FEATURE ARTICLE – Demystifying Chain Volume Measures

INTRODUCTION

Millions of economic transactions take place every day involving the production of goods and the sale of goods and services (commodities). The monetary (or current price) value of each of these transactions is a product of the quantity produced or sold and the unit price. In a particular period, the total (aggregate) value of all transactions taking place in an economy is simply the sum of the individual transaction values in that period.

When it comes to comparing the difference in aggregate values between two time periods, any observed movement is generally a combination of changes in quantity and changes in price. In a lot of cases, the interest of users of economic data lies in understanding the degree to which the dollar value of economic growth (either positive or negative) between two periods is being driven by changes in quantities (ie. physical volumes of production and consumption) as distinct from changes in prices. This need for a measure of economic growth due only to changes in quantities has resulted in the development of two types of data series in which the effects of price changes are removed. The two series, constant price estimates and chain volume measures, indicate changes in quantity (or volume) between time periods by keeping the prices of goods and services constant. Chain volume measures are considered to more accurately reflect volume changes over time and in 1998 replaced constant price estimates as the official Australian Bureau of Statistics (ABS) measure of volume change.

This article explains the derivation and use of chain volume measures. However, to put chain volume measures into context, it is helpful to first explain constant price estimates.

WHAT IS A CONSTANT PRICE ESTIMATE?

A constant price estimate provides a measure of aggregate value which only varies with changes in the quantities produced or sold. It achieves this by removing the direct effect of changes in the prices of commodities over time. Constant price estimates combine quantities of individual commodities involved in economic transactions over a number of periods using unit prices sourced from some common or *base period*. Prices in the base period represent the relative worth of different commodities at that point in time. These *price relativities* are commonly referred to as *weights*. It was ABS practice to update the base period every five years.

The Context – Valuing In Current Prices

Consider the economy of the Republic of Fruitonia which produces apples and oranges. In order to obtain an aggregate value of production for the Fruitonian economy which only varies with changes in quantity, the quantities of apples and oranges produced could simply be added together. However, it does not make sense to add together the quantities of two different commodities if one of those commodities is worth more than the other. To obtain an aggregate value of production for the economy, it is necessary to aggregate the monetary value of the quantities of apples and oranges produced using their unit prices.

Table 1 below presents the unit price, quantity and current price value of apples and oranges produced in three consecutive periods. To put constant price estimates into context, the aggregate monetary value of apple and orange production in the Fruitonian economy in each time period has first been calculated using the actual unit prices that applied in each period. This process is represented by the following formula:

$$\Sigma P_n Q_n$$

where P is the price of the commodity;

Q is the quantity produced; and

n is the current period under consideration.

What does the symbol "Σ" mean?

The symbol **Σ** is shorthand for "The sum of ".

For example, the expression

$\Sigma P_n Q_n$

used in this section of the article is shorthand for summing all of the 'price times quantity' calculations performed for each good produced in the Fruitonian economy in period *n* (to obtain the total value of production in that period).

The current price estimates of value calculated using the above formula are presented in Table 1 below.

TABLE 1: VALUE OF PRODUCTION OF THE FRUITONIAN ECONOMY IN CURRENT PRICES

	Period 0			*Period 1*			*Period 2*		
Commodity	*Price (P_0)*	*Quantity (Q_0)*	*Value in current prices (P_0Q_0)*	*Price (P_1)*	*Quantity (Q_1)*	*Value in current prices (P_1Q_1)*	*Price (P_2)*	*Quantity (Q_2)*	*Value in current prices (P_2Q_2)*
Apples	$1	5	$5	$2	8	$16	$3	13	$39
Oranges	$3	3	$9	$4	5	$20	$5	10	$50
Total (current prices)			**$14**			**$36**			**$89**

As shown in the table, the aggregate value of production in the economy in current prices in Period 0 is $14, increasing to $36 in Period 1 and $89 in Period 2. The growth in aggregate value between Periods 0 and 1 and between Periods 0 and 2 is due to changes in both prices and quantities for each commodity.

