Chapter 1

ISSUES IN MEASUREMENT AND INTERNATIONAL COMPARISON ISSUES OF PRODUCTIVITY – AN OVERVIEW

by

Bart van Ark[1]
Groningen Growth and Development Centre, University of Groningen

Introduction

Recent evidence on growth rates and comparative levels of productivity

At the beginning of the 1970s OECD countries entered a phase of much slower growth compared to the "golden age" of early post-World War II growth. Table 1 shows that average growth rates of labour productivity since 1973 are down by more than 2 percentage points compared to the period 1950 to 1973. At first, the slowdown was ascribed to "shocks" in the world economy, including the breakdown of the Bretton Woods arrangements and the oil shocks of 1973 and 1979. However, productivity growth continued to slow down during the 1980s, at only 2.2 per cent per year on average since 1987. The search for explanations has shifted to more structural factors inhibiting growth in the long term. Compared to the period 1973-87, the growth experiences of individual countries have been more diverse since 1987, as is shown by the strong increase in the coefficient of variation of growth rates.

Table 1 also shows the comparative levels of labour productivity as a percentage of the US level. For the OECD area (excluding the United States) there has been a continuous process of catch-up and convergence in productivity levels. Despite the greater diversity in growth performance since 1987, catch-up and convergence clearly continued after 1987.[2]

The slowdown in growth rates can also be observed for the manufacturing productivity performance of ten OECD countries. Table 2 shows that growth rates of labour productivity in manufacturing have been higher than for the economy as a whole. Between 1950-73 the catch-up of the nine OECD countries on the United States has been much faster for manufacturing than for the economy as a whole, but it has been slightly slower for manufacturing since 1973 (see the memorandum item in Table 1).

Table 1. Annual compound growth rates (%) and comparative levels of GDP per hour worked (United States = 100), 1950-94

	Annual compound growth rate of GDP per hour (%)			Comparative level of GDP per hour worked (United States = 100)			
	1950-73	1973-87	1987-94	1950	1973	1987	1994
Australia	2.6	1.8	1.0	71.5	69.9	76.6	76.6
Austria	5.9	2.7	1.5	31.7	63.8	79.0	81.6
Belgium	4.5	3.0	2.2	46.5	68.1	88.6	96.3
Canada	2.9	1.7	1.0	75.3	78.9	85.9	85.7
Denmark	4.1	1.7	2.1	46.2	62.5	67.6	73.0
Finland	5.2	2.2	2.8	31.9	55.3	64.3	72.8
France	5.0	3.1	1.7	44.4	73.4	95.8	100.7
Germany	6.0	2.5	3.2	33.8	69.2	84.0	98.0
Italy	5.8	2.5	2.6	32.9	64.3	77.8	86.9
Japan	7.7	3.0	2.6	15.2	44.8	57.9	64.6
Netherlands	4.8	2.6	1.5	49.3	77.4	94.7	98.0
Norway	4.2	3.4	2.6	40.4	56.3	76.4	85.4
Sweden	4.1	1.6	1.0	53.7	73.4	78.1	78.3
Switzerland	3.3	1.2	2.6	67.7	75.9	76.5	85.4
United Kingdom	3.1	2.4	1.9	60.5	65.8	78.6	83.5
United States	2.7	1.1	1.0	100.0	100.0	100.0	100.0
Greece	6.4	2.4	1.8	18.7	42.0	50.3	53.0
Ireland	4.3	3.6	5.1	29.9	42.5	59.3	78.6
Portugal	6.0	1.7	2.0	18.0	36.9	39.9	42.8
Spain	6.4	2.9	4.1	19.8	44.4	56.5	69.8
OECD[1]	4.8	2.4	2.2	41.5	61.3	73.0	79.5
Coefficient of variation	0.30	0.30	0.48	0.53	0.26	0.22	0.19
Memorandum item: 10 OECD countries from Table 2 only	4.4	2.2	1.8	48.4	67.5	79.5	84.2

Note: Comparative levels were converted by EKS PPPs for 1990 (instead of Geary-Khamis PPPs used by Maddison).

1. Unweighted average; average of comparative level excludes the United States.

Source: Maddison (1995*a*), updated from 1992 to 1994 with OECD Secretariat estimates on labour input.

Table 2. Annual compound growth rates (%) and comparative levels of value added per hour worked (United States = 100) in manufacturing, 1950-94

	Annual compound growth rate of manufacturing value added per hour (%)			Comparative level of manufacturing value added per hour worked (United States = 100)			
	1950-73	1973-87	1987-94	1950	1973	1987	1994
Australia	3.9	2.7	3.4[2]	37.8	48.6	49.9	54.1[4]
Canada	4.4	1.9	1.6	61.5	87.7	80.8	77.1
Finland	4.6	4.4	7.0[3]	38.3	57.0	74.3	98.7[5]
France	5.7	3.5	3.4	38.3	73.3	84.0	90.5
Germany	6.9	2.7	2.8	32.4	79.6	82.2	85.0
Japan	9.4	4.8	4.1	11.8	49.2	67.5	76.1
Nethedands	6.9	3.5	2.8	37.2	91.3	105.4	108.8
Sweden	5.4	2.4	3.0	49.7	88.7	87.4	91.8
United Kingdom	4.2	3.2	5.1	38.2	52.4	58.0	70.1
United States	2.8	2.5	2.3	100.0	100.0	100.0	100.0
OECD[1]	5.4	3.1	3.6	38.4	69.7	76.6	83.6
Coefficient of variation	0.35	0.30	0.43	0.60	0.28	0.23	0.19

1. Unweighted average of countries included; average comparative level excludes the United States.
2. 1987-92.
3. 1987-93.
4. 1992.
5. 1993.

Source: van Ark (1996).

Table 3. Total factor productivity for the economy as a whole (1950-93) and manufacturing (1973-92)

	Total economy			Manufacturing	
	1950-73	1973-87	1987-93	1973-87	1987-92
	(1)	(2)	(3)	(4)	(5)
Australia	1.7	0.9	0.4	1.3 b	
Austria	3.0	0.6	0.5		
Belgium	3.7	1.3	0.9	4.i	-0.9
Canada	2.0	0.5	-0.2	0.2	
Denmark	2.3	1.0	0.7	1.4	1.7
Finland	2.7	1.5	1.5	3.0	5.3
France	3.8	1.3	1.4	2.1	2.7
Germany	2.5	1.0	1.0	1.1	1.5
Italy	4.1	1.2	1.3	2.9	.3.3
Japan	4.6	1.1	0.8	3.8	1.4
Netherlands	3.5	1.3	1.1	1.6	2.2
New Zealand	0.8				
Norway	2.4	0.3	0.0	0.3	5.2
Sweden	2.5	0.5	0.8	1.3	4.3
Switzerland	1.8	-0.2	0.5		
United Kingdom	2.5	1.0	1.5	1.7	2.9
United States	1.5	-0.2	0.6	0.8	0.3
Greece	1.9	-0.4	0.8		
Ireland	2.9	1.8	3.3		
Portugal	3.9				
Spain	2.5	1.0	1.0		
OECD countries from column 5 only[1]	2.9	0.9	0.9	1.9	2.0
OECD[1]	2.7	0.8	0.9		
Coefficient of variation	0.36	0.71	0.78		

Note: Total factor productivity is defined as (manufacturing) GDP per combined unit of employment (unadjusted for hours) and total capital stock (including residential capital).

1. Unweighted average.
2. 1973-88.
3. 1987-90.
4. 1987-91.

Source: Total economy from Englander and Gurney (1994). Manufacturing on the basis of the OECD STAN database (1970-93).

Labour productivity is a "single factor productivity" or "partial productivity" concept. Growth rates or levels of labour productivity can differ between countries either because the two countries use different combinations of resources (labour, capital and intermediate inputs), or because one of the two countries uses inputs more efficiently. Table 3 shows that growth rates of total factor productivity (TFP) (here expressed as value added per composite unit of labour and capital) in the business sector slowed down after 1973, even though they accelerated slightly since 1987. In a similar way to the performance of labour productivity growth, the variation in TFP growth has strongly increased since 1987.

