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Updated System of National Accounts (SNA):

Chapter 15: Price and volume measures

Chapter 15: Price and volume measures 3

Chapter 15: Price and volume measures

A. Introduction

15.1 Chapter 14 describes how the goods and services account may be compiled and elaborated within in a supply and use table. The changes in the values of flows of goods and services can be directly factored into two components, one reflecting changes in the prices of the goods and services concerned and the other the changes in their volumes. One major advantage of compiling price and volume measures within an accounting framework such as that provided by the supply and use tables, is that a check is provided on the numerical consistency and reliability of the set of measures as a whole. This is particularly important when every flow of goods and services in the economy has to be covered, including non-market goods and services whose valuation is difficult at current values as well as in volume terms.

15.2 Another advantage of compiling price and volume measures within an accounting framework is that price or volume measures can be derived for certain important balancing items. In particular, gross value added can be measured in volume terms by subtracting intermediate consumption in volume terms from output in volume terms, the so-called "double deflation" method. Double deflation may be used at the level of an individual enterprise, industry or sector. However, the primary objective of the System is not simply to provide guidelines on measures of changes in prices and volumes for the main aggregates of the System but to assemble a set of interdependent measures that make it possible to carry out systematic and detailed analyses of inflation and economic growth.

1. Index number theory

15.3 Section B gives an overview of the theory of index numbers as applied in the System. There have been significant developments in this area over the last decade. New manuals have been published on the theory and practice of consumer price indices (CPIs) (ref International Labour Office (ILO), IMF, OECD, Eurostat, United Nations, World Bank, 2004a, *Consumer Price Index Manual: Theory and Practice*, (Geneva: ILO). http://www.ilo.org/public/english/bureau/stat/guides/cpi/index.htm) and on producer price indices (PPIs) (International Labour Office (ILO), IMF, OECD, UN ECE, World Bank, 2004b, *Producer Price Index Manual: Theory and Practice* (Washington: International Monetary Fund). http://www.imf.org/np/sta/tegppi/index.htm.). A further manual on export and import price indices (XMPIs) is in draft in 2007 and due for publication in 2008 (available on the IMF web site: http://www.imf.org/external/np/sta/tegeipi/index.htm). These manuals have been prepared with a common structure to help readers. In particular chapter 14 of the CPI and PPI manuals and chapter 15 of the XMPI manual outline how such indices fit into the framework of the System.

15.4 The first topic in section B concerns the choice of an appropriate methodology for compiling inter-temporal price and volume measures for flows of goods and services in a national accounting context. Section B also deals with the consequences of price variation due to price discrimination; that is, how to treat goods or services that are sold to different purchasers on the same market in the same period of time at different prices. Such differences need to be clearly distinguished from price differences attributable to differences in qualities. This section also discusses the treatment of changes in quality over time, including the appearance of new products and the disappearance of old products.

2. Inter-temporal price and volume series

15.5 Section C shows how the considerations in Section B can be applied to the System and time series of volumes and prices be derived. It discusses not only the elements of the goods and services account but also how stocks of non-financial assets can be decomposed into price and volume elements. Further, the section addresses the question of expressing key aggregates of the System that do not themselves have price and volume components in real terms, allowing an analysis of the impact of terms of trade on national income, for instance.

15.6 Like section B, section C does not aim to be exhaustive in its coverage but draws on, and refers to, other manuals developed over the last decade, specifically Eurostat's *Handbook on Price and Volume Measures in National Accounts* and chapter IX of the International Monetary Fund's *Quarterly National Accounts Manual: Concepts, Data Sources and Compilation.*

3. International price comparisons

15.7 Although most price and volume index numbers were developed to measure changes in prices and volumes over time, they can also be adapted to compare levels of prices and volumes between different regions or countries in the same period of time. Such comparisons are needed in order to be able to compare standards of living, levels of economic development or levels of productivity in different countries.

15.8 These topics are addressed in section D, first in theoretical terms and then in terms of the implications for national accountants. In this area also a new manual is in draft describing the major round of the international comparisons programme (ICP) drawing to a close in respect of 2005. (The *ICP 2003-2006 Handbook* on methods is published by the World Bank in electronic form at: http://web.worldbank.org/WBSITE/EXTERNAL/DATASTATISTICS/ICPEXT/0,,contentMDK:20962711~menuPK:2666036~pagePK:60002244~piPK:62002388~theSitePK:270065,00.html.)

4. Further information

15.9 This chapter aims to do no more than introduce the most important concepts and considerations of the application of index number theory to the derivations of volume series within the System. Further information should be sought from the other manuals cited.

B. An overview of index number theory

1. Quantities, prices and values

15.10 For each individual type of good or service it is necessary to specify an appropriate quantity unit in which that good or service can be measured. Goods or services may be supplied in units that are either discrete or continuously variable. Automobiles, aircraft, microcomputers, haircuts and appendectomies are examples of goods or services provided in discrete or integral units. The quantities of such goods and services are obtained simply by counting the number of units. Oil, electricity, sugar and transportation are examples of goods or services provided in units that vary continuously in respect of characteristics such as weight, volume, power, duration and distance. The choice of physical unit and its price in relation to the unit selected, is therefore a matter of convenience. For example, if the price is quoted per tonne it is one thousand times greater than if it is quoted per kilo. As long as the price is expressed in a manner consistent with the unit of volume, value (v) at the level of a single, homogeneous good or service is equal to the price per unit of quantity (p) multiplied by the number of quantity units (q), that is: $v = p \times q$.

Additivity of quantities, prices and values

15.11 Certain important properties in relation to the additivity of quantities, prices and values may be briefly noted:

a. Quantities are additive only for a single homogeneous product. For example, it is not economically meaningful to add 10 tonnes of coal to 20 tonnes of sugar. Less obviously, the addition of 10 automobiles of one type to 20 automobiles of another type would not be economically meaningful either if they differ in quality.

b. ***The price of a good or service is defined as the value of one unit of that good or service***. It varies directly with the size of the unit of quantity selected and in many cases can therefore be made to vary arbitrarily by changing the unit of quantity, for example, by choosing to measure in tonnes instead of in kilograms. Prices, like quantities, are not additive across different goods or services. An average of the prices of different goods or services has no economic significance and cannot be used to measure price changes over time.

c. Values are expressed in terms of a common unit of currency and are additive across different products. Values are invariant to the choice of quantity unit.

15.12 In a market system, the relative prices of different goods and services should reflect both their relative costs of production and their relative utilities to purchasers, whether the latter intend to use them for production or consumption. Relative costs and relative utilities influence the rates at which sellers and buyers are prepared to exchange goods and services on markets. An aggregation of the values of different goods and services necessarily reflects the choices of what goods and services have been produced and consumed at the currently prevailing prices.

Volume, quantity, price and unit value indices

15.13 ***A volume index is an average of the proportionate changes in the quantities of a specified set of goods or services between two periods of time***. The quantities compared over time must be those for homogeneous items and the resulting quantity changes for different goods and services must be weighted by their economic importance, as measured by their relative values in one or other, or both, periods. For this reason volume is a more correct and appropriate term than quantity in order to emphasise that quantities must be adjusted to reflect changes in quality.

15.14 Unfortunately, it may sometimes happen, especially in the field of foreign trade statistics based on customs documentation, the data on which price and volume indices have to be calculated are insufficient or otherwise not adequate for the purpose. For example, the basic information available may be limited to the total number of units of some group of products imported or exported, or their total weight: for example, the total number of pairs of shoes, or total weight of equipment of a certain type. Indices built up from information of this kind are not volume indices when the numbers, or weights, cover different items selling at different prices. They are sometimes described as "quantity indices" for this reason.

The "price" indices associated with such indices are usually described as average or "unit value" indices. ***Unit value indices measure the change in the average value of units that are not necessarily homogeneous and may therefore be affected by changes in the mix of items as well as by changes in their prices.*** Unit value indices cannot therefore be expected to provide good measures of average price changes over time for groups of non-homogeneous items.

2. Inter-temporal index numbers of prices and volumes

15.15 The index numbers of interest within the System are designed to decompose changes in value aggregates into their overall change in price and overall change in volume components. A price index can be written and calculated as a weighted average of the proportionate changes in the prices of a specified set of goods and services between two periods of time, say a reference period 0 and current period *t*. Similarly, a volume index can be written and calculated as a weighted average of the proportionate changes in the volumes of a specified set of goods and services between two periods of time, say a reference period 0 and current period *t*. There are many index number formulae differing from each other mainly in the weights which they attach to the individual price or quantity relatives and the particular form of average used, whether it is arithmetic, geometric, harmonic, etc. These alternative formulae, their properties and relative merits, are outlined in detail in the CPI and PPI manuals.

Laspeyres and Paasche indices

15.16 The two most commonly used index formulae are the Laspeyres and Paasche indices. The Laspeyres price index (L_P) is defined as a weighted arithmetic average of the price relatives using the value shares of the reference period 0 as weights;

$$L_P = \sum_{i=1}^{n} \left(\frac{p_i^t}{p_i^0} \right) s_i^0 = \frac{\sum_{i=1}^{n} \left(\frac{p_i^t}{p_i^0} \right) p_i^0 q_i^0}{\sum_{i=1}^{n} p_i^0 q_i^0} \equiv \frac{\sum_{i=1}^{n} p_i^t q_i^0}{\sum_{i=1}^{n} p_i^0 q_i^0} \quad ....(1)$$

that is, where p_i^0, q_i^0 and $v_i^0 = p_i^0 \times q_i^0$ are the prices, quantities and values in period 0 of i=1,…,n products and $s_i^0 = v_i^0 / \sum_{i=1}^{n} v_i^0$, the value shares in period 0. Similar expressions with superscripts *t* refer to period *t*.

15.17 Note from (1) that the Laspeyres price index can be defined as the change in value of a basket of products whose composition is kept fixed as it was in the reference period 0. The Laspeyres volume index (L_Q) can be similarly defined as the change in the value of a basket whose composition every period is updated but the prices of the reference period 0 are applied to the new quantities (or volumes), that is:

$$L_Q = \sum_{i=1}^{n} \left(\frac{q_i^t}{q_i^0} \right) s_i^0 \equiv \frac{\sum_{i=1}^{n} p_i^0 q_i^t}{\sum_{i=1}^{n} p_i^0 q_i^0} \quad ....(2)$$

15.18 Paasche indices also exist in both price and volume forms. The Paasche index differs from the Laspeyres index in two respects. It uses a harmonic mean instead of an arithmetic average and the fixed period volumes or prices are those of the current period t. The Paasche price index is given by:

$$P_P = \left[\sum_{i=1}^{n} \left(\frac{p_i^t}{p_i^0} \right)^{-1} s_i^t \right]^{-1} \equiv \frac{\sum_{i=1}^{n} p_i^t q_i^t}{\sum_{i=1}^{n} p_i^0 q_i^t} \quad ....(3)$$

and a Paasche volume index, with fixed current period weights or prices, by:

$$P_Q = \left[\sum_{i=1}^{n} \left(\frac{q_i^t}{q_i^0} \right)^{-1} s_i^t \right]^{-1} \equiv \frac{\sum_{i=1}^{n} p_i^t q_i^t}{\sum_{i=1}^{n} p_i^t q_i^0} \quad ....(4)$$

Deflation and volume series using Laspeyres and Paasche formulae

15.19 The index of the change in monetary values between two periods, $I_V = \sum_{i=1}^{n} v_i^t \Big/ \sum_{i=1}^{n} v_i^{t-1}$, reflects the combined effects of both price and quantity changes. When Laspeyres and Paasche indices are used, the value change will exactly decompose into a price index times a volume index only if the Laspeyres price index is matched with the Paasche volume index, that is: $L_P \times P_Q = I_V$ or the Laspeyres quantity index is matched with the Paasche price index $L_Q \times P_P = I_V$. For example, a price index, 1.05 representing a 5 per cent change multiplied by a volume index of 1.08, an 8 per cent change, yields a value change index of 1.134, a 13.4 per cent change.

15.20 This relationship can be exploited whenever the total current values for both periods are known and either of a price or volume index. Suppose, for example, compilers want to derive a volume index. Laspeyres and Paasche volume indices are derived by dividing (deflating) the value change by appropriate price indices: $L_Q = I_V / P_P$ and $P_Q = I_V / L_P$ respectively. Note that L_Q from the right-hand side of equation (2) generates a time series of Laspeyres volume indices, for periods t=1,…,T of:

$$\frac{\sum_{i=1}^{n} p_i^0 q_i^1}{\sum_{i=1}^{n} p_i^0 q_i^0}, \frac{\sum_{i=1}^{n} p_i^0 q_i^2}{\sum_{i=1}^{n} p_i^0 q_i^0}, \ldots\ldots, \frac{\sum_{i=1}^{n} p_i^0 q_i^T}{\sum_{i=1}^{n} p_i^0 q_i^0} \quad \ldots\ldots\ldots\ldots(5)$$

Multiplying through the series by the common denominator $\sum_{i=1}^{n} p_i^0 q_i^0$ yields the volume series:

$$\sum_{i=1}^{n} p_i^0 q_i^1, \sum_{i=1}^{n} p_i^0 q_i^2, \ldots\ldots, \sum_{i=1}^{n} p_i^0 q_i^T \quad \ldots\ldots\ldots\ldots(6)$$

The relative movements from period to period for this series are identical with those of the associated Laspeyres volume indices given by (5), the two series differing only by a scalar that is the value in period 0.

15.21 Series using prices of a base year of the kind throughout as illustrated by (6) are easy to understand, but are not best practice in national accounts if the time period T is a lengthy one over which there are changes in the structure of the economy. For example, if volume changes are measured over a 10 year period, say 1995 to 2005, at constant 1995 prices, then the volume movements in later years are based on a price configuration that is likely to have changed. Better practice is to change the weights of (rebase) the Paasche deflator in 2000 and link the resulting index to the 1999 one. The resulting volume series over the 10 year period will no longer be at constant 1995 prices, but be a more representative volume index. Even better practice, resources permitting, is to form a series of annual bilateral links of constant price comparisons. The term volume series is better used to describe such series than "in constant prices".

The relationship between Laspeyres and Paasche indices

15.22 Before considering other possible formulae, it is useful to establish the behaviour of Laspeyres and Paasche indices vis-à-vis each other. In general, a Laspeyres index tends to register a larger increase over time than a Paasche index, that is, in general:

both $L_P > P_P$ and $L_Q > P_Q$ ....(7)

It can be shown that relationship (7) holds whenever the price and quantity relatives (weighted by values) are negatively correlated, that is, as prices go up the quantities purchased go down or vice versa. Such negative correlation is to be expected for price takers, including consumers and firms purchasing intermediate inputs, who react to changes in relative prices by substituting goods and services that have become relatively less expensive for those that have become relatively more expensive. A positive correlation would be expected for price setting firms that substitute output towards goods and services that have become relatively more expensive. In such circumstances the inequalities in equation (7) would be reversed.

