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CHOOSING A PRICE INDEX FORMULA

A survey of the literature with an application to price indexes for the tradable and non-tradable sectors

Leanne Johnson

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ABSTRACT

The choice of price index formula can significantly influence the measurement of price change. This working paper contains a survey of the literature relating to the choice of price index formula. The properties of the most commonly used formulae have been examined with special emphasis on the benefits of using chained indexes when circumstances permit. The focus in this paper is on the choice of price index formula at the macro-level. However, the choice of formula at the most disaggregated level is also crucial.

The limited evidence as to the quantitative impact of using alternative formulae motivated an examination of this issue in the context of measuring price change for tradable and non-tradable goods in Australia. The results indicate that alternative formulae may lead to quite divergent measures of price change. The theoretical and empirical evidence presented in this paper emphasise the importance of considering the choice of index formula when compiling or using price indexes.

1. INTRODUCTION

The Laspeyres index formula is used by a clear majority of international statistical organisations in the compilation of their main price indexes. Despite its widespread use there is growing acknowledgement that the Laspeyres index formula may not be the most appropriate choice in many circumstances. This is reflected in the recommendations of the United Nations' System of National Accounts (1993).

In practice the choice of index formula is seldom straightforward, and few aggregate price measures are produced by the consistent application of such formulae. For example, Australia's Consumer Price Index (CPI) is routinely compiled by application of the fixed-weight Laspeyres formula. However, approximately every five years the weights are revised, and the price index series constructed from the new weights is linked to the previous series to form a continuous historical index. In effect, the CPI is a chained Laspeyres index, but its properties are very different to those of an index chained every period or even annually.

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Further complications arise when it is recognised that many of the weights relating to prices at the most disaggregated level in the CPI are frequently updated. The treatment of data at the micro-level *(see Glossary)* is at least as important as the choice of macro-index formula *(see Glossary)*. Diewert (1995b) presents empirical evidence which indicates that the use of an inappropriate index formula to combine prices at the most disaggregated level added 0.5 percentage points per annum to the United States' CPI for the period 1987 to 1994. The use of the Laspeyres index formula rather than a superlative formula *(see Glossary)* would typically add about 0.25 percentage points per annum to the CPI.[1] Other potential sources of bias have also been identified, with the most important being that resulting from the inability of price indexes to take account of the rapid introduction of new goods.

The fact that the choice of price index formula – at both the micro-level and the macro-level – can lead to significant discrepancies is important, and needs to be recognised in circumstances where accuracy to within a fraction of a percentage point per annum is required. Given the widespread use of price indexes *(see Glossary)* in economic analysis and modelling, the potential impact the choice of index formula can have on measurement of price change is an issue which requires careful examination.

This paper aims to analyse the choice of price index formula from both a theoretical and practical perspective. The properties of alternative formulae and the implications of the choice of index formula are demonstrated by reference to price indexes for the tradable *(see Glossary)* and non-tradable sectors of the Australian economy. The development of these price indexes is outlined in Knight and Johnson (1996). The compilation of these price indexes provides a practical setting for determining which index formula is preferable and analysing the quantitative impact of the choice of formula.

In this paper the method of compilation of the disaggregated source data is taken as given; it is the method of compiling the data to form aggregate measures of price change which is of interest. The preferred formulae at the micro-level and the macro-level are generally determined with regard to both theoretical and pragmatic considerations and in neither case does a single formula emerge as clearly preferred in all circumstances. Despite the obvious parallels, the choice of index formula at the micro-level lies outside the scope of this paper and will not be further discussed. The current state of research is well covered in both Woolford (1994) and Diewert (1995a).

Section 2 outlines the price index formulae to be considered in the paper, and the concept of chaining indexes. The different approaches to determining which is the preferred index formula are considered in Section 3. Section 4 discusses the properties of each of the price index formulae,

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1 Two United States studies, a Canadian study and a Dutch study all estimated the extent of this bias on the relevant country's CPI to lie between 0.2 and 0.3 percentage points. All studies were conducted at a highly disaggregated level, while the methodology and time-frames differed between studies.

while Section 5 considers the arguments for and against the use of chained indexes. Section 6 contains a practical illustration of the choice of price index formula, and the quantitative impact of this choice, in the context of measuring price change for tradable output in Australia. Section 7 draws together the main themes of the paper, and suggests areas for future research. It is followed by a list of references and a glossary which provides definitions of the more technical terms used in this paper.

2. PRICE INDEX FORMULAE

2.1 Direct Price Indexes

Direct indexes *(see Glossary)* are calculated by comparing the current period to a fixed base period. In contrast chained indexes *(see Glossary)* compare the current period to the previous period. Direct indexes should not be confused with fixed-weight indexes *(see Glossary)*. Of the index formulae considered, only the direct Laspeyres index maintains fixed weights over the entire period.

Direct indexes provide a measure of price movement between the base period and period t. However, in practice, direct price indexes are often used to obtain an indicator of price change between period t and period $t+1$. For the direct Laspeyres index the price comparison is made for a fixed basket of goods and services, but for other direct index formulae the period-to-period price movements can be greatly influenced by compositional change.

In Table 2.1 the price index formulae to be considered in this paper are outlined. There are numerous other price index formulae that have previously been proposed, both simpler and more complex. Those outlined are the most commonly used. A brief explanation of each of these formulae is provided in this section. The precise properties of these methods of constructing price indexes will be discussed in detail in Section 4.

The reference period is the period for which an index series is given the value of 100.0. The weighting base is the period to which the value weights relate. The weighting base and the reference period need not be the same.[2] For chain indexes the concept of a weighting base is not relevant: the current period is compared to the previous period for all observations rather than to a fixed base period.

The notation used in Table 2.1 is explained below. The definitions refer to industries rather than commodities so as to be consistent with the application to measuring price change for tradable output, which is presented in Section 6.

p_{it} = the value the price index of the commodities produced by industry i takes in period t (period t=0 refers to the reference period and p_{i0} = 100.0 for all i)

v_{it} = the current price value of the output of industry i in period t

$w_{it} = v_{it} / \sum_i v_{it}$
= the share that industry i contributes to the total value of output in period t

[2] For the price indexes presented in Section 6 the reference year is 1989–90=100.0 which coincides with the weighting base year which is also 1989–90.

TABLE 2.1 PRICE INDEX FORMULAE

Name		Formula
Laspeyres	(a)	$L_t = \dfrac{\sum_i v_{i0}.(p_{it}/p_{i0})}{\sum_i v_{i0}}$
	(b)	$= \dfrac{\sum_i p_{it}q_{i0}}{\sum_i p_{i0}q_{i0}}$
	(c)	$= \sum_i w_{i0}.(p_{it}/p_{i0})$
Paasche	(a)	$P_t = \dfrac{\sum_i v_{it}}{\sum_i v_{it}(p_{i0}/p_{it})}$
	(b)	$= \dfrac{\sum_i p_{it}q_{it}}{\sum_i p_{i0}q_{it}}$
	(c)	$= \{\sum_i w_{it}.(p_{i0}/p_{it})\}^{-1}$
Fisher		$F_t = (L_t P_t)^{\frac{1}{2}}$
Tornqvist	(a)	$T_t = \prod_i (p_{it}/p_{i0})^{\frac{1}{2}(w_{i0}+w}$
	(b)	$\ln T_t = \frac{1}{2}\sum_i \{(w_{i0} + w_{it}).\ln(p_{it}/p_{i0})\}$
Vartia		$Vn_t = \prod_i (p_{it}/p_{i0})^{\bar{W}_{it}}$

where for n=1:

(a) $$\bar{W}_{it} = \frac{(v_{it} - v_{i0})/(\ln v_{it} - \ln v_{i0})}{(\sum_i v_{it} - \sum_i v_{i0})/(\ln \sum_i v_{it} - \ln \sum_i v_{i0})}$$

and for n=2:

(b) $$\bar{W}_{it} = \frac{(w_{it} - w_{i0})/(\ln w_{it} - \ln w_{i0})}{(\sum_i w_{it} - \sum_i w_{i0})/(\ln \sum_i w_{it} - \ln \sum_i w_{i0})}$$

The discussions in this paper refer to value weights as the source data used in calculating industry weights are in terms of value. However, in the theoretical literature relating to price indexes it is quite common for weighting to be discussed in terms of quantity weights. Price indexes can be compiled using either value weights or quantity weights and the two versions of the index formula yield equivalent results. The difference is that quantity weights are used in conjunction with actual prices while value weights are used in conjunction with price movements or price indexes.

The Laspeyres (b) and Paasche (b) formulae in Table 2.1 use quantity weights and can be used directly only at the disaggregated commodity level where the concept of quantity is relevant. In these formulae the term p_{it} refers to the actual price of commodity i in period t, while q_{it} refers to the quantity of output of commodity i in period t. These versions of the formulae are not suitable for use in measuring the price of tradables but are included for completeness. The remaining formulae in this table are relevant to calculating price indexes at a more aggregate level using value weights.

The Laspeyres price index is a weighted arithmetic average of all the industry price series. This is illustrated by the Laspeyres (c) formula. The weights used correspond to the value of each industry's output as a share of total output, so it can be seen that the Laspeyres (a) and (c) formulae are equivalent. The weights are calculated at the base year and remain fixed. The denominator of the Laspeyres (a) and (b) formulae refers to the total value of all output in the base period, while the numerator values this base period output at current prices.

The Paasche index differs from the Laspeyres in its use of current period values as weights. The weights vary over time. The numerator of the Paasche (a) and (b) formulae refers to the total value of output at time t, while the denominator measures current output at base year prices.

Fisher's ideal price index is a geometric average of the Laspeyres and Paasche price indexes. It uses information on values in both the base period and the current period for weighting purposes. Equal importance is attached to the two periods being compared. The Tornqvist price index also uses information on values in both the base period and the current period for weighting purposes, with equal importance being attached to the two periods. Like Fisher's ideal index it is a symmetric index, and in most cases the two index formulae will produce very similar results.

The Tornqvist index is a discrete time version of a Divisia index *(see Glossary)*. The growth rate of prices is approximated by logarithmic differences, and the continuous weights by two period arithmetic averages. The Tornqvist index thus provides an approximation to the growth rate of the Divisia index, which is exact *(see Glossary)* when the underlying cost function *(see Glossary)* has the translog form *(see Glossary)*.

The Divisia index is a theoretic continuous time index *(see Glossary)*. If the producer is continuously maximising a well behaved, linearly homogenous, production function *(see Glossary)* subject to a budget constraint, then the Divisia price index equals the appropriate theoretic price index for any non-zero set of quantities. The continuous nature of the Divisia index is appropriate for the theoretical analysis of many economic problems, but not for empirical analysis. Data typically refer to discrete points in time and are not suitable for use in the Divisia framework. The Divisia index can only be approximated on a discrete time basis. An argument often put forward in support of the Tornqvist and Vartia index formulae, and particularly chained indexes, is that they provide a discrete time approximation to the Divisia index.

The Vartia index formulae are similar to the Tornqvist index, but incorporate a far more complex combination of weighting information. The Vartia 1 index is identical to the Vartia 2 formula, except for the definition of $\overline{W}_{it}$, where all of the weight terms are replaced with value terms. The Vartia index is most often used in applications where the property of consistency in aggregation *(see Glossary)* is considered important. The Vartia 2 formula is not consistent in aggregation and as a result is less commonly used. The discussion in this paper focuses upon the Vartia 1 formula.

2.2 Chained Price Indexes

Chaining can be applied to any of the above mentioned formulae. The arguments put forward to support chained price indexes are outlined in Section 5. The main difference between chained indexes and the direct indexes considered so far, is that while direct indexes simply calculate the price movement between the fixed base period and period t, a chained index incorporates price and weighting changes within the intervening period.

In a chained index the current period is compared to the previous period for all observations, rather than comparing each period to a fixed base period. Comparisons to the previous period are likely to be more relevant than comparisons to a fixed base period which may not adequately capture changes over time in tastes, purchasing patterns and in the properties of commodities. These measures of price change relative to the previous period can then be linked together to obtain measures of the change in price relative to the base period. These measures will typically be different to the direct measures of price change over the same period.

Consider an index I_{ab} which refers to an index of the price in period b relative to that which occurred in period a. In such a case, the direct and chained price indexes can be denoted in the following way, regardless of which index formula is used.

