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 (2) is the "true" model of technical change, the value-added-based calculation will overstate[5] the rate of technical change, as

$$\frac{d\ln A^{VA}}{dt} = \frac{1}{s_{VA}}\frac{d\ln A}{dt}.$$

That is, the value-added-based MFP measure equals the gross output-based measure times a scaling factor that corresponds to the inverted share of value-added in gross output. This share cannot exceed unity and consequently, the value-added-based MFP measure will always be at least as large as the gross output-based term.

Empirically, the choice of concepts matters, as Table 2 on productivity in the machinery and equipment industry in Finland demonstrates. The rate of change of the gross output-based MFP measure is 2.7 per cent over the 1990-98 period, com-

Table 2. **Value-added and gross output-based productivity measures: an example**
Machinery and equipment industry, Finland
Averages of annual rates of change (percentages)

	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.

pared 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; meanwhile, the value-added measure rises from 5.7 per cent to 9.8 per cent, or by 4.1 percentage points.

In a closed economy, the difference between the two measures becomes smaller with a rising level of aggregation; at the level of the entire economy, the gross output-based productivity measure will equal 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 macroeconomic level.

Different interpretations have also to be invoked with respect to gross output and value-added-based measures of *labour productivity*, both widely-used productivity indices. Growth in value-added-based labour productivity depends on shifts in capital intensity (the amount of capital available per unit of labour) and 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, despite the fact that such changes need not reflect changes in the individual characteristics of the workforce, nor shifts in technology or efficiency. By contrast, the growth rate of value-added productivity is less strongly affected by changes in the ratio between intermediate inputs and labour, or 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 compensate for the extent 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 into 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. Intra-industry flows of intermediate products must be accounted for in order to generate consistent sets of gross output measures and that may be difficult empirically.

Measuring output

Differences in the methodologies used to obtain quantity series of output can significantly affect productivity measures. Quantity indices of output are normally obtained by dividing a current-price series or index of output by an appropriate price index (*i.e.* by deflation). Only in a few instances are quantity measures derived by direct observation of volume output series.[6] Measurement of volume output is therefore often tantamount to constructing price indices – a task whose full 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.

Independence of measures of output from measures of input. An important precondition 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 extrapolated using quantity indices for one or several inputs. The quantity indicators used are often inputs to the industry under consideration, in particular observations on employment.

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 (Eldridge, 1999).

From the perspective of productivity measurement, the independence of statistics on inputs and outputs is key. Using input-based indicators to construct output series generates an obvious bias in productivity measures; productivity growth will reflect whatever assumption about productivity growth was made by statisticians in constructing the output series (*e.g.* that labour productivity was unchanged). Occurrences of input-based extrapolation are concentrated in activities where market output prices are difficult to observe. For this reason, input-based extrapolation is more frequent and quantitatively more important for service industries than for other parts of the economy (see OECD, 1996*b* for a survey of methods in OECD countries) and can lead to biased productivity measures.

Quality change. The rapid development of information and communication technology products has brought to centre-stage two long-standing questions for the construction of price indices: how to deal with quality changes of existing goods and how to account for new goods.[7] 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.[8]

Typically, statistical agencies derive price indices for products by observing price changes of items in a representative sample. New products, quality changes 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.[9] Unfortunately, these methods are not the same across countries and sometimes yield implausibly large differences. The most widely quoted case is price indices for information and communications technology products such as computers. Their prices decline by between 30 per cent per year in the United States, and 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?

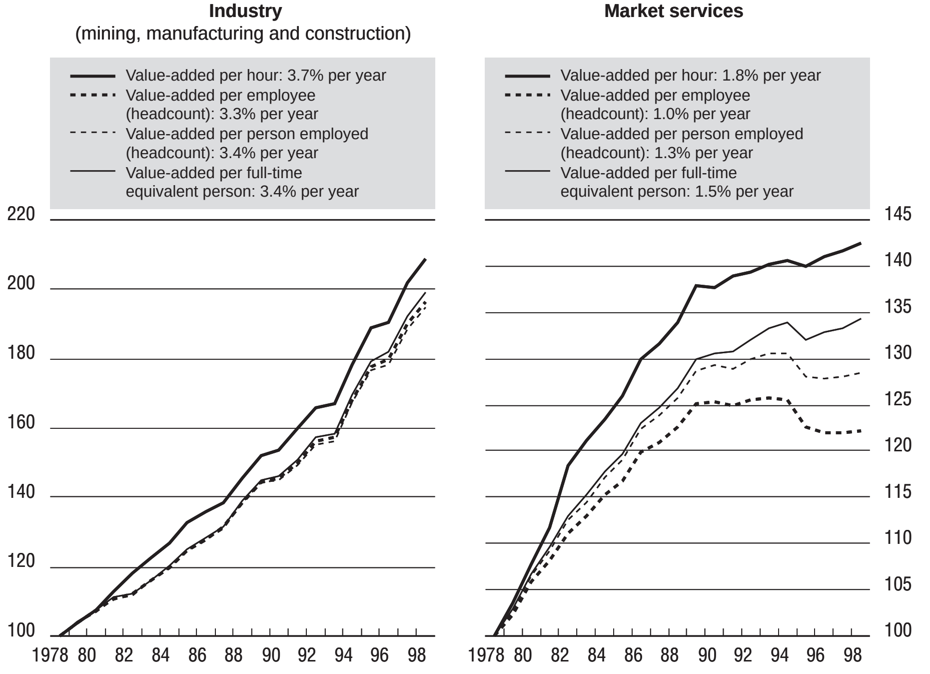
Empirically, the answer to this question depends largely on the level of aggregation at which the analysis is conducted. As shown in Schreyer (2001), the effects of a greater quality adjustment of ICT price measures tend to be comparatively small for the measurement of economy-wide productivity, and 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, implying that some of the effects on measured GDP are offsetting. On the other hand, the effects on measured output volumes are without doubt significant for individual industries such as the office equipment and computer industry. Similarly, measures of individual demand components, in particular the volume of 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. Measures of the volume of investment 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).

Labour input

Different measures of employment. In the spirit of production theory, labour input for an industry is most appropriately measured as the quality-adjusted number of hours actually worked. The simplest, though least recommended, measure of labour input is a head count of jobs or employees. Such a measure fails to reflect changes in average work time per employee, multiple job holding (when the number of employees is the measure), self-employment and 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. Moreover, hours worked will also vary over the business cycle as labour demand rises and falls. 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.

Figure 1. **Labour productivity[1] based on different measures of employment in France**



1. Output is measured as a quantity index of value-added.
Source: INSEE.

An example of the impact on labour productivity measures of choosing different measures for employment is given in Figure 1 below. For France, for the period 1987-98, 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 manufacturing, moving from head counts to full-time equivalent measures hardly changes the productivity series. This is quite different for the service sector where part-time employment has grown rapidly in many countries and now plays an important role in total employment. 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. Consequently, the full-time equivalent measure should avoid the bias arising from a shifting share of part-time employment in the workforce 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, in some cases full-time equivalents are based on crude estimates, such as counting each part-time job (often defined as any job with less than normal working hours) as half a full-time job.

Statistical sources. There are two main statistical sources for measures of labour input: household-based labour force surveys (LFS) and establishment or firm-based surveys (ES). LFS are typically conducted from a socio-economic perspective to provide reliable information about personal characteristics of the labour force, such as educational attainment, age, or the occurrence of multiple job holding, as well as information about the jobs (*e.g.* occupation and type of contract). Also, LFS have the advantage of full coverage of the economy. ES are conducted from a production perspective, and describe labour as an input factor. One distinguishing feature of establishment surveys is that they gather information on jobs rather than on persons employed, thus persons who have jobs in more than one establishment will be counted more than once. Another feature is that ES will often only cover a subset of all establishments in an industry, normally those above a certain size limit. If establishments included in the survey have systematically higher productivity levels than those excluded, productivity estimates based on ES will inadequately reflect the effects of the size composition in an industry.

In a few OECD countries (*e.g.* the Netherlands), statistical offices fully consolidate the two sources into a single, final set of labour accounts. In most countries, both sources are used to construct employment data for national accounts (NA). As such, these NA data qualify as the preferred source for productivity analysis. However, NA statistics often stop short of producing all the relevant labour input measures (in particular hours worked) or such variables are not available at the required sectoral detail. In such cases, multiple sources sometimes have to be combined, although this introduces the risk of not comparing like with like. One such example is the application of data on average hours worked per person, based on LFS, to NA-based statistics on the number of persons employed. This may be acceptable for purposes of constructing measures of productivity *growth* but can create important non-comparabilities when measuring productivity *levels* (see below for a further discussion).