15.23 Consumers are assumed to maximise utility, which in turn is related to combinations of goods and services purchased. Theoretic cost of living indices (COLIs) are defined as the ratio of the minimum expenditures required to enable a consumer to attain a fixed level of utility under the two sets of prices. The COLI increases if it becomes more expensive to maintain the same level of utility. A Laspeyres COLI would hold the preferences and utility fixed in the reference period and a Paasche COLI would hold them fixed in the current period.

15.24 The Laspeyres price index provides an upper bound to the theoretic Laspeyres COLI. This is because under the COLI, consumers can substitute products that have become relatively less expensive for ones that have become relatively more expensive to obtain the same level of utility, something the fixed basket Laspeyres index does not allow. Similarly, the Paasche index can be shown to provide a lower bound to the theoretic Paasche COLI.

Other index number formulae

15.25 Because different formulae give different results, a consideration of alternative approaches to choosing among them is needed and this in turn gives rise to a consideration of further index number formulae.

15.26 It is apparent from the Laspeyres and Paasche price indices in equations (1) and (3) respectively that both indices hold the basket of quantities fixed. The formulae differ in that Laspeyres holds the basket fixed in the reference period and Paasche in the current period. If the objective is simply to measure the price change between the two periods considered in isolation, there is no reason to prefer the basket of the earlier period to that of the later period, or vice versa. Both baskets are equally justifiable from a conceptual point of view. Thus neither formula can be judged superior to the other, yet they can yield different results.

15.27 A compromise solution for the price index is to use a formula that makes symmetric use of the base and current period information on quantities. The Fisher index can be shown to be the most suitable in this regard. (For an explanation of why this is so, see chapter 15 of the CPI and PPI manuals.) The Fisher index (F) is defined as the geometric mean of the Laspeyres and Paasche indices, that is, for price and quantity indices respectively:

$F_P = \{L_P . P_P\}^{½}$ and $F_Q = \{L_Q . P_Q\}^{½}$. .... (8)

15.28 Economic theory postulates indifference curves that show how consumers would alter their expenditure patterns in response to changes in prices. Unless the utility functions the indifference curves represent are similar in periods 0 and t, a Laspeyres and a Paasche index for this period will each refer to a differently shaped utility function. In general, the Laspeyres index will provide an upper bound to its underlying utility function while the Paasche index will give a lower bound to its underlying utility function but the two utility functions will be different.

15.29 In order to resolve this dilemma, a series of indices called superlative indices have been derived that relate to utility functions that adapt over time to the changes in quantities brought about by changes in prices. The Fisher index is one example of a superlative index, a Törnqvist index is another example. A Törnqvist index is the geometric average of the price relatives weighted by averge expenditure shares in two periods. Thus the Törnqvist price and volume indices are defined as:

$$T_P = \prod_{i=1}^{n} \left(\frac{p_i^t}{p_i^0} \right)^{\left(s_i^0 + s_i^t\right)/2} \quad \text{and}$$

$$T_Q = \prod_{i=1}^{n} \left(\frac{q_i^t}{q_i^0} \right)^{\left(s_i^0 + s_i^t\right)/2} \quad \text{...(9)}$$

Both Fisher and Törnqvist indices utilize and attach equal importance to information on the value shares in both periods for weighting purposes. For this reason they may be expected to lie between the bounds of Laspeyres and Paasche indices, as is desired. The difference between the numerical values of the Törnqvist and Fisher indices and other such symmetric indices, is likely to be very small. Note that for both (8) and (9) the volume indices are not at a specific period's constant prices. The term "at constant prices" is a misnomer for such series; volume indices better describes them.

15.30 The above analysis has been from the consumer's or purchaser's perspective. Economic theory also defines Laspeyres and Paasche bounds from the producer's perspective. Revenue maximising producers are expected to increase the relative quantities they produce in response to increases in relative prices. The resulting Laspeyres-Paasche bounds are the reverse of those described above, as quantities produced are substituted towards commodities with above average prices. But the implication for removing substitution bias by the use of Törnqvist and Fisher indices still holds.

Desirable index number characteristics

15.31 There are two frequently quoted characteristics that it is felt index numbers for deflating national accounts should satisfy. These are the "time reversal" and "factor reversal" tests. The time reversal test requires that the index for period t compared with period 0, should be the reciprocal of that for period 0 compared with t. The factor reversal test requires that the product of the price index and the volume index should be equal to the proportionate change in the current values. It follows from the discussion in the preceding section that Laspeyres and Paasche indices on their own do not pass either of these tests. However, it follows from the definitions of Fisher indices in (8) that the Fisher index passes these tests.

15.32 The Fisher index therefore has a number of attractions that have led it to be extensively used in general economic statistics. Indeed, Fisher described his index as "ideal". However, it is worth noting that it also has some disadvantages. The Fisher index requires both reference and current period information for weights, which may affect the timeliness of the index. It is not so easy to understand as Laspeyres or Paasche indices and is not additively consistent (though its contributions to change are). Similar properties apply to the Törnqvist index.

15.33 The CPI and PPI manuals provide in chapters 15, 16 and 17 an extensive account of the various approaches to choosing among index numbers. Also included in chapter 16 is the stochastic approach that favours the Törnqvist index. What is apparent from this extensive body of work is that all three approaches favour the Fisher index; that superlative indices such as the Fisher and Törnqvist index produce very similar results and can all be justified from the economic theoretic approach; and that the difference between superlative indices and the Laspeyres/Paasche indices, or their spread is due to substitution bias.

Index numbers in practice

15.34 The Laspeyres price index in equation (1) has the same price and weight reference period 0. In practice, especially for CPIs where timeliness is of the essence, the price reference period 0 differs from the earlier weight reference period, say b, since it takes time to compile the results from the survey of households, establishments and other sources for the weights to use in the index. The Laspeyres index given by the first expression in equation (1) may have as its weights s_i^b instead of s_i^0. This index is a Young index and, like the Laspeyres index, has the undesirable property of failing the time reversal test.

15.35 Statistical offices often try to overcome this by adjusting the value shares used as weights by the changes in prices between b and 0 to form a Lowe index given by:

$$L_{oweP} = \frac{\sum_{i=1}^{n} \left(\frac{p_i^t}{p_i^0} \right) \left(\frac{p_i^0}{p_i^b} \right) v_i^b}{\sum_{i=1}^{n} v_i^b \left(\frac{p_i^0}{p_i^b} \right)} \equiv \frac{\sum_{i=1}^{n} p_i^t q_i^b}{\sum_{i=1}^{n} p_i^0 q_i^b} \quad \text{.....................(10)}$$

While the Lowe index is often used in practice in CPI compilation, it has the disadvantage of generally falling outside of the Laspeyres-Paasche bounds.

3. Chain indices

The rebasing and linking of indices

15.36 As noted in the previous section, over time the pattern of relative prices in the base period tends to become progressively less relevant to the economic situations of later periods to the point where it becomes unacceptable to continue using them to measure volume changes from one period to the next. It will then be necessary to update the weights. With long time series, it is as inappropriate to use the most current weights for a date long in the past as it is to use the weights from a long time in the past for the current period. It is therefore necessary to link the old series to the new re-weighted series by multiplication. This is a simple numerical operation requiring estimates for an overlapping period of the index/series calculated using both the old and new weights.

15.37 The linking calculation can be undertaken in a number of ways. The current index on the new weights can be multiplied by a linking coefficient of the old to new index to convert the new index to the old index reference period. Alternatively, the index may have its reference period changed at the time of the introduction of new weights and the old index may be revised by dividing it by the linking coefficient. The process of linking an old series and a new one by means of a link for an overlap period is referred to as chaining.

15.38 Whether the chaining is done so as to preserve the earlier reference period in the new series or to change the reference period of the old series to the new one, the calculations have to be undertaken at each level of aggregation, components have to be linked as well as the aggregates.

Chaining each period

15.39 The more frequently weights are updated the more representative will the resulting price or volume series be. Annual chain indices result from compiling annual indices over two consecutive years each with updated weights. These "links" are combined by successive multiplication to form a series. In order to understand the properties and behaviour of chain indices in general, it is necessary to establish first how chain Laspeyres and Paasche indices behave in comparison with fixed base indices.

Chain Laspeyres and Paasche indices

15.40 A chain Laspeyres volume index connecting periods 0 and t is an index of the following form:

$$L_Q = \frac{\sum_{i=1}^{n} p_i^0 q_i^1}{\sum_{i=1}^{n} p_i^0 q_i^0} \times \frac{\sum_{i=1}^{n} p_i^1 q_i^2}{\sum_{i=1}^{n} p_i^1 q_i^1} \times \ldots, \frac{\sum_{i=1}^{n} p_i^{t-1} q_i^t}{\sum_{i=1}^{n} p_i^{t-1} q_i^{t-1}} \quad .(11a)$$

The corresponding chain Paasche volume index, P_Q, has the following form:

$$P_Q = \frac{\sum_{i=1}^{n} p_i^1 q_i^1}{\sum_{i=1}^{n} p_i^1 q_i^0} \times \frac{\sum_{i=1}^{n} p_i^2 q_i^2}{\sum_{i=1}^{n} p_i^2 q_i^1} \times \ldots, \frac{\sum_{i=1}^{n} p_i^t q_i^t}{\sum_{i=1}^{n} p_i^t q_i^{t-1}} \quad ....(11b)$$

Laspeyres and Paasche price indices are obtained by interchanging the *p*'s and *q*'s in the expressions for the volume indices.

15.41 In general, if fixed base indices are replaced by chain indices, the index number spread between Laspeyres and Paasche is likely to be greatly reduced. Chain indices thus have an advantage over fixed base ones. The relationship between a fixed base index and the corresponding chain index is not always the same, however, as it must depend upon the paths followed by individual prices and quantities over time.

15.42 If individual prices and quantities tend to increase or decrease steadily over time it can be shown that chaining will significantly reduce the index number spread, possibly almost eliminating it. Chapters 9 and 19 of the CPI and PPI manuals provide illustrative examples and chapter 15 explains the theory underlying these findings.

15.43 On the other hand, if individual prices and quantities fluctuate so that the relative price and quantity changes occurring in earlier periods are reversed in later periods, it can be shown that the Laspeyres-Paasche index spread is increased by chaining.

15.44 On balance, situations favourable to the use of chain Laspeyres and Paasche indices over time seem more likely than those that are unfavourable. The underlying economic forces that are responsible for the observed long-term changes in relative prices and quantities, such as technological progress and increasing incomes, do not often go into reverse. Hence, for economic statistics with price and volume dimensions it is generally recommended that annual indices be chained. The price and volume components of monthly and quarterly data are usually subject to much greater variation than their annual counterparts due to seasonality and short-term irregularities. Therefore, the advantages of chaining at these higher frequencies are less and chaining should definitely not be applied to seasonal data that are not adjusted for seasonal fluctuations.

Annually chained quarterly Laspeyres-type indices

15.45 Quarterly chain indices can be constructed that use annual weights rather than quarterly weights. Consider a quarterly Laspeyres-type volume index that measures the volume change from the average of year *y*-1 to quarter *c* in year *y*.

$$L_Q^{\overline{(y-1)}\rightarrow(c,y)} = \frac{\sum_i P_i^{y-1} q_i^{c,y}}{\sum_i P_i^{y-1} Q_i^{y-1}} = \sum_i \frac{q_i^{c,y}}{Q_i^{y-1}} s_i^{y-1} \quad ...(12a)$$

The upper case letters *P* and *Q* denote average quarterly values over a year, while *p* and *q* denote specific quarterly values. The superscripts denote the year (*y*) and quarter (*c*). P_i^{y-1} denotes the average price of item *i* in year *y-1* and $p_i^{c,y-1}$

denotes the price of item i in quarter c of year y-1 and s_i^{y-1} is the base period value share, that is the share of item i in the total value in year *y-1*.

Thus:

$$P_i^{y-1} = \frac{\sum_c p_i^{c,y-1} q_i^{c,y-1}}{\sum_c q_i^{c,y-1}};$$

$$Q_i^{y-1} = \frac{\sum_c q_i^{c,y-1}}{4}; \text{ and}$$

$$s_i^{y-1} = \frac{P_i^{y-1} Q_i^{y-1}}{\sum_i P_i^{y-1} Q_i^{y-1}} = \frac{\sum_c p_i^{c,y-1} q_i^{c,y-1}}{\sum_i \sum_c p_i^{c,y-1} q_i^{c,y-1}} \qquad (12b)$$

15.46 The quarterly Laspeyres-type volume indices can then be chained together with annual links. One of two alternative techniques for the annual chaining of quarterly data is usually applied, annual overlaps and one-quarter overlaps. In addition to these two conventional chaining techniques, a third technique sometimes is used based on changes from the same period in the previous year (the "over-the-year technique"). While in many cases all three techniques give similar results, in situations with strong changes in relative quantities and relative prices, the over-the-year technique can result in distorted seasonal patterns in the chain series. While standard price statistics compilation exclusively uses the one-quarter overlap technique, the annual-overlap technique may be more practical for Laspeyres-type volume measures in the national accounts because it results in data that aggregate exactly to the corresponding direct annual index. In contrast, the one-quarter overlap technique and the over-the-year technique do not result in data that aggregate exactly to the corresponding direct annual index. The one-quarter overlap provides the smoothest transition between each link, however, in contrast to the annual overlap technique that may introduce a step between each link, that is, between the fourth quarter of one year and the first quarter of the following year.

15.47 The technique of using annual overlaps implies compiling estimates for each quarter at the weighted annual average prices of the previous year, with subsequent linking using the corresponding annual data to provide linking factors to scale the quarterly data upward or downward. The technique of one-quarter overlaps requires compiling estimates for the overlap quarter at the weighted annual average prices of the current year in addition to estimates at the average prices of the previous year. The ratio between the estimates for the linking quarter at the average prices of the current year and at the average prices of the previous year then provides the linking factor to scale the quarterly data up or down. The over-the-year technique requires compiling estimates for each quarter at the weighted annual average prices of the current year in addition to estimates at the average prices of the previous year. The year-on-year changes in these volume series are then used to extrapolate the quarterly volume series of the chosen reference period.

15.48 Discrepancies between an annual chain volume series and the sum of the four quarters of an annually chained quarterly volume series derived using the one-quarter overlap technique can accumulate over time. Hence, quarterly chain volume series derived this way are usually benchmarked to the corresponding annual chain volume series using a procedure that minimizes the disturbance to the quarterly volume series whilst achieving consistency with the annual chain volume series. There is discussion on this in chapter VI of the IMF manual on *Quarterly National Accounts.*

15.49 If annual volume series are derived from data balanced in a supply and use table expressed in the prices of the previous year as recommended in section C, then it is standard practice to benchmark quarterly data to the corresponding annual balanced estimates. The benchmarking eliminates all discrepancies between the quarterly and annual chain volume series, including those arising from the use of the one-quarter overlap technique.