Direct index : $X_{01}, X_{02}, X_{03} \ldots X_{0k}$

Chained index : $Y_{01}, Y_{02}, Y_{03} \ldots Y_{0k}$

$$
\begin{aligned}
Y_{01} &= X_{01} \\
Y_{02} &= Y_{01}.Y_{12} \\
Y_{03} &= Y_{01}.Y_{12}.Y_{23} = Y_{02}.Y_{23} \\
Y_{04} &= Y_{03}.Y_{34}
\end{aligned}
$$

and so on.

For example, consider the Laspeyres formula.

Direct index : $X_{02} = \sum_i w_{io}.(p_{i2}/p_{i0})$

Chained index : $Y_{02} = \sum_i w_{i0}.(p_{i1}/p_{i0}).\sum_i w_{i1}.(p_{i2}/p_{i1})$

These two indexes are measuring the same thing, but are likely to provide different values for the change in price of the good between period 2 and the base period. From this formula it can be seen that in addition to the price index for the current period relative to the base period, it is necessary to calculate the price index for the current period relative to the previous period, when constructing a chained index. The individual links of the chain can be calculated using whichever is the preferred price index formula.

The above discussion relates to a price index which is chained together every period. Alternatively, price indexes may be linked *(see Glossary)* together on a regular but less frequent basis, or they may be linked on an irregular basis. The discussion in this paper focuses on the case where the current period is compared to the previous period for all observations. Also of interest is the case where price indexes are linked together on a regular, but less frequent, basis. An example which is examined in later sections is annual chaining of quarterly price indexes. The case of price indexes which are linked together on an infrequent basis is not examined in this paper. An example of this is five-yearly chaining of quarterly price indexes. The latter two of these procedures can be seen as lying along a spectrum between fixed-base and chained indexes and their properties can be interpreted in the same light.

In practice it is often not feasible to link the index every period. For example, the Retail Price Index for the United Kingdom, which is a chained Laspeyres index, is released quarterly but only linked on an annual basis. The Australian CPI is also compiled quarterly using the direct Laspeyres formula but is chain linked approximately every five years. 'Long runs of data, therefore, almost inevitably involve some form of chained indexes. Annual chaining is simply the limiting case in which rebasing is carried out each year instead of every five or ten years.'[3]

[3] United Nations (1993), paragraph 16.77. Note that annual chaining is only the limiting case if annual indexes are being compiled.

3. APPROACHES TO CHOOSING AN INDEX FORMULA

3.1 The Axiomatic (Test) Approach

This approach involves outlining properties which are desirable for every price index. In this way, possible index formulae which do not satisfy these properties are excluded. Fisher (1922) outlined four axioms that all price index formulae should satisfy.

- Monotonicity : A price index should increase whenever any of the prices in the current period are raised or any of the prices in the base period are lowered, *ceteris paribus*.
- Proportionality : When all prices in the current period are uniformly greater or lower than those in the base period by some fixed proportion, the index should equal that proportion.
- Price Dimensionality : The same proportional change in the unit of currency in both periods should not change the index.
- Commensurability : A change in the unit of quantity for any commodity in both periods should not change the index.

However, many price indexes satisfy all of these axioms, including the Laspeyres, Paasche, Fisher and Tornqvist formulae which were outlined in Section 2. The Vartia 1 formula does not satisfy the proportionality test although Vartia (1976) did put forward a weaker version of this test which the index satisfies. Several further tests were put forward by Fisher (1922) to guide the choice of index formula.

- Time Reversal Test : The index for time *t* based on time *0* should be the reciprocal of that for time *0* based on time *t*.
- Factor Reversal Test : The product of the price index and the volume index *(see Glossary)* should be equal to the proportionate change in the current values.
- Product Test (weaker version of Factor Reversal Test) : The product of a price index and volume index should equal the proportionate change in value, where the price and volume indexes are not necessarily of the same form, but must both satisfy the above four axioms. The Laspeyres and Paasche indexes satisfy this property but not the factor reversal test. Specifically, the product of a Laspeyres price (volume) index and the corresponding Paasche volume (price) index is equal to the proportionate change in total value.
- Transitivity Test[4] : Let I_{AB} be an index for period B based on period A. Transitivity requires that $I_{AC} = I_{AB}.I_{BC}$. If a formula is transitive the direct and chained indexes compiled using this formula will be equal.

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4 The Transitivity test can be traced back to: Westergaard, H. (1890), *Die Grundzuge der Theorie der Statistik*, Jena: Fischer.

No index formula can satisfy all four axioms and all four of these tests. Not all of these apparently reasonable tests are consistent with one another. The Fisher index satisfies all except the transitivity test but it is not alone in this respect. While the test approach to price index theory is useful, it does not lead to a unique formula, and so is usually considered in conjunction with economic approaches to price index theory.

Many other tests have also been put forward by various authors. The following two tests are particularly relevant to the practical illustration of the impact of choice of index formula, which is presented in Section 6.

- Multiperiod Identity Test:[5] If prices and quantities systematically oscillate around constant values, the price index should return to this constant value. Chained indexes do not satisfy this test. When price and quantity data oscillate, a chained index will often drift away from the corresponding direct index. This test flows from the property of transitivity which is discussed on the previous page.
- Consistency in Aggregation: Consider the broad industry category of manufacturing. It can be broken down into manufacturing of food, textiles, chemicals, metal products etc. Each of these subcategories can be broken down into further classes. Assume there is a price index corresponding to each of these classes, and the aim is to construct a price index for the manufacturing category. Consistency in aggregation requires that the numerical value of the manufacturing index calculated by constructing price indexes for each of the subcategories and aggregating these to produce a single manufacturing index, necessarily coincides with the value of the manufacturing index calculated directly from the price indexes for the classes. Vartia (1976) points out that the Fisher and Tornqvist indexes do not possess the property of consistency in aggregation.

3.2 The Economic Approach

This axiomatic approach to choosing a preferred price index formula assumes that prices and quantities are independent of one another. Neither consumer preferences nor production technology are taken into account. In contrast the economic approach bases its analysis on economic relationships and assumes competitive optimizing behaviour. The two approaches can be partly reconciled as the index formulae preferred under each method will often be the same.

The basic argument put forward to support a price index formula, using the economic approach, is that it is the best approximation possible to the appropriate theoretic index under certain assumptions. An index implied by the economic approach will be referred to as a theoretic index. There is no

[5] For a good discussion of this property see United Nations (1993), paragraphs 16.46–16.49.

unique theoretic index; the theoretic index will differ according to the assumptions made.

The economic approach assumes the consumer or producer is minimising the cost of achieving a given level of utility or output, and that the economic agent chooses the maximum level of utility or output with given budget constraints. The problem is then to find an index formula for quantities or prices which is consistent with this representation.

For example, when the underlying unit cost function is represented by a homogenous *(see Glossary)* quadratic function, and the producer is engaging in profit maximising behaviour, the Fisher index exactly corresponds to the appropriate theoretic index. Diewert (1976) has also shown that the Tornqvist price index is exact for the translog unit cost function. These of course are special cases and similar examples can be provided for other index formulae.

A flexible functional form is one which is capable of providing a close approximation to a range of other functional forms.[6] An index is superlative if it is exactly the same as the appropriate theoretic index for some flexible functional form of the unit cost function. With a superlative index the index formula is not just exact for some special case, but is approximately so for a group of related functional forms of the unit cost function. Thus a more convincing argument in favour of an index, is to be a superlative index, rather than just an exact index.

There is a whole family of superlative price index formulae. However, of the formulae considered in this paper, only the Fisher and Tornqvist indexes possess this property. Whether certain assumptions are preferred about the functional form of the unit cost function, will impact upon which index formula is preferred among these superlative indexes.

A combination of both the axiomatic and economic approaches should be used in determining which price index formula to use. No index formula can be constructed to satisfy all the ideal conditions. The preferred formula will depend on which properties are most relevant to the purpose for which the index is required.

[6] More precisely, Diewert (1976) defined a linearly homogenous function, f, of N variables to be flexible if it could provide a second order approximation to an arbitrary twice continuously differentiable linearly homogenous function. The most commonly used flexible functional form is the translog.

4. PROPERTIES OF DIRECT PRICE INDEXES

4.1 Laspeyres and Paasche

In general economic conditions, the Laspeyres price index will exhibit a higher rate of growth than the corresponding Paasche index. This relationship holds whenever price and quantity relatives *(see Glossary)* are negatively correlated. This is expected for price-takers who react to changes in relative prices by moving consumption away from those products which have become relatively more expensive and towards those which have become relatively less expensive. As the Laspeyres index uses weights which are constant and equal to those in the base period, products which have a relatively rapid rate of price growth are likely to be overweighted in subsequent periods. For this reason the Laspeyres index is likely to have a higher growth rate than the Paasche index which incorporates current weighting information.

It has previously been noted that there is no unique theoretic index; the appropriate theoretic index will depend on the assumptions made. The Laspeyres index provides an upper bound to a theoretic index as it does not allow for substitution in light of changing relative prices. If homotheticity *(see Glossary)* is assumed, the Paasche index provides a lower bound to the same theoretic index. However, the theoretic index can only be identified if the functional form of the underlying cost function is also specified. In practical applications of the two index formulae it is generally observed that the Laspeyres and Paasche indexes do tend to diverge over time with the Laspeyres index exhibiting higher growth in the majority of cases.

This divergence between alternative index formulae is the reason why the choice of price index formula is important. Many price aggregates exhibit small quarterly movements of one percentage point or less. Often a high degree of accuracy is required and it will be important to know whether the choice of index formula alone could be responsible for differences of this magnitude.

Economic theory suggests that any symmetric index which assigns equal weight to the two situations being compared, is likely to provide a far closer approximation to an appropriate theoretic index, than do the Laspeyres and Paasche indexes. This is why the Fisher index and other symmetric formulae are generally preferred under the economic theoretic approach.

The Laspeyres and Paasche indexes on their own do not pass the factor reversal test. However, they do pass the weaker product test. The product of the Laspeyres price index and the Paasche volume index is a value index, as is the product of the Paasche price index and the Laspeyres volume index.

The primary advantages of the Laspeyres index, which explain its wide use, are its minimal data requirements and the ease of understanding what the index measures. Its interpretation as the change in the price of a fixed basket of goods and services is relatively straightforward. Further, unlike other direct indexes, the direct Laspyeres index enables a valid comparison to be made between prices in any two periods. The Paasche index has greater data requirements because current weights are required and such data are usually not available promptly enough. For new goods the Paasche index presents the practical problem of retrospective collection of prices. Diewert (1978) notes that both index formulae are consistent in aggregation, unlike the Fisher and Tornqvist formulae.

A fixed-weight Laspeyres index is not useful in making long-term comparisons since it does not take the changing nature of production and consumption over time into account. In practice the weights of most Laspeyres indexes are revised infrequently. When the weights used in an index are out of date there is a loss of confidence in the index, particularly in periods where the weights are believed to be changing significantly. Over time the Laspeyres index tends to understate the importance of price movements for those commodities which have a growing share of total expenditure. Other index formulae which utilise recent weighting information may therefore be preferred. Chaining of index formulae is a technique used to overcome this inadequacy.

The Paasche and Laspeyres indexes, together with all superlative indexes, can be regarded as discrete approximations to the continuous Divisia index. The Divisia index is the theoretic continous time index which is consistent with a producer continuously maximising a well-behaved, linearly homogenous, production function subject to a budget constraint. However, they are not likely to be the best approximations: chaining will produce a closer approximation. The Laspeyres and Paasche indexes are only consistent with very restrictive functional forms for the underlying unit cost function. Thus, they are not recommended under the economic theoretic approach. There are also many price index formulae which are preferable according to the axiomatic approach. The wide use of the direct Laspeyres price index formula stems from practical considerations and its interpretation as the change in the price of a fixed basket of goods and services. The direct Paasche index is less widely used. However, the implicit price deflators produced as part of the National Accounts are direct Paasche indexes.[7]

4.2 Fisher, Tornqvist and Vartia

The Fisher index is a geometric average of the Laspeyres and Paasche indexes and so will always lie between the two. Any symmetric mean index is likely to quite closely approximate a theoretic index implied by the economic approach. Both the Fisher and Tornqvist formulae are symmetric as they attach equal importance to weighting information from both periods. These

[7] The implicit price deflators are not pure Paasche price indexes as Laspeyres price indexes have been used to deflate the current price values at a disaggregated level.

formulae are quite demanding in their data requirements as, like the Paasche index formula, they require current weighting information. Very rarely are any of these more complex formulae used in practice. However, the situation is changing with several countries producing chained Laspeyres or Fisher volume indexes as part of the National Accounts.