Skill composition of labour. Labour input reflects the time, effort and skills of the workforce. While data on hours worked capture the time dimension, they do 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. 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*a*). 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. In the context of productivity measurement, Jorgenson *et al.* (1987), Denison (1985) and the US Bureau of Labor Statistics (BLS, 1993) have tackled this issue

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 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 unadjusted measures can better identify the sources of growth, by distinguishing between externalities or spill-overs – captured by the productivity residual – and 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 of the formation of human capital, and is thus a step towards measuring the effects of intangible investment.

The theory of the firm stipulates that, under certain conditions (*i.e.* the firm is a price-taker on labour markets and minimises 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 using their relative wage rates (or, more precisely, the shares of each type of labour in total labour compensation).

Even when labour input is differentiated only by a simple trait, such as occupation, information requirements are severe: data are needed that distribute the number of total hours worked across different occupations, by individual industry and by individual year. In addition, quantity measures of labour input (*i.e.* hours worked) have to be accompanied by price measures (*i.e.* 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.[10]

Even when such data are not available, "implicit differentiation" can provide a useful, albeit incomplete, adjustment for labour quality. Implicit differentiation arises when labour input (*i.e.* total hours worked) is measured by detailed industry without, however, distinguishing between different types of labour within each industry. If the rate of change in hours worked by industry are aggregated to the economy-wide level using each industry's share in total labour compensation as its aggregation weight, these weights will be relatively large for industries that pay above-average wages and relatively small for industries with below-average wages. Assuming that above-average wages reflect an above-average skill composition of the workforce, some of the quality change of labour input is implicitly taken into account. Statistics Canada's industry-level productivity statistics provide an example of implicit differentiation, since the indices of labour input at the sectoral level are built up from hours-worked data for more detailed industries that are weighted by their shares in total sectoral labour compensation.

Capital input

In a production process, labour, capital and intermediate inputs are combined to produce one or several outputs. Conceptually, many facets of capital input measurement are directly analogous to labour input measurement (Table 3). Capital goods, whether purchased or rented by a firm, provide a flow of capital services that constitutes the actual input to the production process. Similarly, employees hired for a certain period can be seen as providing flows of labour services from their stocks of human capital. Differences between labour and capital arise because producers usually own capital goods. When the capital good "delivers" services to its owner, no market transaction is recorded. The measurement of these implicit transactions – whose quantities are the services drawn from the capital stock during a period and whose prices are the user costs or rental prices of capital – is one of the challenges of capital measurement.

Constructing measures of capital services.[11] Conceptually, capital services reflect a quantity or physical concept that should 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. Most often, this is done by assuming that service flows are in proportion to the stock of assets, after each vintage has been converted into standard "efficiency" units. The capital stock, so computed, is sometimes referred to as the "productive stock" of a given type of asset. Accordingly, the importance of capital stock measures to productivity analysis derives solely 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.

Several measures of capital frequently encountered in economic statistics do not provide estimates of capital services suited to use in measuring productivity. These include the net or wealth capital stock, which is the current market valuation of an industry's or a country's productive capital. One of the purposes of the wealth stock is to measure economic depreciation, *i.e.* 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.

The "gross capital stock" is a closely related capital measure. 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.

Table 3. **Labour and capital inputs**

	Labour input	**Capital input**
	Human capital	Physical capital
Services to production from input factors:		
Quantity	Labour services, measured as total hours worked	Capital services, measured as total machine hours (typically, assumed to be in fixed proportion to capital stock)
Prices	Compensation per hour	User cost of capital per unit of capital service
Differentiation	By industry and by type of labour input	By industry and by type of capital asset
Factor cost or factor income	Compensation per hour x total hours	User costs x productive capital services
Aggregation weights	Industry-specific and labour-quality-specific shares in total labour compensation	Industry-specific and asset-specific shares of total user costs of capital

In empirical applications, the growth rate of capital services typically exceeds that of the wealth stock. Using the wealth stock as a measure of capital input in productivity calculations would thus imply an overstatement of MFP growth compared with the MFP associated with capital services (see below). On the other hand, gross capital stock measures in productivity calculations potentially lead to an understatement of MFP growth, as gross stocks grow more rapidly than capital services.

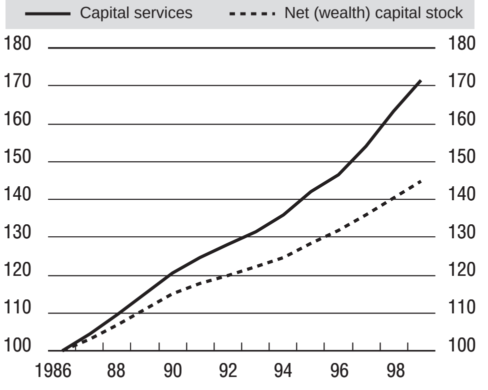
The price of capital services is measured by their rental price. If there were complete markets for capital services, rental prices could be directly observed. In the cases of, for example, office buildings or cars, rental prices do exist and are observable in the market. However, this is not the case 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".

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*a*).

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. 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. To explain, note that wealth measures are based on an aggregation across different assets where each asset is weighted by its market price. The weights that are used to construct capital service measures are higher for short-

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



Source: Australian Bureau of Statistics.

lived assets than for long-lived ones: one dollar invested in a short-lived asset must yield a higher return per year than a dollar invested in a long-lived asset to make that investment worthwhile. If shorter-lived assets grow more rapidly than longer-lived ones, the measure of capital services will grow faster than the wealth measure.

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. The 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. Assuming a capital share of about 0.3, the resulting 1.6 percentage point difference implies approximately a 0.5 percentage point adjustment to the MFP measure (0.3 × 1.6 per cent = 0.48 per cent). Thus, based on net stock rather than 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 compared with the correct capital services measure; 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.

Capital and capacity utilisation. There are many reasons why the rate of utilisation of capital, or more generally, the rate of utilisation of capacity of a firm varies over time: a change in demand conditions, seasonal variations, interruptions in the supply of intermediate products or a breakdown of machinery are all examples of factors that lead to variations in the flow of capital services drawn from a stock of assets. And yet, it is frequently assumed (for want of better information on utilisation rates) that the flow of services is a *constant* proportion of the capital stock. This is one of the reasons for the pro-cyclical behaviour of productivity series: variations in output are reflected in the data series, but the corresponding variations in the utilisation of capital (and labour) inputs are inadequately captured. If machine hours were measured, adjustments could be made. However, in practice, the required data rarely exist and consequently, swings in demand and output are picked up by the residual productivity measure. There have been several attempts to deal with this issue, but a generally accepted solution has yet to be found.

Index numbers

Productivity is usually measured as the ratio of a quantity index of output to a quantity index of inputs. Indices are required because the heterogeneity of goods and services does not permit simply adding up units of different types of commodities. However, aggregation results are in general sensitive to the choice of a specific index number formula. These formulae should therefore be chosen carefully on both conceptual and practical grounds.

A first choice that must be made for comparisons over several periods is whether to compare two periods directly (say, between period 0 and period 2), or indirectly (in which case the change between period 0 and 2 is derived from the change between period 0 and 1, combined with that from period 1 to 2). The economics literature, as well as the 1993 System of National Accounts, are quite unanimous that inter-temporal comparisons over longer periods should be obtained by chaining, *i.e.* by linking the year-to-year movements. The main reason for chaining is that it allows one to adopt weights that reflect economic behaviour: for example, a relative price fall of a good will typically lead to higher consumption of this good and changes in the expenditure share of this item. Chained indices reflect such changes in expenditure patterns because weights are regularly updated. When indices are based on weights that only reflect conditions in a base period that is several years away from the comparison period, there is a risk of weights being out of date and this may introduce a bias into the price or volume measure.

A second choice pertains to the specific index number formula. The most widely used index number formulae are the Laspeyres and Paasche indices (the former uses base-period weights, the latter current period weights), the Fisher index (a geometric average of the Laspeyres and Paasche indices) and the Törnqvist index (a weighted geometric average of its components).