15.50 To conclude, chaining using the one-quarter overlap technique combined with benchmarking to remove any resulting discrepancies between the quarterly and annual data gives the best result. In many circumstances, however, the annual overlap technique may give similar results. The over-the-year technique should be avoided.

Chain Laspeyres or chain superlative indices?

15.51 As explained earlier, the index number spread between Laspeyres and Paasche indices may be greatly reduced by chaining when prices and quantities move smoothly over time. In such circumstances the choice of index number formula assumes less significance as all relevant index numbers lie within the bounds of the Laspeyres and Paasche indices. Nevertheless, there may still be some advantages to be gained by choosing an index for chaining, such as the Fisher or Törnqvist, that treats both periods being compared symmetrically.

15.52 Such indices are likely to approximate more closely the theoretic indices based on underlying utility or production functions even though chaining may reduce the extent of their advantages over their Laspeyres or Paasche counterparts in this respect. A chain symmetric index, such as Fisher or Törnqvist, is also likely to perform better when there are fluctuations in prices and quantities. Chain Laspeyres indices, however, do not require current period data for weights and thus may lead to more timely estimates. Retrospective studies of the difference in national accounts estimates from using chain Laspeyres as against chain Fisher or Törnqvist can help in determining the advantage of using the latter formulae.

Annually chained quarterly Fisher-type indices

15.53 Just as it is possible to derive annually chained Laspeyres-type quarterly indices, so it is possible to derive annually chain Fisher-type quarterly indices. For each pair of consecutive years Laspeyres-type and Paasche-type quarterly indices are constructed for the last two quarters of the first year, year *y*-1 and the first two quarters of the second year, year *y*. The Paasche-type quarterly indices are constructed as backward-looking Laspeyres-type quarterly indices and then inverted. This is done to ensure that the Fisher-type quarterly indices are derived symmetrically. In the forward-looking Laspeyres-type indices the annual value shares relate to the first of the two years, whereas in the backward-looking Laspeyres-type indices the annual value shares relate to the second of the two years.

$$L_Q^{\overline{(y-1)}\to c} = \frac{\sum_i P_i^{y-1} q_i^c}{\sum_i P_i^{y-1} Q_i^{y-1}} = \sum_i \frac{q_i^c}{Q_i^{y-1}} s_i^{y-1} \quad \text{........(13)}$$

$$P_Q^{\bar{y}\to c} = \left[L_Q^{\bar{y}\to c}\right]^{-1} \quad \text{..(14a)}$$

$$L_Q^{\bar{y}\to c} = \frac{\sum_i P_i^{y} q_i^c}{\sum_i P_i^{y} Q_i^{y}} = \sum_i \frac{q_i^c}{Q_i^{y}} s_i^{y} \quad \text{.........................(14b)}$$

and q_i^c is the quantity of item *i* in quarter *c* in the second two quarters of year *y*-1 or the first two quarters of year *y*.

15.54 For each of the four quarters a Fisher-type index is derived as the geometric mean of the corresponding Laspeyres-type and Paasche-type indices. Consecutive spans of four quarter can then be linked using the one-quarter overlap technique. The resulting annually chained Fisher-type quarterly indices need to be benchmarked to annual chain Fisher indices to achieve consistency with the annual estimates.

15.55 A difficulty arises at the end of the series because it is not possible to construct Paasche-type quarterly indices that use annual weights for the current year, at least using actual observed data. One solution is to construct "true" quarterly chain Fisher indices for the latest year or two and use these to extrapolate the annually chained Fisher-type indices. But this should only be done using seasonally adjusted data. As long as the irregular variation in quarterly price and volume relativities is not very great, quarterly chain Fisher indices of seasonally adjusted data can be expected to produce satisfactory results in most circumstances.

Chaining and data coverage

15.56 One major practical problem in the construction of index numbers is the fact that products are continually disappearing from markets to be replaced by new products as a result of technological progress, new discoveries, changes in tastes and fashions, and catastrophes of one kind or another. Price and volume indices are compiled by comparing the prices or quantities of goods of the same characteristics or quality (that is, homogenous goods) over time. This is not easy in product areas such as personal computers where quality changes rapidly.

15.57 Chaining helps ameliorate the problems of such constant quality comparisons since the likelihood of an overlap of a product in two consecutive price periods is almost bound to be greatest and the chain indices can accommodate the changes in weight that accompany a new and a disappearing product.

Additivity and chaining

15.58 An aggregate is defined as the sum of its components. Additivity in a national accounts context requires this identity to be preserved for a volume series. Although desirable from an accounting viewpoint, additivity is actually a very restrictive property. Laspeyres volume indices are the only index number formulae considered here that are additive.

15.59 A single link in a chain index is sufficient to destroy additivity even when additive indices, such as Laspeyres volume indices, are linked together. If, therefore, chain volume indices are converted into time series of values by using the indices to extrapolate the values of the base period, the index components may fail to add to aggregates in later periods. A perverse form of non-additivity can occur when the chain index for the aggregate lies outside the range spanned by the chain indices for its components, a result that may be regarded as intuitively unacceptable by many users. Whether published in monetary terms or indices, it is advisable to inform users that chain volume series are not additive via a footnote or other meta data.

15.60 There is a general tendency for the discrepancies from chaining to become larger the further a period is away from the reference year. If the reference year is chosen to be near the end of the series then the discrepancies will be relatively small for the latest quarters. Indeed, if the chain Laspeyres formula is used and if the reference year is chosen to coincide with the latest base year then the quarters following the reference year are additive. Another advantage of having the reference year near the end of chain volume series is that when they are expressed as monetary values their magnitudes do not differ greatly from the current values for the latest periods if price change is occurring at a modest rate. Maintaining this situation requires re-referencing the series every year when a new link is added to the chain and this entails revising the chain volume series for their entire lengths. Note that re-referencing entails revising levels but not growth rates.

15.61 Although additivity may be preserved by never undertaking a weight change this advantage is significantly outweighed by the disadavantage of increasing irrelevance of the weights in use. Rates of change for sub-periods of a series, including annual rates, can be usefully phrased in terms of contributions to change, as explained below.

Variables that change sign

15.62 Index number formulae are generally not applicable to time series that can take positive, negative and zero values. Nevertheless, there are ways of deriving pseudo chain volume series expressed in terms of monetary values in such cases. The most commonly used approach is to identify two associated time series that take only positive values and are such that when differenced yield the target series. An example is the stock of inventories at the start and end of the period as opposed to the change during the period. Chain volume series are not additive and so it is evident that this is an imperfect method since by construction an additive relationship is produced. It follows that the series to be differenced should be as closely aligned in terms of price and volume composition as possible with the target series. Hence, a chain volume series of changes in inventories is derived as a chain volume series of closing inventories less a chain volume series of opening inventories. Sometimes public gross fixed capital formation can take negative values as a result of the sale of assets to the private sector, in which case the chain volumes series of acquisitions and sales could be differenced.

Contributions to growth

15.63 When the Laspeyres formula is used and the base year and reference year coincide there is additivity in subsequent periods and the contribution by a component I_i to the growth of an aggregate, such as GDP, between two periods *(t-n)* and *t* can be obtained readily as follows:

$$\%\Delta_i^{(t-n)\to t} = \frac{100(I_i^t - I_i^{t-n})}{\sum_i I_i^{t-n}} \quad \text{.................................(15)}$$

But even when these conditions are not met and there is no additivity in the volume series, additive contributions to growth can still be derived using an appropriate formula. The exact formula to be used depends on the chaining formula used in the construction of the aggregate and the time span the percentage change covers. The fact that the changes in the components add to the change in the aggregate addresses the principal disadvantage of chain volume measures that the components themselves are not additive. When chain volume series are derived using either the Laspeyres formula for annual indices or the annual chaining of Laspeyres-type quarterly indices, then year-to-year or quarter-to-quarter contributions to growth can be derived easily using data expressed in the prices of the previous year prior to chaining. Such data are additive and so equation (15) can be used be used with *n*=1. If contributions to growth are not published by the national statistical office, the user can estimate them. Assuming the one-quarter overlap technique has been used, the formula for calculating the contribution to the percentage change from period t-1 to period t is:

$$\%\Delta_i^{(t-1)\to t} = \frac{100.(I_i^t - I_i^{t-1})s_i^{t-1}}{\sum_i I_i^{t-1} s_i^{t-1}} \quad \text{...................(16)}$$

4. Quality differences, price variation and price discrimination

15.64 In general, most types of goods or services, whether simple food products such as potatoes or high technology products such as computers, are available on the market in many different qualities whose physical characteristics differ from each other. For example, potatoes may be old or new, red or white, washed or unwashed, loose or prepacked, graded or ungraded. Consumers recognize and appreciate the differences and are prepared to pay different prices. For some goods and services, such as personal computers and telecommunication services, there is a rapid turnover in the highly differentiated varieties and this, as considered below, creates severe problems for the measurement of price changes.

15.65 The same generic term, such as potato, computer or transportation is used to describe goods and services that differ from each other in their price determining characteristics. The price or quantity of a good or service of one quality cannot be directly compared to that of a different quality. Different qualities have to be treated in exactly the same way as different kinds of goods or services.

15.66 Differences in quality may be attributable to differences in the physical characteristics of the goods or services concerned and be easily recognized, but not all differences in quality are of this kind. Goods or services delivered in different locations, or at different times, such as seasonal fruits and vegetables, must be treated as different qualities even if they are otherwise physically identical. The conditions of sale, or circumstances or environment in which the goods or services are supplied or delivered can make an important contribution to differences in quality. For example, a durable good sold with a guarantee, or free after-sales service is higher quality than the same good sold without guarantee or service. The same goods or services sold by different kinds of retailers, such as local shops, specialist shops, department stores or supermarkets may have to be treated as different qualities.

15.67 It is generally assumed in economic analysis that whenever a difference in price is found between two goods and services that appear to be physically identical there must be some other factor, such as location, timing or conditions of sale, that is introducing a difference in quality. Otherwise, it can be argued that the difference could not persist, as rational purchasers would always buy lower priced items and no sales would take place at higher prices.

15.68 Nevertheless, empirically, different prices are observed in markets for identical products sold with the same conditions of sale. There are a number of possible reasons for this. Purchasers may not be well informed about the range of prices on offer and in general will not check every available price for a product every time it is purchased. As prices change, not all suppliers may change their prices at the same time.

15.69 When there is price variation for the same quality of good or service, the price relatives used for index number calculation should be defined as the ratio of the weighted average price of that good or service in the two periods, the weights being the relative quantities sold at each price. Suppose, for example, that a certain quantity of a particular good or service is sold at a lower price to a particular category of purchaser without any difference whatsoever in the nature of the good or service offered, location, timing or conditions of sale, or other factors. A subsequent decrease in the proportion sold at the lower price raises the average price paid by purchasers for quantities of a good or service whose quality is the same and remains unchanged, by assumption. It also raises the average price received by the seller without any change in quality. This must be recorded as a price and not a volume increase.

15.70 There is an important exception to this general rule, however. If different purchasers face different prices and an individual purchaser is not able to change to another price, then the difference in price is treated as a difference in volume. The constraint on the availability of different prices must be institutional and not simply an income constraint. For example, power supply is often sold at one rate to commercial customers and a different one to private households. Neither the commercial customer nor the household have the choice to be billed at the alternative rate. If the proportion of power sold to the two groups of customers changes from one period to another, this is treated as a volume change regardless of the physical units involved.

5. The measurement of changes in quality over time

15.71 Goods and services and the conditions under which they are marketed are continually changing over time, with some goods or services disappearing from the market and new qualities or new goods or services replacing them. National accountants use disaggregated price indices to deflate changes in consumption, production and investment values as the principle means of determining volume changes in such aggregates. Deficiencies in price indices carry over to estimates of volume changes. For example, estimates of price indices for computers that do not fully incorporate the increases in quality over time will overstate price changes and understate volume changes. National accountants need to be aware of the extent and nature of methods used by price compilers to take account of such quality changes, if they are to use them properly as deflators. This in turn requires that price compilers keep explanatory notes on such methods used, a policy advocated by the CPI and PPI manuals (chapter 8).

15.72 There are of course costs associated with implementing quality adjustment procedures tailored to the specific product groups. What is important for national accountants and price index compilers to appreciate is that quality change is an increasing feature of product markets and that default procedures of dealing with quality change, notably treating all replacements as comparable, or dropping varieties from the sample if missing, implicitly incorporate valuations of quality differences. Such valuations are unlikely to be appropriate and improvements can and should be made.

15.73 An unfortunate common procedure to deal with missing values is to carry forward the price from the previous period into the current period. This introduces into the index undue stability and is strongly discouraged.

15.74 A brief overview of some of the more common techniques follows. More extensive discussion can be found in all the three price manuals, those for CPI, PPI and XMPI. The techniques can be divided into those that are direct or explicit methods and those that are indirect or implicit.

Direct methods

15.75 In principle, the price relatives that enter into the calculation of inter-temporal price indices should measure pure price changes by comparing the prices of a representative sample of identical goods and services in different time periods. This is called the matched models method. Price index compilers maintain detailed product descriptions of the items being priced in successive periods to ensure proper matching. When a model is missing because it is obsolete a problem of quality adjustment arises to continue the series and price statisticians have a number of methods they can use to deal with it.

15.76 One possibility is to use the estimated relative costs of production as the basis for estimates of their relative prices and hence their relative qualities. It may often be feasible for producers to provide such estimates. If, however, the new quality feature was available as an option in the previous period, but now is a standard feature, the estimate of the valuation of the quality change may be based on the (relative) price of this option.

15.77 An extension of the costs of production approach is known as model pricing. It is often applied to products made to order. A particular case in point is measuring building costs. The characteristics of buildings and other structures are so variable that it may be almost impossible to find identical buildings and structures being produced in successive periods of time. In these circumstances, a small number of hypothetical and relatively simple standard buildings and structures may be specified and their prices estimated in each of the periods. The specifications of these standard buildings or structures are chosen on the advice of construction experts who are also asked to estimate what their prices would be in each of the periods. Model pricing for services is described in the OECD/Eurostat manual *Methodological Guide for Developing Producer Price Indices for Services*.

Hedonics

15.78 A more general and powerful method of dealing with changes in quality is to make use of estimates from hedonic regression equations. Hedonic regression equations relate the observed market prices of different models to certain measurable price-determining characteristics. Provided sufficiently many differentiated models are on sale at the same time, the estimated regression equation can be used to determine by how much price varies in relation to each of the characteristics or to predict the prices of models with different mixes of characteristics that are not actually on sale in the period in question.