Calculating Constant Price Estimates

To measure the degree to which changes in quantities only have determined the change in aggregate values between Periods 0 and 1 and between Periods 0 and 2, *constant price estimates* of the aggregate values can be calculated by replacing the prices in Periods 1 and 2 with the corresponding prices from the base period (which, in our example, is determined to be Period 0). This process is represented by the following formula:

$$\Sigma P_o Q_n$$

where *n* is the current period under consideration, and

o is the period determined to be the base (or weighting) period of the constant price estimates series.

The formula has been applied to the data in Table 1 to obtain constant price estimates of the aggregate value of production for the Fruitonian economy in Periods 1 and 2. These are shown in Table 2 below.

TABLE 2: CONSTANT PRICE ESTIMATES OF VALUE FOR THE FRUITONIAN ECONOMY

	Period 0			*Period 1*				*Period 2*			
Commodity	*Price (P_0)*	*Quantity (Q_0)*	*Value in current prices (P_0Q_0)*	*Price (P_1)*	*Quantity (Q_1)*	*Value in current prices (P_1Q_1)*	*Constant price estimate of value (P_0Q_1)*	*Price (P_2)*	*Quantity (Q_2)*	*Value in current prices (P_2Q_2)*	*Constant price estimate of value (P_0Q_2)*
Apples	$1	5	$5	$2	8	$16	$8	$3	13	$39	$13
Oranges	$3	3	$9	$4	5	$20	$15	$5	10	$50	$30
Total (current prices)			**$14**			**$36**				**$89**	
Total (constant prices)							**$23**				**$43**

Calculating Constant Price Estimates *continued*

Holding prices constant (at Period 0 levels), the aggregate value of production in the economy in Period 0 is $14, increasing to $23 in Period 1 and $43 in Period 2. Constant price estimates of value indicate how much of the change in aggregate value was due to changes in quantities. The growth in aggregate value in current price terms between Periods 0 and 1 ($14 to $36) was 157.1% and in constant price terms ($14 to $23) was 64.3%, indicating that changes in quantities accounted for less than half the overall change in aggregate value. Between Periods 0 and 2, the aggregate value in current price terms ($14 to $89) increased by 535.7%, while the increase due to changes in quantities between the two periods ($14 to $43 in constant price terms) was 207.1%.

Constant Price Estimates As Index Numbers

Another way of expressing constant price estimates is in *index number* form. A constant price index which values quantities over a number of periods at the prices of a base period is equivalent to a *Laspeyres fixed–weight volume index*. Such an index measures the percentage change in the total value of production by holding prices constant at base period levels. The Laspeyres fixed–weight volume index is given by the formula:

$$\frac{\sum P_o Q_n}{\sum P_o Q_o} \times 100$$

where n is the current period under consideration, and

o is the base (or weighting) period of the index series and the *reference period* of the series at which the *index value* is equal to 1 and the index number is 100.0.

Index values and index numbers for Periods 0, 1 and 2 are calculated as follows:

	Period 0	*Period 1*	*Period 2*
	$\frac{(1 \times 5) + (3 \times 3)}{(1 \times 5) + (3 \times 3)} \times 100$	$\frac{(1 \times 8) + (3 \times 5)}{(1 \times 5) + (3 \times 3)} \times 100$	$\frac{(1 \times 13) + (3 \times 10)}{(1 \times 5) + (3 \times 3)} \times 100$
Index value	= **1.000** x 100	= **1.643** x 100	= **3.071** x 100
Index number	= **100.0**	= **164.3**	= **307.1**

The resulting index values and index numbers are presented in Table 3 below.

TABLE 3: CONSTANT PRICE INDEX VALUES AND NUMBERS FOR THE FRUITONIAN ECONOMY

	Period 0			Period 1				Period 2			
Commodity	Price (P_0)	Quantity (Q_0)	Value in current prices (P_0Q_0)	Price (P_1)	Quantity (Q_1)	Value in current prices (P_1Q_1)	Constant price estimate of value	Price (P_2)	Quantity (Q_2)	Value in current prices (P_0Q_2)	Constant price estimate of value
Apples	$1	5	$5	$2	8	$16	$8	$3	13	$39	$13
Oranges	$3	3	$9	$4	5	$20	$15	$5	10	$50	$30
Total (current prices)			**$14**			**$36**				**$89**	
Total (constant prices)							**$23**				**$43**
Index value			**1.000**				**1.643**				**3.071**
Index number			**100.0**				**164.3**				**307.1**