To help decide between different index number formulae, a series of intuitively appealing criteria have been developed in the index number literature, starting with the impressive work by Irving Fisher (1922). Examples of such criteria are the *identity test* (if the prices of period 1 are the same as those of period 0, then the price index should take a value of one) or the *commensurability test* (the price index should be independent of the units of measurement). Many other criteria exist (see Balk, 1995 for a survey), and the different index number formulae can be checked against them.

Another approach makes use of economic theory to define price or quantity indices theoretically. A well-known example is the Konüs (1924) cost of living index derived from the micro-economic theory of the consumer. It is represented as the ratio of the minimum expenditure in period 1 over minimum expenditure in period 0, while maintaining utility constant. Empirically, it is not normally possible to measure such a theoretically defined index directly as the specific form and parameters of utility or cost functions are unknown. However, Diewert (1976) showed that there are functional forms (such as the translog functional form) that provide approximations to arbitrary, twice differentiable homogenous functions. He further showed that these functional forms can be exactly represented by certain index number formulae that he called "superlative" index numbers. This provides a strong economic rationale for the use of superlative index numbers, such as the Fisher and the Törnqvist index. Empirically, it turns out the choice between different types of superlative indices matters little and can thus be left to the individual researcher.

ESTIMATING PRODUCTIVITY LEVELS

International comparisons of productivity growth can give useful insights in growth processes, but should ideally be complemented with international comparisons of income and productivity levels. An examination of levels gives insights into the possible scope for further gains, and also places a country's growth experience in the perspective of its current level of income and productivity. OECD has published estimates of productivity levels in various studies (*e.g.* Englander and Gurney, 1994; Pilat, 1997; Scarpetta, *et al.*, 2000). Most of these studies have not looked in detail at measurement issues, or examined how differences in productivity levels should be interpreted.

International comparisons of productivity levels require three components, namely comparable information on output (typically GDP), comparable information on factor inputs (labour, capital) and conversion factors (or purchasing power parities, PPPs) to translate output and factor inputs in national currencies to a common currency. This section discusses the available estimates and some of the main measurement issues, in particular the use of PPPs for currency conversions, as well as the correspondence between output and labour input measures for level comparisons. The discussion focuses on productivity at the aggregate level. The estimation of sectoral productivity levels raises additional measurement issues that go beyond the scope of this paper.[12]

Output, labour and capital input

Comparability of output measures

The measurement and definition of economic output is treated systematically across countries in the 1993 System of National Accounts (SNA 93). The revisions to the SNA introduced at that time tend to increase the level of total GDP, although not uniformly over time or across countries. The SNA revisions raised the level of GDP in all of the OECD countries who have implemented these changes, with the increases ranging from 0.3 per cent for Belgium's 1996 GDP, to 7.4 per cent for Korea's 1996 GDP (Scarpetta, *et al.*, 2000). Although most OECD countries have now implemented the new SNA, Switzerland and Turkey are exceptions. Thus, GDP (and consequently productivity) levels in these countries are likely to be underestimated compared with countries that have implemented the new system, although the extent of this bias is unknown. Once the introduction of the new SNA is completed, international comparability is likely to have improved.

A second factor that may influence the comparability of GDP across countries is size of the non-observed economy. In principle, GDP estimates in the national accounts take account of this part of the economy. In practice, questions can be raised about the extent to which official estimates have full coverage of economic activities that are included in GDP according to the SNA, or to which extent misreporting is involved. Large differences in coverage could substantially affect comparisons of productivity levels. Little is known about the possible size of the non-observed economy in different OECD member countries, although work is currently underway to address this issue (OECD, 2000).

Comparability of labour-input measures

Equally important for international comparisons of productivity levels are comparable measures of labour input. Labour input is commonly measured along three dimensions: the number of persons engaged; the total number of hours worked of all persons engaged; and the total number of hours worked adjusted for the quality of individual workers. Employment statistics are quite well standardised across OECD countries as most countries provide labour force statistics along agreed guidelines. In principle, therefore, they pose few problems for international comparisons. The main difficulty is to ensure that the employment data are consistent in coverage with other data that are required to make comparisons of productivity, notably GDP and hours worked.

There are two issues that arise here. The first question is whether countries integrate estimates of employment in the national accounts. These estimates could be based on different sources, such as labour force surveys and enterprise statistics, and would, in principle, be more consistent with GDP than estimates relying on only one single source. In practice, not all OECD countries integrate employment statistics in the national accounts, implying that labour force statistics remain the most comparable source.

The second, closely related, problem is whether estimates of hours worked are consistent with the employment data. Estimates of hours worked are typically based on two alternative sources, labour force surveys and enterprise statistics. Labour force surveys are based on surveys of households, whereas enterprise statistics survey firms. Both sources seem to have some advantages and disadvantages for comparisons of productivity levels (OECD, 1999*a*; Van Ark and McGuckin, 1999):

- Labour force surveys may underestimate absences due to illness and holidays.
- Evidence on time use related to labour force surveys suggests that persons who work long hours may overestimate their working time.
- Labour force surveys potentially pick up extra hours worked by managers and professionals that are over and above the conventional hours of work in an establishment and that are clearly not picked up by establishment sources.
- Enterprise statistics are less likely to provide full coverage of all persons engaged in the economy, and may underestimate overtime.

In principle, this suggest that labour force surveys may somewhat overestimate total hours worked, whereas enterprise surveys may underestimate hours worked. Much depends on the quality and coverage of the surveys, however, and several OECD countries provide comprehensive estimates of hours worked based on a mix of sources. The OECD has recently produced estimates of hours worked that draw on such a mix of sources, where hours worked estimates from labour force surveys were adjusted downwards to compensate for known biases (Scarpetta, *et al.*, 2000). Cross-country comparability can thus be improved as compared to the use of original national sources for some countries, but there remains a margin of uncertainty.

The quality of labour input is much more difficult to compare across countries, in particular in terms of levels. Education systems and standards differ considerably across countries, information on firm-level training is not collected or incomplete in most countries, and reliable data are scarce in all these areas. While some efforts have been made – primarily at the level of individual sectors – to account for qualitative differences in labour input across countries, the statistical basis is limited, and the results are therefore not necessarily robust.[13] The OECD has therefore not yet estimated quality-adjusted levels of labour input for international comparisons of productivity levels. The decomposition of GDP per capita below therefore ignores quality aspects of labour input in the estimation of labour productivity levels.

Comparability of capital-input measures

Estimates of labour productivity levels are quite common. Much more difficult and more controversial is the comparison of levels of capital productivity and of multi-factor productivity.[14] The main controversy concerns the comparison of capital input across countries (Van Ark, 1996). Official estimates of capital stock embody a wide variety of assumed asset lives and retirement patterns.[15] Some of the variation across countries may be accounted for by compositional differences and differences in technological progress, which cause the capital stock to become obsolete more rapidly in some countries. However, this is difficult to verify and in most cases the statistical basis for the variation in asset lives and retirement patterns is weak, since statistical offices collect such information only infrequently.

A second problem concerns the conversion of capital stocks in national currency values into a common currency. This requires PPPs for capital stock. In principle, these can be derived from official PPPs for investment by converting investment series to a common currency and then calculating capital stock in a common currency. This requires reliable PPPs for investment and deflators for investment. PPPs for investment have been criticised in some recent evaluations of the PPP programme (OECD, 1997), however, and it is therefore not clear how reliable they are. Further progress is needed in making capital stocks more comparable across countries so as to improve the basis for comparisons of capital and multi-factor productivity.[16]

Purchasing power parities for international comparisons

The comparison of income and productivity across countries also requires purchasing power parity (PPP) data for GDP. Exchange rates are not suitable for the conversion of GDP to a common currency, since they do not reflect international price differences, and since they are heavily influenced by short-term fluctuations. Over the past two decades, OECD has regularly published estimates of PPPs, derived from its joint programme with Eurostat. Benchmark estimates of PPPs are currently available for 1980, 1985, 1990, 1993 and 1996, and work is underway for a new benchmark comparison for 1999.[17] In using these PPP estimates for international comparisons of income and productivity, two issues must be addressed, namely the choice of aggregation method and the choice of benchmark year.