The difference between the Fisher and Tornqvist indexes is likely to be very small compared to the difference between the Laspeyres and Paasche indexes. It is also likely to be small compared to the difference between the Laspeyres index and the Fisher or Tornqvist indexes, or that between the Paasche index and the Fisher or Tornqvist indexes. The precise choice of symmetric index is likely to be of secondary importance due to the fact they approximate each other quite closely. This is especially the case when the Laspeyres and Paasche indexes do not diverge greatly.

The Fisher index satisfies the time reversal and factor reversal tests, while the Laspeyres and Paasche indexes do not. The Tornqvist index does not satisfy the factor reversal test but does satisfy the product test. All of the indexes considered assume constant returns to scale *(see Glossary)*, and so it may be invalid to apply these methods to monopolistic or imperfectly competitive situations. The Fisher and Tornqvist indexes come close to satisfying transitivity *(see Glossary)* in practical illustrations, but the Laspeyres and Paasche indexes do not.

The Fisher and Tornqvist indexes are superlative, while the Vartia, Laspeyres and Paasche indexes are not. The Fisher index exactly corresponds to the appropriate theoretic index if the unit cost function can be represented by a homogenous quadratic function. As the homogenous quadratic function is an example of a flexible functional form *(see Glossary)*, the Fisher index provides a close approximation to a range of other theoretic indexes. It is a superlative index. Similarly, the Tornqvist index is exact for a translog unit cost function. This is a flexible functional form which is capable of closely approximating a wide range of other possible underlying functions. Therefore the Tornqvist index is superlative.

The direct Laspeyres and Paasche indexes are assymmetric. The weights of the direct Laspeyres index relate only to the base period, while the weights for the direct Paasche index relate only to the current period. When the change in prices between the base period and period t is being measured, a symmetric price index which gives equal weight to the two periods being compared is generally preferred. Symmetric indexes, such as the Fisher and Tornqvist, are better equipped to deal with oscillating conditions than are the Laspeyres and Paasche indexes. The Laspeyres and Paasche indexes will generally provide upper and lower bounds for the symmetric indexes.

The lack of additivity *(see Glossary)* of all but the direct Laspeyres index is a disadvantage for many types of analysis where interrelationships between various flows in the economy are the main focus of interest. This argument refers to volume indexes rather than price indexes, and is relevant to the compilation of the National Accounts and most macro-econometric models.

Eventually a direct Laspeyres index must be rebased and it will lose its additivity. Additivity of components of a volume index cannot be maintained over a long period.

The Vartia 1, Laspeyres and Paasche indexes are consistent in aggregation. The Fisher and Tornqvist indexes are not consistent in aggregation. It has been proven by Diewert (1978) that the Fisher and Tornqvist indexes (and all other superlative price indexes) are approximately consistent in aggregation. In practice there is almost no difference between the results from using this formula and from using the Vartia 1 formula. As the latter is consistent in aggregation, and all superlative indexes are a second order differential approximation of it, all superlative indexes are approximately consistent in aggregation. Therefore, this practical objection to using the Fisher or Tornqvist formulae loses its force. The degree of approximation becomes even closer if the chain principle is used.

The Tornqvist index may behave badly when the price of individual goods approaches zero. In such a case the weight decreases faster than the logarithm of the individual index and so an extreme price decrease for a good does not reduce the composite price index. The Fisher and Vartia indexes do not suffer from this problem.

Vartia proposed the use of the Vartia 1 and Vartia 2 formulae, both of which comply with the time and factor reversal tests (as does the Fisher index) and behave correctly in the face of extreme price and quantity changes. The Vartia 1 formula is concentrated on in this paper as it is the only symmetric formula which is consistent in aggregation. The Vartia 2, Tornqvist and Fisher formulae are only approximately consistent in aggregation.

The Vartia index is not superlative. It is consistent only with the Cobb-Douglas unit cost function, which is not a flexible functional form. However it is a widely used and accepted functional form. An unusual feature of the Vartia index is the fact that the sum of the weights is generally less than unity. The Vartia index also has the disadvantage that rescaling the prices for a period will generally not change the relevant observation of the price index by the same scale factor.

It generally does not matter much which superlative index is used out of the possible set as they will differ only slightly. Practical studies have shown that the Fisher, Tornqvist and Vartia indexes are always very similar, even more so when chained. These three always lie between the Laspeyres and Paasche indexes. The Vartia index differs more from the Tornqvist and Fisher indexes than the latter pair do from each other. For successive years, the results do not change much with regard to the formula, but over long time-series the choice of formula becomes more important. Empirical studies have also shown that computed Tornqvist, Fisher and Vartia indexes do not show up any differences due to aggregation. These empirical studies are discussed in more depth in Section 6.

The Fisher formula is consistent with both a linear aggregator function (infinite substitutability between the goods to be aggregated) and a Leontief aggregator function (zero substitutability between commodities to be aggregated). For this reason, and due to its simple form and consistency with revealed preference theory, Diewert prefers it to alternative formulae such as that of Tornqvist.

The Tornqvist index is exactly equal to the Divisia index when the underlying function has the translog form. The Tornqvist formula, and other superlative formulae, are likely to provide far closer approximations to the Divisia index than the Laspeyres or Paasche formulae.

The United Nations' System of National Accounts guidelines (1993) recommend the use of the Fisher index over Laspeyres and Paasche indexes. No explicit choice is made between the Fisher and Tornqvist indexes, although in later discussion the Tornqvist index is ignored with the final recommendation being a chained Fisher index.[8]

4.3 Summary of Properties

Table 4.1 summarises the properties of the five direct price index formulae which are outlined in Table 2.1. A *Y* indicates the price index formula satisfies this property, a *N* indicates the formula does not satisfy the property, while an *A* indicates the formula approximately satisfies the property. Note that the table refers to the Vartia 1 index only; the Vartia 2 index is not consistent in aggregation and is not in common use. The properties outlined in this table have been discussed in more detail in the preceding pages.

In addition to the properties summarised in the above table, the divergence between alternative price index formulae should also be re-emphasised. It is for this reason that the issue of choosing a price index formula becomes important. If we require accuracy in the measurement of price changes it is important to know whether the choice of formula alone could be responsible for much of the observed change.

Symmetric indexes, such as the Fisher, Tornqvist and Vartia indexes, are likely to provide far closer approximations to a theoretic index implied by the economic approach than do the Laspeyres or Paasche indexes. The choice between these symmetric indexes is of less importance due to the fact that they approximate each other very closely in practice.

Table 4.1 specifically considers the properties of direct price index formulae. However, a table which summarised the properties of the corresponding chained index formulae would be almost identical. The properties pertain to the formula itself and hold regardless of whether the index is linked together using the chain principle. For example, a formula is transitive if the direct

8 United Nations (1993), paragraph 16.73(b).

and chained indexes compiled using this formula are equal. Therefore it is the Fisher (Tornqvist) formula which is approximately transitive, and this holds true whether the direct or chained approach is used in the compilation of an index. A similar argument applies to the concepts of a superlative index formula or a symmetric index formula.

As with their direct counterparts, the chained Fisher and Tornqvist indexes are only approximately consistent in aggregation while the chained Laspeyres, Paasche and Vartia indexes are exactly consistent in aggregation. One notable difference is that all chained index formulae use current weighting information, including the chained Laspeyres index. The next section considers the properties of chained indexes.

TABLE 4.1 PROPERTIES OF DIRECT PRICE INDEX FORMULAE

Property	L_t	P_t	F_t	T_t	$V1_t$
Consistency in aggregation	Y	Y	A	A	Y
Factor Reversal Test	N	N	Y	N	Y
Product Test	Y	Y	Y	Y	Y
Proportionality	Y	Y	Y	Y	N
Transitivity	N	N	A	A	A
Superlative	N	N	Y	Y	N
Divisia-type indexes	N	N	N	Y	Y
Use of current weights	N	Y	Y	Y	Y
Symmetric	N	N	Y	Y	Y
Weights sum to unity	Y	Y	Y	Y	N

5. PROPERTIES OF CHAINED PRICE INDEXES

5.1 Properties

The gap between the Laspeyres and Paasche indexes will often be substantially reduced by the use of chaining. It is expected that the chained Laspeyres index will increase less than the direct Laspeyres index and the chained Paasche index will increase more than its direct counterpart. This will not always be the case, but is likely to occur whenever prices and quantities are roughly monotonic.

Chaining tends to reduce the divergence between alternative price index formulae. This is the case provided that changes in prices and quantities are fairly smooth and that chaining is done frequently. Chaining usually reduces the divergence between alternative formulae as price and quantity changes will generally be smaller between adjacent periods than changes relative to a fixed base.

The use of the chain principle allows a closer match between products in consecutive time periods than is obtainable with direct indexes where periods which may be considerably apart are compared. The number of goods whose prices can be compared directly is reduced the further apart the time periods become. If a chained index is employed the amount of price information which can be used is greatly increased. The problem created by new and disappearing products and changes in the quality of products is minimised by using this more up to date and relevant weighting structure.

Chained indexes are likely to be an improvement over direct indexes for the purpose of long-run comparisons. This is because weights have maintained their consistency across the intervening periods. For medium and long-run periods where tastes, incomes, technology and the availability of resources change substantially, chained indexes provide the only worthwhile economic comparisons.

In the shorter run, if there is a close correspondence between production or expenditure in the base period and period t, direct indexes provide a valid comparison between the two periods. Symmetric direct indexes are preferred to the direct Laspeyres or Paasche indexes for measuring price change between two such periods.

Direct indexes only provide a measure of price change between the base period and any other period. However, they are often used to provide indirect measures of the change in price between period t and period $t+1$. The interpretation of the direct Laspeyres index as measuring the change in price of a fixed basket of goods and services, means that such a comparison can be made for that formula. Any direct index formula which introduces current weighting will produce a series which does not allow comparison between any two periods unless one period is the base period. Only chained versions of such formulae can be considered as relevant in a situation where consistent time-series are required for analysis.

The relationship between a direct index and the corresponding chained index will not always be the same. It will depend on the paths followed by individual prices and quantities over time. If the prices and quantities that occur in the base period (period *0*) are returned to in period *n*, the direct Laspeyres and Paasche indexes will be equal in the two periods. However, chained indexes which use the intervening period *t* as a link do not possess this property. The more prices and quantities fluctuate, the more the chained index is likely to diverge from its corresponding direct index. This is known as drifting *(see Glossary)*. For this reason chained indexes should not be used when prices fluctuate substantially.

If a chained index is exactly equal to its direct counterpart the index formula is transitive. By definition there is no drifting. None of the formulae considered satisfy this property exactly, although the Fisher, Tornqvist and Vartia formulae are approximately transitive.

A chained index should be used when relative prices in period *0* and period *n* are different from each other and chaining involves linking through intervening periods in which the relative prices and quantities are intermediate. A chained index should not be used if linking is through a period in which the prices and quantities lie outside the range of those which occur in period *0* and period *n*. This is likely to occur if price and quantity data are seasonal and the index is linked every period. It may also occur when price and quantity data is unseasonal but still volatile. Generally situations will be favourable to the use of the chain principle. However, sub-annual chaining of data which is subject to seasonality is not desirable. Unfortunately, the existence of such conditions can only be known after the event which poses problems in determining whether chain indexes should be adopted. It is necessary to make an informed judgement, reflecting past experience, as to the likelihood that future conditions will be suitable for the use of chain indexes.

Systematic price fluctuations (oscillations) must have a period longer than the length of a single link to cause drifting of chained indexes. Thus, seasonality of prices is not a problem where an annual link is used. Oscillations which complete their cycle within a link do not contribute bias to a chained index, although the intervening values may be affected. According to Forsyth and Fowler (1981), oscillating prices, regardless of the length of the cycle, cause no problems unless the item quantity moves simultaneously with its price.

When price and quantity data are fluctuating substantially, it is possible that an aggregate chained index may lie outside the range of its components. Such a situation should be avoided wherever possible, by not using chained indexes when prices are volatile or in the context of price wars.