15.79 Hedonic regression equations have been estimated for high technology goods such as computers and electronic goods and for services such as air transportation. It has also been used for housing by regressing house prices (or rents) on characteristics such as area of floor space, number of rooms or location. The method has been used not only for inter-temporal price measurements but also for international comparisons.

Indirect methods

15.80 When the two qualities are not produced and sold on the market at the same time it becomes necessary to resort to indirect methods of quantifying the change in quality between the old and new qualities. In such cases it is necessary to estimate what would be the relative prices of the old and new models, or qualities, if they were produced and sold on the market at the same time and to use the estimated relative prices to determine measures of the relative qualities.

15.81 When a model is missing a replacement of a comparable quality may be found and the price comparisons continued. If there is no comparable replacement, the price in the missing period may be imputed using the measured price changes of a product group expected to experience similar price changes. Dropping the product from the calculation is equivalent to an imputation that assumes the price change for the missing model would follow those of all goods and services in the index. The assumptions behind such imputations are less soundly based than those behind the more targeted imputation. In either case, items subject to quality change tend to be atypical and unrepresentative, so that assuming that their prices change at the same rate as for goods or services whose characteristics do not change is questionable.

15.82 If the replacement model is not directly comparable in quality, then the price change of the new model may be readily linked to the price series of the old one if the two models are for sale in the market at the same time, in an overlap period. The implicit assumption is that the difference in prices at the time of the overlap link is a good valuation of the difference in quality, an assumption that will not be valid if the overlap period is at an unusual point in time in the model's life cycle, say when it is about to be come obsolete and discontinued or has just been introduced at an unusually high price to obtain temporary monopoly profits in a segmented market.

Rapidly changing differentiated product markets

15.83 Problems of adjusting price changes for changes in quality are of a quite different order in product markets with a rapid turnover of differentiated varieties. The matched model method breaks down. Models of like quality can only be compared over relatively short periods and are not representative of the overall market. The summation in index number formulae such as (1) over n items is misrepresented since in period t the items produced or consumed may be quite different from those on the market in period 0.

15.84 Price index number compilers use a short-run formulation to ameliorate the difficulties of comparing the prices of like with like when there is a rapid turnover in differentiated goods and services. A Laspeyres price index, for example, comparing prices in period 0 and t, is given as:

$$L_P = \frac{\sum_{i=1}^{n} p_i^0 q_i^0 \left(\frac{p_i^{t-1}}{p_i^0}\right)\left(\frac{p_i^t}{p_i^{t-1}}\right)}{\sum_{i=1}^{n} p_i^0 q_i^0} \quad \text{....................................(17)}$$

15.85 If a new type of good, say digital cameras, is introduced in period t-1 to replace an old variety of non-digital ones, then the compiler has only to wait for the good to be on the market for two successive periods before it can be included in the index. This provides a mechanism for changing the representative items within a product category that has an assigned weight. Additional weighting information may be required to augment the weighting given to cameras within the wider group. However, a chain formulation in which weights are regularly updated would be a better mechanism to achieve this.

15.86 While a chain index with a short-run formulation such as in equation (17) will ameliorate the measurement problem in markets with a rapid turnover of differentiated varieties, it cannot take account of the effect on the overall price change from period *t-1* to period t of the new variety introduced in period t and of the old model that was dropped in period t-1. Two successive price quotes are required to implement the formula in (17) and a chain index. Hedonic indices are a means of incorporating such affects. They can take a number of forms, but essentially the prices and values of price-determining quality characteristics, say the speed, RAM, etc. of different varieties of personal computers are collected in each period. A Paasche-type hedonic imputation (or characteristics) price index would be derived by first estimating a hedonic regression of price on quality variables based on period t-1 data and then using the estimated coefficients to impute for t -1 the prices of the varieties available in period t, including those not available in t-1. Prices for period t characteristics valued at period t prices can be directly compared with the estimated period *t-1* valuation of period t characteristics to yield a Paasche-type price index. A Laspeyres-type hedonic index can be similarly defined using an estimated period t regression and constant period t-1 characteristics set, as can a Fisher-type hedonic index as a geometric mean of the two. An alternative formulation is to pool the two sets of observations in periods 0 and t and include a dummy variable in the hedonic regression equation to distinguish observations in one period from those in the other. The coefficient on the dummy variable would be an estimate of the price change between the two periods having controlled for the effect of quality changes.

Further elaboration

15.87 A detailed account of all the methods referred to above is available in chapters 7 and 8 of the CPI and PPI manuals. This includes the use of imputations, overlap prices, comparable replacements, non-comparable replacements using estimates from production costs, option costs and hedonic regressions, as well as methods for markets with a rapid turnover of differentiated varieties including short-run relatives, chaining, product augmentation and hedonic indices.

15.88 Further discussion of this topic can also be found in a manual entitled *Handbook on Hedonic Indices and Quality Adjustments in Price Indices: Special Application to Information Technology Products* published by OECD in 2006.

6. Practical advantages of compiling chain indices

15.89 It has been shown that on theoretical grounds volume and price indices need to be chain to form long time series. The question is how often. It has been argued that annual chaining is generally best on theoretical grounds, but what of the practicalities? There are a number of matters to consider, including data requirements, computing requirements, human resource requirements, loss of additivity, revisions and informing users.

a. If annual current values and corresponding volume or price data are available, then annual chaining is possible. No other data are required.

b. The computing requirements of deriving annual chain indices are greater than those for constant price estimates (that is, fixed-weighted Laspeyres-type indices). Although, chain volume measures can be compiled using a spreadsheet it is better to use software designed for dealing with time series. The complexity of the software code depends on the formula used and the method of linking. For instance, it is quite simple to develop software to derive annually chained Laspeyres-type quarterly volume measures using the annual overlap method.

c. After the initial training of staff, experience has shown that compiling chain volume measures does not require more staff time than constant price estimates. The computer software takes care of the additional computation.

d. Experience has shown that if the benefits of chain volume measures, along with the loss of additivity, are carefully explained to users via documentation and seminars before their introduction, chain volume measures are generally accepted. Particular attention should be given to informing the key users, including economic journalists, well beforehand.

e. When constant price estimates are rebased, say every five or ten years, then it is typically the case that the growth rates in recent years are revised. If price and volume relativities have been changing rapidly, then the growth rates of those aggregates affected can be changed dramatically. Such is usually the case for any aggregate in which computers have a significant share. With annual chaining history is only "re-written" a little each year, not in one large jump every five or ten years. Not surprisingly, the sort of big revisions associated with chaining only every five or ten years can have a detrimental effect on user confidence in the national accounts, not least because users learn they can expect similar revisions in the future. Annual chaining not only measures changes better, it is likely to increase confidence in the resulting national accounts volume indices.

C. Derivation of volume measures in the national accounts

15.90 Movements in the volume of GDP and other national accounts aggregates are often calculated by valuing the various components holding the prices of the previous year or of some fixed base year constant. Thus, for example, the measures of GDP components are frequently referred to as being "at constant prices". When time series are constructed by multiplying the values of the base year by fixed base Laspeyres volume indices, it is appropriate to describe the resulting series as being at the constant prices of the base year. However, when the values of a reference year are extrapolated by multiplying them by annual chain volume indices it is no longer strictly correct to describe them in this way. This is reflected by the non-additivity of the resulting data. It is recommended, therefore that they should not be referred to as being "at constant prices". It is preferable to avoid the term "real GDP" also, as this may suggest the deflation of GDP by some general price not necessarily that of GDP itself. More accurate terms are "chain volume series", "chain volume measure" or "chain volume index" if the series is expressed in index number form. If it is desirable to specify the reference year in the term, then "chain volume series in the [currency] of the reference year [X]" may be used. The use of the term "at constant prices" is also inappropriate for series that are linked less frequently than annually and to volume series based on the use of Fisher or Törnqvist formulae, whose price configurations are not constant over the duration of the series. For such series the terms "volume series" or "volume index" is appropriate to describe a series or index.

1. Price deflation vs. quantity revaluation

15.91 Volume and price indices can only be derived for variables that have price and quantity elements. All transactions involving the exchange of goods and services and the levels of stocks of non-financial assets have this characteristic but income flows and financial assets and liabilities do not. Some balancing items have the characteristic but others do not and so they need to be considered individually.

15.92 While both volume and price measures are of major importance in the national accounts, the principal focus of users is on the growth rates of volume measures, rather than prices. The compilation of the national accounts in volume and current value terms reflects this priority, with the price indices of aggregates being derived implicitly, by dividing indices of the current values by the corresponding volume indices.

15.93 When independent, reliable and comprehensive data are available at current values it is generally not necessary to construct volume measures by aggregating quantity relatives. In most cases it is preferable and more practicable to use price indices to deflate current value data. Even for cases like electricity where the volume measure seems to be easily available, a direct volume measure is inappropriate because of the treatment of prices applying in different markets as explained in paragraph 15.70. A change in the composition of the type of user leads to a change in the price and volume of electricity in the System even though the physical measure of electricity distributed may not have changed.

15.94 Price information is easier to collect and aggregate, as explained in section B, than is volume information because all prices are expressed in a common unit whereas volumes come in a multitude of units. Further, price relatives for a representative sample of goods and services can be used as typical for all goods and services in the same group in a way that volume measures would not be representative. More importantly, the volume changes associated with new and disappearing products can be properly reflected when current values are deflated by price indices. The techniques to be used are described in section B.

15.95 For some products, for example closely specified agricultural products or minerals, it may be that the current value data have been constructed by multiplying a volume measure by an appropriate price. These are instances when there is no aggregation problem across the group of products and adjustments for quality differences are more easily and more satisfactorily made to the volume measures directly. While some such products may be of significant value in some countries, it will be a small number of the total number of products that can best be treated in this way.

15.96 Chapter 14 describes the supply and use tables and explains how the supply table expands the production account by itemising the products each industry produces so that these can be identified in the use table where the allocation of each product between intermediate consumption and final demand is spelled out. Compiling supply and use tables at current values ensures consistency in the different measures of GDP. More powerfully, compiling supply and use tables in volume terms ensures that both the volumes and prices in the System are consistent. In principle, tables at current values and in volume terms should be compiled at the same time in order to make the best use of all the information available to the compiler.

15.97 It is often the case that not all the detailed data required for compiling supply and use tables are available each period and estimates have to be made to fill the empty cells. For example, detailed data for intermediate consumption by product by industry are often collected infrequently. It is generally better to make an initial assumption of a constant composition of intermediate inputs over time in volume terms than in current values. Furthermore, adjustments to the raw and estimated data can be greatly informed by evaluating growth rates in prices and volumes from the previous and/or following period. For these reasons it is recommended that supply and use tables should be compiled at current values and in volume terms at the same time and balanced simultaneously.

15.98 It is necessary to compile supply and use tables in volume terms to have the benefit of additivity across the components of the table. In order to derive annual chain Laspeyres measures, the supply and use tables should be expressed in the prices of the previous year, that is, as Laspeyres volume indices from the previous year to the current year, referenced to the values in the previous year. In order to obtain annual chain Fisher volume measures, it also necessary to derive supply and use tables in the prices of the following year. Such values are in effect backward-looking Laspeyres indices referenced to the prices of the following year and are therefore additive. Paasche volume indices are obtained by taking the inverse of the backward-looking Laspeyres indices. Fisher volume indices can then be derived as the geometric mean of the Laspeyres and Paasche volume indices between two adjacent years. However, Fisher volume indices are not additive, though percentage contributions to change measured using Fisher indices are additive.

15.99 To obtain a Laspeyres volume measure the appropriate price index used to deflate the current value is a Paasche index and vice versa. However, the available price indices are nearly always constructed using the Laspeyres/Lowe formulae, because construction of a Paasche price index has exactly the same data requirements as the direct derivation of a Laspeyres volume index and faces the same problems. If robust current value data and Laspeyres price indices are available at a sufficiently detailed level then Paasche volume indices, at the detailed level, can be aggregated using the Laspeyres formula to obtain an approximation of a true Laspeyres volume measure of the aggregate.

15.100 A Fisher volume index can be obtained either by taking the geometric mean of Laspeyres and Paasche volume indices or by deflating an index of the change in current values by a Fisher price index.

2. Available price indices

15.101 There are four major types of price index available to derive volume measures in the national accounts: consumer price indices (CPIs), producer price indices (PPIs), export price indices (XPIs) and import price indices (MPIs). Provided they span all the industries and products in the supply and use tables and are available at the required level of detail, they can be used to derive the great bulk of the volume measures in it.

Without them, efficient and effective volume estimation of the national accounts is hardly possible.

15.102 There are two defining aspects of recording transactions: timing and valuation. It is therefore critical that the price indices and the current values they are used to deflate correspond in both these aspects, as well as scope. The four types of price indices are usually available monthly and so quarterly and annual deflators can be obtained for flow and stock variables by averaging the monthly indices appropriately to centre the average at the desired valuation point. For flow variables this is usually the mid-point of the period, while for stock variables it is usually, but not always, the end of the period. For flow variables, the average price of the period should reflect known variations within the period. This is particularly important when there is a strong seasonal pattern, large irregular movements in certain months or hyperinflation. When none of these factors is present, the average price will be close to the observed price at the middle of the time period. The fact that this is frequently the case does not imply that the mid-period price is always the conceptually correct one to take, however.

15.103 CPIs are measured at purchasers' prices, PPIs are measured at basic prices and both XPIs and MPIs are generally measured at FOB prices. If the current value data to be deflated are valued differently, then either suitable adjustments must be made to the price indices or the current values must be decomposed into components that match the valuation basis of the price indices.

3. Volume measures of the output estimate of GDP

Market output

15.104 In principle, PPIs can be compiled for all market output and then they can be used to deflate current values to obtain volume estimates. In practice, there are some products for which it is very difficult to derive price indices and special steps must be taken to derive the corresponding volume measures. For example, in the case of financial intermediation service charges indirectly measured (FISIM) a model using nominal values of the assets and liabilities associated with different types of financial institution and products and the corresponding interest rates of the base year is often used to make the estimates in current values. Volume estimates can be obtained by simply replacing the current period interest rates with the interest rate in the base year and applying these to the real values of the corresponding assets and liabilities.

Non-market output of government and NPISHs

15.105 The current value of the output of non-market goods and services produced by government units or NPISHs is estimated on the basis of total costs incurred in their production, as explained in chapter 6. This output consists of individual goods and services delivered to households and collective services provided to the community as a whole. The fact that such output is valued on the basis of the value of inputs needed to produce them does not mean that it cannot be distinguished from the inputs used to produce it. In particular, the change in the volume of output can be different from the change in the volume of input. Changes in productivity may occur in all fields of production, including the production of non-market services.