Aggregation method

The choice of aggregation method for constructing PPPs has been a source of debate over the past two decades. Initial work on international comparisons, such as the seminal study by Kravis, Heston and Summers (1982), provided a wide range of aggregation methods. The latest benchmark comparisons by OECD and Eurostat offer only two alternatives, namely those based on the Geary-Khamis (GK) method, and those based on the Elteto-Koves-Szulc (EKS) method.[18] Aggregation takes place after price ratios for individual goods and services have been averaged to obtain unweighted parities for small groups of homogeneous commodities. It involves weighting and aggregating the unweighted commodity group parities to arrive at PPPs and real values for each category of expenditure up to the level of total GDP.

The two methods differ substantially. The EKS method treats countries as a set of independent units with each country being assigned equal weight. The EKS prices are obtained by minimising the differences between multilateral binary PPPs and bilateral binary PPPs. The EKS PPPs are thus close to the PPPs that would have been obtained if each pair of countries had been compared individually. The GK method treats countries as members of a group. Each country is weighted according to its share in GDP and the prices that are calculated are characteristic of the group overall. Both methods have advantages and disadvantages:

- For countries with price structures that are very different from the average, the GK approach leads to higher estimates of volumes (and GDP per capita) than if more characteristic prices would have been used. This effect is particularly important when comparing countries with great differences in income levels. The GK approach leads to results that are additively consistent, however, which implies that the real value of aggregates is the sum of the real value of its components. This is an advantage for national accounts and permits comparisons of price and volume structures across countries.

- The EKS method leads to results that are more characteristic of each country's own prices, and thus leads to estimates of GDP per capita that are relatively similar to those resulting from the use of characteristic prices. Its results are not additive, however.

For OECD countries, the differences between the two methods are relatively small, since national price structures are similar. Most comparisons of income and productivity utilise the EKS results, however, since these do not seem to overestimate income levels for low-income economies and are more closely aligned with index number theory.[19] The EKS method is also the method officially accepted by Eurostat for administrative purposes.

Benchmark year

The second issue to be addressed concerns the choice of benchmark year. For several OECD countries, the OECD/Eurostat estimates of PPPs are currently available for five benchmark years. This raises a problem of which benchmark to choose for international comparisons. In principle, it seems appropriate to use the most recent benchmark, *i.e.* 1996, since this is most likely to reflect current price differences in the OECD area. To indicate the sensitivity of comparisons of income and productivity to the choice of benchmark, Table 4 provides an overview of comparative estimates of GDP per capita for 1999, based on alternative benchmark results. It suggests that there is some variation in results between the different benchmark years, but that there are relatively small differences in results between recent benchmark years, *i.e.* 1990, 1993 and 1996. For most countries, the 1996 benchmark gives slightly higher estimates of GDP per capita relative to the United States than the 1993 benchmark. France, Belgium, Norway and Spain are exceptions and have slightly lower levels of GDP per capita with the 1996 benchmark.

Estimates of income and labour productivity levels

Clearly, data for international comparisons of income and productivity are not perfect and some choices between different sources have to be made. In this paper, GDP is derived from the OECD SNA database, which incorporates the latest comparative information on GDP from OECD member countries. Data on employment are from the OECD *Labour Force Statistics*, as this source is more standardised across countries than employment data from the national accounts and since the estimates of hours worked that are used in this paper are closely linked to labour force surveys. To convert GDP to a common currency, this paper uses the 1996 benchmark PPPs as the most recently available.

Table 5 presents the resulting income and productivity level estimates for 1999. It shows a considerable diversity in real per-capita GDP levels across the OECD countries. The United States is at the top of the OECD income distribution, followed by Switzerland and Norway that have levels of GDP per capita between 80 and 90 per cent of the US level. Luxembourg also has a very high level of GDP per capita, which is partly due to the large share of frontier workers in total employment (56 000 out of 226 000 workers in 1997). These contribute to GDP and employment, but are not included in the working-age and total population. The bulk of the OECD, including all the other major economies, has income levels that are between 65 and 80 per cent of the US level. Following this group are

Table 4. **Estimates of GDP per capita for 1999 and the impact of alternative purchasing power parities**

	Alternative PPPs for 1999, national currency/USD					Alternative estimates of GDP per capita, United States = 100				
	Official 1999 PPP, based on the 1996 EKS index	Based on the 1993 EKS index	Based on the 1990 EKS index	Based on the 1985 Fisher index	Based on the 1980 Fisher index	Official estimate, based on the 1996 EKS index	Based on the 1993 EKS index	Based on the 1990 EKS index	Based on the 1985 Fisher index	Based on the 1980 Fisher index
Australia	1.30	1.30	1.30	1.41	..	75.6	75.5	75.8	69.4	..
Austria	13.6	13.7	14.2	17.0	14.8	72.8	72.2	69.6	58.2	66.7
Belgium	37.1	36.5	39.2	44.8	37.5	73.4	74.6	69.4	60.8	72.6
Canada	1.17	1.21	1.22	1.19	1.12	79.3	76.5	76.0	77.9	82.6
Czech Republic	13.4	..	..	..	..	39.5	..	..	..	..
Denmark	8.54	8.92	9.41	10.81	9.15	79.1	75.7	71.8	62.5	73.8
Finland	6.15	6.14	6.22	7.05	..	67.2	67.3	66.4	58.6	..
France[1]	6.63	6.34	6.32	7.23	6.22	65.2	68.2	68.5	59.8	69.6
Germany	1.98	2.05	2.12	2.52	2.18	70.4	68.1	65.7	55.3	64.0
Greece	239.2	250.3	277.6	294.2	278.5	44.7	42.8	38.5	36.4	38.4
Hungary	100.7	..	..	..	..	33.3	..	..	..	..
Iceland	85.5	89.8	..	..	..	77.8	74.1	..	..	..
Ireland	0.73	0.72	0.77	0.84	0.72	75.1	75.4	70.6	64.8	75.3
Italy	1 601.1	1 681.2	1 675.2	1 911.2	1 694.7	68.2	64.9	65.1	57.1	64.4
Japan	158.7	161.6	165.9	190.0	168.3	75.3	74.0	72.1	62.9	71.0
Korea	642.9	677.7	..	..	..	47.5	45.0	..	..	..
Luxembourg	40.6	40.7	..	..	..	122.2	121.9	..	..	..
Mexico	5.61	..	..	..	..	25.0	..	..	..	..
Netherlands	1.99	2.13	2.14	2.32	2.11	77.5	72.3	72.0	66.3	72.9
New Zealand	1.46	1.46	1.52	1.84	..	55.1	54.8	52.9	43.6	..
Norway	9.50	9.38	9.76	9.71	8.16	83.1	84.3	80.9	81.4	96.9
Poland	1.84	..	..	..	..	25.6	..	..	..	..
Portugal	128.9	..	..	..	..	48.6	..	..	..	..
Slovak Republic	13.8	..	..	..	..	32.4	..	..	..	..
Spain	130.5	127.5	131.1	146.1	130.7	53.8	55.1	53.6	48.1	53.8
Sweden	9.78	9.77	9.56	10.48	..	68.0	68.1	69.6	63.5	..
Switzerland[2]	1.90	1.98	2.11	..	..	84.7	81.1	76.2	..	..
Turkey[2]	185 567	183 857	183 799	177 331	..	18.7	18.9	18.9	19.6	..
United Kingdom	0.66	0.67	0.66	0.74	0.69	67.6	66.3	66.9	60.0	63.8
United States	1.00	1.00	1.00	1.00	1.00	100.0	100.0	100.0	100.0	100.0

1. Includes Overseas Department.
2. Countries still using the 1968 SNA, *i.e.* GDP may be underestimated compared with other OECD countries.

Source: GDP and employment from OECD SNA database; PPP estimates for 1980, 1985 and 1990 from Maddison (1995); 1993, 1996 and 1999 from OECD Statistics Department.