The index numbers indicate that the growth in aggregate value in constant price terms between Periods 0 and 1 was 64.3%, and between Periods 0 and 2 was 207.1%. These percentage changes are the same as those calculated previously from constant price estimates expressed in dollar terms. In fact, index values can be used to express a constant price series in dollar terms. This is achieved by multiplying the index value for the period in question by the current price estimate of value for the base period. For example, multiplying the index value in Period 1 (1.643) by the current price estimate of value in our base period, Period 0 ($14), we obtain the constant price estimate of value of $23.

Limitations Of Constant Price Estimates

Although constant price estimates and equivalent fixed–weight volume indexes have been widely used to analyse volume changes, there are several limitations associated with the use of these measures. These limitations are fundamentally due to the base price being used in calculating volume changes remaining constant over time, with no account being taken of volume, price or commodity changes.

Cheaper commodities are substituted for dearer commodities.
Economic theory suggests that the Laspeyres fixed–weight volume index tends to overstate the 'true' rate of growth of the value of commodities in the economy. This overstatement is often referred to as substitution bias, or the substitution effect. It occurs because, over time, consumers substitute commodities which have become relatively cheaper for those which have become relatively more expensive. Substitution bias tends to increase with the passage of time and distorts growth rates, particularly in dynamic areas of the economy where price relativities are likely to be subject to change.

Price relativities change over time.
Prices of commodities tend to grow at different rates over a period of time and therefore price relativities or weights change. This affects the usefulness of constant price estimates, particularly for periods further away from the base period when price relativities become more and more out of date and irrelevant to real–world economic circumstances.

Limitations Of Constant Price Estimates *continued*

Commodities appear and disappear and quality changes.

Due to the continually changing set of commodities in the economy, new commodities appear while older ones disappear. This makes it increasingly difficult to calculate direct Laspeyres fixed–weight volume indexes as the set of commodities common to both periods becomes progressively smaller. The quality of commodities also changes over time and may become so significantly improved or decreased that the commodities can no longer be considered to be the same, and direct comparisons with the value of those commodities in earlier periods cannot be made. As we move further away from the base period, direct Laspeyres fixed–weight volume indexes have increasingly poor coverage because there are less and less commodities common to the current and base periods and fewer comparisons can be made.

In 1998, the ABS adopted chain volume measures to replace constant price estimates and fixed–weight volume indexes as the preferred measure of volume change. Chain volume measures provide better indicators of volume growth, by addressing and overcoming the above limitations.

WHAT ARE CHAIN VOLUME MEASURES?

Chain volume measures are an alternative set of volume measures to constant price estimates. As with constant price estimates, chain volume measures only vary with changes in the quantities of commodities produced or sold. However, unlike constant price estimates and fixed–weight volume indexes, which value quantities using the prices of some base period which were updated (or reweighted) once every five years, chain volume measures value quantities by using prices in a base period which is updated annually. These annually reweighted (rebased) volume change measures are then linked, or "chained" together to produce a time series of chain volume measures.

Calculating Chain Volume Measures

Continuing with our example of the Fruitonian economy, Tables 4 and 5 present the unit price, quantity and current price value of apples and oranges produced in three consecutive periods. To calculate a chain volume measure or chain–linked volume index of value for the Fruitonian economy, two steps are required.

Step 1. Derive annually rebased volume estimates, in index number form, using the *Laspeyres volume index formula.*

The formula is given by:

$$\frac{\sum P_{n-1}Q_n}{\sum P_{n-1}Q_{n-1}} \times 100$$

where n is the current period under consideration, and

n-1 is the period before the current period and the base period for values in period n.

As the weights of a chain volume index change from year to year due to annual rebasing, a time series of chain volume indexes has no fixed base period in the sense in which a constant price estimate or fixed–weight volume index does. However, chain volume measures must have a *reference period* or reference year, in which the index equals 100.0. It is also worth noting that the chain volume measure in the reference period expressed in dollar terms equals the corresponding current price value.