15.106 In practice, there are three possible methods of compiling volume estimates of the output of non-market goods and services. The first is to derive a pseudo output price index such that when it is compared to the aggregate input price index the difference reflects the productivity growth thought to be occurring in the production process. Pseudo output price indices can be derived in various ways, such as by adjusting the input price index according to the observed productivity growth of a related production process or by basing the growth of the pseudo output price index on the observed output price indices of similar products. However, such data are rarely available for the goods and services produced by government and NPISHs.

15.107 The second approach, the "output volume method," is recommended for individual services, in particular, health and education. It is based on the calculation of a volume indicator of output using adequately weighted measures of output of the various categories of non-market goods and services produced. These measures of output should reflect fully changes in both quantity and quality.

15.108 The third approach, called the "input method", may be used for collective services such as defence for which the "output volume method" is hardly applicable because there are, in general, no adequate quality-adjusted quantity measures of output. The "input method" consists of measuring changes in output by changes in the weighted sum of volume measures of all the inputs. The latter should fully reflect both changes in quantity and quality. They are generally best derived by deflating the various input costs by corresponding constant-quality price indices, or when such price indices are unavailable, using volume indicators that reflect input volume change (for example, number of hours worked by employees).

15.109 It is useful at this stage to define the terms input, activity, output and outcome. Taking health services as an example, input is defined as the time of medical and non-medical staff, the drugs, the electricity and other inputs purchased and the consumption of fixed capital of the equipment and buildings used. These resources are used in primary care and in hospital activities, such as a general practitioner making an examination, the carrying out of a heart operation and other activities designed to benefit the individual patient. To the extent that they do, the health care provided constitutes the output associated with these input activities. Finally there is the health outcome, which may depend on a number of factors apart from the output of health care, such as whether or not the person gives up smoking.

15.110 The measurement of the volume of output of non-market individual services should avoid two pitfalls. The first of these is that it should not be restricted to reflect the input or the activity of the unit producing the services. Inputs are not an appropriate measure and while activities may be the only available indicator and hence have to be used, they too are an intermediate variable. What should be measured is the service rendered to the customer. The second risk is that if outcome is defined in terms of the welfare objectives of the non-market service (for example, level of health for the measurement of the health service, or level of education for the measurement of the education service) the change in the volume of the output of the non-market unit cannot be reflected by the change in the indicators of outcome. This is because indicators of outcome can be affected by other aspects that are not directly related to the activity of the non-market services. For example, in the case of health, it is well-known that there are many factors other than the output of the non-market health units, such as sanitation, housing, nutrition, education, consumption of tobacco, alcohol and drugs, pollution, whose collective impact on the health of the community may be far greater than that of the provision of health services. Similarly, the output of education services is quite different from the level of knowledge or skills possessed by members of the community. Education services consist principally of teaching provided by schools, colleges, universities to the pupils and students who consume such services. The level of knowledge or skills in the community depends in addition on other factors, such as the amount of study or effort made by consumers of education services and their attitudes and motivation.

15.111 In the light of these observations, the "output volume method" is the recommended method for compiling indicators of volume change of non-market services. The method is based on quantity indicators, adequately quality-adjusted, weighted together using average cost weights. Two criteria should be respected to compile adequate indicators of volume change. In the first place, the quantities and costs used should reflect the full range of services for the functional area under review and cost weights should be updated regularly. If part of the costs of the functional area is not covered by the quantity indicator, it should not be assumed that the uncovered part follows the changes of the part that is covered. If no direct output volume method is applicable for this part, an input method should be used for it. Secondly, quantity indicators should be adjusted for quality change. For example, services should be sufficiently differentiated with the aim of arriving at categories that can be regarded as homogeneous. An aspect of quality change is then captured by changes in the proportions of different categories if the weights assigned to each category are frequently updated. In addition, the quantity indicator of each category can be augmented by an explicit quality adjustment factor. One way of identifying explicit quality adjustment factors is by reviewing the effects that the service has on measures of outcome.

15.112 It is recommended these volume indicators be tested for a substantial period of time with the aid of experts in the domain prior to their incorporation in the national accounts. Expert advice is particularly relevant in the areas of health and education, which usually dominate the provision of individual services. Further, the consequences of the estimates including the implications for productivity measures should be fully assessed before adoption. Unless and until the results of such investigations are satisfactory, it might be advisable to use the second best method, the "input method".

15.113 Measuring changes in the volume of collective services is generally more difficult than measuring the volume changes in individual services because the former are hard to define and to observe. One reason is that many collective services are preventive in nature: protecting households or other institutional units from acts of violence including acts of war, or protecting them from other hazards, such as road accidents, pollution, fire, theft or avoidable diseases are concepts that are difficult to translate into quantitative measures and this is an area in which further research is needed.

15.114 When it is not possible to avoid using an input measure as a proxy for an output measure, the input measure should be a comprehensive one: it should not be confined to labour inputs but cover all inputs, including those of capital. In addition, explanatory information should accompany the national estimates that draw users' attention to the methods of measurement.

Output for own final use

15.115 Output for own final use falls into two categories: goods and services produced and consumed by household unincorporated enterprises and fixed assets produced for own use. Included in the above are changes in inventories of finished goods and work-in-progress.

15.116 For much output for own final use the use of pseudo output price indices is an effective, low-cost option. For goods produced and consumed by household enterprises, CPIs are likely to be available for similar goods. Similarly, there are likely to be output price indices available for fixed assets such as equipment, buildings and structures produced for own capital formation. For some types of fixed asset produced on own account there may be no output price indices available for similar products and different strategies may need to be considered. This is discussed further in the section on gross fixed capital formation.

Intermediate consumption

15.117 Countries that compile PPIs generally do so for outputs, though countries with developed statistical systems may also compile input PPIs. Such input PPIs are directly applicable to the deflation of intermediate consumption. If input PPIs are not compiled, output PPIs, MPIs and, to a limited extent, CPIs may be used instead. Intermediate consumption is valued at purchasers' prices, while output PPIs are valued at basic prices and MPIs at the FOB price. There is thus a margin between the valuation of goods used as intermediate consumption at purchasers' prices and output PPIs and MPIs, which is accounted for by transportation costs (unless the producer provides these services without a separate invoice), possible insurance costs, wholesale and retail trade margins and taxes. The size of this margin will depend on circumstance. Often trade margins on goods for intermediate consumption are much smaller than for final consumption and the taxes may be smaller under a VAT system. For services used as intermediate consumption, the difference in valuation comprises only taxes less subsidies on products.

15.118 The current value estimates of goods in intermediate consumption must either be decomposed into constituent parts for which there are price indices, or price indices must be constructed that match the valuation basis of the current value data. The latter is probably the easier to apply and requires constructing a model of the domestic and imported supply of intermediate goods at basic prices and then adding the various margins to obtain estimates of supply at purchasers' prices. If this is done in both current values and volume terms an implicit Paasche price index for intermediate goods can be derived at purchasers' prices.

15.119 As noted earlier, the most robust way of estimating intermediate consumption in volume terms is within the framework of a supply and use table in volume terms where information on volume growth rates and as well as price information may be used.

Gross domestic product and gross value added

15.120 When gross domestic product (GDP) is derived by summing final domestic expenditures and exports and subtracting imports or by subtracting intermediate consumption from output and adding taxes less subsidies on products, provided that the volume indices being aggregated are additive, (that is, Laspeyres indices), volume measures of GDP can be obtained.

15.121 The gross value added at basic prices of an establishment, enterprise, industry or sector is measured by the amount by which the value of the outputs produced by that establishment, enterprise, industry or sector exceeds the value of the intermediate inputs consumed. This may be written as:

$$\sum PQ - \sum pq$$

where the Q's refer to outputs, P's their basic prices, q's to intermediate inputs and p's their purchasers' prices. Value added in year t at prices of year t is given by:

$$\sum P^t Q^t - \sum p^t q^t$$

while value added in year t at the prices of the base year is given by:

$$\sum P^0 Q^t - \sum p^0 q^t \quad \text{...(18)}$$

This measure of value added is generally described as being obtained by "double deflation" as it can be obtained by deflating the current value of output by an appropriate (Paasche-type) price index and by similarly deflating the current value of intermediate consumption.

15.122 Within an integrated set of price and volume measures such as those relating to the flows of goods and services in supply and use tables or an input-output table, gross value added has in principle to be measured by the double deflation method. However, the resulting estimates are subject to the errors of measurement in the volume estimates of both output and intermediate consumption. This may be especially true if output PPIs are applied to inputs, many of which are imported. Assuming that such errors are at least partly random, the errors will tend to be cumulative, making value added extremely sensitive to error, especially in industries or sectors where value added accounts for only a relatively small proportion of the value of the total output. It is therefore advisable to compare the growth rates of the price and volume measures of value added over recent years with the corresponding growth rates of output and intermediate inputs and, if possible, with volume estimates of inputs of labour and capital services to check for plausibility.

15.123 Although it is recommended that volume estimates of transactions in goods and services and hence gross value added should be derived in a supply and use framework, it is not essential. Indeed, it may not be practical to do so due to a lack of data and/or a lack of resources. In these circumstances, or if the data on output and intermediate input are judged to be of insufficient quality, it may be better to abandon the attempt to measure value added as the difference between two series subject to error and to try to estimate the volume movements of value added directly using only one time series, that is a "single indicator" method instead of double deflation.

15.124 The choice to be made between the use of a single indicator method (which may yield biased results) or a double deflation method (which may yield volatile results) must be based on judgement. The same choice need not be made for all industry groups. Further, the single indicator method may be used for quarterly figures until the year is complete and better double deflation estimates are available.

15.125 In certain non-market service industries, it may be necessary to estimate movements in the volume of value added on the basis of the estimated volume changes of the inputs into the industries. The inputs may be total inputs, labour inputs on their own or intermediate inputs on their own. For example, it is not uncommon to find the movement of the volume of value added estimated by means of changes in compensation of employees at constant wage rates, or even simply by changes in numbers employed, in both market and non-market service industries. (There is extensive work being carried out to improve these working assumptions by trying to measure the outputs of government-provided health and education more objectively.)

15.126 Compilers of data may be forced to adopt such expedients, even when there is no good reason to assume that labour productivity remains unchanged in the short- or long-term. Sometimes, volume changes for intermediate inputs may be used, for example, short-term movements of the volume of value added for the construction industry may be estimated from changes in the volume of building materials consumed such as cement, bricks, timber, etc. The use of indicators of this kind may be the only way in which to estimate short-term movements in output or value added, but they are not acceptable over long time periods.

4. Volume measures of the expenditure estimate of GDP

15.127 Each of the components of the expenditure estimate of GDP can also be expressed in volume terms as described in turn below.

Household final consumption expenditure

15.128 CPIs should be available for all observable consumption expenditures by households. A major component where CPIs are unlikely to be available is the measure of the services of owner-occupied dwellings. It is not possible to be very prescriptive about how to derive volume estimates of the services of owner-occupied dwellings because circumstances vary significantly between countries. But a model of some sort is used to make the imputation in which there are volume and price components. In general it is a matter of using appropriate prices in the model to get current value estimates and volume estimates.

15.129 Three alternative approaches are outlined in chapters 10 and 23 of the CPI manual, but only the use-based approach is recommended for measuring the consumption of housing services in the national accounts. This approach can take either a user-cost formulation that attempts to measure the changes in the cost to owner-occupiers of using the dwelling, or a rental-equivalence formulation based on how much owner-occupiers would have to pay to rent their dwellings. The latter method is more generally adopted for CPIs.

Final consumption expenditure by government and NPISHs

15.130 The final consumption expenditure of general government and NPISHs consists of their non-market output less any revenue from incidental sales plus the value of goods and services purchased from market producers for onwards transmission to individual households at prices that are not economically significant. (The derivation of this identity is discussed in chapter 9.) The volume measure of their final consumption expenditure should correspond to the volume measure of non-market output reduced proportionately for the receipts from incidental sales plus the value of the goods and services purchased from market producers deflated by the prices paid for them (not the prices received from households).

Gross fixed capital formation

15.131 The availability of appropriate price indices for gross fixed capital formation varies considerably between different types of asset. Although capital formation is a different use from intermediate consumption, often similar prices apply to both because the level of margins and taxes are similar.

15.132 There are often CPIs for new dwellings and PPIs for new buildings and structures. The costs of ownership transfer should be deflated separately. The current value and volume estimates are usually derived by deriving estimates of the constituent parts, the conveyancing costs, taxes, etc. separately.

15.133 Suitable price indices are not generally available for most types of equipment and so PPIs, MPIs and, to a limited extent, CPIs are used instead. If the current value estimates of gross fixed capital formation on equipment are derived using a commodity flow approach then the same approach can be used in volume terms.

15.134 Price indices for equipment vary considerably in their growth rates. For example, price indices for computer equipment have fallen rapidly year after year while price indices for transport equipment have tended to increase. It is therefore important in such cases that the different types of equipment are deflated separately using the matching price indices (or, equivalently, an appropriately weighted Paasche price index is used to deflate the aggregate).

15.135 Intellectual property products are generally not well served by available price indices. There are several reasons for this. One is that many intellectual products are produced for own use and there may therefore be no observed market prices. Another is that intellectual property products are very heterogeneous. However, these are not insurmountable difficulties and there are strategies for addressing them. As examples, the two major items in this category, software and databases and research and experimental development, are considered.

15.136 When deriving volume estimates of the capital formation of software and databases it is advisable to decompose software into three components: packaged (or off-the-shelf), custom-made and own account and to deflate them and databases separately. There are several reasons for doing this.

a. The three components of software and databases vary in the extent to which price data are available to compile price indices.

b. It is likely that their prices and volumes grow at different rates, particularly between packaged software, the other two software components and databases.

c. Despite the previous point, price indices for packaged software may be used to construct price indices for the other two software components if more appropriate price indices are unavailable.

d. Volume estimates of the items are useful indicators in their own right.

15.137 Packaged software is purchased on a very large scale, generally via licences-to-use and there is an abundance of price data available. The challenge is to construct price indices free of the effects of changing specifications and any other aspects of quality change.

15.138 Custom-made software is also sold on the market, but each custom-made software product is a one-off, which presents an obvious problem for compiling price indices. Although each custom-made product is different, different products may share common components, or a strategy used to develop one product may be able to be used for another. This not only suggests a possible way of compiling a price index, but also suggests means by which productivity gains could be made that would put downward pressure on prices. In section B the use of model pricing was outlined for measuring price changes of custom-made buildings. A similar approach may be applied to custom-made software.