Table 5. **Breakdown of GDP per capita in its components, 1999**

	GDP per head of population (as % of US)	Effect of % working-age population (15-64 years) to total population	Effect of % labour force to working-age population	Effect of unemployment	Effect of working hours	Total effect of labour force participation	GDP per hour worked (as % of US)	GDP per person employed (as % of US)
	(1)	(2)	(3)	(4)	(5)	(6)(2) + (3) + (4) + (5)	(7)(1) – (6)	(8)(1) – (2) – (3) – (4)
Australia	76	1	–4	–2	–3	–8	84	81
Austria	73	2	–6	0	–17	–22	95	77
Belgium	73	0	–15	–7	–14	–36	110	96
Canada	79	3	–2	–3	–4	–6	86	82
Czech Republic	40	2	–3	–2	3	1	39	42
Denmark	79	1	2	–1	–16	–14	93	77
Finland	67	1	–3	–5	–8	–15	82	74
France[1]	65	–2	–10	–6	–14	–32	97	84
Germany	70	2	–6	–4	–16	–23	94	78
Greece	45	1	–11	–4	2	–12	56	59
Hungary	33	1	–10	–1	–2	–12	45	43
Iceland[2]	78	–2	9	1	–2	6	72	70
Ireland	75	1	–11	–1	–9	–21	96	87
Italy	68	1	–19	–7	–13	–38	106	93
Japan	75	3	0	0	–1	1	74	73
Korea	47	4	–9	–1	14	7	40	54
Luxembourg	122	1	13	2	–14	2	120	106
Mexico	25	–2	–5	1	1	–6	31	32
Netherlands	78	2	–4	1	–30	–32	109	79
New Zealand[2]	55	0	–2	–2	–3	–7	62	59
Norway	83	–1	3	1	–27	–25	108	81
Poland	26	1	–5	–3	..	–7	..	32
Portugal	49	1	–2	0	–3	–5	53	50
Slovak Republic	32	1	–4	–5	..	–8	..	40
Spain	54	2	–14	–9	–2	–23	76	75

Table 5. **Breakdown of GDP per capita in its components, 1999** (*cont.*)

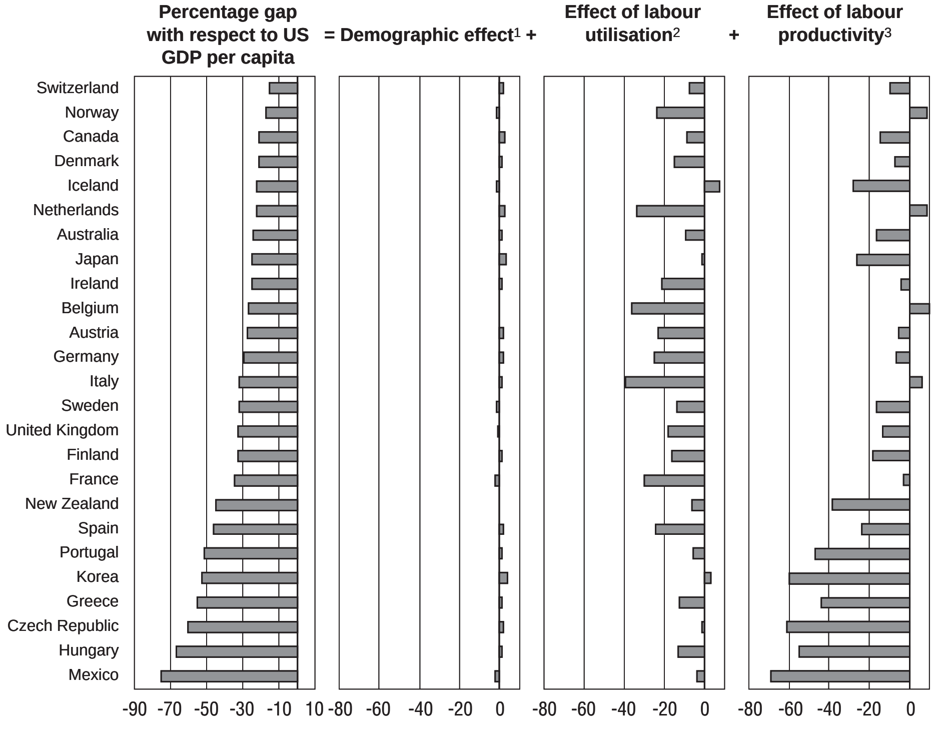
	GDP per head of population (as % of US)	Effect of % working-age population (15-64 years) to total population	Effect of % labour force to working-age population	Effect of unemployment	Effect of working hours	Total effect of labour force participation	GDP per hour worked (as % of US)	GDP per person employed (as % of US)
	(1)	(2)	(3)	(4)	(5)	(6)(2) + (3) + (4) + (5)	(7)(1) – (6)	(8)(1) – (2) – (3) – (4)
Sweden	68	–2	–1	–2	–10	–15	84	73
Switzerland[2]	85	2	5	1	–14	–6	91	77
Turkey[2]	19	0	–8	–1	..	–9	..	28
United Kingdom	68	–1	–3	–1	–14	–19	87	72
United States	100	0	0	0	0	0	100	100
Euro-area[3]	66	1	–11	–5	–12	–27	92	80
European Union	66	1	–9	–4	–13	–25	91	79
G7 countries	83	1	–4	–2	–5	–10	92	87
OECD[4]	72	1	–6	–2	–3	–10	82	78

1. Includes Overseas Departments.
2. GDP estimates for Iceland, New Zealand, Switzerland and Turkey are based on the SNA 68.
3. Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain.
4. Excluding Poland, Slovak Republic and Turkey.

Source: OECD, GDP and population from OECD *National Accounts*, working-age population, labour force and employment from OECD *Labour Force Statistics*; hours worked from OECD calculations, see Scarpetta, *et al.* (2000). GDP converted to common currency by 1999 OECD PPP.

Figure 3. **Differentials in GDP per capita and their determinants, 1999**

Percentage point differences in PPP-based GDP per capita with respect to the United States



1. Based on the ratio of the working-age population (15-64 years) to the total population.
2. Based on employment rates and average hours worked.
3. GDP per hour worked.

Source: Table 5.

a number of lower-income economies, including Greece, Korea, Portugal, Spain and New Zealand, some of which have experienced very high growth over the recent period. Mexico, Turkey and the former centrally-planned economies (Czech Republic, Hungary and Poland) are at the bottom of the OECD income distribution.

Figure 3 shows clearly that levels of GDP per capita are not the same as differences in labour productivity, *i.e.* GDP per hour worked. The differences is particularly marked for certain European countries, such as France, Italy, Belgium and the Netherlands, that have levels of GDP per hour worked that are higher or comparable to the United States but much lower levels of GDP per capita. Low labour utilisation, *i.e.* low employment rates and short working hours, explains the bulk of this gap. For most other OECD countries, in particular those at the bottom end of the OECD income distribution, labour productivity is closely linked to levels of GDP per capita.

High labour productivity is often associated with strong economic performance. However, some countries, with high levels of labour productivity have very low levels of labour utilisation, suggesting that high labour productivity may partly be due to increasing the capital-labour ratio and to pushing low-productivity workers into unemployment or out of the labour force. Estimates of GDP per hour worked should therefore ideally be looked at in combination with estimates of GDP per capita.

THE INTERPRETATION OF PRODUCTIVITY MEASURES

Productivity is an important yardstick of economic performance. Different productivity measures are, however, often used without sufficient clarity about the specific measure that is being used and its correct interpretation. This section briefly touches on six of the most common uses made of productivity measures and possible pitfalls: the relationship between productivity growth and technological change; the link between productivity and costs; productivity over the business cycle; the difference between productivity and efficiency; the links between industry and firm-level productivity growth; and innovation and productivity growth.

The link with technological change

Multi-factor productivity growth is often interpreted as an indicator of technological progress. This is not entirely correct for three reasons: *i*) technological change does not necessarily translate into MFP growth; *ii*) MFP growth is not necessarily caused by technological change; and *iii*) MFP may understate the eventual importance of productivity change in stimulating the growth of output. These three factors are discussed below.

Some technological change does not translate into MFP growth because embodied technological change, such as advances in the quality of new vintages of capital or improved human capital, is reflected instead in the measured contributions of capital and labour to output growth. Disembodied technical change, on the other hand, will be reflected in MFP growth as it relates to advances in scientific knowledge, and to the diffusion of knowledge on how things are done, including better management and organisational change. MFP should also include the spill-over effects from capital and labour, *e.g.* network effects arising from investment in information technology products.

Conceptually, and following Jorgenson (1995*a*), the MFP term reflects all those effects on output growth that are *not* investment, where investment is understood as the commitment of current resources in the expectation of future returns, implying that these returns can be internalised by the investor. The distinction is important because the diffusion of embodied technical change is dependent on market transactions: investment in the improved capital or intermediate good will be undertaken until its marginal contribution to revenue generation just equals its user cost, itself dependent on the market price of the capital good. The diffusion of disembodied technical change is not necessarily associated with market transactions. Information may circulate freely and its use by one person does not normally restrict its use by another one.