When the divergence between alternative formulae can be reduced by chaining, the choice of price index formula becomes less important. There may still be advantages in choosing a Fisher or Tornqvist index. These indexes more closely approximate the theoretic indexes implied by the economic approach and are consistent with a range of functional forms for the underlying unit cost function. Chained Fisher and Tornqvist indexes are likely to perform better than chained Laspeyres and Paasche indexes when there are fluctuations in prices and quantities. They are likely to be less sensitive to chaining through unlike periods. In particular, the chained Fisher index comes very close to achieving transitivity.

The Divisia index provides a satisfactory theoretical basis for the use of the chain principle. Chained Vartia and Tornqvist indexes can be regarded as the best approximations of the Divisia index. Chained indexes are generally better approximations to this continuous time index than are direct indexes.

A further advantage of chain indexes 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 measure into question.'[9]

5.2 Obstacles to use of Chaining

The benefits of using chained indexes have been recognised in official statistics with most consumer and producer price indexes incorporating some form of chain linking. Indexes may be linked annually or far less frequently at the macro level, while frequent chaining is usual at the micro level. Chain linking Laspeyres indexes every five or ten years is a common practice and leads to a more representative price index than using the fixed-weight Laspeyres formula. However, this practice fails to achieve the wider benefits of using a chained index with regular and frequent linking.

There are several reasons why the chain principle is not fully implemented in official statistics. These disadvantages of chained indexes are outlined below:

- Costly as requires information on both prices and quantities in all periods.
- Collecting the required information is time consuming and may delay publication of the index.
- Chained indexes may be liable to systematic drifting in oscillatory conditions.

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9 United Nations (1993), paragraph 16.74.

- Chained indexes do not possess the property of additivity. This is only a concern for volume indexes.
- There is insufficient understanding about the properties and behaviour of chained indexes.

The tradable and non-tradable price indexes presented in this paper are compiled retrospectively and so these obstacles to compiling chained indexes are not encountered. The main impediment to statistical agencies releasing chained price indexes is the difficulty of obtaining the information needed for regular changes to the weights in a timely fashion. This would require a regular and detailed collection of expenditure or value information. This information would then be used to form the weights used in compiling the price index. Due to the cost of implementing such a procedure and the time constraints to which price indexes are compiled, releasing chained price indexes based on current weighting data is generally not feasible. As a consequence the chained price indexes which do appear in official statistics are generally linked infrequently. However, international statistical agencies are increasingly compiling chained volume indexes as part of the National Accounts.

It is not necessary for the frequency of linking to be exactly the same as the frequency of the index. For consumer and producer price indexes it is generally undesirable to chain link an index quarterly as the presence of seasonal price and quantity data which is highly correlated would lead to substantial drifting of the chained index from its direct counterpart. Of those countries which produce a chained index, many construct a quarterly index with annual links.

Others construct estimates of the unknown current weights based on period *t-1* or *t-2* or some average of the two. Countries whose indexes are nominally a fixed-weight Laspeyres index may use some form of chaining in calculating the micro-level component indexes.

5.3 Why should Chained Indexes be used ?

The United Nations' System of National Accounts (1993) recommends the use of the chained approach to constructing indexes in preference to the direct approach. In particular a chained Fisher index is recommended, with linking on an annual basis.[10]

[10] Note that the guidelines do not make an explicit choice between the Fisher and Tornqvist formulae. The Tornqvist index is mentioned as being quite similar in properties to the Fisher index, but later in the report the focus is solely on the Fisher index in comparison to the Laspeyres and Paasche indexes.

Some relevant paragraphs from the United Nations' System of National Accounts (1993) are reproduced below:

> 'On balance situations favourable to the use of chain Laspeyres and Paasche indexes over time seem more likely than those that are unfavourable.'[11]
>
> '...the index number spread between Laspeyres and Paasche indexes may be greatly reduced by chaining when prices and quantities move smoothly over time. ... When the index number spread can be reduced by chaining, the choice of index formula assumes less significance as all relevant index numbers lie within the upper and lower bounds of the Laspeyres and Paasche indexes. Nevertheless, there may still be some advantages to be gained by choosing an index such as the Fisher or Tornqvist that treats both period being compared symmetrically.'[12]
>
> 'The preferred measure of year to year inflation for GDP is therefore a chained Fisher price index, price changes over longer periods being obtained by chaining the year to year price movements.'[13]
>
> 'Chaining avoids introducing apparent changes in growth or inflation as a result of changing the base year.'[14]
>
> 'Although the preferred measure of real growth and inflation for GDP is a chain Fisher index, or alternatively a chain Laspeyres or Paasche index, it must be recognised that the lack of additive consistency can be a serious disadvantage for many types of analysis in which the inter-relationships between various flows in the economy are the main focus of interest. ... The need to publish two sets of data that may appear to conflict with each other should be readily appreciated by analysts engaged in macroeconometric modelling and forecasting.'[15]

Case studies support the view that chaining generally reduces the spread between Laspeyres and Paasche indexes. Chaining also reduces the difference between Tornqvist, Fisher and Vartia indexes, although these differences are usually minimal to begin with. In accordance with theory, the use of the chain principle appears to bring the results from all index formulae closer together, as compared to the direct approach. However, a chained price index with weights changing seasonally may be unstable and increasingly diverge from the direct index.

The choice between chained and direct indexes does matter, especially in periods with turbulent economic conditions. In studies which have included the two oil crises significant differences were found between the two approaches.[16] The difference in outcomes also depends on the aggregation level of the calculations.

11 United Nations (1993), paragraph 16.49.

12 United Nations (1993), paragraphs 16.50, 16.51.

13 United Nations (1993), paragraph 16.73(b).

14 United Nations (1993), paragraph 16.74.

15 United Nations (1993), paragraph 16.75.

16 See Diewert (1978) and Netherlands Central Bureau of Statistics (1982).

Forsyth and Fowler (1981) summarise the essential argument in favour of chained indexes over binary indexes *(see Glossary)* as follows. 'At present index number work throughout the world is dominated by the use of binary indexes ... the great superiority of chain over binary indexes lies in their much greater representivity in all time comparisons'.[17]

The main arguments in support of chained price indexes are summarised below:

- Reduces the divergence between alternative price index formulae. The choice of formula therefore becomes less important.
- Valid price comparisons can be made between any two periods in a chained price index.
- Allows the problems created by new and disappearing products to be minimised, through the use of an up-to-date weighting structure.
- Leads to a substantial improvement over direct indexes for the purpose of long run comparisons.
- Provides a better approximation to the Divisia index than do direct indexes.
- Avoids introducing apparent changes in the growth rate of the price index as a result of changing the weighting base period.

The arguments in favour of chaining price index formulae appear to outweigh the disadvantages. This assumes that the required data are available and that price and quantity time-series are roughly monotonic. However, if prices and quantities are volatile, direct indexes are to be preferred.

If it is decided that the chaining method is desirable and feasible, several further decisions are required. The formula to be used in the links needs to be determined, according to the properties outlined in Section 4 and practical considerations. The length of the links also needs to be determined. The links are usually of equal length, but this is not necessary. The length of the link should not be more than a few years where data are quarterly as weighting information quickly becomes out of date. It is usual for linking to be done annually for quarterly indexes due to weighting data not being collected at a quarterly frequency or not being collected with the required timeliness, and to avoid the problems caused by seasonality.

[17] Forsyth and Fowler (1981), p. 243.

6. AN EMPIRICAL APPLICATION

The original motivation for this paper lies in a continuing project which aims to develop price indexes and measures of output for the tradable and non-tradable sectors of the Australian economy. A good or service is defined as tradable if it is actually traded internationally, as are exports, or if it could be traded internationally at some plausible variation in relative prices. This latter category includes domestically produced goods and services which substitute for imports in the domestic market or could compete with exports in the international market but are currently consumed domestically.

It became clear that in constructing price indexes for these sectors, the choice of index formula would be an important issue, and one which had not previously been considered in the literature relating to tradables. In Section 6.1, a brief outline of the project is provided. Details of the methodology and results will be available in Knight and Johnson (1996). Section 6.2 discusses the choice of an appropriate index formula, while Section 6.3 provides quantitative evidence as to the impact of this choice.

6.1 Development of Tradable and Non-Tradable Price Indexes

The tradable/non-tradable dichotomy is seen by Goldstein and Officer (1979) to have special relevance to the analysis of international trade, exchange rate, inflation and resource allocation issues. The distinction between the tradable and non-tradable sectors is increasingly being referred to in policy discussion, particularly in relation to Australia's external imbalance. However, there is a recognised difficulty in obtaining data along tradable and non-tradable lines. This project seeks to address the problem through the compilation of a database containing integrated output and price data at both an industry and sectoral level.

The distinction between the tradable and non-tradable sectors of the economy is particularly relevant to econometric modelling of a small, open economy such as Australia. It has an important place in Australia's contribution to open economy macroeconomics, specifically the 'Australian model' of Salter (1959) and Swan (1960, 1963). In this model, a small open economy is comprised of traded and non-traded sectors. The relative prices of traded and non-traded commodities determine the allocation of resources between the sectors.

Previous estimates of the relative price of traded and non-traded goods in Australia have been made by Wilson (1931), Shann (1982), Pitchford (1986) and Dwyer (1987, 1990, 1992). These estimates of relative domestic prices have been used to measure the internal competitiveness of Australia's tradable sector. The development of measures of tradable and non-tradable prices enables an analysis of the extent to which relative domestic prices influence the allocation of employment and investment across sectors.

Further, the price indexes compiled in this project will be a valuable resource for those seeking to explore the determinants of international trade flows, the behaviour of real exchange rates or the sources of inflationary pressure.

The tradable sector can be broken down into the importable and exportable subsectors. The volatile nature of the terms of trade indicates that price movements for importables and exportables can differ considerably. Similarly, the contribution of these subsectors to tradable output may change significantly over time. The adopted methodology facilitates analysis at the broad level of tradables and at the more detailed level of importables and exportables.

The methodology used in compiling these measures is largely based on the work of Dwyer (1992). Measures of industry gross product were obtained from the Input/Output tables at the 109 industry level.[18] Using these data, estimates of the export orientation and the scope for import substitution were formed for each of the industries. If these estimates exceeded a given threshold value an industry was classified as exportable or importable for the relevant year. The industry profiles of the importable, exportable, tradable and non-tradable sectors, and their total gross product, have been estimated using this methodology. The industry profile of the sectors has been determined in each year for which an input/output table was released.

This method of classification is a substantial improvement upon the standard practice of subjectively assigning broad industry categories to the tradable and non-tradable sectors. Not only is this method more objective but it can reflect the dynamic changes which occur in the composition of the tradable and non-tradable sectors over time. Further, by working with a highly disaggregated classification, identification of the size of these sectors is more precise. The observable characteristics of Australian production are also better represented by allowing for the tradable sector to include industries with a substantial degree of export orientation or import substitution, rather than specific industries being unrealistically assumed to be solely export or import industries.

For each of the 109 industries a corresponding price index has been formed using disaggregated price data from a variety of sources. Where possible the source price indexes correspond to the concept of the price received by domestic producers for their output, regardless of whether it is sold domestically or exported. The information on the profile and output of each of the sectors defines a set of weights. From this price and weighting data, composite price indexes relating to the importable, exportable, tradable and non-tradable sectors have been compiled.[19] It is in compiling these sectoral price indexes that the choice of index formula becomes relevant. The issues raised in making this choice will be discussed in Section 6.2.

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18 *Australian National Accounts: Input Output Tables* (5209.0).

19 Composite price indexes have also been compiled at the 28 industry level of the input/output tables.

A study by the Netherlands Central Bureau of Statistics (1982), which closely parallels the application of index theory to measuring the price of tradables, provided a guide to the expected quantitative implications of the choice of price index formula. The Dutch study involved the construction of annual time-series over the period 1951–77 for 106 disaggregated private consumption expenditure categories and their corresponding price indexes. There were several intermediate levels of aggregation between the 106 and 1 (total consumption) category levels. Over 1,000 price series were used to compile the 106 level price data. These price indexes were combined to form the composite indexes using weights on the expenditure shares of each category. The Laspeyres, Paasche, Fisher and Tornqvist formulae were considered on both a direct and chained basis.