15.139 Methods for compiling price indices for heterogeneous products and products whose specifications are changing rapidly are described in the OECD *Handbook on Hedonic Indices and Quality Adjustments* and *the PPI manual.*

15.140 A substantial proportion of software in gross fixed capital formation is undertaken on own account. It is therefore not possible to derive a true output price index for such software. It is then a matter of choosing between a pseudo output price index and an input price index, obtained by weighting together price indices of the inputs. As already noted, input volume estimates used as a proxy for output do not reflect any productivity growth and so this is not recommended. In the absence of a better alternative, the most obvious option is to use the price index for custom-made software.

15.141 Databases are generally heterogeneous products with a small market since most databases are made for in-house purposes. As for own-account software, this makes it difficult, if not impossible, to develop a true output price index and once again the choice is between a pseudo output price index and an input price index. In this case, how to derive a suitable pseudo output price index is not so obvious.

15.142 Research and experimental development (R&D) is another activity that is often undertaken on own account. However, given the heterogeneous nature of R&D, the choice for deflation lies between deriving pseudo output price indices and using input price indices.

Changes in inventories

15.143 Changes in inventories can make a significant contribution to growth, particularly in the quarterly national accounts. As noted in paragraph 15.62, because changes in inventories can take positive, negative or zero values, a chain index should not be derived directly. Chain volume estimates of changes in inventories should be derived by first deriving chain volume estimates of the opening and closing stocks of inventories and then differencing them.

15.144 Volume estimation should be undertaken at a detailed level for different types of inventories, (work-in-progress, finished goods, materials and supplies, goods for resale). Deflation of stocks of inventories must be related to the composition of those inventories in terms of products rather than to the industry holding those inventories. PPIs, MPIs, CPIs and labour cost indices are all commonly used in deriving deflators, with adjustments to the appropriate valuation basis. It is important to understand how businesses value their inventories as this can determine not only the type of products but also the average length of time over which goods are kept in inventories.

15.145 When goods are sent abroad for processing without a change of ownership, it must be remembered that some inventories may be held outside the national territory but national prices should be applied to them to derive their corresponding volumes.

Acquisition less disposal of valuables

15.146 National statistical offices generally do not compile price indices for valuables. Unless there is a better alternative, the aggregate should be decomposed into its major constituents and the most suitable price indices available should be used.

Exports and imports

15.147 Exports and imports consist of both goods and services. For both exports and imports, goods and services are expressed in volume terms using quite different deflators because of the very different sources available for goods and services. New initiatives are under way to improve price indices for external trade in services that should lead to improved data in this area.

15.148 The valuation of imports and exports of goods is discussed in chapter 14. In principle they should be valued when change of ownership between a resident unit and a non-resident owner takes place and including or excluding transportations cost according to whether the supplier does not or does include transportation to the purchaser in the price charged. In practice, however, many countries are dependent for data on imports and exports of goods on customs declarations that value imports on a CIF basis but exports on a FOB basis. This assumes that change of ownership always takes place at the border of the exporting country. For balance of payments purposes, imports of goods should be converted to a FOB basis also but this is usually done at an aggregate level and may only be disaggregated in the supply and use context if at all.

15.149 If both the XPI and MPI are compiled on a FOB basis, it should be a simple matter to deflate the current value estimates of exports and imports of goods at as detailed a level as practical in order to approximate the use of Paasche price indices. In order to compile detailed volume estimates of imports of goods in the supply and use tables either the CIF estimates should be put onto a FOB basis or the MPIs need to be adjusted to a CIF basis.

15.150 XPIs and MPIs are compiled by three general methods the nature of which is largely dependent on the source data used. The first and predominant method, at least in terms of the number of countries using it, is unit value indices compiled from detailed import and export merchandise trade data derived from administrative customs documents. As pointed out in section B, unit value indices are not price indices since their changes may be due to price and (compositional) quantity changes. However, they are used by many countries as surrogates for price indices. The second method is to compile price indices using data from surveyed establishments on the prices of representative items exported and imported. The surveyed prices will be of items that are defined according to detailed specifications so that the change in price of the same item specification can be measured over time. The third method is a hybrid approach that involves compiling establishment survey-based price indices for some product groups and customs-based unit value indices for others.

15.151 The case for unit value indices derived from merchandise trade figures is based on the relatively low cost of such data. Their use as deflators requires some caution as they have been shown to be subject to bias when compared with price indices. The bias in unit value indices is mainly due to changes in the mix of the heterogeneous items recorded in customs documents, but also to the often poor quality of recorded data on quantities. The former is particularly important in modern product markets given the increasing differentiation of products. Unit value indices may suffer further in recent times due to an increasing lack of comprehensiveness of the source data with increasing proportions of trade being in services and by e-commerce and hence not covered by merchandise trade data. Further, countries in customs and monetary unions are unlikely to have intra-union trade data as a by-product of customs documentation. Finally, some trade may not be covered by customs controls, such as electricity, gas and water, or be of “unique” goods, such as ships and large machinery, with profound measurement problems for unit values.

15.152 As noted above, current data sources for price indices for international trade in services are less comprehensive than in other areas. If MPIs and XPIs are available for exports and imports of services they can be readily used to derive the required volume estimates. If they are not, volume estimates of exports of services can be mostly derived using an assortment of PPIs and CPIs. For example, volume estimates of freight transport services could be derived using PPIs according to the form of transport, while volume estimates of accommodation services could be derived using the appropriate CPIs. If MPIs are not available for imports of services then price indices of the countries exporting the services may have to be used.

15.153 It must be remembered that if imports are valued including transport services, then these transport services should be excluded from total imports of services.

5. Volumes and prices for stocks of fixed assets and consumption of fixed capital

15.154 Consider first a single type of asset. Stocks of fixed assets are quantities of capital goods, typically of different vintages, that are valued and aggregated with a consistent set of prices. “Consistent” is to be understood here as relating to the same period or point in time and being based on the same price concept, such as purchasers’ prices. Measuring stocks at historical prices, that is, by adding up quantities that have been valued with prices of different periods is therefore an inconsistent valuation. It is sometimes found in enterprise accounts but does not constitute an economically meaningful measure in the context of the System.

15.155 The price vector used to value the quantities of assets has to refer to a point in time (beginning or end of period) when stocks are constructed for the opening or closing balance sheets. For other purposes, quantities of assets may be valued with a price vector that refers to the average of an accounting period. For example, measures of consumption of fixed capital are often derived by subtracting the closing stock of assets from the opening stock plus gross capital formation. In this case all variables have to be valued at the same, average-period prices in order to eliminate holding gains and losses.

15.156 The process by which many capital stock measures are constructed is the perpetual inventory method (PIM). For a given type of asset, time series of gross fixed capital formation are deflated by means of the purchasers’ price index of the same asset type, so that the quantities of assets are expressed in volume terms of a particular reference period. These time series in volume terms are then added to yield a stock measure, where account is taken of retirement, efficiency losses or consumption of fixed capital, depending on the nature of the stock measure constructed. The resulting stock measure is thus expressed in volume terms of the reference period chosen. This reference period may be the current period and stock measures valued in this way have often been labelled “current price capital stocks”. However, this is not entirely accurate: as the description of the PIM showed, deflation is needed to arrive at these measures. Thus, they constitute a special case of a constant price valuation, namely valuation at the price vector of the current period.

15.157 Even when the PIM is not applied, for example in the case of direct surveys of assets, the valuation of different vintages of a particular asset may not rely on book values that reflect historical prices. Consistent valuation requires that older vintages are valued by the age-specific prices of the point in time to which the survey refers.

15.158 The next step is to aggregate the movements in capital stocks of individual asset types at volume terms to form volume indices of broader measures of the changes in capital stocks. The simplest volume index is constructed by adding up the volume series of different asset types and measuring the change in this aggregate between two periods. This is tantamount to using a Laspeyres-type index number formula with the period on which volume series for individual assets are based as the weight reference period. Other types of index number formulae are of course possible, in which case different weighting schemes are applied to changes in the asset-specific capital stocks. The use of linked or chain indices, as discussed earlier, will be appropriate when building up a series that extends to the distant past since the current period price configuration will not remain representative.

15.159 Further details on the PIM, on the different types of capital stocks and their measurement are provided in chapter 20 and in the OECD manual *Measuring Capital*.

6. Components of value added

15.160 The price and volume measures considered up to this point relate mainly to flows of goods and services produced as outputs from processes of production. However, it is possible to decompose some other flows directly into their own price and volume components.

Compensation of employees

15.161 The quantity unit for compensation of employees may be considered to be an hour's work of a given type and level of skill. As with goods and services, different qualities of work must be recognized and quantity relatives calculated for each separate type of work. The price associated with each type of work is the compensation paid per hour which may vary considerably between different types of work. A volume measure of work done may be calculated as a weighted average of the quantity relatives for different kinds of work weighted by the relative values of compensation of employees in the previous year or a fixed base year. Alternatively, a "price" index may be calculated for work by calculating a weighted average of the proportionate changes in hourly rates of compensation for different types of work, again using relative compensation of employees as weights. If a Laspeyres-type volume measure is calculated indirectly by deflating the compensation of employees at current values by an index of hourly rates of compensation, the latter should be a Paasche-type index.

Taxes and subsidies on products

15.162 Taxes on products are of two kinds, specific taxes linked to the volume of the product and ad valorem taxes levied on the value of the product. A measure of the tax volume of the former can be derived by applying the base year rate of the specific taxes to current volume figures and for the latter by applying the ad valorem rates to current values deflated by appropriate prices. When these elements of tax volumes are aggregated, an implicit "tax price" can be derived as well as an implicit tax volume index. Together these indices show how far tax yields have increased because of changing tax rates and how far the changes are due to changes in the composition of the items subject to tax. The calculation for subsidies is carried out in an analogous manner.

Net operating surplus and net mixed income

15.163 When GDP is determined as the difference between output and intermediate consumption plus taxes less subsidies on production gross value added is derived as an accounting residual. This is so in both current values and volume terms. In order for there to be an identity between different estimates of GDP in volume terms, it is not possible to give a price and volume dimension to gross value added. Rather the residual item is described as being "in real terms". If volume estimates of consumption of fixed capital and compensation of employees are available, net operating surplus and net mixed income can be derived but only in real terms and without a volume and price dimension. Thus it is not possible to derive an independent measure of GDP from the income approach since one item is always derived residually.

15.164 Thus, the limit to a set of integrated price and volume measures within the accounting framework of the System is effectively reached with net operating surplus. It is conceptually impossible to factor all the flows in the income accounts of the System, including current transfers, into their own price and volume components into unequivocal price and volume components. However, any income flow can be deflated by a price index for a numeraire set of goods and services to measure the increase or decrease of the purchasing power of the income over the numeraire but this is quite different from decomposing a flow into its own price and volume components. A particular instance where this is common is in the calculation of terms of trade effect on real income as described immediately below.

7. Quarterly and annual estimates

15.165 In principle, the same methods used to derive annual volume estimates should be used to derive quarterly volume estimates. Guidelines on data sources and methods for compiling price and volume quarterly estimates are given in the IMF's *Quarterly National Accounts manual*, chapters 3 and 9 respectively. In practice, annual data are generally more comprehensive and accurate than quarterly data. Although there are important exceptions, such as exports and imports of goods, the overall situation is one of a much richer and more accurate, albeit less timely, suite of annual data than quarterly data. For this reason, a sound approach is to compile balanced annual supply and use tables expressed in current values and in the prices of the previous year and to derive quarterly estimates that are consistent with them. This approach lends itself to the compilation of annually chained quarterly Laspeyres volume measures, although it can be adapted to the compilation of annually chained quarterly Fisher measures, too. See paragraphs xxxx of section C for details.

8. Summary recommendations

15.166 The recommendations reached above on expressing national accounts in volume terms may be summarized as follows:

a. Volume estimates of transactions in goods and services are best compiled in a supply and use framework, preferably in conjunction with, and at the same time as, the current value estimates. This implies working at as detailed a level of products as resources permit.

b. In general, but not always, it is best to derive volume estimates by deflating the current value with an appropriate price index, rather than constructing the volume estimates directly. It is therefore very important to have a comprehensive suite of price indices available.

c. The price indices used as deflators should match the values being deflated as closely as possible in terms of scope, valuation and timing.

d. If it is not practical to derive volume estimates of value added in a supply and use framework and either the volume estimates of output and intermediate consumption are not robust or the latter are not available then satisfactory estimates can often be obtained using an indicator of output, at least in the short term. For quarterly data this is the preferred approach, albeit with the estimates benchmarked to annual data. An output indicator derived by deflation is generally preferred to one derived by quantity extrapolation.

e. Volume estimates of output and value added should only be derived using inputs as a last resort since they do not reflect any productivity change.

f. The preferred measure of year-to-year movements of GDP volume is a Fisher volume index; changes over longer periods being obtained by chaining: that is, by cumulating the year-to-year movements.

g. The preferred measure of year-to-year inflation for GDP and other aggregates is, therefore, a Fisher price index; price changes over long periods being obtained by chaining the year-to-year price movements, or implicitly by dividing the Fisher chain volume index into an index of the current value series.

h. Chain indices that use Laspeyres volume indices to measure year-to-year movements in the volume of GDP and the associated implicit Paasche price indices to measure year-to-year inflation provide acceptable alternatives to Fisher indices.

i. Chain indices for aggregates cannot be additively consistent with their components whichever formula is used, but this need not prevent time series of values being compiled by extrapolating base year values by the appropriate chain indices.

j. A sound approach to deriving quarterly current value and volume estimates is to benchmark them to annual estimates compiled in a supply and use framework. This approach lends itself to the construction of annually chained quarterly volume measures using either the Fisher or Laspeyres formulae.

15.167 Two further advantages of using chain indices may be noted. For reasons explained in Section B, the quality of the inflation measures is greatly improved compared with the year-to-year movements in the implicit Paasche type deflators calculated on a reference period. A second advantage is that chaining avoids introducing apparent changes in growth or inflation as a result of changing the base year. When the base year for a time series of fixed weight Laspeyres type volume indices is brought forward, the underlying trend rate of growth may appear to slow down if the previous base has become very out of date. This slowing down is difficult to explain to users and may bring the credibility of the measures into question.

D. Measures of real income for the total economy

1. The concept of real income

15.168 Many flows in the System, such as cash transfers, do not have price and quantity dimensions of their own and cannot, therefore, be decomposed in the same way as flows related to goods and services. While such flows cannot be measured in volume terms they can nevertheless be measured "in real terms" by deflating their values with price indices in order to measure their real purchasing power over some selected basket of goods and services that serves as numeraire.

15.169 It is possible by use of a numeraire to deflate any income flow in the accounts and even a balancing item such as saving may be deflated by a price index in order to measure the purchasing power of the item in question over a designated numeraire set of goods and services. By comparing the deflated value of the income with the actual value of the income in the base year, it is possible to determine by how much the purchasing power of the income has increased or decreased. Income deflated in this way is generally described as "real income".