When the measure for the quantity of capital services used in the MFP calculation is based on a price index that reflects quality changes in capital goods, embodied technological change is captured by the growth contribution of capital and not by the residual MFP. Conversely, when the capital goods price index is not adjusted for quality change, both embodied and disembodied technological change will be picked up by the MFP residual. As Hulten (1992) showed, the embodiment part of technology can be measured by comparing capital input based on quality-adjusted price indices and capital input based on unadjusted price indices. This idea was also pursued by Greenwood *et al.* (1997) and Bassanini *et al.* (2000).

Data and resource constraints often do not permit a careful differentiation and full coverage of all labour and capital inputs. As a consequence, some of the embodiment effects of technological change and some or all of the changes in the skill composition of labour input are picked up by the MFP residual. Thus, the correct interpretation of the productivity term with respect to technological change requires knowledge about the methodology used to compute time series of capital and labour input.

Just as some technological change does not correspond to MFP growth, some MFP growth is not caused by technological change. Even where the residual reflects part or all of technological change, several other factors will also bear on measured MFP. Such factors include adjustment costs, economies of scale, cyclical effects, inefficiencies and measurement errors. This is confirmed by econometric studies that link MFP growth to technology variables, in particular research and development and patents or those that explicitly control for adjustment costs or allow for non-constant returns to scale. Research and development expenditure, for example, tends to show a statistically significant relation to productivity growth, but only explains a relatively small part of the overall annual movements in MFP.[20] This indicates the presence of other factors. Measures of MFP are thus better interpreted as measures of improvements in overall efficiency than as pure expressions of technical change.

Finally, MFP may understate the eventual importance of productivity change in stimulating the growth of output. This reflects the fact that in growth accounting models, capital is considered an exogenous input to the production process. In a dynamic context, this is no longer the case and a feedback mechanism exists 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. Typically, however, additional output per person will lead to additional savings and investment, and to a rise in the capital-labour ratio. A traditional growth accounting framework 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, 2000).

Productivity growth and changes in costs

Productivity measures are typically derived on the basis of production functions and quantity measures of inputs and outputs. Under certain conditions (*e.g.* cost minimisation), an equivalent and intuitively appealing "dual" approach exists that expresses advances in productivity as downward shifts of a cost function. A cost function shows the minimum input cost of producing a certain level of output, given a set of input prices. Thus, the MFP productivity residual can be measured either in the residual growth of output not explained by the growth of inputs, or as the residual decline in average costs not explained by changes in input prices. A slightly different formulation is that productivity growth equals the diminution of total costs that is explained neither by a fall in output nor by substitution of inputs that have become relatively more expensive for those whose relative price has fallen.

The formulation of MFP in terms of average costs demonstrates once more that productivity is not necessarily technological change and that technological advances do not necessarily translate into a change of the MFP residual. It is intuitively plausible that total and average costs can be reduced by factors other than technological change, such as organisational innovations or learning by doing (Harberger, 1998). The cost approach also shows how embodied technological change can reduce the costs of inputs and trigger substitution processes without, however, changing the rate of multi-factor productivity growth.

The role of the business cycle in productivity growth

Most productivity measures are pro-cyclical, accelerating during periods of economic expansion and decelerating during periods of recession. In part, this is due to inadequate measurement. While cyclical variations in volume output tend to be measured quite accurately in economic statistics, variations in the rate of utilisation of inputs are not picked up as fully. In particular, changes in the rate of utilisation of capital equipment (*i.e.* changes in machine hours) are rarely captured in these measures. Labour input, if measured by hours actually worked, better reflects the changing rate of utilisation of manpower, but remains an imperfect measure. Consequently, increases in the rate of capacity utilisation in periods of expansion will cause output measures to show more rapid growth, but input measures may remain stable or grow less rapidly. The result is a rise in measured productivity growth. The converse holds for periods of recession.

Even if capacity utilisation were accurately measured, difficulties would remain in reconciling the standard productivity model with the realities of the business cycle. Much of the economic and index number theory used to guide the construction of these measures relies on long-term, equilibrium relationships. Since little or no account is taken of unforeseen events or disequilibria, the economic model of productivity measurement is more appropriately applied to periods of continued and moderate expansion, than to rapidly changing phases of the business cycle. This limitation means that year-to-year changes in productivity growth should not be interpreted *prima facie* as shifts in disembodied technology. For this purpose it is preferable to examine productivity growth patterns over longer periods of time or adjust productivity estimates for cyclical fluctuations.[21] Moreover, it is wise not to draw strong conclusions about shifts in productivity from the evidence of just a few years.

The difference between productivity and efficiency

Productivity and efficiency are related, but not identical concepts (Sharpe, 1995). A firm or industry is considered to be inefficient if it could produce more output with existing inputs, *i.e.* the firm is not on the production possibility curve, but within it. Productivity relates the quantity of output produced to one or more inputs used in its production, irrespective of the efficiency of their use. In analysing productivity growth across countries, the difference between these two concepts allows a distinction between three different processes. First, productivity growth can result from innovative activity that results in an outward shift of the global production possibility frontier. Second, firms can improve productivity by adopting production processes and products developed elsewhere (imitation). Diffusion differs conceptually from efficiency gains, as the latter relates to improvements made in using a given technology – even when this technology is outdated by international standards. Third, productivity growth may also be due to reduced (technical) inefficiency. An inefficient firm or industry uses more resources and factor inputs than required by a particular technology, thus tying resources to low-productivity activities and reducing the overall allocative efficiency of an economy. Understanding the reasons behind productivity growth is therefore necessary before attributing such changes to specific sources.

How productivity at the industry level is related to that at the firm level

The main focus of this paper has been productivity measurement at the industry and aggregate level of the economy. Industries and branches are themselves made up of individual firms and establishments and new micro-level databases have greatly enhanced the possibilities for empirical research to better how understand individual units' productivity performance carries over to what is observed at the industry level. Several important conclusions have arisen from a significant body of studies (Haltiwanger, 2000; Bartelsman and Doms, 2000; OECD, 2001*b*). First, there are large differences in productivity performance between individual units. Second, there is a continuous and large-scale re-allocation of outputs and inputs between producers, including within industries. Third, this re-allocation contributes significantly to aggregate productivity growth. For example, Haltiwanger reports that for the United States manufacturing sector, roughly half of multi-factor productivity growth over the course of a recent decade can be accounted for by the re-allocation of outputs and inputs away from less productive to more productive businesses.

These findings do not invalidate the theory of productivity measurement in this paper that essentially treats an industry, a sector or even the entire economy as if it were a single firm. Rather, it adds to the understanding and interpretation of measured productivity growth. For example, it points to one mechanism by which an industry *as a whole* implements technical change: if new technology is mainly adopted by new establishments, productivity growth occurs with entry and exit, and this requires re-allocation. Technical advances at the industry level are then associated with the diffusion of new technology among establishments, rather than with a simultaneous shift in the production frontier of an existing set of businesses. This provides an additional interpretation of changes in the productivity residual at the industry level. Micro-level data studies with their focus on firm dynamics, entry and exit and re-allocation of resources also form a natural link to the question how innovation and "creative destruction" (see below) translate into industry-level productivity growth. Nonetheless, micro-level approaches cannot replace the more aggregate type of productivity measurement. This is due to poor data quality at the firm or establishment level (*e.g.* for capital input) and the timeliness and exhaustiveness of the available data sets. But micro-level studies enhance our understanding of the underlying drivers and dynamics of productivity growth.

Innovation and productivity

Most approaches to measuring productivity are firmly rooted in a neo-classical equilibrium concept. Equilibrium conditions are very important because they help to guide measurement of parameters that would otherwise be difficult to identify. Although its usefulness is generally recognised, it has been argued that an equilibrium approach sits uneasily with the notion of innovation and productivity growth. Evolutionary economists (*e.g.* Dosi, 1988; Nelson and Winter, 1982; Nelson, 1981) argue that innovation and technical change occur as a consequence of information asymmetries, and market imperfections. In a quite fundamental sense, innovations and information asymmetries are one and the same phenomenon. Indeed, such asymmetries can scarcely be termed market imperfections when they are necessary conditions for any technical change to occur in a market economy (Metcalfe, 1996). The point made by evolutionary economists is that equilibrium concepts may be the wrong tools to approach the measurement of productivity change, because if there truly was equilibrium, there would be no incentive to search, research and to innovate, and there would be no productivity growth.