If Period 0 is set as the reference period in which the index number is 100.0, annually rebased volume estimates of value (in index number form) for Periods 1 and 2 are calculated as follows.

Period 1
(based on Period 0 prices)..

$$\frac{(1 \times 8) + (3 \times 5)}{(1 \times 5) + (3 \times 3)} \times 100$$

= 1.643 x 100

= **164.3**

Period 2
(based on Period 1 prices).....

$$\frac{(2 \times 13) + (4 \times 10)}{(2 \times 8) + (4 \times 5)} \times 100$$

= 1.833 x 100

= **183.3**

The resulting estimates are presented in Table 4 below.

TABLE 4: ANNUALLY REBASED VOLUME ESTIMATES OF VALUE FOR THE FRUITONIAN ECONOMY

	Period 0			***Period 1***				***Period 2***			
Commodity	*Price (P_0)*	*Quantity (Q_0)*	*Current price estimate of value (P_0Q_0)*	*Price (P_1)*	*Quantity (Q_1)*	*Current price estimate of value (P_1Q_1)*	*Annually rebased volume estimate of value*	*Price (P_2)*	*Quantity (Q_2)*	*Current price estimate of value (P_2Q_2)*	*Annually rebased volume estimate of value*
Apples	$1	5	$5	$2	8	$16	$8	$3	13	$39	$26
Oranges	$3	3	$9	$4	5	$20	$15	$5	10	$50	$40
Total (current prices)			**$14**			**$36**				**$89**	
Total (annually rebased estimate)							**$23**				**$66**
Index number			**100.0**				**164.3**				**183.3**

Each index number in the series in Table 4 is a Laspeyres volume index calculated using the previous year as the base period, ie the base period for Period 1 is Period 0 and the base period for Period 2 is Period 1. Therefore it is not possible to directly compare the annual volume estimate in Period 2 with the annual volume estimate in Period 1 because they have different base periods which reflect different price relativities. In order to derive a time series of comparable terms, the individual indexes need to be compounded (or chained) together to produce a chain volume index.

Step 2. Compound (or chain) the individual indexes to produce a continuous chain volume time series, ie a *Laspeyres chain volume index*.

This is achieved using the following formula:

$$\frac{\sum P_o Q_1}{\sum P_o Q_o} \times \frac{\sum P_1 Q_2}{\sum P_1 Q_1} \times \ldots\ldots\ldots \frac{\sum P_{n-1} Q_n}{\sum P_{n-1} Q_{n-1}} \times 100$$

Calculating Chain Volume Measures *continued*

In our example, if Period 0 is set as the reference period in which the index number is 100.0, the Laspeyres chain volume index for Period 1 is calculated as follows:

1.00 x 1.643 x 100

= 164.3

Similarly, the Laspeyres chain volume index for Period 2 is calculated as:

1.00 x 1.643 x 1.833 x 100

= 301.2

TABLE 5: CHAIN VOLUME ESTIMATES OF VALUE FOR THE FRUITONIAN ECONOMY (Reference Period = Period 0)

	Period 0			***Period 1***				***Period 2***			
Commodity	*Price (P_0)*	*Quantity (Q_0)*	*Current price estimate of value (P_0Q_0)*	*Price (P_1)*	*Quantity (Q_1)*	*Current price estimate of value (P_1Q_1)*	*Chain volume estimate*	*Price (P_2)*	*Quantity (Q_2)*	*Current price estimate of value (P_2Q_2)*	*Chain volume estimate*
Apples	$1	5	$5	$2	8	$16	$8	$3	13	$39	$13
Oranges	$3	3	$9	$4	5	$20	$15	$5	10	$50	$30
Total (current prices)			**$14**			**$36**				**$89**	
Total (chain volume estimate) *(a)*							**$23**				**$42.17**
Chain volume index number			**100.0**				**164.3**				**301.2**

(a) Chain volume index referenced to Period 0 current price estimate.