15.170 Despite the terminology used, "real" incomes are artificial constructs that are dependent on two points of reference.

a. Real incomes are measured with reference to the price level in some selected reference year; they vary depending upon the choice of reference year.

b. Real incomes measure changes in purchasing power over some selected numeraire; they vary according to the choice of numeraire.

15.171 As there may often be no obvious, or uncontroversial choice of numeraire there has always been some reluctance to show real incomes in national accounts on the grounds that the choice of numeraire should be left to the user of the statistics and not the compiler. However, when major changes in prices occur, it can be argued that compilers of statistics are under an obligation to present at least some measures of real income. Not all users of the accounts have the opportunity, inclination or expertise to calculate the real incomes which may be most suited to their needs. Moreover, there is a demand from many users for multi-purpose measures of real income, at least at the level of the economy as a whole and the purpose of this section is to indicate how such measures may be compiled.

2. Trading gains and losses from changes in the terms of trade

15.172 In a closed economy without exports or imports, GDP is equal to the sum of final consumption plus capital formation. This sum is described as domestic final expenditures. GDP is also a measure of the income generated in the economy by production. Although income cannot be expressed as the product of prices and volumes, if GDP can be deflated, then in effect this must also be a measure of income at real terms. However, with the inclusion of imports and exports, GDP is no longer identical to domestic final expenditure and deflation of GDP must allow for the deflation of imports and exports as well as of domestic final expenditures. Even if imports and exports are equal in current values, they usually have different prices so there is an impact on real income measures of import and export prices. This is generally done by considering the terms of trade and calculating what is known as the trading gains and losses from changes in the terms of trade.

15.173 Further, the total real income that residents derive from domestic production depends also on the rate at which exports may be traded against imports from the rest of the world.

15.174 ***The terms of trade are defined as the increase in the price of exports relative to the price of imports.*** If the prices of a country's exports rise faster (or fall more slowly) than the prices of its imports (that is, if its terms of trade improve) fewer exports are needed to pay for a given volume of imports so that at a given level of domestic production goods and services can be reallocated from exports to consumption or capital formation. Thus, an improvement in the terms of trade makes it possible for an increased volume of goods and services to be purchased by residents out of the incomes generated by a given level of domestic production.

15.175 ***Real gross domestic income (GDI) measures the purchasing power of the total incomes generated by domestic production***. It is a concept that exists in volume terms only. When the terms of trade change there may be a significant divergence between the movements of GDP in volume terms and real GDI. The difference between the change in GDP in volume terms and real GDI is generally described as the "trading gain" (or loss) or, to turn this round, ***the trading gain or loss from changes in the terms or trade is the difference between real GDI and GDP in volume terms.*** The differences between movements in GDP in volume terms and real GDI are not always small. If imports and exports are large relative to GDP and if the commodity composition of the goods and services that make up imports and exports are very different, the scope for potential trading gains and losses may be large. This may happen, for example, when the exports of a country consist mainly of a small number of primary products, such as cocoa, sugar or oil, while its imports consist mainly of manufactured products. Trading gains or losses, T, are usually measured by the following expression:

$$T = \frac{X-M}{P} - \left\{\frac{X}{P_x} - \frac{M}{P_m}\right\} \quad \text{.....................................(19)}$$

where

X = exports at current values

M = imports at current values

P_x = the price index for exports

P_m = the price index for imports

P = a price index based on some selected numeraire.

P_x, P_m and P all equal 1 in the base year. The term in brackets measures the trade balance calculated at the export and import prices of the reference year whereas the first term measures the actual current trade balance deflated by the numeraire price index. It is perfectly possible for one to have a different sign from the other.

15.176 There is one important choice to be made in the measurement of trading gains or losses, the selection of the price index P with which to deflate the current trade balance. There is a large but inconclusive literature on this topic, but one point on which there is general agreement is that the choice of P can sometimes make a substantial difference to the results. Thus, the measurement of real GDI can sometimes be sensitive to the choice of P and this has prevented a consensus being reached on this issue.

15.177 It is not necessary to try to summarize here all the various arguments in favour of one deflator rather than another, but it is useful to indicate what are the main alternatives that have been advocated for P. They can be grouped into three classes, as follows:

a. One possibility is to deflate the current balance, X-M, either by the import price index (which has been strongly advocated) or by the export price index, with some authorities arguing that the choice between P_m and P_x should depend on whether the current trade balance is negative or positive;

b. The second possibility is to deflate the current balance by an average of P_m and P_x: various different kinds of averages have been suggested, simple arithmetic or harmonic averages, or more complex trade weighted averages;

c. The third possibility is to deflate the current balance by some general price index not derived from foreign trade: for example, the price index for gross domestic final expenditure, or the consumer price index.

15.178 The failure to agree on a single deflator reflects the fact that no one deflator is optimal in all circumstances. The choice of deflator may depend on factors such as whether the current balance of trade is in surplus or deficit, the size of imports and exports in relation to GDP, etc. On the other hand, there is general agreement that it is highly desirable and for some countries vitally important, to calculate the trading gains and losses resulting from changes in the terms of trade. In order to resolve this deadlock it is recommended to proceed as follows:

a. Trading gains or losses, as defined above, should be treated as an integral part of the System;

b. The choice of appropriate deflator for the current trade balances should be left to the statistical authorities in a country, taking account of the particular circumstances of that country;

c. If the statistical authorities within a country are uncertain what is the most appropriate general deflator P to be used, some average of the import and export price indices should be used, the simplest and most transparent average being an unweighted arithmetic average of the import and export price indices. (This is referred to in the specialist literature on the subject as the Geary method.)

15.179 These proposals are intended to ensure that the failure to agree on a common deflator does not prevent aggregate real income measures from being calculated. Some measure of the trading gain should always be calculated even if the same type of deflator is not employed by all countries. When there is uncertainty about the choice of deflator, an average of the import and the export price indices is likely to be suitable.

3. The interrelationship between volume measures of GDP and real income aggregates

15.180 The usual way to calculate real income figures is to start from real GDI and then follow the normal sequence of income aggregates, but with every intervening adjustment deflated to real terms. This is illustrated as follows:

a. Gross domestic product in volume terms:,

plus the trading gain or loss resulting from changes in the terms of trade;

b. *equals* real gross domestic income;

plus real primary incomes receivable from abroad;

minus real primary incomes payable abroad;

c. *equals* real gross national income;

plus real current transfers receivable from abroad

minus real current transfers payable abroad;

d. *equals* real gross national disposable income;

minus consumption of fixed capital in volume terms;

e. *equals* real net national disposable income.

15.181 The transition from (a) to (b) is the trading gain on changes in the terms of trade explained immediately above. The steps needed in order to move from (b) to (d) above involve the deflation of flows between resident and non-resident institutional units, namely, primary incomes and current transfers received from abroad and paid to abroad. There may be no automatic choice of price deflator, but it is recommended that the purchasing power of these flows should be expressed in terms of a broadly based numeraire, specifically the set of goods and services that make up gross domestic final expenditure. This price index should, of course, be defined consistently with the volume and price indices for GDP.

15.182 Each step in the process should first be calculated for adjacent years in additive volume terms and longer series derived as chain indices.

15.183 A possible alternative approach is to move from GDP in volume terms to net domestic final expenditure in volume terms and then make a single adjustment for the impact on purchasing power of the current external balance using the deflator for net final domestic expenditure to reduce the current external balance to real terms. The advantage of this alternative is a single numeraire, the set of goods and services making up net domestic final expenditures is used throughout. It may be easier, therefore, to grasp the significance of real net national disposable income as this deflator is explicit.

15.184 However, the alternative framework measures the trading gain or loss by using the deflator for net domestic final expenditures as the general deflator P, for the trading gain or loss from changes in the terms of trade whereas it can be argued that P ought always to be based on flows which enter into foreign trade. On balance, therefore, the original framework presented above is to be preferred.

E. International price and volume comparisons

1. Introduction

15.185 Users want to compare GDP and its components not only over time for a given country or countries in analyzing economic growth, for example, but also across countries for a given time period in analyzing relative economic size. A commonly-used method of making such comparisons is to adjust national accounts values to a common currency using exchange rates, which has the advantage that the data are readily available and completely up to date. This is adequate if users need a ranking of a country's relative spending power on the world market. However, it is not adequate for comparisons of productivity and standards of living because it does not adjust for the differences in price levels between countries and thus does not give a measure of countries' relative sizes in the volume of goods and services they produce.

15.186 Purchasing power parities (PPPs) are used in producing a reliable set of estimates of the levels of activity between countries, expressed in a common currency. ***A PPP is defined as the number of units of B's currency that are needed in B to purchase the same quantity of individual good or service as one unit of A's currency will purchase in A.*** Typically, a PPP for a country is expressed in terms of the currency of a base country, with the US dollar commonly being used. PPPs are thus weighted averages of the relative prices, quoted in national currency, of comparable items between countries. Used as deflators, they enable cross-country comparisons of GDP and its expenditure components.

15.187 This section first examines the index number issues in aggregate comparisons of prices and volumes across countries. The International Comparison Program (ICP) produces internationally comparable economic aggregates in volume terms and PPP estimates every three to five years, depending on the region. Established in 1968, the ICP has grown to cover all regions of the world and for the 2005 round involved 107 countries. The results were combined with the OECD/Eurostat PPP program for 43 countries, bringing the total to 150 countries.

15.188 Compiling PPP-based data is a costly and time-consuming exercise, so it is not possible to make such comparisons as a matter of course. World-wide coordination is required to collect the data and compile the PPP-based estimates. However, national accountants in participating countries need to understand the basic principles of the comparison and the practical demands that are made on them for data to compile PPP indices and thus GDP volume comparisons. This material is the subject of the last part of this section.

2. Index number issues

15.189 The theory of index numbers developed in a time series context cannot be applied mechanically to international comparisons simply by replacing the term "period" by the term "country." International comparisons differ in a number of respects.

a. Time series are ordered by the date of the observation, but countries have no such a priori ordering. In consequence there is no pre-determined way to order countries when compiling chain indices.

b. For international price comparisons different price collectors will be reporting on the prices of the items in different countries. There thus is a need for flexible but detailed structured product descriptions (SPDs) for each item so that only the prices of like items are compared, either by comparing the prices of exactly the same item specification drawn from the SPD in both countries, or by statistically adjusting (quality adjusting) the prices of different specifications drawn from the SPD.

c. International comparisons are conducted on a less regular basis, in part because they present a large scale coordination challenge, involving the statistical offices of all participating countries as well as international organizations.

15.190 At the heart of the PPPs are price comparisons of identical or closely similar product specifications. The 2005 ICP round used SPDs to define these specifications and to ensure the quality of the detailed price comparisons. For each item there is a specification describing the technical characteristics of the item in detail so a data collector can precisely identify it in the local market. Besides the technical characteristics, the specification also includes other variables that need to be considered when pricing the item, such as the terms of sales, accessories and transportation and installations costs. The database formed from these structured descriptions and the prices collected for them permit more precise matching of items between countries.

Representativity versus comparability

15.191 Two critical criteria in selecting products to be priced for calculating PPPs are "representativity" and "comparability". Representative products are those products that are frequently purchased by resident households and are likely to be widely available throughout a country. Representativity is an important criterion in the ICP because the price levels of non-representative products are generally higher than those of representative products. Therefore, if one country prices representative products while another prices non-representative products in the same expenditure category, then the price comparisons between the countries will be distorted. On the other hand, comparability relates to the physical characteristics of a product. Products are considered to be comparable if their physical characteristics, such as size and quality, and economic characteristics, such as whether candles are used as a primary source of light or are primarily decorative, are identical.

15.192 In practice, difficult trade-offs are involved in selecting products that are both representative and comparable to use in calculating PPPs. The product lists for calculating PPPs are developed in a way that balances the competing aims of within-country representativity and cross-country comparability. In this respect, they are generally quite different from the products that would be priced by any individual country to compile its price indices (such as the consumer price index or any of a range of producer price indices) and which are used in producing the deflators used to calculate volume estimates in the time series national accounts. In the case of time series within a country, representativity is the key criterion in selecting the products to be priced while comparability with other countries is unimportant, once a representative product is selected for pricing, the important issue is to price the same product in subsequent periods so that price changes in the product can be measured over time. For the ICP, representativity is required only at a point in time and not over time.

Aggregation

15.193 PPPs are calculated and aggregated in two stages: estimation of PPPs at the level of basic headings and aggregation across basic heading PPPs to form higher-level aggregates. The estimation of basic heading level PPPs is based on price ratios of individual products in different countries. Typically no information about quantities or expenditures is available within a basic heading and, thus, the individual price ratios cannot be explicitly weighted when deriving PPPs for the whole basic heading. Two aggregation methods dominate PPP calculations at this level, the EKS method and the Country Product Dummy (CPD) method. A description of these methods can be found in chapter 11 of the ICP Handbook http://go.worldbank.org/LGVPTQ6YJ0. Weights are of crucial importance at the second stage when the basic heading PPPs are aggregated up to GDP. The main approaches used in the aggregation are overviewed in the paragraphs below.

Binary comparisons

15.194 As outlined in section C, the monetary value of GDP, or one of its components, (I_V) reflects the combined differences of both price and quantities, that is: $L_P \times P_Q = I_V$ or $L_Q \times P_P = I_V$. Price and volume indices may be compiled between pairs of countries using the same kinds of index number formula as those used to measure changes between time periods. A Laspeyres-type price index for country B compared with country A is defined as:

$$L_P = \sum_{i=1}^{n} \left(\frac{p_i^B}{p_i^A} \right) s_i^A \equiv \frac{\sum_{i=1}^{n} p_i^B q_i^A}{\sum_{i=1}^{n} p_i^A q_i^A}$$

and a Paasche-type index as:

$$P_P = \left[\sum_{i=1}^{n} \left(\frac{p_i^A}{p_i^B} \right)^{-1} s_i^B \right]^{-1} \equiv \frac{\sum_{i=1}^{n} p_i^B q_i^B}{\sum_{i=1}^{n} p_i^A q_i^B} \quad \text{.........................(20)}$$

where the weights s_i^A and s_i^B are component shares of GDP at current values of countries A and B.

15.195 Given the complementary relationships between Laspeyres and Paasche price and volume indices noted earlier, it follows that a Laspeyres-type volume index for B compared with A can be derived by deflating the ratio of the values in B to A, each expressed in their own currencies, by the Paasche-type price index (20). A Paasche-type volume index is similarly derived by deflating the ratio of values of B to A by a Laspeyres-type price index (19).

15.196 The differences between the patterns of relative prices and quantities for two different countries tend to be relatively large, compared with those between time periods for the same country. The resulting large spread between the Laspeyres- and Paasche-type inter-country price and volume indices in turn argues for an index number formula, such as Fisher, that makes symmetric use of both country's price and quantity information.