Such criticism has to be taken seriously in the interpretation and use of productivity measures. An important lesson from this debate is that accounting is not explaining the underlying causes of growth. Griliches (1997) makes a related point:

> *"We can take productivity growth calculation and allocate it in great detail to the various missed components, reducing thereby the role of the "unallocated" residual. But this, while very instructive and valuable, only shifts the problem to a new set of questions: why was there all this investment in human capital? Will it continue? Where did the improvements in capital equipment come from? [...] Real explanations will come from understanding the sources of scientific and technological advances and from identifying the incentives and circumstances that brought them about and that facilitated their implementation and diffusion. Explanation must come from comprehending the historical detail."*

This does not invalidate the usefulness of the standard equilibrium approach to productivity measurement, discussed in this paper, but alerts us to some of its limits. What emerges is the complementarity of approaches: growth accounting and productivity measurement allow the systematic and consistent quantification of the proximate sources of growth. It has explanatory power in that it captures the workings of supply of, demand for and substitution between categories of measurable inputs. At the same time, growth accounting has to be complemented by institutional, historical and case studies if one wants to explore the underlying causes of growth, innovation and productivity change.

IN CONCLUSION

The measurement of productivity continues to generate substantial interest in many countries, since productivity is a key yardstick of economic performance. This paper has discussed the main measurement difficulties that need to be confronted when calculating productivity indicators and has provided guidance to researchers and statisticians in addressing these difficulties. Substantial progress has been made in recent years to improve the comparability of productivity statistics. In many countries, however, basic source data are still the key limitation to the development of comparable indicators of productivity. In addition, statisticians, researchers and policy makers need to be more aware of the way in which productivity statistics are used and their appropriate interpretation.

NOTES

1. Multi-factor productivity is sometimes referred to as total factor productivity. Multi-factor productivity implies that several factors are included as inputs, though not necessarily all. Total factor productivity suggests that all possible factors are included. In practice, this is seldom the case.
2. This definition is consistent with the System of National Accounts 1993.
3. Recently, Nordhaus (2001) discussed the link between industry-level and aggregate productivity measures based on value added. He presented alternative methods for measuring productivity growth that are derived from the link between productivity and welfare. Nordhaus showed that, under a number of restrictive assumptions, a welfare-related productivity measure can be constructed as a weighted average of productivity growth in individual industries. One specific conclusion is that macroeconomic productivity gains that arise from shifts between industries with different productivity levels should be excluded from welfare-oriented productivity measures.
4. This is a general form of double-deflation, expressed in a continuous-time Divisia index.
5. To interpret value-added-based MFP growth as a measure of disembodied technical change, one has to assume that technical change operates only on primary inputs, and not on intermediate ones. There is little empirical evidence to support this assumption.
6. For a discussion regarding the United States, see Eldridge (1999).
7. See the OECD *Handbook on the Quality Adjustment of Price Indices for ICT Products* (forthcoming) and the *Eurostat Handbook on Price and Volume Measures in National Accounts* (forthcoming).
8. For an overview, see Bresnahan and Gordon (1996).
9. For example, Lowe (1996) provides an overview of how quality change is handled in the Canadian National Accounts.
10. For empirical results see United States Bureau of Labor Statistics (1993), Fosgerau *et al.* (2001) and Scarpetta *et al.* (2000).
11. For specific information about the practical and conceptual issues regarding the construction of capital stock measures, see the OECD *Manual on Capital Measurement* (2001).
12. Van Ark (1996) and Pilat (1997) discuss these issues in greater detail. See also O'Mahony (1999).
13. Estimates of quality-adjusted labour input are available for some countries, see for example O'Mahony (1999).
14. Levels of capital productivity and multi-factor productivity for five major OECD economies (United States, Japan, Germany, France, United Kingdom) are estimated in O'Mahony (1999).

15. An additional problem concerns the deflators that are used to measure investment. See Colecchia and Schreyer (2001).
16. Ongoing work on the OECD *Capital Stock Manual* and the OECD *Productivity Manual* may help in enhancing the comparability of capital stock estimates across countries.
17. The Internet site of the OECD Statistics Department provides an overview of some of the key issues related to the construction of purchasing power parities, see *www.oecd.org/std/ppps.htm*. An evaluation of the PPP programme was prepared by the former chief statistician of the Australian Bureau of Statistics, Ian Castles, in 1997 (OECD, 1997), and has led to a range of improvements in the construction of PPPs. The recent benchmark study for 1996 also contains an extensive discussion of many of the issues related to the OECD/Eurostat work on PPPs (OECD, 1999*b*).
18. See Elteto and Koves (1964); Szulc (1964); Geary (1958); and Khamis (1970). More elaborate descriptions of these methods and the differences between them are available in OECD (1999*b*). See also Van Ark (1996), Pilat (1997) and OECD (1998) for a discussion of the use of PPPs for international comparisons of productivity.
19. The EKS method is closely related to superlative index numbers, such as the Theil-Tornqvist index.
20. See the paper by Guellec and Van Pottelsberghe in this issue of OECD *Economic Studies*.
21. More detail on the trend-adjustment of productivity growth is available in Scarpetta *et al.* (2000).

BIBLIOGRAPHY

ARK, B. VAN (1996),
"Issues in Measurement and International Comparison of Productivity – An Overview", in OECD (1996), *Industry Productivity – International Comparison and Measurement Issues*, Paris, pp. 19-47.

ARK, B. VAN and R.H. McGUCKIN (1999),
"International comparisons of labor productivity and per capita income", *Monthly Labor Review*, July 1999, pp. 33-41.

BALK, B. (1995),
"Axiomatic price index theory: A survey", *International Statistical Review* 63, pp. 69-93.

BARRO, R.J. and X. SALA-i-MARTIN (1995),
Economic Growth, MIT Press.

BARTELSMAN, E. and M. DOMS (2000),
"Understanding productivity: lessons from longitudinal microdata", *Journal of Economic Literature* 38(3), September, pp. 569-94.

BASSANINI, A., S. SCARPETTA and I. VISCO (2000),
"Knowledge, technology and economic growth: recent evidence from OECD countries", OECD *Economics Department Working Papers* No. 259.

BRESNAHAN, T.F. and R.J. GORDON (eds.) (1996),
The Economics of New Goods, Studies in Income and Wealth, University of Chicago Press.

BUREAU OF LABOR STATISTICS (1993),
Labor Composition and U.S. Productivity Growth, 1948-90, US Government Printing Office.

COLECCHIA, A. and P. SCHREYER (2001),
"The impact of information and communications technologies on output growth", STI *Working Paper* 2001/07, OECD, Paris.

DEAN, E.R., M.J. HARPER and M.S. SHERWOOD (1996),
"Productivity measurement with changing-weight indices of outputs and inputs", in OECD (1996*a*), *Industry Productivity – International Comparison and Measurement Issues*, pp. 183-215.

DENISON, E.F. (1985),
Trends in American Economic Growth 1929-82, Brookings Institution, Washington, D.C.

DIEWERT, W.E. (1976),
"Exact and superlative index numbers", *Journal of Econometrics*, pp. 115-45.

DOSI, G. (1988),
"Sources, procedures and micro-economic effects of innovation", *Journal of Economic Literature* 36.

ENGLANDER, S. and A. GURNEY (1994),
"Medium-term determinants of OECD productivity", OECD *Economic Studies*, No. 22, Spring, pp. 49-109.

ELDRIDGE, L.P. (1999),
"How price indexes affect productivity measures", *Monthly Labor Review*, February, pp. 35-46.

ELTETO, O. and P. KOVES (1964),
"On an index computation problem in international comparisons" (in Hungarian), *Statistztikai Szemle*, Vol. 42, pp. 507-518.

FISHER, I. (1922),
The Making of Index Numbers, Boston.

FOSGERAU, M., S.E. HOUGAARD JENSEN and A. SØRENSEN (2001),
"Measuring educational heterogeneity and labour quality: A note", CEBR *Discussion paper* 2001-6, www.cebr.dk.

GEARY (1958),
"A note on comparisons of exchange rates and purchasing power between countries", *Journal of the Royal Statistical Society*, Vol. 121, 97-99, pt. 1.

