The Australian Economic Review, vol. 41, no. 1, pp. 105–13

Data Surveys

The CPI and Other Measures of Australian Inflation

Sarantis Tsiaplias
Melbourne Institute of Applied Economic and Social Research, The University of Melbourne

1. Introduction

The consumer price index, or CPI, measures changes in the prices of goods or services acquired or utilised by households for consumption purposes. According to the US Bureau of Labor Statistics (2007), the CPI is a measure of the average change over time in the prices of consumer items. The CPI is, therefore, a restricted measure of inflation; a measure confined to the inflation faced by the household sector of the economy. This article reviews the measures of Australian consumer inflation and contrasts such measures with complementary, non-consumption, measures of inflation in the Australian economy.

The following comments are generally applicable to consumer price indices and assist in both differentiating the CPI from other price forms and identifying issues inherent in the estimation of a CPI.

(i) A CPI measures goods or services consumed by households. Business expenditure is not measured in a CPI. There is, however, an ongoing debate about whether the CPI should be constructed as a measure of the cost of living (namely, achieving a certain level of utility) or the cost of a given basket of goods and services (Advisory Commission to Study the Consumer Price Index 1996). The Australian CPI accords with the latter construct.

(ii) Not all goods or services consumed by a household are measured in a CPI; the CPI only measures changes in prices of goods or services acquired or utilised for consumption purposes (items acquired for day to day living, according to the Bureau of Labor Statistics 2007). The change in the price of a good or service that is used by a household for investment purposes, for example, is not measured in a CPI.

(iii) A CPI may be constructed to measure changes in numerous contexts (over time, across regions, over economic sectors). Most indices, however, are concerned with price changes in the time domain.

The points above allude to some of the difficulties encountered in constructing an intertemporal measure of consumer prices.[1] In theory, assuming perfect information, a CPI over the time period t_0 to t_1 ($t_1 > t_0$) may be constructed as:

$$P_{t_0,t_1} = \sum_{\forall i} \sum_{\forall k} w_{ik,t_0,t_1} \frac{p_{k,t_1}}{p_{k,t_0}} \tag{1}$$

where $p_{k,t}$ is the price of good or service k at time t and w_{ik,t_0,t_1} is the proportion of total consumption expenditure attributed to household i for good or service k in the time period t_0 to t_1. Subject to the choice of an appropriate weighting scheme, the summation over goods and services for all households captures the price change over the relevant time period.

In practice, however, it is impossible to evaluate the expenditure decisions of all households and over all goods and services.[2] Instead, statistical bodies such as the Australian Bureau of Statistics (ABS) apply sampling techniques to both households and products to capture aggregate price changes. The approach used to deduce the Australian CPI, as well as some of the estimation issues inherent in the CPI derivation, is reviewed in Section 2. Section 3 discusses

core or underlying measures of consumer inflation, while Section 4 provides an overview of non-consumer measures of Australian inflation. The fifth section presents a statistical synopsis of the consumer and non-consumer inflationary measures of the Australian economy. Section 6 concludes the review.

2. The Construction of the Australian CPI

2.1 The Composition of the CPI

The ABS, being responsible for overseeing the Australian CPI, samples price changes for a fixed basket of goods and services chosen by reference to factors such as historic household expenditure statistics and the relationship (or correlation) between goods and services included in the fixed basket. The weights associated with the items in the fixed basket are determined using a sample of households from the eight major capital cities in Australia (Adelaide, Brisbane, Canberra, Darwin, Hobart, Melbourne, Perth and Sydney) (ABS 2005a).

The current series of the CPI is divided into 11 groups, 33 subgroups and 90 expenditure classes (ABS 2005b). The divisional structure is based on the *Classification of Individual Consumption According to Purpose* reference classification published by the United Nations Statistics Division. The 11 groups represent broad commodity categories such as food or transportation while the subgroups and expenditure classes provide further disaggregation. Prices for individual items are collected at the elementary aggregate level. Table 1 provides an example of the subdivisional structure used by the ABS.

Price changes are available for each of the expenditure classes, subgroups and groups. An aggregate CPI figure, deemed a measure of headline inflation, is also reported. In contrast to the reporting frequency observed in the United States, Canada and several European nations, the official Australian CPI is reported on a quarterly basis.[3] To alleviate any information gap stemming from the quarterly nature of the official Australian CPI, the Melbourne Institute of Applied Economic and Social Research publishes a monthly CPI figure.[4]

Table 1 An Example of the Subdivisional Structure of the ABS CPI

Group	*Subgroup*	*Expenditure class*	*Elementary aggregate*
Food	Dairy and related products	Milk	Fresh milk
			Flavoured milk
			Soy milk
		Ice cream and other	
		Cheese	
	Bread and cereal products	Breads	
		Cakes and biscuits	
		Cereals	
		Other cereal products	

Table 2 Weighted Indices

1. Laspeyres

$$I_{L,t} = 100 \sum_{\forall i} w_{i0} \left(\frac{p_{it}}{p_{i0}} \right)$$

where p_{it} is the price of product i at time t, and w_{i0} is the proportion of total expenditure attributed to product i at time 0. The weight w_{i0} is constructed as:

$$\frac{p_{i0}q_{i0}}{\sum_{\forall k} p_{k0}q_{k0}} = \frac{e_{i0}}{\sum_{\forall k} e_{k0}}$$

where q_{it} is the quantity sold of good i at time t.