In the Dutch study, estimates of private consumption expenditure were made (as compared to estimates of gross product in the tradables study which is outlined earlier in this section) at a similar level of disaggregation to that of the current study. Price indexes corresponding to expenditure categories (industries) were compiled. Composite price indexes referring to aggregate consumption categories (tradable and non-tradable output) were constructed. In both the Dutch study and the tradables study the choice of price index formula was important, as was the issue of consistency in aggregation.

The Dutch study indicates that the choice between the chained Tornqvist and Fisher formulae is unlikely to have an impact upon the results, particularly in periods where price behaviour is roughly monotonic. The results are somewhat different to those obtained when one of the alternative formulae is used. In particular the direct Paasche and Laspeyres indexes can display large differences, although the gap is somewhat reduced by chaining. Whatever the choice of price index formulae, the results are highly correlated. The evidence indicates that the lack of consistency in aggregation of the Fisher and Tornqvist indexes is unlikely to pose a problem. This is because in practice they are virtually consistent in aggregation, at least to any reasonable level of accuracy.

6.2 Choice of Index Formula

There is no single index formula which can be said to be preferable in all circumstances. It is necessary to relate the choice to the purpose for which the index is being compiled. In Sections 4 and 5 the theoretical properties of index formulae were discussed in general, but were not specifically related to a practical example. In this section the main factors influencing the choice of index formulae for measuring the price of tradables are discussed. All of the broad categories are likely to remain relevant to the choice of price index formula in any context, although their relative importance and the preferred formula will depend on the precise application. In Section 6.2.2, recommendations are made regarding the preferred index formula for measuring the price of tradables in Australia.

6.2.1 Factors influencing the Choice of Formula

In many practical implementations of price index theory the availability of data will be a crucial factor. A lack of regularly updated weighting data is a key reason for the widespread use of the direct Laspeyres index. In this project, data requirements are met for the direct and chained Laspeyres, Paasche, Tornqvist and Fisher indexes. The direct Laspeyres index requires only the component price series and base year weights. The direct Paasche and Tornqvist indexes, together with all of the chained indexes, require the component time-series of weights and prices. The Fisher index requires the Laspeyres and Paasche indexes as inputs.

Some interpolation of weighting data was necessary due to the infrequent release of input/output tables. There is a substantial lag before weighting information for the current period becomes available. This necessitates the use of extrapolation or forecasting of weighting information to produce price indexes for the current period. Data availability is likely to be of prime importance in choosing a price index formula and in the practical implementation of that choice.

The nature of the data is also a key factor in the choice of index formula. If prices growth is relatively steady over time, as it is for industries belonging to the non-tradable sector, then there is little or no benefit from adopting a more complex formulation as all index formulae provide similar results. The exportable and importable sectors include mining, agriculture and manufacturing industries where prices tend to be volatile. This evidence suggests that the choice of index formula could make a sizeable difference to measures of price change in the tradable sector, but is likely to be unimportant for the non-tradable sector.

Chained indexes tend to exhibit substantial drifting if used when price and weighting data are highly seasonal. In such circumstances the use of chained indexes with sub-annual linking is not recommended. Seasonality was observed only in the price indexes for 'restaurants, hotels and clubs' and several agricultural industries.[20] The general absence of seasonality in the 109 industry price indexes meant that chaining indexes on a quarterly rather than an annual basis was feasible in this project. In other applications, seasonal price data may be prevalent and annual linking would be preferred to quarterly linking of chained indexes.

Drifting of chained indexes due to seasonal data is most likely to occur in the exportable sector. Experimental data analysis for this sector showed little difference between chained indexes constructed using annual and quarterly

20 Prices are seasonal in the Cereal grains, Milk cattle and pigs, and Meat cattle industries.

links, since the interpolated quarterly weights effectively serve as an approximation to annual chaining. The evidence supports the conclusion that seasonality is not a problem with this dataset and that chained indexes with quarterly links are appropriate. The decision to link quarterly or annually is particularly relevant to the Laspeyres and Paasche formulae. The choice is of lesser relevance for superlative formulae as the direct and chained indexes are very similar due to the approximate transitivity of these formulae.

The weighting time-series are obtained by interpolating industry gross product data. As a consequence, the time-series of weights is generally smooth. However, the methodology can result in quite volatile weighting data. Consider an industry which contributes 5% to exportable output in 1980–81, but drops out of the exportable sector the following year. In 1981–82 the weight of this industry to the exportable sector falls to zero. The weight of this industry to the non-tradable sector rises from zero in 1980–81 to maybe 2% in 1981–82. Interpolated quarterly weights are used rather than the annual average. This smooths the effect of shifting industries on weighting patterns and the composite price indexes. Nevertheless, shifting industries can lead to significant changes in the weighting pattern and the adopted index formula needs to be able to cope with this feature of the data.

The theoretical properties of the various formulae and of chaining are discussed in Section 4 and Section 5. The properties which were particularly relevant in the context of tradables are now discussed in turn.

Most important is the fact that alternative formulae produce results which tend to diverge over time. Price movements in the tradable and non-tradable sectors need to be accurately measured for the indexes to be useful in analysis. Therefore it is important to know whether the choice of formula alone could be responsible for much of the observed change. The importance of the choice of price index formula is dependent on the extent of the index number spread.

The microeconomic justification for an index refers largely to the functional form of the unit cost function for which a formula is exact, and whether the formula is superlative. Also grouped under this broad category are theoretical properties such as the Divisia nature of certain formulae and constant returns to scale. Superlative formulae approximate each other very closely, and so using a superlative formula to compile price indexes for tradables and non-tradables largely overcomes the problem of the index number spread. A similar argument applies to symmetric formulae, especially when chaining is used. Diewert (1993) claims that the Tornqvist price index, which has a very satisfactory economic interpretation in the case of a single producer, also has a reasonable economic interpretation in the aggregate production context.

Consistency in aggregation requires that the numerical value of the tradables price index calculated by aggregating the price indexes compiled for the importable and exportable sectors, necessarily coincides with a tradables price index which is compiled directly from the data for all contributing industries. Similarly, if a formula which is consistent in aggregation is used, the overall price index will be exactly the same regardless of whether it is calculated directly or indirectly through several stages of aggregation. The Fisher and Tornqvist formulae are only approximately consistent in aggregation.

Drifting of chained indexes occurs when prices and quantities are inversely correlated and fluctuate a great deal. It is most evident when data are highly seasonal. The term refers to the divergence between a chained index and its direct counterpart. The extent of drifting is dependent on the extent to which an index formula satisfies the property of transitivity. The price and weighting data used in this project are not generally seasonal but can be quite volatile in industries belonging to the tradable sector.

The use of an up-to-date and relevant weighting structure is crucial to the development of price indexes which accurately reflect compositional change in the tradable and non-tradable sectors. The fixed-weight Laspeyres index does not allow for change in the composition of sectors. The use of chained indexes allows a closer match between industries in consecutive time periods than do direct indexes where periods which are considerably apart are compared. Therefore, problems created by shifting industries can be minimised by chaining.

The Vartia index has the property that the weights do not necessarily sum to unity and it does not satisfy the proportionality test. These factors would complicate the interpretation of any results compiled using this formula.

The empirical evidence relating to these theoretical properties was an important factor in choosing the preferred price index formula. The evidence is outlined in Section 6.3 and includes the results of previous studies into the empirical properties of price index formulae. The analysis of the impact of the choice of index formulae when measuring the price of tradables was important in determining whether appropriate choices had been made.

Taken together, the two sources of empirical evidence indicate the following:

- The choice of formula can significantly influence the measurement of prices in the tradable sector as alternative formulae may diverge considerably. When prices are less volatile the choice of formula is less important.
- For all practical purposes the Fisher and Tornqvist formulae are consistent in aggregation.
- Chaining may not be desirable when price and quantity data are volatile or even if there is a single dramatic change. In the context of developing

measures of relative domestic prices there are overall benefits from adopting the chain principle when a superlative formula is used in the links. The situation is less clear in the case of the Laspeyres and Paasche formulae.

- The Fisher and Tornqvist formulae closely approximate each other, particularly when chained.

The choice of index formula for use in compiling a tradables price index is predicated on the data not being exceptionally volatile or seasonal. Exactly how volatile does the source data have to be for the chain principle to no longer be beneficial? Unfortunately, there are no clear answers. If the results had indicated that chaining was worsening the divergence between alternative formulae or causing considerable drifting of chained indexes, the choices outlined in Section 6.2.2 would have been revised.

The recommendations of the United Nations' System of National Accounts (1993) were important in choosing the most appropriate index formula. Some relevant extracts are provided in Section 5.3. Specifically, the recommendations of the Fisher/Tornqvist formulae and of chained indexes over direct indexes were influential.

Users of a measure of the price of tradables may require the index to have certain properties. It is generally expected that the tradables price index would be used in economic analysis and that a measure of effective price change which reflects changes in the composition of the tradable sector over time would be required. Further, an index which enables direct comparisons to be made between any two periods is required. For this reason chain indexes are preferred to direct indexes, which only enable direct comparisons to be made between the fixed base period and any other period.[21]

It is felt that the chained Tornqvist index would best meet the needs of users. However, in circumstances where it is desirable to analyse purely the price movements, unaffected by changes in composition, a fixed-weight index will be preferred to a current weighted index.[22] Due to the diversity of user requirements, in addition to the preferred chained Tornqvist index, results are also compiled using the direct Laspeyres formula.

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21 However, the interpretation of the direct Laspeyres index as the change in price of a fixed basket of goods and services, allows for a valid indirect comparison to be made between any two periods.

22 While a fixed-weight Laspeyres index is used to compile price indexes for the sectors from the 109 industry price indexes, the source data often incorporates changing weighting patterns. For example, several of the 109 industries are represented by National Accounts derived deflators. These are Paasche price indexes. The direct Laspeyres index cannot measure pure price change as it does not completely abstract from changes in the composition of industries. However, it is a useful approximation of this concept.

When used in analysis it is likely the growth rate of the price index will be used rather than the price index itself.[23] Therefore it is desirable that the growth rate, and not just the price index itself, has desirable properties. Due to the logarithmic formulation of the Tornqvist formula it is likely to satisfy this requirement. Users may prefer a chained index to a direct index as chaining avoids introducing apparent changes in inflation as a result of changing the base year.

6.2.2 Preferred Price Index Formula

The following choices were made concerning the method to be used in compiling the composite price indexes for the tradable and non-tradable sectors. It should be emphasised that these recommendations are specific to the retrospective compilation of price indexes for the tradable and non-tradable sectors of the Australian economy. The preferred price index formula will depend on the purpose for which the index is being compiled and pragmatic considerations such as those outlined in Section 5.2.

- *A chained index is preferred to a direct index, regardless of the formula chosen.*
  The arguments for and against chained indexes are summarised in Section 5. This conclusion is supported by the recommendations of the United Nations' System of National Accounts (1993). The benefits of using a chained index appear to outweigh any disadvantages, especially if the Fisher or Tornqvist formulae are used as they are less sensitive to chaining through unlike periods. Most importantly, chain indexes allow direct comparisons to be made between any two periods, whereas direct indexes only enable direct comparisons to be made between the fixed base period and any other period. The point has been made that the chain principle should not be used where data exhibit substantial or regular fluctuations. Do the 109 industry price series suffer from such fluctuations? Despite the existence of several price series which are quite volatile, most of the component series are roughly monotonic.[24] Seasonal fluctuations are not generally evident in the price data.[25] This recommendation would be revised if the results indicated that the data were sufficiently volatile to overcome the potential benefits of chaining.

- *The chained index is to be linked on a quarterly basis rather than an annual basis.*
  When price data are quarterly, the price index may be chained annually if up-to-date quarterly weighting data are not available or if price and quantity data are seasonal and correlated. Since historical data are used, timeliness is not a problem. If price and quantity data were seasonal and

[23] The growth rate of prices can be calculated as the first difference of the logarithm of the price index.

[24] Agricultural, mining and food manufacturing industries exhibit significant fluctuations in prices.

[25] Only a few of the 109 industries (several agricultural industries and the restaurants, hotels and clubs industry) show signs of seasonal price behaviour.

correlated, chained indexes with quarterly links would be likely to diverge considerably from their direct counterparts. Fortunately this is not a problem with this dataset as prices are generally not seasonal. The use of interpolated quarterly weights serves as an approximation to annual chaining and has the additional advantage of smoothing the impact of shifting industries. There is no reason why the composite price indexes should not be linked quarterly.