Importance of productivity for economic performance

Productivity is essentially a concept for analysis as well as policy orientation in the long term. In the short term, labour productivity measures can be volatile, in particular at a disaggregated level as they are strongly affected by the business cycle and shifts in product composition due to changing competitive pressures. Policies to enhance productivity, including investment in productive resources and the creation and diffusion of knowledge, will therefore only show results in the long run.[3]

The crucial importance of productivity for economic growth can be derived from its relation to other indicators of economic performance. Among other factors, these include accumulation of physical and human capital, technological progress, resource allocation and efficiency, and competitiveness. The various factors are strongly interdependent which complicates establishing of policy priorities. Nevertheless, some issues on the relation between productivity and other growth indicators have been more or less clearly established in the literature. Some of these are briefly summarised below.

Capital accumulation and technological change are the major "engines of growth". Even though the two are closely intertwined, much of the post-war literature on growth has dealt with the relative importance of each factor compared to the other. Essentially the question came down to what part of technological change should be included with the capital stock (see below). The underlying neo-classical growth models (usually referred to as the "Solow" model), however, were highly restrictive as they assumed constant returns to scale and treated technological change as exogenous to the growth process. In fact some empirical studies have stuck more rigorously than others to the assumptions of these theoretical models.[4]

A number of issues have caused a reorientation of growth models over the past two decades. Firstly, it appeared that convergence of per capita income and productivity had not occurred on such a wide scale as predicted by the original "Solow" model, and that it was mainly restricted to the OECD countries. Secondly, it was recognised that, despite the slowdown in TFP growth, the ratio of physical capital to labour has continued to increase since the early 1970s (Englander and Gurney, 1994). Thirdly, there was an increased concern about the so-called "Solow paradox", which suggests that rapid technological change was not reflected in an acceleration of TFP growth.

Greater attention was therefore given to "new growth" models which treat at least part of technological change as endogenous to the growth process. The endogeneity is explained by the learning effects of capital accumulation, in particular if the concept of capital is broadened to include human capital. As the social value from accumulation of "broad" capital exceeds the private marginal product, capital may be characterised by constant or increasing scale effects instead of by diminishing returns. So far empirical measures have not shown strong evidence in favour of increasing returns, although the models seem to perform better when human capital or R&D measures are incorporated.[5]

The rise in interdependencies between countries through trade and capital mobility has increased the importance of international productivity studies. The principal notion behind comparative advantage is that countries specialise in industries for which the cost per unit of output is relatively low compared to other countries. Competitiveness therefore relates not only to productivity, but also to the relative cost at which products are manufactured and sold. Costs are determined by prices of inputs and by the exchange value of a country's currency.[6] Competitiveness also depends on factors such as product customisation, after-sales service and quality aspects. Although the latter could also be incorporated in the productivity measures, they are not easily quantified in practice.

Productivity measures, in particular total factor productivity, should also be related to changes and differences in efficiency. It is useful to make a distinction between efficiency related to the allocation of resources, and efficiency related to maximising output per unit of input. Allocative inefficiency implies that part of the distance between average practice (as reflected by the productivity measure) and best practice is explained by a mis-allocation of labour, capital and technology to less productive uses. Greater competition on product, labour and capital markets at the national as well as the international scale helps to reduce allocative inefficiency.

Another part of productivity differentials can be better explained by technical inefficiency than by allocative inefficiency. Even when obstacles to inefficient allocation are removed, an industry may still use more resources than the minimum required per unit of output. Recent research on the performance of individual plants making use of microdata suggests a range of factors associated with productivity differences between firms, for example, size, age of machinery, location, skills of managers and the workforce, R&D intensity and export shares. So far, empirical work on microdata has been mainly restricted to manufacturing, and few international comparisons have been undertaken in this field. Microproductivity studies will therefore not be dealt with in this chapter.[7]

Purpose and plan of the chapter

It is generally recognised that measurement issues seriously complicate the analysis of productivity in relation to economic growth. These problems gain in number and complexity in the framework of international comparisons. This chapter aims to provide a view of the current state of art in productivity measurement, and discusses the issues which still need to be tackled. To limit the scope of the chapter, it will focus on international comparisons of productivity and, within that framework, especially (although not exclusively) on levels of productivity at sector and industry level. The latter are underdeveloped in comparison to growth rates. The analysis of comparative economic performance, however, is seriously deficient without comparisons of levels which throw light on the size of productivity gaps between countries.

Recent developments in economic growth theory re-emphasize the importance of making the appropriate links between economic theory and empirical measurement. In this respect, the literature has concentrated more on issues related to productivity growth than on comparative levels. The following section therefore starts with some of the theoretical and empirical issues relating to the measurement of productivity *growth*. Problems involved in measuring output and inputs, and issues concerning the aggregation of productivity measures are dealt with. The third section concentrates on productivity *levels*. A distinction is made between the expenditure and the industry-of-origin approaches, and differences between various types of currency conversion factors are discussed. Specific attention is paid to the measurement of comparative output and productivity in services, and to weighting problems in cross-country comparisons. The fourth section briefly discusses the characteristics of some international data sets on productivity. The final section summarises some of the issues which may need to appear on the future research agenda.

Measurement issues in productivity growth analysis

The output concept and problems of aggregation

Much of the productivity literature is concerned with performance of the economy as a whole. From a theoretical point of view, the existence of an aggregate production function can only be assumed under three very strong assumptions, namely that:

- value added is a function of capital inputs, labour inputs and the level of technology;
- the production function is the same in all industries;
- producers face identical factor prices.

In practice these assumptions are rarely fulfilled; this argues in favour of a less restrictive bottom-up approach, in which aggregate results are constructed at the industry level. Empirical studies indeed suggest large differences in estimates of productivity growth for the total economy constructed from the industry level compared to aggregate-level estimates.[8]

For the economy as a whole, value added is the preferred output concept. It avoids double counting of intermediate inputs, such as raw materials, energy inputs and business services, and is comparable to the domestic or national product as shown in national accounts. It, therefore, allows an integrated approach in using primary statistics (such as production statistics) in conjuction with secondary sources (such as input-output tables and national accounts). However, the value-added concept creates a problem for productivity studies because intermediate inputs are transferred from a "source" of output growth to an "explanation" of output growth. In contrast to value added, gross output allows symmetrical treatment of intermediate inputs, capital and labour. At the industry level, where purchases of intermediate inputs from outside the sector are much larger than at the aggregate level, the use of gross output is therefore the most appropriate concept for productivity measurement.

If, from a theoretical point of view, the bottom-up approach in combination with gross output is favoured, the question is how to aggregate productivity figures by industry to aggregate levels. The usual practice has been to make use of Domar/Hulten weights to sum industry growth rates. These weights represent the ratio of total output to output exclusive of intra-industry purchases. It has been suggested that aggregation should not be carried out over gross output, but over "sectoral" output. The latter approach, which was recently adopted in the productivity measures of the US Bureau of Labor Statistics, implies that output is essentially conceived of as expenditure on goods and services by the sector, excluding transactions within the sector.[9] The aggregation procedures described above require knowledge of intra-sector transactions, which can be either estimated or derived from input-output tables. Ideally, to avoid inconsistencies, input-output tables should be integrated with national accounts.

Even though gross output is preferred, value added remains a useful concept, in particular for international comparisons of productivity, because of:[10]

- its greater simplicity; it avoids the need for estimates of intra-industry transactions;
- its closer resemblance to primary statistics, such as production censuses and representative firm data;
- greater comparability in an international perspective.

At industry level, value added is usually measured on a gross (*i.e.* including depreciation) and domestic (*i.e.* excluding production outside a country's borders) basis, and preferably, at factor cost (*i.e.* excluding indirect taxes and including subsidies). With this concept one can get as close as possible to a productivity concept which measures industrial efficiency. At the aggregate level, the choice of the ideal value-added concept (gross or net, and national or domestic product) and the output spectrum that should be covered (whether or not to include the housing sector or the government sector), is less straightforward. Maddison (1987) suggests that the different concepts do not make much difference for international comparisons of growth rates, as long as concepts and coverage are the same across countries. Baily and Schulze (1990) also show that, despite fundamentally different views on the measurement of capital (see below), the main differences between the US growth accounting measures from Denison (1985) and Jorgenson, Gollop and Fraumeni (1987) are accounted for by the fact that the latter include capital depreciation and cover the economy inclusive of the government sector and the flow of services from consumer durables.