Multilateral comparisons

15.197 The need for multilateral international comparisons may arise, for example, to determine GDP aggregates for blocks of more than two countries or rankings of the volumes of GDP, or per capita GDP, for all the countries in a block. It is desirable that such rankings are transitive.

Transitivity

15.198 Consider a group of *m* countries. As binary comparisons of volumes and prices may be made between any pair of countries, the total number of possible binary comparisons is equal to *m*(*m*-1)/2. Let the price, or volume, index for country *j* based on country *i* be written as ${}_iI_j$. A set of indices is said to be transitive when the following condition holds for every pair of indices in the set:

$${}_iI_j \times {}_jI_k = {}_iI_k \quad \text{..(21)}$$

This condition implies that the direct (binary) index for country *k* based on country *i* is equal to the indirect index obtained by multiplying the direct (binary) index for country *j* based on country *i* by the direct (binary) index for country *k* based on country *j*. If the entire set of indices is transitive, the indirect indices connecting pairs of countries are always equal to the corresponding direct indices. In practice, none of the standard index formulae in common use, such as Laspeyres, Paasche or Fisher, is transitive.

15.199 The objective is to find a multilateral method that generates a transitive set of price and volume measures while at the same time assigning equal weight to all countries. There are four quite different approaches that may be used. The first approach achieves transitivity by using the average prices within the block to calculate the multilateral volume indices. The second approach starts from the binary comparisons between all possible pairs of countries and transforms them in such a way as to impose transitivity. The third method uses regression techniques to estimate missing prices by using price relatives for other products on a country-by-country basis. The fourth method is a multilateral chaining method based on linking bilateral comparisons such that countries that are most similar in their price structures are linked first.

The block approach

15.200 The most widely used form of the block approach uses the average prices of the block to revalue quantities in all countries in the block. This automatically ensures transitivity. The volume index for country B relative to country A is defined in the first expression in equation (20) as:

$$GK_Q = \frac{\sum_{i=1}^{n} \overline{p}_i q_i^B}{\sum_{i=1}^{n} \overline{p}_i q_i^A} = \frac{\sum_{i=1}^{n} \overline{p}_i q_i^C}{\sum_{i=1}^{n} \overline{p}_i q_i^A} \times \frac{\sum_{i=1}^{n} \overline{p}_i q_i^B}{\sum_{i=1}^{n} \overline{p}_i q_i^C} \quad \text{.......(22)}$$

and can be seen to be transitive. The average price $\overline{p}_i$ for each individual good or service is defined as its total value in the block, expressed in some common currency, divided by its total quantity:

$$\overline{p}_i = \frac{\sum_{j=1}^{m} c^j p_i^j q_i^j}{\sum_{j=1}^{m} q_i^j} \text{ where}$$

$$\sum_{j=1}^{m} q^j = \sum_{j=1}^{m} \frac{v_i^{\,j}}{p_i^{\,j}} \quad \text{..(23)}$$

and the summation is over the m different countries in the block. The term c^j in expression (23) is a currency converter which could be either a market exchange rate or a PPP used to convert each country's expenditure on item i, $v_i = p_i q_i$ into the common currency.

15.201 The most common block method is the Geary Khamis (GK) method in which the currency converters used in (23) are the PPPs implied by the volume indices defined by (20). In this method, the average prices and PPPs are interdependent being defined by an underlying set of simultaneous equations. In practice, they can be derived iteratively, initially using exchange rates as currency converters for average price, for example. The resulting volume indices are then used to derive the implied set of PPPs, which are themselves used in turn to calculate a second set of average prices, volume indices and PPPs, etc.

15.202 The advantages of a block method such as the GK method include:

a. The block of countries is recognized as an entity in itself;

b. The use of a single vector of prices ensures transitivity and the volume measures are additively consistent and can be presented in value terms using the average prices of the block (it is possible to present the results for a group of countries in the form of a table with countries in the columns and the final expenditure components in the rows, in which the values add up in the columns as well as across the rows); and

c. It is possible to compare ratios, such as the shares of GDP devoted to gross fixed capital formation, because the same vector of prices is used for all countries.

15.203 However, comparisons between any two countries, based on the multilateral block results, may not be optimally defined. It was shown in the description on transitivity that best practice price and volume comparisons between countries A and B should make symmetric use of information on their prices and quantities. However, country A's relative prices may be close to the average for the block while country B's may be atypical resulting in relatively low volumes for A compared to B. . This is called the "Gerschenkron effect." When the bigger and richer countries have larger weights, due to their influence in (23), the result is an average price structure that is different from that of poor countries and generally higher. Consequently, PPP-based expenditures are generally understated for poor countries

The binary approach

15.204 An alternative approach to the calculation of a set of multilateral volume measures and PPPs is to start from the binary comparisons between all possible $m(m\text{-}1)/2$ pairs of countries. If each binary comparison is considered in isolation, the preferred measure is likely to be a Fisher index.

15.205 Fisher indices are not transitive but it is possible to derive from them a set of m-1 transitive indices that resemble the original Fisher indices as closely as possible, using the least squares criterion. Minimizing the deviations between the original Fisher indices and the desired transitive indices leads to the so-called EKS formula, proposed independently by Elteto, Koves and Szulc.

15.206 The EKS index between countries i and k is the geometric average of the direct index between i and k and every possible indirect index connecting countries i and k, in which the direct index is given twice the weight of each indirect index. Transitivity is achieved by involving every other country in the block in the EKS index for any given pair of countries.

15.207 The EKS index:

a. provides the best possible transitive measure for a single aggregate between a pair of countries, in much the same way as a chain Fisher index may provide the best possible measure of the movement of a single aggregate over time;

b. gives equal weights to the two countries being compared; and

c. is not affected by the relative sizes of the countries, a desirable attribute.

However, the consequences are similar to those for chain indices in a time series context. It is not possible to convert the EKS volume indices for an aggregate and its components into a set of additively consistent values. This is in contrast to the GK method.

Ring comparisons

15.208 The outline of the above methods assumes that there is one set of comparisons comprising all the countries in a block. As the number of countries participating increases, it becomes difficult to administer them as a single group. Moreover, it is difficult to find items that are both nationally representative and globally comparable at the same time for countries far apart both geographically and in their level of development. There are thus advantages to a regionalized approach to the compilation of PPPs. Product specifications are prepared for each region and independent sets of PPPs prepared for countries on a region by region basis.

15.209 While this approach probably improves the quality of PPPs at the regional level, there is still the need to combine the regions to obtain a global comparison. Traditionally, a "bridge country" was chosen to provide the link between regions. The bridge country participated in the price surveys of more than one region. The ring approach extends this idea and identifies a subset of countries in each region to act as "ring countries". These countries comprise a synthetic "region" that intersects with all of the regions whose comparisons are to be linked together.

15.210 The method chosen depends on a number of factors including the purpose of the analysis, level of aggregation, sparseness of data, whether the aggregation is within regions, across ring countries, or for the whole data set and the importance attributed to additivity and symmetric treatment of countries.

3. Practical considerations for national accountants

PPPs and the national accounts

15.211 One of most important uses of PPPs is to calculate comparable estimates of GDP and its major components, expressed in a common currency where the effects of differences in price levels between countries are removed. The national accounts are integral to PPP estimates in two ways. In the first place, the national accounts provide the weights that are used to aggregate prices from a detailed level to broader aggregates, up to GDP itself. Secondly, the national accounts provide the values that are "deflated" by the PPPs to provide the volumes (also referred to as "real expenditures") expressed in a common currency that enable GDP and its expenditure components to be compared between countries

15.212 The PPP exercise also produces comparative price level indices (CPL). A CPL index is the ratio of the PPP for a country relative to the official exchange rate. CPLs are typically reasonably close to unity for countries where imports are a high proportion of domestic demand and where exports cover a wide range of products. For a country where imports are smaller in proportion, and may be concentrated on a subset of goods, for example investment goods, and exports are confined to agricultural products, the CPLs may be a long way from unity.

15.213 It is important that the volumes in the ICP not be confused with the time series volumes described earlier in this chapter because they are different measures, although there are some similarities in that they are both designed to measure values that have had the direct effects of price differences removed from them. In a time series of volumes, the effects of price changes from one period to another are removed to produce the volume measures from which rates of economic growth are calculated. In the case of an inter-country comparison, which is the basis for PPP-based volume measures, the effects of differences due to exchange rates and those due to different price levels within each country are removed from the national accounts values to provide a comparison between the volumes in the countries concerned.

15.214 The lowest level for which PPPs can be compared across all countries involved in a comparison is referred to as the "basic heading" and it is also the lowest level for which national accounts values are required as weights. In effect, the national accounts values provide the weights to aggregate the basic heading level data to broader national accounting aggregates, including GDP itself. The basic heading is also the level at which product specifications are determined, with a number of products representative of the expenditure within each basic heading being specified for pricing.

15.215 Expenditure-based estimates of GDP have been used in most PPP-based comparisons during the past half-century or so because the prices for final expenditures are more readily observable than those for outputs and inputs, which would be required for a comparison of the production-based estimates of

GDP. Consistency in the national accounts is critical in producing comparable estimates across countries so the SNA has played an important part in PPP-based comparisons by providing the framework for obtaining consistent estimates of GDP and its major aggregates.

15.216 The ICP is the broadest-based project to produce PPPs; about 150 countries participated world-wide in the 2005 round of the ICP. The volume estimates produced from the 2005 ICP present a snapshot of the relationships between countries from all over the world, expressed in a common currency. The ICP is a very expensive and resource-consuming project and so it provides benchmarks at infrequent intervals. As a result, PPP benchmarks, such as the one from the 2005 ICP, have to be extrapolated using time series from the national accounts of the countries involved. It is interesting to compare the outcomes of an extrapolation with the benchmarks from two sets of PPPs compiled several years apart. In practice, the extrapolated series do not tie in exactly with the benchmarks and there are several reasons for the differences that arise. An important one is the issue of the consistency between the prices used in the time series national accounts and those used in calculating PPPs as explained in the section on representativity and comparability earlier. Further, the price and volume structure may change significantly over time in a way not picked up in the extrapolation techniques.

Why ICP growth rates differ from national growth rates

15.217 The method commonly used to extrapolate PPPs from their benchmark year to another year is to use the ratio of the national accounts deflators from each country compared with a numeraire country (generally the United States of America) to move each country's PPPs forward from the benchmark. The PPPs derived are then applied to the relevant national accounts component to obtain volumes expressed in a common currency for the year in question.

15.218 Theoretically, the best means of extrapolating PPPs from a benchmark year would be to use time series of prices at the individual product level from each country in the ICP to extrapolate the prices of the individual products included in the ICP benchmark. In practice, it is not possible to use this type of procedure in extrapolating PPP benchmarks because the detailed price data needed are not available in all the countries. Therefore, an approach based on extrapolating at a macro level (for GDP or for a handful of components of GDP) is generally adopted. Leaving aside the data problems involved in collecting consistent data from all the countries involved, a major conceptual question arises with this process because it can be demonstrated mathematically that it is impossible to maintain consistency across both time and space. In other words, extrapolating PPPs using time series of prices at a broad level such as GDP will not result in a match with the benchmark PPP-based estimates even if all the data are perfectly consistent.

15.219 One of the reasons for differences between GDP time series and PPP benchmark comparisons stems from the definition of product. As explained in paragraphs 15.66-67, location is an essential product characteristic in the national accounts whereas the PPP comparisons use average prices of the whole country. Another problem is that the weighting patterns underlying the deflators in the time series national accounts will differ from those in the PPP benchmarks over time. In addition, as noted above, the products priced for the PPPs will differ from those underlying the time series because of the requirements in spatial price indices for representativity within each country and comparability between countries, while in time series the main requirement is for consistency over time. Generally, many more products will be priced for a country's price indices than it is possible to price for calculating PPPs. Finally and often the most critically, the prices underlying the deflators in the national accounts are adjusted to remove changes in quality over time and the methods of making such quality adjustments can differ significantly between countries. In particular, the extent of using hedonic methods for adjusting products whose characteristics change rapidly varies significantly from country to country. Electronic products (such as computers) feature prominently in hedonic quality adjustment, although some countries also use hedonics to quality adjust products such as clothing and housing. Comparing price changes in a country that uses hedonics in quality adjusting the price indices underlying its national accounts deflators with those in one that does not do so will lead to potentially large inconsistencies between the benchmarks and the extrapolated series.

15.220 Possibly the single biggest factor that affects the difference between extrapolated GDP series and PPP benchmark results is due to exports and imports: they often represent a large share of GDP and their price movements can be strong. GDP volume measures in the national accounts are unaffected by changes in terms of trade whereas they influence directly real GDP in spatial comparisons. For example, an increase of energy prices results in an increase of GDP volumes for energy exporting countries relative to other countries whereas in the national accounts of energy exporting countries, GDP volumes remains unchanged if the same amount of energy is exported.

Non-market services

15.221 Another area that leads to consistency problems between countries' PPP-based volumes is the group of so-called "comparison-resistant services". They are predominantly (although not exclusively) non-market services, with government services being a major part of the non-market services that have to be priced for PPP projects. The main problems in pricing non-market services relate to the quality of the services being produced and the productivity of the labour used in producing them. One of the conventions used in producing the estimates for the government sector in most countries' national accounts is that the value of output is measured as the sum of the labour and material inputs used in producing the service(s), which involves an assumption that an increase in costs translates into an equivalent increase in output. In addition, an assumption that is commonly made in the national accounts is that the productivity of the labour involved in producing such services does not change over time either. A similar assumption, that productivity is identical in all the countries in a comparison, generally has to be made between countries in calculating PPPs. It is a reasonable assumption when countries at roughly the same level of economic development are involved in the PPP comparison. However, when countries at very different levels of economic development are being compared then the validity of the assumption breaks down.

15.222 The choices faced by the compilers of PPPs are either to assume that productivity levels are identical across countries, even when they are at very different stages of economic development, or to adjust the non-market services estimates in some way to account for productivity differences. Apart from the problems involved in determining an appropriate conceptual approach to adjust for productivity differences between disparate economies, obtaining the data required to make such adjustments also proves problematical particularly when the method involves adjustments based on relative levels of capital intensity in the countries involved. Despite the problems, it is sometimes necessary to make productivity adjustments for non-market services because the problems involved in doing so are rather less than the consequences of assuming equal productivity in all the countries in a comparison.

Conclusion

15.223 PPP-based comparisons of activity levels between countries are an important use of national accounts. Despite the conceptual and empirical difficulties, PPP-based volumes provide a much firmer basis for international comparisons than the commonly used alternative of converting national accounts aggregates to a common currency using exchange rates.