- *The Fisher and Tornqvist formulae are preferred to the Laspeyres, Paasche and Vartia formulae.*
  The main reason for this choice is the minimisation of the index number spread. Further support for the use of these formulae is provided in Section 4.2 and Table 4.1. These two preferred formulae are very similar: their advantages and disadvantages tend to balance out. If a choice is to be made, the Tornqvist index is preferred for the purpose of compiling composite price indexes for the tradable and non-tradable sectors. Due to its strong microeconomic justification in the context of production, Divisia nature, growth formulation and symmetric formula the Tornqvist index is often preferred in economic modelling.[26]

- *A range of price indexes is calculated corresponding to alternative formulae.*
  This makes the sensitivity of measures of price change to the choice of formulae more transparent, and allows users to choose the index formula most suitable for their intended use. The chained Tornqvist is the main index to be released and is recommended for most analysis and modelling applications. If a pure measure of the change in price is required, one that does not allow changes in the composition of the sector or industry to impact upon the measure of price change, the direct Laspeyres index would be preferred. An additional benefit of calculating price indexes using a range of formulae is the in-built checking mechanism this provides. This is very important given the complexity of calculations. It is only intended to release the chained Tornqvist and direct Laspeyres indexes, while price indexes calculated using other formulae will be available on request.[27]

6.3 Impact of the Choice of Formula

In this section a closer look is taken at the impact of the choice of index formula on the measurement of sectoral price indexes. In particular we are looking to identify the extent of the index number spread in this application. The effect of using chained indexes when price data fluctuate will also be examined. Also of interest is how closely the Tornqvist and Fisher formulae approximate the property of consistency in aggregation.

26 See Martin and Nguyen (1989).

27 Composite price indexes have been compiled using direct and chained Laspeyres, Paasche, Fisher and Tornqvist formulae, for the tradable, non-tradable, importable and exportable sectors and for each of the 28 aggregate industries.

6.3.1 Impact on measurement of prices

Eight different price index formulae were considered: these were the direct and chained Laspeyres, Paasche, Fisher and Tornqvist formulae. These formulae are used to compile composite price indexes for the importable, exportable and non-tradable sectors. The sectoral price indexes have a reference year of 1989–90 = 100.0.

Table 6.1 illustrates the divergence between alternative formulae, by reproducing the values for the different non-tradable price indexes for the September quarter 1994. The Tornqvist and Fisher formulae closely approximate each other whether the direct or chained approach is used. In the example given, chaining reduces the gap between the Laspeyres and Paasche formulae. This is a standard argument in favour of the chained approach. However, if price data are volatile or seasonal this benefit of chained indexes may no longer hold.

The differences between the alternative formulae, and the benefits of chaining, may seem quite small. However, the results in Table 6.1 are of a magnitude which is typical of other studies in the field. The greater volatility of prices in the importable and exportable sectors causes greater divergence between the results from the alternative price index formulae.

TABLE 6.1 THE INDEX NUMBER SPREAD
Non-Tradable Sector

Price index formulae	*Value in September quarter 1994*
Direct Laspeyres	113.9
Direct Paasche	113.1
Direct Fisher	113.5
Direct Tornqvist	113.5
Chained Laspeyres	113.7
Chained Paasche	113.3
Chained Fisher	113.5
Chained Tornqvist	113.5

While there has been fairly extensive literature relating to price index theory, the empirical literature is rather limited. There are several practical illustrations of the index number spread. Studies by Fowler (1970), Diewert (1978) and the Netherlands Central Bureau of Statistics (1982) use different real-world data sets to show that chaining brings the results from alternative formulae closer together, and specifically that chaining reduces the gap between the Laspeyres and Paasche formulae. Diewert considers the divergence between the direct Paasche and Laspeyres indexes to be of concern given their wide use.

Figure 6.1 is a graphical representation of the extent to which the choice of index formula impacts upon the measured value of importable prices. The graph is of the chained Tornqvist index, with the hi-lo marks representing the maximum/minimum value provided by any of the formulae at each point in time. It can be observed that the chained Tornqvist index always lies between the extremes. The same formula does not necessarily remain the maximum (minimum) over the entire period. However, the maximum (minimum) formulae will always be a direct or chained Laspeyres or Paasche index, not one of the symmetric formulae.

The impact of the choice of index formula on the measurement of importable prices is significant. This is particularly true in the early to mid 1980's. Around 1989–90 when all formulae are set to equal 100 there is almost no difference between formulae. Working back from the base period there is little detectable difference between the formulae until late 1986 when a sharp price movement is picked up to differing extents by the various formulae. This discrepancy is never fully corrected for. A similar effect is apparent in early 1991.

In Table 6.2, annual growth rates for prices in the importable sector are provided based on each of the alternative formulae. The notation used represents direct indexes by the letter *D*, chained indexes by the letter *C* and the formula by its first letter (e.g. direct Paasche is represented by *DP*). From this table it can be seen that while the chained Laspeyres and Paasche indexes provide similar estimates of the annual growth rate of importable prices, their direct counterparts can differ significantly. This is particularly evident in 1979–80. The small gap between the Fisher and Tornqvist formulae is also reduced by chaining.

It is when measuring change over longer periods of time that the choice between direct and chained indexes becomes most important. Over such a length of time when the composition of the sector may change substantially, the use of a chained price index formula can provide quite different results from a direct index formula. However, the price indexes resulting from the various formulae are all highly correlated with one another.[28] This is particularly true for the Fisher and Tornqvist formulae, especially when chained. A similar result is obtained for both the exportable and non-tradable sectors.

[28] All formulae pairs have correlation coefficients of at least 0.98.

FIGURE 6.1 IMPACT OF FORMULAE ON IMPORTABLE PRICES

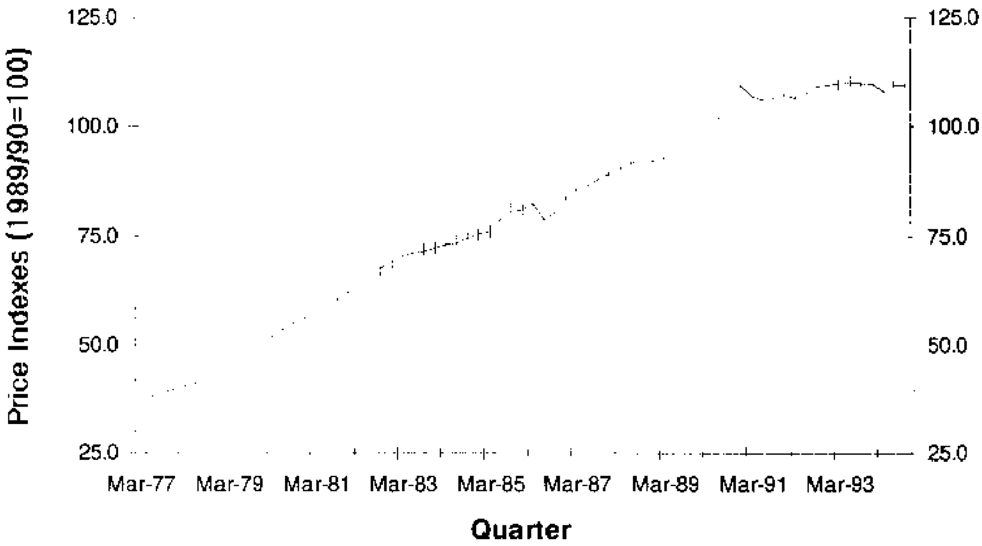

TABLE 6.2 IMPACT OF FORMULA ON PERCENTAGE GROWTH RATE OF IMPORTABLE PRICES

YEAR	*DL*	*DP*	*DF*	*DT*	*CL*	*CP*	*CF*	*CT*
1977-78	8.4	8.6	8.5	8.6	8.0	7.8	7.9	7.9
1978-79	13.0	11.5	12.2	12.0	10.9	10.5	10.7	10.7
1979-80	20.6	17.3	18.9	18.4	17.7	17.2	17.4	17.4
1980-81	11.2	9.0	10.1	9.8	10.4	10.4	10.4	10.4
1981-82	9.5	11.9	10.7	11.0	11.1	10.9	11.0	11.0
1982-83	8.1	8.5	8.3	8.7	8.4	8.3	8.4	8.4
1983-84	3.8	4.5	4.2	4.1	3.7	3.6	3.7	3.6
1984-85	7.7	5.9	6.7	6.8	7.2	7.0	7.1	7.1
1985-86	-2.6	1.7	-0.5	-0.2	1.0	-1.8	-0.4	-0.2
1986-87	10.5	9.6	10.1	10.1	10.1	9.7	9.9	9.9
1987-88	5.5	6.6	6.1	6.0	6.0	5.8	5.9	5.9
1988-89	4.4	4.9	4.6	4.6	5.0	4.4	4.7	4.7
1989-90	6.4	6.5	6.5	6.5	6.6	6.4	6.5	6.5
1990-91	3.8	3.7	3.8	3.8	4.8	2.7	3.8	3.8
1991-92	1.6	1.3	1.5	1.5	1.5	1.4	1.5	1.5
1992-93	2.8	2.5	2.7	2.7	2.7	2.6	2.7	2.7
1993-94	-0.6	-0.6	-0.6	-0.6	-0.4	-0.8	-0.6	-0.6

The main criticism of chained indexes is that when prices are fluctuating chained indexes may exhibit drifting. As a consequence the index number spread may not be reduced by adopting the chain principle. A single dramatic price movement such as that observed in 1985–86 can create a substantial discrepancy between the different formulae for measuring price indexes.

Forsyth and Fowler (1981) conducted an empirical investigation of this property. Their study provides a practical illustration using oscillating price data with inversely correlated quantity data. The chained Laspeyres and Paasche indexes drift away from their direct counterparts. However, the chained Fisher index comes very close to achieving transitivity. The authors state that 'a binary index only achieves transitivity at a great sacrifice of representivity whereas a chained index with an appropriate choice of link formula is sufficiently flexible to achieve an acceptable level of transitivity while maintaining the greatest possible representivity.'[29]

Similar results are obtained in this study, despite the fact that the source data are not seasonal. The results for the index number spread of non-tradables which are presented in Table 6.1 are somewhat atypical. They show that chaining can reduce the index number spread, while for the importable and exportable sectors chaining generally increases the gap between the Laspeyres and Paasche formulae. This is because price and weighting data are relatively volatile in these sectors. However, chaining consistently brings the Fisher and Tornqvist formulae closer together, although the gap is small to begin with. In the exportable sector, the chained Fisher and Tornqvist price indexes tend to drift away from their direct counterparts, although the extent of drifting is less severe than for the Laspeyres and Paasche price indexes.

It has previously been noted that exportable prices are volatile compared to prices in the other sectors. As a consequence, the impact of the choice of index formula is likely to be most apparent in this sector. Figure 6.2 illustrates the magnitude of the index number spread for the exportable sector. The impact of the choice of index formulae is more significant than for the importable sector. For example, in the March quarter of 1980 the direct Paasche formula provides the minimum value of 61.0 and the chained Paasche formula provides the maximum value of 70.0. This is a difference of over 10%.

As is the case for the importable sector, the divergence between alternative formulae becomes evident at the times when prices are particularly volatile in late 1986 and early 1991. There is no advantage to using a chained Laspeyres or Paasche index when prices are volatile. In fact, even if prices exhibit only one sharp movement in a period, this can be sufficient to cause the chained Laspeyres and Paasche indexes to diverge substantially.