Issues in measurement of labour inputs

In recent decades, measurement of labour input has greatly improved, although few countries use an integrated system of labour accounts in which measures from population censuses, employment surveys and production statistics are made consistent. Integrated labour accounts are important for at least three reasons:[11]

- to include self-employed persons, home workers and family workers;
- to achieve a unique allocation of persons employed to individual sectors and industries;
- to estimate the number of hours actually worked per person.

Estimates of working hours are of particular importance for international comparisons, as there are large differences among countries in shares of full-time and part-time employees in the labour force, the incidence of short-time working (including voluntary reductions in labour time for employment policy purposes), holidays and sickness.[12] Denison (1967, 1985) has suggested adjusting the decline in working hours of some categories of full-time workers for a rise in efficiency per hour, but so far this has not been followed up in productivity measurement.

Quality of labour (*i.e.* the "human capital" content of labour) is partly measured by changes in the age-sex composition of the labour force. These are implemented through the use of weights, reflecting earnings by age-sex category. The other component of labour quality relates to the education of the working population. Growth accounting has mostly made use of estimates of the number of years of schooling incorporated in the labour force.[13]

In international comparisons at the industry level, it is important to distinguish between different types of schooling, because the impact on human capital creation and productivity growth is not the same among countries and industries. The need to distinguish between general and vocational education has been recognised, in particular in relation to productivity comparisons among European countries.[14] Empirical evidence suggests greater output elasticities for vocational education compared to general education; this is also confirmed by international comparisons of human capital and productivity at the firm level.[15] Company training also adds significantly to the stock of human capital. However, from an internationally comparative perspective, there is little empirical evidence to assess the quantitative impact of company training on productivity performance.[16]

Issues in measurement of capital inputs

In contrast to human capital, the contribution of physical capital accumulation to growth has traditionally received more attention in the literature.[17] Essentially the question comes down to what part of technological change should be seen as part of the capital stock. According to the "Denison/Kendrick" view, all technical progress should be included in the growth residual (reflecting "advances in knowledge" according to Denison's terminology), and be separated from investment, which (as Denison stated later) represents consumption forgone. Changes in quality of capital are therefore disembodied from the stock whatever their origin.[18] The "Jorgenson/Griliches" approach, on the other hand, assigns a greater part of technical progress to capital. This is done by estimating the service flow from different vintages of capital. In other words, the Jorgenson approach implies that substitution between all types inputs (capital-capital, labour-labour and capital-labour) is incorporated. In a recent exchange between Denison, Griliches, Hulten and Rymes, Hulten provided a useful analysis of the Denison-Jorgenson controversy: whereas Denison's approach implies an answer to the question of how much output growth is explained by technical change (or "advances in knowledge"), Jorgenson's approach aims to measure how far the production function shifts relative to a given capital-labour ratio.[19]

In an international comparative perspective, the discussion of the contribution of capital to growth is more complex. Countries which operate below the technology frontier may experience a "catch-up bonus", deriving from technology diffusion through accumulation of new capital. Indeed, empirical studies for the post-World War-II period suggest a greater degree of embodied technological change in the European countries and Japan than in the United States; this is reflected by the strong relation between the rise in capital intensity and TFP growth in the former group.[20]

From a productivity measurement perspective, three issues need to be addressed in relation to the estimation of capital:

- the choice of weights to aggregate capital stock by type of equipment and by industry;
- the role of quality in the estimation of deflators for capital stocks;
- the construction of capital stock estimates themselves.

The first two issues are directly related to the discussion of the literature above, whereas the third received less attention but is crucial from a measurement point of view.

If one prefers to measure service flows from the capital stock, which reflect quality changes in the capital stock, the use of rental prices of individual capital inputs is the most appropriate weight for aggregating the stock. Rental prices account for differences in depreciation rates among capital goods, and therefore give a weight to the individual capital items according to their real contribution to output. Proponents of measuring capital without accounting for quality change favour the use of asset prices as weights. In international comparisons, the latter type of weight is more often applied due to difficulties in obtaining rental weights. However, in some cases they have been imputed on the basis of asset prices, income and property tax rates and asset depreciation.[21]

The controversy between the "Denison" and "Jorgenson" approaches in measuring capital had important consequences for the discussion of the adjustment of price indices for quality change. Essentially, the quality discussion revolved around the question of whether to apply the "resource cost" approach or the "user value" approach. According to the first approach, price indices should only account for quality changes which are reflected in a rise in costs of inputs. The user value approach takes account not only of resource cost, but also the full spectrum of quality change as perceived from a utility perspective. Triplett (1983) proposed a resolution of the issue by advocating the use of the "resource cost" approach for the output of goods and the "user value" approach for inputs. From an output perspective, "constant quality" implies an assumptio of no change in technology and in the characteristics of the product. From an input perspective, "constant quality" implies no change in the utility of the product.[22]

In terms of statistical practice, the quality issue is a major cause of inconsistencies in productivity growth measures across countries. The reason that the literature in this field has remained largely North-American is because the European countries and Japan have barely dealt the problem of quality change in their national statistics. In fact most national accounts measures of real GNP growth in Europe and Japan assume that changes in quality are adequately measured by comparing prices of "matched models" over time. This implies that price changes are assumed to be exclusive of quality changes, and that the price change implicit in a new model is identical to that of matched models. These are clearly heroic assumptions for many types of goods. The alternative is the use of hedonic price indices: in this approach various characteristics of goods and services are priced by regression techniques in order to take account of the effect of changes in those characteristics on the price index. In the United States, hedonic price indices are now in use for various categories, most importantly single family homes and (since 1986) computers.[23]

It could be argued that the issue of quality change in capital has received more attention in the literature than the measurement of the "unadjusted" capital stock. Most OECD countries now have detailed stock estimates of physical assets, mostly estimated on the basis of the perpetual inventory method (PIM). This method cumulates investments over time while assuming service lives, retirement patterns, premature scrapping (because of wars, etc.) and (if one wishes to measure net instead of gross stock) depreciation.[24] However, the official estimates have been criticised for their lack of comparability across countries. This is mainly due to the wide variation in assumed asset lives across countries and, to a lesser extent, to different models of retirement. Asset lives can, of course, differ across countries because of differences in the composition of the capital stock. Variation in technological progress, which makes the existing stock obsolescent more rapidly, is another explanation. However, differences in asset-life assumptions can hardly account for these facts. O'Mahony (1993) has shown that asset-life assumptions have an important impact on the growth and, in particular, levels of the capital stock.[25]

Finally, capital input can be further broadened by including non-human intangible capital, defined as knowledge that is not embodied in labour. Knowledge also features prominently in some versions of "new growth" models. However, it is still measured in an imperfect manner, *i.e.* either by input measures such as expenditure on research and development, or by output measures such as patents. One of the main problems with patents is that the actual "economic content" is very difficult to determine due to different patenting practices over time and across countries. Most important from the perspective of measurement by industry, however, is that technology creation and technology use often take place in different industries, complicating the analysis of the relation between technological change and productivity growth.[26]

International comparisons of productivity levels

Expenditure versus industry-of-origin approach

For international comparisons of levels of output and productivity for the economy as a whole, one may apply either the expenditure approach or the industry-of-origin approach. The expenditure approach concentrates on comparisons of categories of private consumption, government consumption and capital formation. Comparisons by industry of origin deal with sectors of the economy, such as agriculture, industry and services, and branches and industries within these sectors.[27] For comparisons of the economy as a whole, the expenditure approach is easier to carry out than the industry-of-origin approach. This is because the former concentrates on comparisons of final products, and therefore avoids duplication of output which is used as an intermediate input elsewhere. In addition, as will be noted below, purchasing power parities derived from the expenditure side are currently more readily and widely available than similar conversion factors by industry of origin.