GREENWOOD, J., Z. HERCOWITZ, and P. KRUSELL (1997),
"Long-run implications of investment-specific technological change", *American Economic Review* Vol. 87(3), pp. 342-62.

GRILICHES, Z. (1997),
"R&D and the productivity slowdown: is recovery around the corner?", unpublished mimeo.

HALTIWANGER, J. (2000),
"Aggregate growth: what have we learned from microeconomic evidence?", OECD *Economics Department Working Papers*, No. 276, OECD, Paris.

HARBERGER, A.C. (1998),
"A vision of the growth process", *American Economic Review*, March, pp. 1-32.

HILL, P. (1999*a*),
"The productive capital stock and the quantity index for flows of capital services"; paper presented at the third meeting of the Canberra Group on Capital Stock Statistics, Washington, D.C.

HULTEN, C. (1992),
"Growth accounting when technical change is embodied in capital", *American Economic Review*, Vol. 82 (4), pp. 964-80.

HULTEN, C. (2001),
"Total factor productivity: A short biography", in: Hulten, Dean and Harper (eds.). *New Developments in Productivity Analysis*, University of Chicago Press for the National Bureau of Economic Research

JORGENSON, D. (1963),
"Capital theory and investment behaviour", *American Economic Review*, Vol. 53, pp. 247-259.

JORGENSON, D. (1995*a*),
Productivity Volume 1: Postwar US Economic Growth, MIT Press.

JORGENSON, D. (1995*b*),
Productivity Volume 2: International Comparisons of Economic Growth, MIT Press.

JORGENSON, D., F. GOLLOP and B. FRAUMENI (1987),
Productivity and US Economic Growth, Harvard University Press, MA.

JORGENSON, D. and Z. GRILICHES (1967),
"The explanation of productivity change", *Review of Economic Studies* 34.

KHAMIS, S.H. (1970),
"Properties and conditions for the existence of a new type of index number", *Sankhya*, Series B, Vol. 32, Parts 1 and 2.

KONÜS, A.A. (1924),
"The problem of the true index of the cost of living", translated in *Econometrica* (1939) 7, pp. 10-29.

KRAVIS, I.B., A. HESTON and R. SUMMERS (1982),
World Product and Income, Johns Hopkins University Press, Baltimore.

KURODA, M., K. MOTOHASHI and K. SHIMPO (1996),
"Issues on the international comparison of productivity: theory and measurement", in OECD (1996*a*),
Industry Productivity – International Comparison and Measurement Issues, Paris, pp. 49-95.

LOWE, R. (1996),
"Handling quality changes in the Canadian National Accounts price deflators", in OECD(1996*a*), *Industry Productivity – International Comparison and Measurement Issues*, pp. 143-157.

MADDISON, A. (1991),
Dynamic Forces in Capitalist Development, Oxford University Press, Oxford.

MADDISON, A. (1995),
Monitoring the World Economy, 1820-1992, OECD, Paris.

METCALFE, S. (1996),
"The economic foundations of technology policy: equilibrium and evolutionary perspectives", in P. Stoneman (ed.) (1996), *Handbook of the Economics of Innovation and Technological Change*, pp. 409-512.

MORRISON, C.J. (1986),
"Productivity measurement with non-static expectations and varying capacity utilization", *Journal of Econometrics* 33.

MOULTON, B.R., R.P. PARKER and E.P. SESKIN (1999),
"A preview of the 1999 comprehensive revision of the national income and product accounts – definitional and classificational changes", *Survey of Current Business*, August, pp. 7-20, Bureau of Economic Analysis.

NADIRI, I. and I. PRUCHA (2001),
"Dynamic factor demand models and productivity analysis", Hulten, Dean and Harper (eds.), *New Developments in Productivity Analysis*, University of Chicago Press for the National Bureau of Economic Research.

NELSON, R. (1981),
"Research on productivity growth and productivity differences: dead ends and new departures", *Journal of Economic Literature*.

NELSON, R. and S. WINTER (1982),
An Evolutionary Theory of Economic Change, Cambridge, Mass., Harvard University.

NORDHAUS, W.D. (2001),
"Alternative methods for measuring productivity growth", NBER *Working Paper* 8095, National Bureau of Economic Research, Cambridge, MA.

OECD (1996*a*),
Industry Productivity: International Comparison and Measurement Issues, OECD Proceedings, Paris.

OECD (1996*b*),
Services: Measuring Real Value Added, Paris.

OECD (1996*c*),
OECD *Input-Output Tables*, Paris.

OECD (1997),
"Review of the OECD-Eurostat PPP Program", Paris, available at *www.oecd.org/std/ppp/pps.htm*.

OECD (1998*a*),
Technology, Productivity and Job Creation, Paris.

OECD (1998*b*),
"The dynamics of industrial performance – what drives productivity growth", OECD *Science, Technology and Industry Outlook* 1998, Paris.

OECD (1999*a*),
Employment Outlook, Paris.

OECD (1999*b*),
"Purchasing power parities and real expenditures – EKS Results, 1996", Paris.

OECD (2000),
"Underground, informal and illegal activities (non-observed economy): creation and content of a measurement handbook", STD/NA(2000)21, OECD, Paris.

OECD (2001*a*),
OECD *Productivity Manual: A Guide to the Measurement of Industry-Level and Aggregate Productivity Growth*, OECD, Paris, *www.oecd.org/subject/growth/prod-manual.pdf*.

OECD (2001*b*),
"Productivity and firm dynamics", OECD *Economic Outlook*, No. 69, Paris, June.

O'MAHONY (1999),
Britain's Productivity Performance 1950-1996 – *An International Perspective*, National Institute of Economic and Social Research, London.

PILAT, D. (1997),
"Competition, productivity and efficiency", OECD *Economic Studies*, No. 27, 1996/II, pp. 107-145, OECD, Paris.

RYMES, T.K. (1971),
On Concepts of Capital and Technological Change, Cambridge.

SCARPETTA, S., A. BASSANINI, D. PILAT and P. SCHREYER (2000),
"Economic growth in the OECD area: recent trends at the aggregate and sectoral level", OECD *Economics Department Working Papers*, No. 248, OECD, Paris.

SCHREYER, P. (2001),
"Computer price indices and international growth comparisons", Growth Project Background Papers, OECD, Paris, *www.oecd.org/subject/growth/products/index.htm*.

SHARPE, A. (1995),
"International perspectives on productivity and efficiency", *Review of Income and Wealth*, Vol. 41, No. 2, June, pp. 221-237.

SZULC, B. (1964),
"Index numbers of multilateral regional comparisons" (in Polish), *Przeglad Statysticzny*, Vol. 3, pp. 239-254.

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This study investigates the long-term effects of various types of R&D on multi-factor productivity growth, which are the spillover effects of R&D activities. Econometric estimates are conducted on a panel of 16 OECD countries, over the period 1980-98. All results are averages over countries and time, and little can be said about country specificities. Major results are as follows: an increase of 1 per cent in business R&D generates 0.13 per cent in productivity growth. The effect is larger in countries that are intensive in business R&D, and in countries where the share of defence-related government funding is lower; a 1 per cent increase in foreign R&D generates 0.46 per cent in productivity growth, and the effect is larger in countries intensive in business R&D; 1 per cent more in public R&D generates 0.17 per cent in productivity growth. The effect is larger in countries where the share of universities (as opposed to government labs) is higher, in countries where the share of defence R&D is lower, and in countries which are intensive in business R&D.

This paper discusses the main measurement issues in calculating productivity indicators, and provides guidance to researchers and statisticians in addressing these difficulties. It draws on the OECD Productivity Manual and on recent OECD work on productivity levels. The paper examines a range of issues related to the measurement of productivity growth, including the choice of output measure (gross output versus value added), the measurement of output, labour and capital input, as well as index number issues. It also discusses OECD estimates of productivity levels and the key measurement issues in deriving these estimates, including the appropriate conversion from one currency unit to another. A final section discusses the interpretation of productivity measures, including their most common applications and the possible pitfalls. The paper concludes that substantial progress has been made in recent years to improve the comparability of productivity statistics. In many countries, however, basic source data are still the key limitation to the development of comparable indicators of productivity. In addition, statisticians, researchers and policy makers need to be more aware of the appropriate uses and interpretation of productivity statistics.