29 Forsyth and Fowler (1981), p. 243.

FIGURE 6.2 IMPACT OF FORMULAE ON EXPORTABLE PRICES

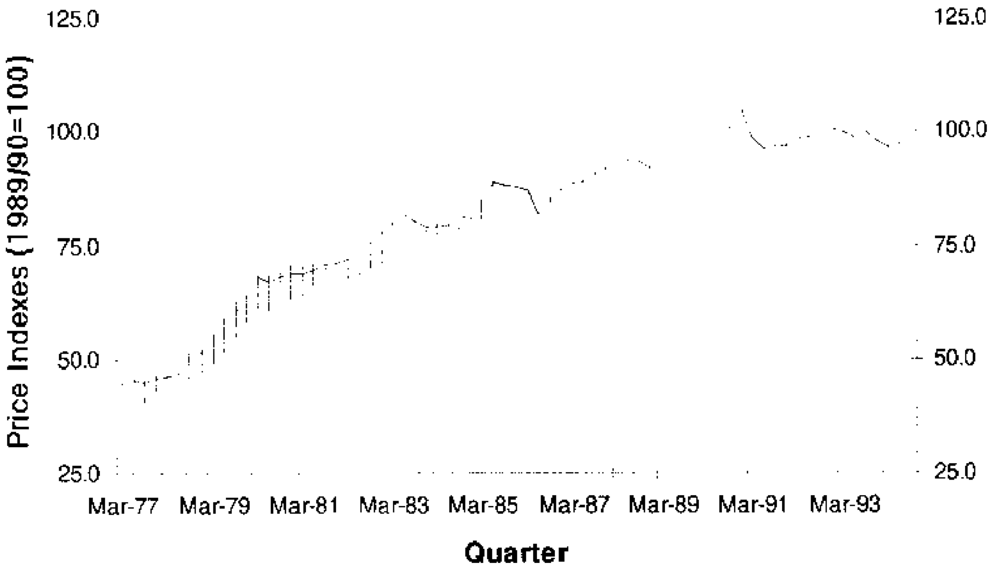

TABLE 6.3 IMPACT OF FORMULA ON PERCENTAGE GROWTH RATE OF EXPORTABLE PRICES

YEAR	*DL*	*DP*	*DF*	*DT*	*CL*	*CP*	*CF*	*CT*
1977-78	3.7	4.7	4.2	4.4	3.8	3.5	3.7	3.7
1978-79	21.7	22.1	21.9	22.1	21.6	21.0	21.3	21.3
1979-80	19.4	17.5	18.5	18.1	18.4	16.6	17.5	17.5
1980-81	5.4	5.5	5.4	5.3	4.2	3.8	4.0	4.0
1981-82	7.1	5.2	6.1	6.3	5.2	5.0	5.1	5.1
1982-83	11.5	13.7	12.6	12.7	12.1	11.3	11.7	11.7
1983-84	-2.1	-0.4	-1.3	-1.3	-2.5	-2.5	-2.5	-2.5
1984-85	12.8	12.6	12.7	12.5	11.7	11.4	11.6	11.6
1985-86	-8.1	-5.6	-6.9	-6.8	-7.1	-8.6	-7.8	-7.8
1986-87	9.7	9.1	9.4	9.4	9.1	8.5	8.8	8.8
1987-88	7.5	5.1	6.3	6.2	5.8	5.3	5.6	5.5
1988-89	4.4	5.9	5.1	5.2	5.3	4.5	4.9	4.9
1989-90	2.3	2.5	2.4	2.4	2.7	2.1	2.4	2.4
1990-91	-3.7	-6.0	-4.9	-4.8	-3.7	-6.0	-4.9	-4.8
1991-92	2.4	3.0	2.7	2.7	3.2	2.2	2.7	2.7
1992-93	1.0	-0.9	0.1	0.2	0.4	0.1	0.2	0.2
1993-94	-2.5	-0.5	-1.5	-1.7	-1.3	-2.0	-1.7	-1.7

For the exportable sector, the formulae have provided widely differing results in terms of the level of the price index. The same is true to a lesser extent for the importable sector. From Table 6.3 it can be seen that the choice of price index formula can strongly influence the annual growth rate obtained. Measures of the growth rate of the Laspeyres and Paasche price indexes are brought closer together by chaining in the importable sector, and this effect is also apparent in the exportable sector. In general, the chained indexes provide lower estimates of the annual percentage change in exportable prices than do the direct indexes. This is because the chained indexes diverge from their direct counterparts due to the relative volatility of conditions in the exportable sector.

These results tend to support the use of the Fisher and Tornqvist formulae. Both the gap between the levels, and the gap between the growth rates, of the price indexes compiled using these symmetric formulae are consistently reduced by chaining. Using the chained Laspeyres or Paasche indexes rather than their direct counterparts does not have clear benefits in this project. The drifting which is apparent in the exportable sector between the direct and chained superlative formulae is also of concern.

By focusing on the importable and exportable sectors the extent of the index number spread may be overstated. Figure 6.3 shows the impact of the choice of index formula on the price index for the non-tradable sector. Since prices increase in a roughly monotonic fashion for this sector, all formulae provide similar values for the sectoral price index.[30] From Table 6.4 it can be seen that the annual growth rate varies little with respect to the formula used in compiling the non-tradables price index. It is also evident that in the non-tradable sector chaining brings the results from all formulae closer together. The Tornqvist and Fisher formulae, whether constructed on a direct or chain basis, produce almost identical measures of both the growth rate and level of price indexes.

The choice of formula has an average impact of 0.3 percentage points per annum on the growth rate of non-tradable prices between 1977–78 and 1993–94.[31] This is typical of the results of studies in this field, and indicates that when price and quantity data are roughly monotonic the choice of index formula is less crucial.

[30] The stability of prices in the non-tradable sector is partly due to the fact that non-tradable commodities are less subject to external shocks. However, the sector is dominated by service industries for which price change is particularly difficult to measure. In particular, for many service industries only annual data are available, and must be interpolated to produce a quarterly price index. As a result the apparent stability of prices in the non-tradable sector may in part be a consequence of data limitations.

[31] The average of the gap between the highest and lowest estimates of the growth rate of prices. The average gap between the annual growth rates of the recommended direct Laspeyres and chained Tornqvist formulae is approximately half that. This also holds true for the importable and exportable sector results.

FIGURE 6.3 IMPACT OF FORMULAE ON NON-TRADABLE PRICES

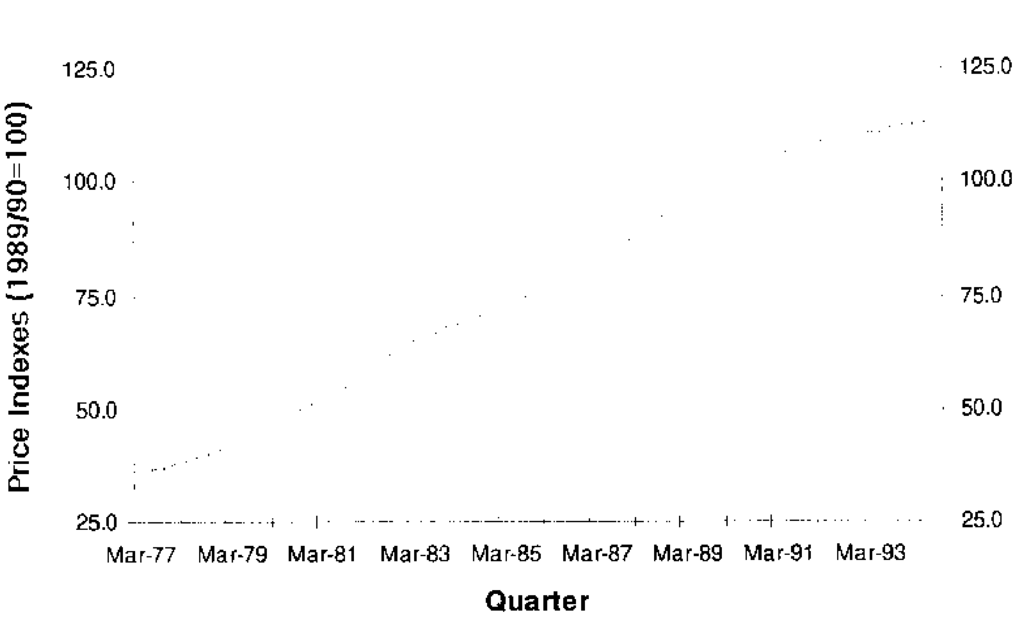

TABLE 6.4 IMPACT OF FORMULA ON PERCENTAGE GROWTH RATE OF NON-TRADABLE PRICES

YEAR	*DL*	*DP*	*DF*	*DT*	*CL*	*CP*	*CF*	*CT*
1977-78	6.5	6.6	6.5	6.6	6.8	6.7	6.7	6.7
1978-79	11.4	11.7	11.5	11.6	12.6	12.1	12.4	12.4
1979-80	10.9	10.4	10.7	10.6	10.9	10.7	10.8	10.8
1980-81	9.6	10.4	10.0	10.0	9.9	9.8	9.9	9.9
1981-82	11.3	11.4	11.3	11.3	11.4	11.3	11.4	11.4
1982-83	11.3	11.4	11.4	11.3	11.2	11.1	11.2	11.2
1983-84	5.0	5.6	5.5	5.5	5.6	5.5	5.5	5.5
1984-85	5.4	5.6	5.5	5.5	5.6	5.5	5.5	5.5
1985-86	4.7	5.0	4.9	4.9	4.9	4.6	4.8	4.8
1986-87	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1
1987-88	7.7	7.4	7.5	7.5	7.5	7.5	7.5	7.5
1988-89	7.3	7.2	7.2	7.3	7.2	7.1	7.2	7.2
1989-90	5.0	5.0	5.0	5.0	5.1	5.0	5.0	5.0
1990-91	4.5	4.3	4.4	4.4	4.5	4.3	4.4	4.4
1991-92	2.6	2.4	2.5	2.5	2.5	2.5	2.5	2.5
1992-93	1.7	1.6	1.7	1.7	1.7	1.6	1.7	1.7
1993-94	2.1	1.8	2.0	2.0	2.0	1.9	2.0	2.0

However, in the importable and exportable sectors the choice of formula has a much larger impact on the growth rate of prices of about 1.8 percentage points per annum over the same period for exportables and 1.4 percentage points per annum for importables. The results for the tradable sector indicate that the choice of index formula can have a significant impact upon the measurement of price change.

6.3.2 Consistency in Aggregation

While the Laspeyres and Paasche formulae are exactly consistent in aggregation, the Fisher and Tornqvist formulae do not have this property. However, they are approximately consistent in aggregation. Diewert (1978) tested for consistency in aggregation in the commonly used formulae. The chained Laspeyres, Paasche and Vartia indexes are exactly consistent in aggregation. The chained Fisher and Tornqvist index formulae are shown to be approximately consistent in aggregation 'to a very high degree of approximation indeed.'[32]

In this project it is desirable that the price indexes be consistent in aggregation. In particular we want the importable and exportable price indexes to combine to equal the tradable price index. Similarly we want the overall price index to be the same regardless of whether it is aggregated from importables, exportables and non-tradables, just tradables and non-tradables, or directly from the 109 component industries.

The tradables price index is calculated using two methods. The first method estimates the tradables price index by directly compiling a composite price index from the importable and exportable price indexes. The second method estimates the tradables price index by constructing a composite price index of all 109 level industries which contribute to the tradable sector.

In accordance with theory the Laspeyres and Paasche formulae are found to be exactly consistent in aggregation whether the direct or chained approach is used. The same price index is obtained regardless of which calculation method is used. For our purposes the chained Tornqvist index is approximately consistent in aggregation to a sufficiently high degree of approximation. The price index varies only slightly with the calculation method to the published level of accuracy. This is important as it is the preferred formula for measuring the price of tradables. Similar results are obtained for the direct Tornqvist index and the direct and chained Fisher indexes.

32 Diewert (1978), p. 896.

6.3.3 Re-examining the Choice of Price Index Formula

If the requirement is to obtain a pure measure of price change, abstracting from compositional changes in the sector of interest, the direct Laspeyres index is recommended. The above analysis shows that this measure can differ considerably from the alternative formulae.

The price index formula which is generally recommended is the chained Tornqvist formula. The use of chain indexes is preferred to direct indexes. While direct indexes simply calculate the price movement between the fixed base period and any other period, a chained index incorporates price and weighting changes within the intervening period, and so enables direct comparisons to be made between any two periods. Chaining also tends to reduce the spread between alternative formulae. The literature suggests that this property will not hold if the data are subject to substantial fluctuations.

The results presented in this paper are generally reflected in the empirical literature. They serve to highlight the fact that in practice alternative formulae can lead to quite different measures of price change. The results show that chaining is not necessarily beneficial. In certain, quite common, conditions chaining may worsen the index number spread – the chief advantage claimed of it. However, in the context of roughly monotonically changing prices, the use of the chain procedure is recommended.

When prices growth is relatively steady, as in the non-tradable sector, the choice of price index formula is not crucial. However, real world price data are not always this well-behaved. The results for the importable and exportable sectors indicate that the choice of index formula can have a significant impact upon the measurement of price change.