For comparisons by sector and industry, only the industry-of-origin approach can be applied, because total output consists of final products as well as intermediate products. Cross-country comparisons, even at industry level, are generally made for value added rather than gross output because of the almost complete absence of price information for intermediate inputs in combination and the lack of an integrated system of input-output tables which can be compared across countries.

Apart from making comparisons at sectoral and industry level, the industry-of-origin approach is also useful at the total economy level as a consistency check on the expenditure approach. The latter depends largely on expenditure information from national accounts. Although national accounts are relatively well harmonized across the OECD countries, there still are differences which may affect estimates of levels more than growth rates. Kravis and Lipsey (1991) emphasize the importance of defects in national accounts, rather than problems in measurement of PPPs, for errors in ICP comparisons, even though these are considered smaller for advanced economies than for low income countries.[28] The industry-of-origin approach uses information from a range of sources which include production censuses, input-output tables and information for industry and trade. Cross-checks between expenditure and industry-of-origin estimates are important in order to assess the reliability of the various estimates.

Purchasing power parities and unit value ratios

International comparisons are strongly hindered by the need for a conversion factor which takes account of cross-country differences in relative price levels in order to express each country's output in a common currency. For comparisons of total economy performance, expenditure PPPs are most easily obtained from the regular surveys carried out by the UN, EUROSTAT and the OECD. For comparisons of productivity for the economy as a whole, GDP PPPs have been most extensively applied by Maddison.[29]

For comparisons by industry of origin, one can effectively choose between two different methods:

- direct comparisons of physical quantities of output (tonnes, litres, units);

- converting output by industry to a common currency with a currency conversion factor which approaches cross-country differences in producer prices.

Conceptually, the two approaches are the same, but in practice they yield different results because of differences in sampling, weighting and coverage. In the past, international productivity studies often applied the physical quantity method, but more recent studies have switched to the currency conversion method. This is primarily due to the increase in the number of products and product varieties, so that the percentage of output which can be covered by physical comparisons is much lower than in the past. With price comparisons, the representativity of matched output for non-matched output is greater than for quantity ratios. The physical quantity method is still in use for comparisons at plant level, where quality differences can be better accounted for, and for comparisons of output in services.[30]

The most commonly used currency conversion factors in industry-of-origin comparisons are unit value ratios (UVRs). Unit values are obtained as the ratio of values and quantities of items as reported in production statistics, which are matched across countries.[31] The UVR method faces three major problems which affect the comparability of the estimates across countries:

- In many sectors and industries, unit value ratios are based on a limited sample of items, and rather far-reaching assumptions are employed concerning their representativity for non-measured price relatives. For example, in manufacturing where the average percentage of output covered by unit value ratios is between 15 and 45 per cent, it is usually assumed that UVRs for matched items within a manufacturing branch are representative for non-matched items.

- Comparisons of unit values are affected by differences in product mix, because production censuses often include output values for product groups rather than for specific products. In international comparisons the problem is aggravated because of the lack of a harmonized product coding system, so that items need to be further aggregated in order to obtain a correct match between countries.

- Unit value ratios need to be adjusted for differences in product quality across countries. The quality problem was discussed in some detail above, but it is more serious in international comparisons as the frequency of so-called "unique products" (which are products which are only observed in one case) is higher than for comparisons over time.

The problems described above are of least concern for approximately 20-25 per cent of GDP in OECD countries, which includes output from agriculture, mining, utilities, certain manufacturing industries (in particular basic goods industries, such as pulp and paper, wood products, metallic and non-metallic mineral products) and transport and communication. In these sectors, output coverage is usually large and there are few quality differences across countries.[32] The problems feature most significantly, however, in manufacturing industries producing durable consumer goods and investment goods: in these industries, the part of output covered by UVRs is often well below 10 per cent.

The unit value ratio problems can be tackled in three ways:

- unit value ratios can be "improved" and coverage expanded to account for the under-representation of heterogenous products, the valuation of unique products, and product quality differences across countries;

- statistical procedures can be applied to obtain confidence intervals of UVRs by industry and to detect outlier UVRs;

- alternative approaches can be developed which make use of expenditure PPPs, or which apply an integrated approach with micro-studies to obtain price information from plants.

Most work on UVRs has been carried out for manufacturing, on which the following paragraphs will concentrate. The expansion of unit value ratio coverage can be strengthened by the use of a harmonized product classification system across countries. So far, harmonization across countries has been limited to the 4-digit industry level. Recent efforts by EUROSTAT to create a product classification (PRODCOM) across the European Union member States could be an important step forward. However, an important prerequisite for harmonization between the EU, North America and Japan is agreement on whether the classification should be set up from a supply side (production process) or a demand side (commodity) perspective. The supply side perspective would be more useful for productivity measurement.

So far, quality adjustments for cross-country comparisons have been made mainly on an *ad hoc* basis, making use of product information from individual plants or groups of plants. The McKinsey Global Institute study on manufacturing productivity explicitly based quality adjustments on the "resource cost" criterion (see above): UVRs are adjusted only when recognised by consumers in such a way that they are willing to pay a price premium, and when these are the result of differences in the product and production process. Remaining notions of quality (which were the result of advertising, taste, etc.) were treated as differences in consumer preferences which may explain differences in productivity and which can improve the competitive situation of companies and industries, but which are not used in adjusting the productivity measure itself.[33] Hedonic techniques, to deal more systematically with quality differences, have scarcely been applied in international comparisons of output and productivity levels.[34]

It has been suggested that pricing of narrowly specified items, as is, for example, applied in the ICP expenditure approach, is superior to the use of unit values, and that expenditure PPPs should therefore also be used for industry-of-origin comparisons.[35] In some cases, GDP PPPs have been applied to all sectors and industries, but this is an inferior method as it does not take account of differences in price levels across sectors and industries.[36] A more sophisticated method is to select expenditure PPPs for representative items which are allocated to specific industries.[37] One problem with this so-called "proxy PPP method" is that it is based on market prices for final products. In a comparison between Japan and the United States, Jorgenson and Kuroda (1990) applied PPPs which were "peeled off" for indirect taxes and transport and trade margins. Hooper and Vrankovich (1995) went one step further and adjusted the expenditure PPPs for import and export prices: "output PPPs" should, of course, include prices of exported goods but exclude those of imported goods. As Hooper and Vrankovich acknowledge, the latter step is difficult and, in particular in open economies, might introduce a lot of noise in the estimates. The major problem of the PPP approach is that it does not cover intermediate products – which in manufacturing account for at least one-third of output.

Clearly, specified prices are less affected by differences in product mix and product quality, even though there remain some considerable problem areas in estimating PPPs, in particular in services. The number of matched items in expenditure PPP comparisons (on average 300 to 700, although more matched items are likely for comparisons across OECD countries) is also higher than for unit value ratios (on average some 200 items). However, in the case of expenditure comparisons, there is a bigger question mark on the representativity of the narrowly specified items for total expenditure. The unit value approach has the additional advantages that quantities and unit values come from the same source, and that the unit values reflect actual transaction prices at producer level for all locations and over the whole period. It may, therefore, be useful to develop statistical techniques which measure the reliability of UVRs and (proxy) PPPs by industry. As confidence in the conversion factors is determined partly by the output coverage percentage of matched items and partly by the variance in UVRs within the industry, a reliability measure must include both elements.[38]

In view of the advantages and disadvantages of both the UVR method and the expenditure PPP method for international comparisons of output and productivty, some authors propose a mixed methodology. For example, O'Mahony (1992) supplemented UVRs with expenditure PPPs for machinery. The mixed method was more fully applied in a recent paper by the OECD (1996*a*). Table 4 compares price levels relative to the United States, which are based on different types of UVRs, (proxy) PPPs and combinations of these. The table shows that:

- GDP PPPs are distinctly different from UVRs and proxy PPPs;
- proxy PPPs suggest higher price levels relative to the United States than the UVR and combined UVR/proxy PPP methods;