The Laspeyres chain volume index indicates that the growth in aggregate value of the economy in chain volume terms between Periods 0 and 1 was 64.3%, and between Periods 0 and 2 was 201.2%.

As with constant price estimates, chain volume indexes can also be expressed in dollar terms by multiplying the index value for the period in question by the current price estimate of value in the reference period. As the reference period for our chain volume series is Period 0, chain volume estimates of value for Periods 1 and 2 can be calculated by multiplying their respective index values by the current price estimate of value in Period 0 ($14). For Period 1, the chain volume estimate of value is $23 (1.643 x $14) and for Period 2 is $42.17 (3.012 x $14).

Updating The Reference Period

The reference period for a series of chain volume indexes can be any period in which the index number is set to 100.0. In our example above, the reference period for the series is Period 0, but any of the three periods could have been chosen to be the reference period. The impact of changing the reference period is shown in Table 6 below, where the reference period has been updated to Period 1.

TABLE 6: CHAIN VOLUME ESTIMATES OF VALUE FOR THE FRUITONIAN ECONOMY (Reference Period = Period 1)

	Period 0				***Period 1***				***Period 2***			
Commodity	*Price (P_0)*	*Quantity (Q_0)*	*Current price estimate of value (P_0Q_0)*	*Chain volume estimate*	*Price (P_1)*	*Quantity (Q_1)*	*Current price estimate of value (P_1Q_1)*	*Chain volume estimate*	*Price (P_2)*	*Quantity (Q_2)*	*Current price estimate of value (P_2Q_2)*	*Chain volume estimate*
Apples	$1	5	$5	$10	$2	8	$16	$16	$3	13	$39	$26
Oranges	$3	3	$9	$12	$4	5	$20	$20	$5	10	$50	$40
Total (current prices)			**$14**				**$36**				**$89**	
Total (chain volume estimate) *(a)*				**$21.91**				**$36**				**$66**
Chain volume index number				**60.9**				**100.0**				**183.3**

(a) Chain volume index referenced to Period 1 current price estimate.

Updating the reference period results in revisions to the levels of chain volume measures for their entire history. However, re–referencing does not alter growth rates. A comparison of the growth rates calculated from Table 5 (reference period Period 0) with the growth rates calculated from Table 6 (reference period Period 1) shows that, in both cases, the growth in aggregate value between Periods 0 and 1 is 64.3% and between Periods 0 and 2 is 201.2%. It should be noted that revisions to growth rates can occur as a result of revisions to the underlying data.

Non–Additivity

Additivity, a property pertaining to a set of index numbers under which an aggregate is defined as the sum of its components, only exists in volume estimates when a fixed set of prices is used. Thus, fixed–weight volume indexes of the kind the ABS previously used when deriving constant price estimates were additive. As weights of a chain volume index change from year to year, chain volume indexes have no base period in the sense of a fixed–weight index base period and therefore non–additivity exists in the chain volume measures. *Non–additivity* occurs because the values of component chain volume measures expressed in dollar terms do not generally add up to the dollar value of the aggregate chain volume measure. Looking at the chain volume estimates of value for Period 2 in Table 5, the concept of non–additivity becomes clear. The chain volume estimates of value for apples and oranges in Period 2, calculated using the chain volume indexes for the individual commodities, are $13 and $30 respectively. Adding these together should result in a chain volume estimate of aggregate value of $43, but the actual estimate is $42.17. In Period 1 the chain volume estimates of value for apples ($8) and oranges ($15) do add to the chain volume estimate of aggregate value of $23. This is because only values in the reference period (Period 0) and the following period (Period 1) are additive.

Choosing a reference period that is close to the current period reduces the impact of non–additivity, and the ABS has chosen to make the reference period the same as the latest base period for chain volume measures. In Table 6 above, the reference period was updated from Period 0 to Period 1. As shown in the table, the values in the reference period (Period 1) and the following period (Period 2) are additive, but non–additivity now exists in Period 0. The ABS updates both the base period and the reference period of chain volume measures on an annual basis every June quarter, ensuring that additivity always exists for the latest two years.

WHY ARE CHAIN VOLUME MEASURES BETTER?