The evidence in the preceding pages suggests that there may be little gain from using the chained Laspeyres and Paasche indexes over their direct counterparts when prices are subject to one or two sharp movements, such as occurred in the importable and exportable sectors in 1985–86 and 1990–91.[33] The data should be carefully examined prior to adopting a chaining procedure, as one of the main benefits of using a chained index may not hold if the data exhibit large fluctuations or significant one-off shocks.

The recommendations as to the choice of index formula are predicated on the data not being exceptionally volatile or seasonal. The question of exactly how volatile the source data has to be before the use of the chain principle is no longer beneficial has no clear answers. The results provide a clear warning against indiscriminate use of chained indexes in circumstances where they may not be appropriate.

33 These sharp price movements are caused by fuel price shocks.

This is particularly true for price indexes corresponding to products/ industries which are subject to price wars or frequent external shocks. This includes prices for fuel, agricultural and mineral products. When price indexes are compiled at a highly aggregate level, price volatility is averaged out and the use of chained indexes is less likely to be problematic. However, the results for the exportable sector indicate that even at an aggregate level, chaining does not necessarily reduce the gap between the Laspeyres and Paasche formulae.

The alternative formulae provide a relatively wide range of estimates of price change for the importable and exportable sectors. The classification methodology can lead to a relatively volatile weighting pattern when industries shift between sectors. It is apparent that the extent of the divergence between alternative price index formulae may be less severe in other applications where prices are relatively monotonic and the weighting time-series are relatively smooth.

There may still be gains from using a symmetric mean index such as the chained Fisher or Tornqvist indexes. Such indexes more closely approximate the theoretic indexes implied by the economic approach. These formulae are consistent with a range of functional forms for the underlying unit cost function. They are likely to perform better than the chained Laspeyres and Paasche indexes when prices and quantities fluctuate. This is because they are less sensitive to chaining through unlike periods due to their approximate transitivity.

The evidence presented in Table 6.2 and Table 6.3 shows that chaining reduces the already small gap between the Fisher and Tornqvist formulae. Except in circumstances where price and weighting data are roughly monotonic, if a chained index is to be used, then a symmetric formula is strongly preferred to the Laspeyres or Paasche formulae.[34]

However, for the exportable sector, it is also apparent that the direct and chained symmetric price indexes diverge significantly from one another. The extent of drifting is noticeably less than for the Laspeyres or Paasche formulae, but is still of concern. For this reason care should be taken in interpreting the results for this sector.

The volatility of prices in the exportable sector casts doubt over the appropriateness of the chained Tornqvist formula for measuring prices in this sector. As a key use of this data is as a measure of relative domestic prices it is not appropriate for different price index formulae to be used to represent price movements in different sectors. The direct Laspeyres index applies the 1989–90 industry composition over the entire period. This is not appropriate for the majority of applications as it does not reflect the significant changes which have occurred in the orientation of production between sectors. None of the other direct index formulae are suitable as they do not enable valid comparisons throughout the entire period

34 The choice of formula is likely to be unimportant in such circumstances anyway.

considered. Chained symmetric price index formulae are clearly preferable to chained Laspeyres or Paasche formulae for the exportable sector.

For these reasons, while the use of a chained symmetric price index may not be ideal for the exportable sector, it remains the preferred measure of price change.[35] The results indicate that chaining has clear overall benefits for the representivity of the importable and non-tradable price indexes when a symmetric formula is used in the links.

Due to its symmetric formula, Divisia nature, growth formulation and microeconomic justification, the chained Tornqvist index remains the recommended index formulae for the purpose of compiling price indexes for the tradable and non-tradable sectors. The Fisher index may be preferred for applications relating to expenditure, but the Tornqvist index is generally preferred for applications relating to productivity or production. As a price index relating to the domestic production of the tradable and non-tradable sectors is required, the Tornqvist formula is preferred.

[35] Ideally, a matrix based on a direct symmetric formula and enabling comparison between any two periods, would be the best measure of price change in the exportable sector. However, while useful in making comparisons between any two specific periods, the absence of a time-series negates the usefulness of such an approach in econometric analysis. A Laspeyres price index with five-yearly chaining, as commonly used in official statistics, would also provide an appropriate measure of price change in the exportable sector.

7. CONCLUSION

This paper has sought to assist users of price data in understanding the role the choice of index formula at the macro-level plays in measuring price movements. A survey of the literature concludes that chained indexes are to be preferred to direct indexes, unless price and quantity data are volatile.[36] Further, if price and quantity data are seasonal then it is not advisable to compile chain indexes with sub-annual links. It is also apparent from the theoretical and empirical evidence that symmetric formulae such as the Fisher and Tornqvist are generally to be preferred to the more commonly used Laspeyres and Paasche formulae. While the chained Fisher and Tornqvist indexes are recommended for most purposes, there are circumstances where alternative formulae may be preferred.

Choosing an index formula for measuring the price of tradables within Australia has shed light on some of the practical considerations which arise when deciding upon a preferred formula. The analysis of the quantitative impact of the choice of index formula illustrated the extent to which the measurement of price movements is dependent on that choice. For example, chained indexes generally provide lower inflation estimates for the exportable sector than do direct indexes. The evidence points to the importance of considering the issue of choice of index formula when constructing or using price indexes.

The empirical evidence suggests substantial price and quantity fluctuations are necessary before the use of chained indexes is drawn into question. Of course, what is meant by 'substantial' price and quantity fluctuations is very much open to interpretation. The results of this paper show that aggregate, real world price indexes may fluctuate sufficiently for chaining to no longer clearly reduce the index number spread; chaining may increase the divergence between the Laspeyres and Paasche formulae. Price data for fuel, agricultural and mineral products and for exports as a whole may well exhibit sufficient volatility for the choice of formula to significantly influence the measurement of price change. A single dramatic price movement, such as the rise in fuel prices associated with the Gulf War, can be sufficient to cause the alternative formulae to assume considerably divergent levels.

The results of this paper indicate there is plenty of scope for future research in the field of price indexes.[37] In particular, further empirical work to clarify the properties of alternative formulae and the susceptibility of chained indexes to seasonality, volatility and dramatic price movements seems warranted. Such research assumes greater importance given the move away from direct indexes to more complex formulae which has been foreshadowed by the recommendations of the United Nations' System of National Accounts (1993).

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36 This conclusion is, of course, subject to the assumption that issues such as timeliness and data availability can be resolved.

37 This is equally true for research into the choice of index formula at the micro-level. See Section 1 for a brief discussion of this issue.

GLOSSARY

Additivity
The property of additivity is satisfied if an aggregate remains equal to the sum of its components when the values of both the aggregate and its components in some reference period are extrapolated over time using a set of volume indexes. Although desirable from an accounting viewpoint, this property is quite restrictive and is only satisfied by the Laspeyres index.

Binary Index
See the definition for a direct index.

Chained Index
An index which is calculated by comparing the current period to the most recent period, for all observations.

Cost function
The total cost function shows that for any set of input costs ($p_i ... p_m$) and for any output level (Q) the minimum total cost (TC) incurred by the firm is TC=f($p_i, ... p_m, Q$). The average or unit cost function is the cost per unit to produce y units of output. It can be represented as $\frac{TC}{Q} = c(p)$.

Consistency in aggregation
An index is defined as consistent in aggregation if the value of the index calculated in two stages necessarily coincides with the value of the index as calculated in the ordinary way (i.e. a single stage).

Constant returns to scale
A production function is said to exhibit constant returns to scale if a doubling of all inputs results in a precise doubling of output. All homothetic production functions exhibit constant returns to scale.

Direct Index
An index which is calculated by comparing the current period to a fixed base period, for all observations.

Divisia index
The Divisia index is the theoretic continuous time index which is consistent with a producer continuously maximising a well-behaved, linearly homogenous, production function subject to a budget constraint. As data are not available on a continuous time basis the Divisia index can only be approximated on a discrete time basis.

Drifting
A chained index is likely to diverge from its direct counterpart when prices and quantities are correlated and fluctuate substantially. This phenomenon is known as drifting, and the extent of drifting is dependent on the extent to which an index formula satisfies the property of transitivity.

Exact index
An index formula is exact for a specific functional form if when the underlying cost function is represented by that specific functional form, and the producer is engaging in profit maximising behaviour, the theoretic index

which results from these assumptions exactly corresponds to that index formula.

Fixed-base Index
See the definition for a direct index

Fixed-weight index
An index in which the weighting pattern is fixed for the life of the index.

Flexible functional form
A functional form which provides a second order approximation to an arbitrary function.

Homogeneity
A function, $f(X_1, X_2, \ldots X_n)$ is homogenous of degree k if

$$f(mX_1, mX_2, \ldots mX_n) = m^k f(X_1, X_2, \ldots X_n)$$

Homotheticity
A function is homothetic if it can be represented as a monotonic transformation of a function that is homogenous of degree one. The slopes of the contour lines for such a function depend only on the ratios of the variables that enter the function not on their absolute levels.

Index number spread
The index number spread refers to the fact that alternative index formulae produce results which tend to diverge over time. If accuracy in measurement is required it is important to know whether the choice of formula alone could be responsible for much of the observed change.

Linking
The technique used to join a new index series which reflects a changed weighting pattern to the previous index series to form a continuous series. Also referred to as chaining.

Micro-Level
The choice of index formula at the micro-level refers to the method by which the basic price and quantity data collected from respondents in a survey are combined to form a measure of price change for a highly disaggregated commodity category.

Macro-Level
The choice of index formula at the macro-level refers to the method by which the price indexes for the disaggregated commodity or industry categories are combined to form price indexes for more aggregate commodity, industry or sectoral categories.

Price index
An indicator used to measure the average of the proportionate changes in the prices of a specified set of goods and services.

Price (quantity) relative
The ratio of the price (quantity) of a specific product in period t to the price (quantity) of the same product in the base period. It is a pure number which is independent of the unit of measurement. Price (quantity) indexes can be derived from weighted averages of these price (quantity) relatives.

Production function
The mathematical relationship between inputs and outputs. The relationship is often expressed in the following generalised form $Q=f(K,L,M...)$ where Q represents the output of a particular good during a period, K represents capital use during the period, L represents labour input and M represents raw materials used.

Quantity index
The average of the proportionate changes in the quantities of a specified set of goods and services, where the quantity data are non-homogenous. Indexes built up from information of this kind are not volume indexes when the basic quantity data covers different items selling at different prices.

Superlative index
An index is superlative if it is exactly the same as the theoretic index for some flexible functional form. A superlative index is not just exact for some specific functional form, but for a group of related functional forms of the unit cost function.

Theoretic Index
An index implied by the economic approach is referred to as a theoretic index. The economic approach assumes the consumer or producer is minimising the cost of achieving a given level of utility or output, and that the economic agent chooses the maximum level of utility or output with given budget constraints. The problem is then to find an index formula for quantities or prices which is consistent with this representation. The precise nature of a theoretic index differs according to the assumption made regarding producer behaviour, functional form, returns to scale etc.

Tradable
A good or service is defined as tradable if it is actually traded internationally, as are exports and imports, or if it could be traded internationally at some plausible variation in relative prices. This latter category includes domestically produced goods and services which substitute for imports in the domestic market or could compete with exports in the international market but are currently domestically consumed.

Transitivity
Let I_{AB} be an index for period B based on period A. Transitivity requires that $I_{AC} = I_{AB}.I_{BC}$. Extended to multiple time periods transitivity requires that the direct index and the chained index compiled using the same formula are equal.

Translog unit cost function

The total cost of production is a function of the price (p) and quantity (x) of the m inputs into production. The translog function is the most frequently used flexible function in empirical work. The translog form of the unit cost function is as follows.

$$
\begin{aligned}
\ln c = {} & \beta_0 + \beta_1 \ln p_1 + \dots + \beta_M \ln p_M \\
& + \frac{\delta_{11}(\ln p_1)^2}{2} \\
& + \delta_{12} \ln p_1 \ln p_2 + \frac{\delta_{22}(\ln p_2)^2}{2} \\
& + \qquad \vdots \\
& + \quad \dots \quad \dots \quad + \frac{\delta_{MM}(\ln p_M)^2}{2}
\end{aligned}
$$

Volume index

An indicator used to measure the average of the proportionate changes in the quantities of a specified set of goods and services.

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