- the differences between the UVRs and the UVR/proxy PPPs were small at the aggregate level for total manufacturing, although there were more significant differences at branch and industry level.[39]

Table 4. Comparison of relative price levels for international comparisons of manufacturing output, 1987

	Canada	France	Germany	Japan	United Kingdom	United States
Exchange rate (national currency/US$)	1.33	6.01	1.80	144.6	0.604	1.00
Relative price levels						
(currency conversion factor/exchange rate)						
ICP expenditure PPP						
Multilateral (EKS)	98	113	122	147	93	100
Bilateral (Fisher)	96	110	114	136	101	100
Proxy PPP	108	134	131	151	131	100
Unit value ratio (UVR)	101	120	123	120	117	100
Combined UVR/Proxy PPP	105	121	127	123	112	100

Source: ICP expenditure PPPS, multilateral variant from OECD *National Accounts*, Vol. 1 (1993). ICP expenditure PPPS, bilateral Fisher variant provided by EUROSTAT for 1990 and backdated to 1987 with GDP deflators. Proxy PPP is the "OPR" variant from Hooper and Vrankovich (1995) for 1990 backdated to 1987 with manufacturing GDP deflators. UVRs are ICOP estimates (see van Ark, 1996, forthcoming). Combined UVR/Proxy PPP from OECD (1996*a*).

Whichever concept of PPP or UVR is chosen, the main problem in industry-of-origin comparisons is that, ideally, a conversion factor is required not only for output, but also for inputs. Labour inputs can be compared on a quantity basis, even though appropriate weights are required within each country for the various labour categories (age/sex/education) for which mostly wage information is used. For comparison of capital inputs, expenditure PPPs on capital formation can be used. Price comparisons for intermediate inputs are, however, more troublesome. Most comparisons of productivity at value-added level have, therefore, used a “single deflation” procedure, which implies that conversion factors for output are also used for value added. In practice, double deflation (*i.e.* the use of separate UVRs – or PPPs – for output and for intermediate inputs) easily leads to volatile results because of significant measurement problems. Firstly, double-deflated estimates are sensitive to the weights used in the index, although this problem may be overcome by the use of translogarithmic indexes based on average value shares of the two countries in each binary comparison.[40] Secondly, double deflation requires meticulous measurement of the value and prices of material inputs, for which coverage needs to be quite substantial. In particular where intermediate inputs make up a large part of gross output, small measurement errors show up more significantly in the double-deflated value-added measures. In practice, therefore, the single deflation method provides more robust results for international comparisons than the double deflation method.[41]

Comparison of services

The increasing output and employment share of services in the OECD countries, in combination with the relatively slow growth of real output in services, has led to increased attention being paid to the measurement of services productivity. However, so far there has been little work in an international comparative perspective. Measurement problems concerning output, prices and quality in services are not fundamentally different from those for commodity sectors, except that they are more significant; partly because of the lack of primary statistics, such as censuses and price surveys, for services. In addition, when measuring output and productivity in the services sector, one also faces a conceptual problem of how to define the adequate quantity, quality and price measure of the item.[42]

International comparisons of output and productivity levels in services began with the work of Paige and Bombach (1959) comparing the United States and the United Kingdom. Since that time no comprehensive comparative productivity studies (*i.e.* studies which cover all the services sectors of the economy) had been undertaken until the work of the ICOP project at Groningen University.[43] In particular for non-market services, an integrated use of the expenditure and industry-of-origin approaches might be favoured as output and expenditure are not very different. The state of the art in measuring comparative output levels in services can be summarised as follows:[44]

- *Transport and communication*: Comparisons of physical quantities and UVRs in terms of passenger and tonne kilometres, phone calls, mail delivered, etc.. A specific problem in transport is the "terminal element", as the relative importance of terminal services (which is part of the transport sector) is inversely related to the average distance of each movement, which is a drag on the relative productivity performance of the transport sector in the country with the shortest distances.[45]

- *Wholesale and retail trade*: The "product" of this service is represented by the margin between total sales and purchases. Most authors have used ICP expenditure PPPs on individual consumer items to deflate value added. Maddison and Mulder (1993) applied a double deflation procedure, using ICP PPPs for sales and ICOP UVRs for selected products from agriculture and manufacturing to deflate purchases.

- *Finance and insurance*: Comparisons of physical quantities, such as cheques traded, number of bank accounts or (for the insurance sector) life insurance policies. Pilat (1994) used a proxy physical quantity indicator, namely M2, which is the sum of cash in circulation, demand deposits and time and saving deposits. Another proxy indicator is net interest received on deposits held by banks.

- *Housing services and real estate*: Estimates of the stock of residential capital can be compared with expenditure PPPs for residential investment.

- *Education*: Output can either be approached with a physical input indicator (teachers) or a physical output indicator (number of students, etc.). Adjustments need to be made for quality differences across countries, for example by using information on achievement levels of students.

- *Health*: One can either use proxy PPPs for specified health services from ICP, or apply a composite index of physical quantities (doctors, hospital beds, etc.). Quality adjustments need to be made either with information on the "mix of diseases" or by using an aggregate quality indicator such as the newly developed "DALY" (disability adjusted life year) indices of the World Bank (Mulder, 1996).

- *Defence and general government*: Output estimates (like expenditure estimates) are largely based on input indicators. Recent research on time series of productivity in Sweden and the United States suggests ways to measure government services by physical output indicators, but this method requires a large number of series and involves serious constraints in terms of applying quality-adjusted weights.

- *Other services (business services, personal services, recreation, legal and social services)*: Proxy ICP PPPs for tourism, hotels and restaurants, personal care and miscellaneous services.

Pilat (1994) shows that about 60 per cent of services output in Japan and the United States in 1975 could be compared on the basis of ICP proxy PPPs, 30 per cent on the basis of physical indicators, and only 10 per cent (*i.e.* transport and communications) on the basis of a unit value ratio approach. More recent research suggests that a greater use of UVRs could be made for the distribution sector, and that physical indicators may also be applied for the health and government sectors.

Maddison (1983) argues that the expenditure approach, as practised by ICP, may overstate the real product of, in particular, low-income countries because of its treatment of services. Firstly ICP relies heavily on input information (employment and capital input) to obtain expenditure estimates for comparison-resistant services, such as health, education and government. Secondly, expenditure studies contain so-called "disguised" services (in particular transport and distribution), which are included in the final expenditure on commodities rather than services. As the ICP procedure is based on the "potato is a potato" rule, it does not account for differences in the share of those services in commodity expenditure, which leads to an over-statement of overall GDP in countries where such services are relatively unimportant. These will be mainly low-income countries, but the problem also applies to comparisons across OECD countries.[46]

A related problem in estimating services output and productivity concerns the so-called "outsouring" of services production from commodity sectors to services sectors. For the OECD countries there are clear indications that an increasing part of services production (defined as all production of services irrespective of the industry where it is produced) is produced in services industries.[47] This complicates the comparison of services productivity in relation to commodity productivity, as outsourcing is largely a matter of changes in vertical integration between services and commodity producing units.

Weighting procedures

The expenditure approach and the industry-of-origin approach also differ in the weighting systems used for aggregation. Following the pioneering studies of Gilbert and Kravis (1954) and Gilbert (1958), expenditure studies began using specifically designed surveys. As a result, items and basic headings were harmonized across countries, allowing experimentation with an almost unlimited range of index numbers, representing different weighting systems, for aggregation. Industry-of-origin comparisons are generally of a binary nature, mainly because there are no harmonized primary statistics across countries.[48] This significantly constrains the choice of index numbers, and causes major index number problems.

Extensive literature exists on the choice of weighting systems for international comparisons. However, only those points which are relevant to productivity comparisons by industry of origin are summarised here.[49]

Basically, two different types of indices can be distinguished:

- Bilateral indices. These are based on pair-wise comparisons which can be sub-divided into three categories:[50]

– index numbers which use the weights of the base (denominator) country (Laspeyres index numbers);

– index numbers which use the weights of the "own" (numerator) country (Paasche index numbers);

– an average of the two indices above, of which the geometric average (the Fisher index) is the most well-known and frequently used type.