Table 7 summarises constant price and chain volume estimates of the aggregate value of the Fruitonian economy for Periods 0, 1 and 2.

TABLE 7: CONSTANT PRICE AND CHAIN VOLUME ESTIMATES OF VALUE FOR THE FRUITONIAN ECONOMY

	Period 0	*Period 1*		*Period 2*	
Commodity	*Current price estimate of value*	*Constant price estimate of value*	*Chain volume estimate of value*	*Constant price estimate of value*	*Chain volume estimate of value*
Apples	$5	$8	$8	$13	$13
Oranges	$9	$15	$15	$30	$30
Total (current prices)	**$14**				
Total (constant prices) *(a)*		**$23**		**$43**	
Total (chain volume estimate) *(b)*			**$23**		**$42.17**
Constant price index number	**100.0**	**164.3**		**307.1**	
Constant price growth rates		**64.3%**		**207.1%**	
Chain volume index number	**100.0**		**164.3**		**301.2**
Chain volume growth rates			**64.3%**		**201.2%**

(a) Base period for constant price series is Period 1.

(b) Reference period for chain volume measures is Period 1.

The choice of chain volume measures over constant price estimates as a better indicator of volume growth has been made for a number of reasons:

Chain Laspeyres volume indexes more accurately reflect the true rate of commodity growth.

Over time, a chain Laspeyres volume index tends to increase less than a Laspeyres fixed–weight volume index. A comparison of the differing growth rates for the economy from Period 0 to Period 2 (see Table 7 above) reveals that the growth rate of the constant price series (207.1%) is slightly higher than the growth rate of the chain volume measures (201.2%). Chain volume measures substantially reduce the substitution effect that is inherent in Laspeyres fixed–weight volume indexes and which causes overstatement of the 'true' rate of growth of commodities in the economy. Chain volume measures overcome substitution bias by compiling indexes based on more up–to–date price relativities.

Chain volume measures take account of changing price relativities.

Chain volume measures provide better indicators of movement in real output and expenditure because they take account of changes to price relativities that occur from one period to the next by compiling indexes between consecutive periods and annually updating the base period. This is particularly important for areas of the economy in which prices are subject to rapid change. Computers are a prime example of changing price relativities. As technology has become more advanced, computers have become relatively less expensive than they were ten or twenty years ago. The rate of decline in the relative price of computers has been so rapid that a fixed–weight volume index using prices of even just five years ago would be outdated. Another example of changing price relativities is oil, which has experienced large fluctuations in price over time, as is currently occurring.

Chain volume measures maximise useable price and quantity information.
Chain volume measures are more reliable and have greater coverage because they compile indexes between each pair of consecutive periods. This maximises the number of commodities common to both periods and enables more value comparisons to be made.

INTRODUCTION OF CHAIN VOLUME MEASURES IN *Western Australian Statistical Indicators* (ABS Cat. 1367.5)

From the March quarter 2003, chain volume measures will be introduced in *Western Australian Statistical Indicators* (ABS cat. 1367.5) for the following indicators:

- State Final Demand (Table 3)
- Quarterly Retail Turnover (Table 11)
- Private New Capital Expenditure (Table 16)
- Value of Building Approved (Table 20)
- Value of Building Work Commenced (Table 22)
- Value of Building Work Done (Table 23)

Current price estimates for these indicators will continue to be published.

ADDITIONAL INFORMATION

For more information about chain volume measures, please refer to the Information Paper *Introduction of Chain Volume Measures in the Australian National Accounts*, ABS Cat. 5248.0.

REFERENCES

Australian National Accounts: National Income, Expenditure and Product, ABS Cat. 5206.0

Australian System of National Accounts: Concepts, Sources and Methods 2000, ABS Cat. 5216.0

Handbook on Price and Volume Measures in National Accounts, Eurostat

Information Paper: Introduction of Chain Volume Measures in the Australian National Accounts, ABS Cat. 5248.0

Revised International Standards in Australian National Accounts, ABS Cat. 5251.0

System of National Accounts 1993, Commission of the European Communities (Eurostat), International Monetary Fund, Organisation for Economic Co–operation and Development, United Nations, World Bank