♦ Multilateral indices. These are based on an average of weights representative of all countries in a comparison. Two of these indices have been applied in the framework of international comparisons of manufacturing productivity:[51]

– The Geary Khamis method, which derives an "international" price for commodities simultaneously with the purchasing power parity. The international price, which is essentially an average of the prices of all countries included in the comparison, is used to reprice the quantities in order to obtain values expressed in the same currency.

– The generalised Theil-Törnqvist index (or EKS multilateral index), which is a multilateral version of the binary Theil-Törnqvist index. The latter is a geometric average of binary (Fisher) UVRs weighted at average value shares of two countries.

Among the binary indices, the Fisher index which, so far, has been mostly used in industry comparisons of output and productivity, performs relatively well in terms of index number characteristics and economic theoretic properties.[52] However, all binary indices are characterised by some major index number problems of which the three most important are:[53]

♦ Lack of transitivity, which in the present context means that a PPP between two countries does not equal the ratio of PPPs between each of these two countries and a third country. This implies that binary indices cannot provide a unique ranking of countries according to their productivity levels.

♦ Lack of base country invariance, which implies that the results depend on the base (or "numeraire" country) with which each country is compared. Base country invariance can only be achieved if the weights represent an average of all countries in the sample.

♦ Lack of additivity (or matrix consistency), so that the matrix of real quantities cannot be consistently added up across the columns (representing the countries) and the rows (representing the products or industries).

Multilateral indexes satisfy some of the properties (in particular transitivity and base country invariance), but do not solve all problems. Firstly, the two multilateral indices discussed above have their own shortcomings: the Geary-Khamis index is biased towards the weight of the largest country in terms of output; and the generalised Theil-Törnqvist index lacks additivity. Secondly, the multilateral procedures can only be applied at the level for which the product and industry statistics can be harmonized across all countries. Below that level, *i.e.* usually at product level, the price comparisons remain essentially binary and still face the problems described above.

One of the most important properties of any index for international comparison, however, is country characteristicity. This property requires that index numbers reflect to the greatest extent possible the relative price and quantity structure of each country. A binary index usually performs better on this property than a multilateral index, as the binary index uses only the weights of the two countries which are compared. Among the multilateral indices, the generalised Theil-Törnqvist index, which is based on binary Theil-Törnqvist indices, performs better on country characteristicity than the Geary-Khamis PPPs.

However, when two countries are very dissimilar in terms of price and quantity structure, an indirect comparison through a third country might be preferred over a direct comparison between the two countries. In a multicountry comparison, this leads to the creation of a chain index. Clearly chaining over time is easier than chaining across space because of the natural sequence of observations. Hill (1988) suggests that the links across countries might be established by the pattern of relative prices in each country, which would reduce the index number spread between the Paasche and Laspeyres indices, and therefore improve the reliability of the geometric (Fisher) average.[54]

International productivity data sets

International productivity comparisons have a long history, but only in the past decade have a number of publicly available data sets on productivity covering at least two decades, a significant number of countries and a certain degree of sectoral disaggregation been constructed. The US Bureau of Labor Statistics (BLS) is one of the governmental agencies with the longest history in publishing international productivity series. BLS has published indices on labour productivity growth for 12 countries which generally go back to 1950. However, the agency has invested in particular in productivity series for manufacturing, which are published in combination with estimates of labour compensation and unit labour cost. More recently BLS has also started to publish multifactor productivity series for manufacturing since 1956, but so far these are limited to France, Germany and the United States. The latter series are of specific interest, because they make use of Törnqvist indices and rental weights for capital stock, and are, in this respect, most comparable to earlier studies of Jorgenson *et al.*[55] BLS has always refrained from international comparisons of productivity levels because of the methodological problems described above.

At the OECD there are two data sets on sectoral and industry statistics. The International Sectoral Database (ISDB) provides information on employment, gross domestic product, investment, capital stock, employee compensation and imports and exports for around 30 branches for 14 OECD countries (Meyer-zu-Schlochtern, 1988, 1994). Some scholars have made extensive use of ISDB for productivity and unit labour cost comparisons (Dollar and Wolff, 1993; Hooper and Vrankovich 1995). ISDB is mostly based on OECD national accounts for output and employment, but gaps are filled with information from, for example, Eurostat's national accounts and OECD labour force statistics. ISDB goes back to 1960, although the database has a number of gaps. ISDB does not provide a currency conversion factors, but users either applied a single GDP PPP for all sectors (Dollar and Wolff, 1993) or developed their own proxy expenditure PPPs (Hooper and Vrankovich, 1995).

The second OECD database is STAN, which provides similar information to ISDB but exclusively for manufacturing industries and at a more disaggregated level for 21 OECD countries from 1970 onwards. STAN is much used in industry studies which also make use of other indicators, such as statistics on trade, research and development, etc., (OECD, 1996*b*). The STAN database is complete but many of the data points were estimated as no official figures were available from Member countries. Like ISDB, STAN does not provide industry-specific PPPs for level comparisons, only exchange rates and GDP PPPs.

Recently Eurostat has also started to develop a database with competitiveness indicators for manufacturing (Eurostat, 1996). Although still under development, thedata base is the most ambituous of those described here, as it aims to include trade data, output and value-added information, profitability indicators, labour input and labour compensation and R&D indicators back to 1980. It also aims to cover industries at the 3-digit NACE headings. International comparisons are made using EUROSTAT PPPs for GDP.

Since the early 1970s, Dale W. Jorgenson *et al.* have made international comparisons of productivity.[56] The studies mostly cover the United States, Japan and Germany, although two studies also include Canada, France, Italy, Japan, Korea, the Netherlands and the United Kingdom. All studies are based on Törnqvist indices, but mostly make comparisons of the growth of real value added. Only the comparisons between Japan and the United States are based on gross output, which is decomposed into intermediate inputs, capital and labour, and disaggregated for about 30 sectors. The use by Jorgenson and Kuroda (1990) of an integrated input-output framework in the comparisons between Japan and the United States is unique, and has not been replicated in other studies so far. Unfortunately, the studies make use of proxy PPPs for final expenditure which are not adjusted for relative import and export prices.

For many decades statistical studies of productivity in the United Kingdom have been undertaken at the National Institute for Economic and Social Research (NIESR).[57] The country coverage of the National Institute's studies is mainly Germany, the United Kingdom and the United States, even though there have also been a few comparisons with France, Japan and the Netherlands. Most NIESR studies have concentrated on manufacturing and distribution, but more recently the National Institute's research programme has been expanded to cover other market services as well. An attractive feature of these studies is the direct link to studies on human capital, in particular the effect of vocational training on productivity.[58]

Since 1983 a substantial research effort has been undertaken at the University of Groningen to carry out industry-of-origin studies for all sectors of the economy. The International Comparisons of Output and Productivity (ICOP) project was initiated by Angus Maddison, following his earlier work on industry-of-origin comparison.[59] The ICOP project now covers about 30 countries in Asia, Eastern and Western Europe, and North and South America. Comparisons of manufacturing output and productivity, which are exclusively based on unit value ratio comparisons and disaggregated into 16 manufacturing branches, are available for almost all of these countries. Comparisons for agriculture are made for 13 countries, and other sectors are extensively covered for Brazil, Japan, Korea, Mexico and the United States. ICOP has exclusively focussed on comparisons of value added, mostly developed on a binary basis with the United States as the numeraire country. The database has been extended with comparisons of total factor productivity and unit labour cost for a limited number of countries, including France, Germany, Korea, Japan, the United Kingdom and the United States. The ICOP project has put out over 80 research reports, in which methods, procedures and basic data are given, so that methods can be replicated and revised.[60]

Proposals for a research agenda

Measurement issues seriously complicate the analysis of productivity in an international perspective and create an important constraint for policy making. In past decades substantial progress has been made to improve the link between economic theory and productivity measurement. However, transformation of those insights into the practice of international comparisons has been slow. This is partly caused by a persistent lack of comparable data, in particular at sector and industry level. In addition, there is a need for clearer views on a number of important measurement issues.

In 1976, Kravis concluded that because of the wide range of measurement problems in TFP, the best strategy for international comparisons would be to concentrate on labour productivity comparisons. In this view, factor inputs and intermediate inputs should be treated as external variables which explain the results (Kravis, 1976). After two decades, this conclusion is still valid. Even though capital stock measures now exist for most OECD countries, these are rarely available at the sectoral or industry level, and there are legitimate concerns about their international comparability. In practice many studies still rely on investment-output ratios, which only under very strict assumptions can be seen as a good proxy for capital stock. Human capital is often approximated by student enrollment rates or at best by years of schooling, without distinction between different types of education. Direct measures of technology, such as the stock of R&D, licences or patents are only available on a limited scale, and suffer from important problems in terms of international comparability. Finally, measurement of intermediate inputs is not well-developed, and they are mostly only estimated in the framework of input-output tables. Better measurement of inputs therefore deserves priority in order to improve productivity measures.

Compared to commodity sectors, measurement of services productivity has received even less attention in international comparisons. In recent years some progress has been made in measurement of productivity growth for market services (including transport and communications, distribution, and financial services), but substantive international research efforts have yet to be undertaken. Censuses and surveys of the type that have been in use for the commodity sectors (in particular manufacturing) for periods ranging from several decades to more than a century, are still sparse. For non-market services, which are the most "comparison resistant", the use of imperfect output measures is probably unavoidable for a period longer than for market services. However, an international investigation into measures representing changes and differences in quality in, for example, education, health and government admistration, would be a first useful step toward improved measurement of output of non-market services.

All these problems, however, cannot be solved simply by additional data. The role of quality change in international comparisons of growth and levels of output and productivity is strongly underdeveloped. There are important inconsistencies among countries in their handling of quality. It will be necessary to apply hedonic techniques on a wider scale, in particular in the area of non-durable and investment goods and probably also in some services industries. International co-ordination in this field is important as the indices are sensitive to the choice of variables and the specifications of the model.

International comparison of productivity levels by sector and by industry is seriously hampered by the general lack of appropriate currency conversion factors for expressing output in a common currency. There is a strong need for a clearer view on the advantages and disadvantages of using different types of conversion factor (and on the sensitivity of results) to express industry output in a common currency. A compromise solution to the problems arising from the use of either UVRs or PPPs for industry-of-origin comparisons is to make use of the best elements of each. UVRs may be most useful for industries, which:

- produce relatively many intermediate goods;
- produce relatively homogenous goods, *i.e.* where product mix and product quality are relatively unimportant;

- have a relatively high export share, as PPPs are more sensitive to the adjustment for import and export prices.

Proxy PPPs are more usefully applied in industries where product mix and product quality problems are important.

Given the slow progress in the creation of harmonized statistics on products and industries across countries, it is to be expected that binary indices will remain in use for industry-of-origin comparisons for some time yet. Multilateral indices stemming from binary indices (such as the generalised Theil-Törnqvist method) are most useful complement to bilateral indices. It is also suggested that the possibility of developing chain indices for international comparisons should be examined more closely.

Finally, many of the issues discussed above suggest that international comparisons by sector and industry could benefit from a greater use of input-output tables, in particular when these are integrated with national accounts and made consistent across countries. The following uses of input-output tables for international productivity comparisons are suggested:

- analysis of the impact of changes in sectoral shares on overall productivity, for example because of outsourcing of services and changes in vertical integration;

- development of better techniques for double deflation of output and intermediate inputs;

- development of techniques to analyse value-added shares in final output;

- analysis of the consistency of the expenditure and industry-of-origin approach in terms of basic information on output and inputs.

NOTES

1. I would like to thank Dirk Pilat and Paul Schreyer for helpful suggestions and comments, but of course they bear no responsibility for the contents of this chapter.
2. Compare Maddison (1995*a*) for figures on per capita income. It appears that growth rates of per capita income have been significantly slower than those of labour productivity; that the catch-up of per capita income on the United States has also been slower than for productivity; and that coefficients of variation for per capita income growth are higher than for productivity growth. The difference between per capita income and labour productivity performance can be explained by differences in labour force participation rates and working hours per person across countries.
3. See Baumol, Blackman and Wolff (1989).
4. See, for example, Maddison (1995*a*) in discussing the work of Denison and Jorgenson.
5. For an overview of recent contributions to growth theory, see *Quarterly Journal of Economics* (May 1991 and May 1994), *Journal of Economic Perspectives* (Vol. 8, No. 1). See also Barro and Sala-i-Martin (1995) and Mankiw (1995).
6. See, Hooper and Larin (1989), O'Mahony (1995) and van Ark (1995*a*) for recent examples of international comparisons of unit labour cost.
7. See Caves (1992) for a review of studies estimating efficiency frontiers. See Jensen and McGuckin (1995) for a review of research on longitudinal databases. Some international comparative work has been done on the basis of a case studies making extensively use of field surveys of matched plants (for example, Daly, Hitchens and Wagner, 1985; Mason, van Ark and Wagner, 1994).
8. See, for example, Jorgenson (1990) and Oulton and O'Mahony (1994).
9. For an up to date review of these procedures in multifactor productivity estimates by the US Bureau of Labor Statistics, see Gullickson (1995). Similar measures are also applied for Canada.
10. See Gullickson (1995), footnote 12. See also Baily (1986) who shows that "gross output" productivity growth can be related to "value added" productivity growth on the basis of changes in the ratio of material inputs to gross output and the relative prices of materials to output. Jorgenson (1990) states that the aggregate value model can be used for long-term (*i.e.* covering at least four decades) productivity analysis, but that it is inappropriate for analysing sources of growth over shorter periods. Durand (1994) shows that the value added concept can be useful for economic analysis at industry level, when the value added on each commodity delivered to final demand equals the sum of the values added to them by the industries. According to Durand this can be done by replacing the output and input price indices used in the traditional double deflation process by a weighted average of final demand commodity prices.
11. See Maddison (1980) for a detailed proposal along those lines.
12. For example, in 1992 annual working hours within the OECD differed at a rate of 1:1.4, with the Netherlands at 1 338 hours per person per year and Japan at 1 876 hours per person (Maddison, 1995*a*).
13. Recent "new growth" studies, which assess the contribution of education to growth at aggregate level on the basis of regression analysis, have mostly used school enrollment rates which is a very rough measure of "educational content" of the labour force. See, for example, Barro and Sala-i-Martin (1995), Chapter 10.
14. See, for example, Prais (1995), for a review of studies of Germany, France, Japan, the Netherlands, Switzerland and the United Kingdom by the National Institute of Economic and Social Research.
15. See O'Mahony (1992*b*) for a cross-country regression between Germany and the United Kingdom. See Mason, van Ark and Wagner (1994) for a comparison of food processing plants in France, Germany, the Netherlands and the United Kingdom.
16. See McKinsey Global Institute (1993) on the role of "organisation of functions and tasks" within firms for productivity analysis. This variable refers to the optimisation of time and motion in the production process (just-in-time delivery systems and lean production), the organisation of work and the management structure.

17. For a useful insight in the history of this debate from both perspectives, see Jorgenson (1990) and Denison (1993). Here I abstain from the discussion on the Cambridge controversy which is less relevant from the viewpoint of productivity measurement at industry level.
18. Even though the positions of Kendrick and Denison on these issues are relatively close, Kendrick also refrains from adjusting productivity for quality change in labour input due to age-sex mix and education. Furthermore Kendrick prefers to use gross instead of net capital stocks (Kendrick, 1961, 1973).
19. See the Panel Discussion on "Implications of BEA's Treatment of Computer Prices and Productivity Measurement" in Foss, Mancer and Young (1993).
20. See, for example, Wolff (1991) and Englander and Gurney (1994) for comparisons at the aggregate level, and Dollar and Wolff (1993) for international comparisons at industry level. These studies also show a slowdown in TFP growth since 1973 whereas capital intensity (relative to the United States) continued to increase.
21. For an application of this method in the BLS measures of international multifactor productivity growth rates, see Lysko (1995).
22. It should be clear from this discussion that the quality issue does not remain limited to the measurement of capital input, but has major implications for a wide range of outputs, including fertilizers, automobiles, computers and other investment goods. See Griliches (1990).
23. Hedonic price indices for computers have also been applied in Australia and Canada (see Miller, 1994). Recently there have been some contributions to hedonic pricing from European scholars, in particular for computers. See, for example, Stoneman *et al.* (1992) for the United Kingdom, Moreau (1991) for France, and Gnoss and von Minding (1990) on Germany. See also Wyckoff (1993) for a review. Triplett (1990) makes the useful point that the choice between the hedonic price method and the matched-model approach should not be equalled with the distinction between the user value and resource cost approach. Hedonic price indices are essentially a better method in dealing with "missing" prices when quality changes.
24. See Ward (1976) and OECD (1993) for a review of practices in OECD countries.
25. See O'Mahony (1993) and Maddison (1995*b*) who standardise PIM estimates of capital stock for asset lives and retirement patterns between France, Germany, Japan, the United Kingdom and the United States at a sectoral and aggregate level respectively. (Maddison also includes the Netherlands, but these estimates were recently revised by Groote, Albers and de Jong, 1996). See Blades (1993) for a critical view of the standardising approach.
26. See Kendrick (1976) for an early application of R&D as a measure of "nonhuman intangible capital" in a growth accounting framework for the United States. See Pilat (1994) for a comparison between Japan and the United States. See O'Mahony and Wagner (1996) for a comparison between Germany and the United Kingdom since 1973. All these studies show a rather small contributions of R&D to growth.
27. For a good review of expenditure studies, see Kravis (1984). For a review of industry-of-origin studies, see Kravis (1976) and van Ark (1993, 1996). In principle, one could also make international comparisons following the income approach, but in practice this approach has seldom been applied, and in any case has remained limited to income from labour (for example, the UK Board of Trade Study of 1907-11; Williamson, 1995).
28. Van Ark (1995*a*) describes a range of differences in national accounts methodologies which particularly affect sectoral and industry output. Among other things, these concern differences in the use of income statistics, production statistics or integrated input-output tables to estimate output by industry; the use of a "primary activity" or "enterprise" classification in allocating output to industries; and differences in industry classification
29. Expenditure comparisons were pioneered by Gilbert and Kravis (1954) and Gilbert *et al.* (1958). Since the late 1960s surveys were conducted at regular intervals by the International Comparisons Project (ICP). See, for example, Kravis, Heston and Summers, 1982) and the subsequent Penn World Tables (for example, Summers and Heston, 1988, 1991), which were derived from the ICP estimates. For, productivity comparisons making use of Maddison (1995*a*), see Tables 1 and 2.

30. See Maddison and van Ark (1988, 1989) for a review of the two approaches and for a description of the conditions under which these yield the same results. See also Kravis (1976).
31. The UVR-method was most extensively applied for the first time in the OEEC study of Paige and Bombach (1959), and later replicated in other studies, including most studies in the the framework of the ICOP (International Comparisons of Output and Productivity) project at the University of Groningen..
32. The percentage is even higher for low income countries where these sectors still have a greater output share. For comparisons of agricultural output and productivity, see Maddison and van Ooststroom (1995), Prasada Rao (1986, 1992), Terluin (1990) and van der Meer and Yamada (1990).
33. See McKinsey Global Institute (1993). See Gersbach and van Ark (1994) for a detailed account of quality adjustment procedures in the McKinsey study, in particular for investment good industries. Even though adjustments at industry level were in some cases substantial, there were no significant systematic biases in the comparative estimates for manufacturing as a whole for these three countries.
34. In ICP, hedonic price indexes were constructed for rents and automobiles (Kravis, Heston and Summers, 1982)
35. See, for example, Lichtenberg and Griliches (1989), who show on the basis of a sample of products from 238 US industries that unit value relatives and the producer price index from 1972 to 1977 did not differ strongly in terms of the growth rate, but that the measurement error-variance of the former was five times as large as that of the latter.
36. See, for example, Dollar and Wolff (1993).
37. See, for example, Prais (1981), Roy (1982) and Hooper and Larin (1989).
38. See Timmer (forthcoming).
39. See OECD (1996*a*).
40. See Jorgenson and Kuroda (1990).
41. Single and double deflation provide the same result only when the UVRs for gross output equal those for the intermediate inputs, and the value added share for each unit of output is the same within each industry and across countries. See Paige and Bombach (1959) and van Ark (1993, 1996).
42. See Griliches (1992) for a range of papers on output, price and productivity measurement of services, although they concentrate mainly on intertemporal comparisons for the United States, except the paper of Heston and Summers.
43. Estimates for selected sectors are available from, for example, Smith and Hitchens (1985) and McKinsey Global Institute (1992). Recently, the National Institute of Economic and Social Research has begun a new series of comparisons of services between Britain, Germany, France and the United States. Dollar and Wolff (1993) provide comparative level estimates of services productivity based on the OECD Sectoral Data Base, but it makes use of expenditure GDP PPPs which affect the reliability of their results.
44. See Pilat (1994) on Japan, Korea and the United States, Mulder (1994) on productivity in transport, communication and distribution in France, the United Kingdom and the United States, and Maddison and Mulder (1993) and Mulder (1996) on distribution in Brazil, Mexico and the United States. See also Maddison and van Ark (1994).
45. See Mulder (1994) for a correction for terminal services making use of a weighted average for “moving” services and terminal services.
46. Maddison and van Ark (1994) show that for low income countries like Brazil, Korea and Mexico, the expenditure approach yields higher GDP estimates than the industry-of-origin approach, whereas the difference between the two approaches is smaller for a more advanced country like Japan. See also Pilat (1994).
47. In this respect, Heston and Summers (1992) make the useful distinction between services production and services output.
48. The main exception is agriculture, for which multilateral output and productivity accounts are constructed on the basis of FAO data on output and farm prices. See Prasada Rao (1986, 1992).
49. See, for example, Hill (1981) and Kravis, Heston and Summers (1982) for a more extensive discussion.

50. For multi-country comparisons which use binary indexes, one usually applies a star comparison, which means that all countries are compared on a binary basis with the same "numéraire" country, which in most cases has been the United States.
51. See Pilat and Prasada Rao (1996) and Pilat (1994).
52. See Diewert (1981).
53. Other index properties such as the factor reversal test and transaction equality are discussed in Kravis, Heston and Summers (1982). See also Pilat and Prasada Rao (1996).
54. See, van Ark, Monnikhof and Timmer (1996) for a cross-country comparison of price and quantity structures in manufacturing based on ICOP studies.
55. See Lysko (1995) for a description of the BLS estimates of multifactor productivity in France, Germany and the United States. The major difference with the BLS estimates of multifactor productivity by industry for the US business sector, is that aggregation is done over value added rather than gross output.
56 See Jorgenson (1995) for a collection of most of his articles on international comparisons, some of which were co-authored with one or more of the following persons: Laurits R. Christensen, Klaus Conrad, Dianne Cummings, Mitsuo Ezaki, Mieko Nishimizu and Masahiro Kuroda.
57. In fact, one of the first industry-of-origin comparisons of productivity between the United Kingdom and the United States during the 1930s was undertaken at the National Institute (Rostas, 1948). See also Smith, Hitchens and Davies (1982), Smith and Hitchens (1985), van Ark (1990) and O'Mahony (1992). See also Roy (1982) for an example of the "proxy PPP" approach.
58. See Prais (1995) for a review. See also O'Mahony and Wagner (1996).
59. See in particular Maddison (1970, 1983).
60. See van Ark (1993, 1995*a*, 1996) and Table 2 of this chapter for comparisons of manufacturing, Maddison and van Ooststroom (1995) for comparisons of agriculture and this chapter for comparisons of services. See also Maddison and van Ark (1994), Pilat (1994) and Mulder (1996).

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