2. Paasche

$$I_{P,t} = 100 \frac{1}{\sum_{\forall i} w_{it} \left(\frac{p_{i0}}{p_{it}} \right)}$$

3. Fisher

$$I_{F,t} = (I_{L,t} I_{P,t})^{1/2}$$

2.2 The Indexing and Weighting Schemes

Several indexing schemes are available for the purpose of deducing price changes. The popular Laspeyres, Paasche and Fisher indices differ in terms of the information incorporated in the weighting system used to deduce index values (see Table 2). The Laspeyres index weights according to time 0 expenditure whereas the Paasche index, which incorporates a form similar to that of the harmonic mean, weights according to time t expenditure. The

Table 3 Unweighted Indices

1. Geometric mean

$$I_{GM,t} = \prod_{\forall i} \left(\frac{p_{it}}{p_{i0}} \right)^{1/N}$$

2. Average price relative

$$I_{APR,t} = \frac{1}{N} \sum_{\forall i} \left(\frac{p_{it}}{p_{i0}} \right)$$

3. Ratio/Relative of average prices

$$I_{RAP,t} = \frac{1}{N} \sum_{\forall i} p_{it} \Big/ \frac{1}{N} \sum_{\forall i} p_{i0}$$

Fisher index is an equally weighted combination of both. The three weighted index forms are by no means exhaustive (see, for example, Hill 2004).

The ABS introduces new weights (approximately) every five years as updated Household Expenditure Survey data become available. The estimation of new weights is used to commence a new CPI series (the 15th and latest CPI series was introduced in 2005). The amended set of weights pertains to the expenditure class level and is fixed for the entire life of the series. In line with the fixed nature of the expenditure class level weights, the index is constructed pursuant to the Laspeyres form.

From time to time the ABS also introduces weight changes below the expenditure class level. These weight changes incorporate time varying preferences regarding the importance and availability of particular goods or services. Given the absence or costly nature of introducing weights at the elementary aggregate level, however, the ABS typically elects to use unweighted indices to capture low level price movements.[5] Table 3 presents a non-exhaustive list of popular forms for constructing unweighted price movements. The geometric mean is generally adopted and tends to return a value between the average price relative (generally larger) and the ratio of average prices (generally smaller). The final CPI figure is therefore a reflection of fixed, initial weights constructed by reference to Household Expenditure Surveys, time varying weights reflecting inter-series preferences regarding goods and services, and equal weighting schemes incorporating uncertainty about expenditure at elementary aggregate levels.

It is important to distinguish between a CPI series and the reference period. The reference period denotes the (re)initialisation of the CPI to a starting value of 100 and need not correspond with the introduction of a new weighting scheme (the current reference period is 1989–90). Following initialisation, a straightforward process of linking or chaining is used to create the intertemporal index of consumer prices. The process follows the form (using, for example, a Paasche style index):

$$\begin{aligned} I_{P,0,chained} &= (I_{P,0} I_{P,0})/100 \\ I_{P,1,chained} &= (I_{P,1} I_{P,0})/100 \\ I_{P,2,chained} &= (I_{P,2} I_{P,1})/100 \end{aligned} \tag{2}$$

where $I_{P,0} = 100$ is used to initialise a new series of the CPI.

2.3 Estimation Issues

There is an extensive literature regarding the presence of measurement error or bias in the estimation of consumer price indices (Braithwait 1980; Manser and McDonald 1988; Lebow and Rudd 2003). The literature has generally suggested that CPI estimates tend to overstate consumer costs. Lebow and Rudd (2003) estimate that the cost of living for US households is overstated by approximately 0.9 per cent per year. Similar estimates of positive bias in the CPI are provided by the Advisory Commission to Study the Consumer Price Index (1996). Although the aforementioned statistics refer to the US economy, the methodological similarity between the US and Australian measures (both measures are derived pursuant to the fixed weighted Laspeyres form) suggests that a similar level of bias is inherent in the Australian measure.

The types of bias affecting measures of consumer prices are generally classified as belonging to one of four types.

(i) *Substitution bias* may be characterised in terms of upper or lower level substitution, or in terms of item or outlet substitution.

Upper level substitution takes place when a household substitutes across classes (for example, meat rather than fish) while lower level substitution takes place within classes. In turn, item bias occurs where a household substitutes a higher priced item *a* with item *b* without loss in its utility. In this scenario, an index with fixed weights (for example, a Laspeyres type index where price relatives are weighted by reference to w_0 for the next five years) would show a price rise although consumers are largely unaffected (Manser and McDonald 1988; Unayama 2004). Outlet substitution would result in a similar bias where a household elects to purchase an item from (less expensive) outlet *b* rather than outlet *a*.

(ii) *Quality adjustment bias* occurs where an item changes substantially (that is, consumer utility for the item is now different) yet its price relative is still determined by reference to its predecessor. The index therefore imputes a price rise or fall for an existing item that would be more accurately treated as a new item. Lebow and Rudd (2003) estimate that inaction or delay in accounting for quality adjustments and new goods is responsible for the greatest portion of CPI bias.

(iii) *New goods bias* is related to quality adjustment bias and defines the situation where new goods are not included in the index in a timely fashion; consequently the index fails to capture consumer utility attributed to the new item.

(iv) *Elementary index bias* occurs where an inappropriate index formula for elementary aggregates is adopted (for example, when equal weights for price relatives are clearly inappropriate).

An equally important, although perhaps less obvious, estimation issue pertains to the periodic extraction of weights from surveys such as the Household Expenditure Survey (see also, Grossack 1981; Lebow and Rudd 2003). In addition to ordinary sampling error, several potential issues may be identified. An unfortunately timed survey, where certain goods or services are significantly over- or underpriced, may skew expenditure weights and result in an inaccurate depiction of household expenditure. Certain forms of expenditure may also be omitted or inaccurately reported (for example, tobacco or gambling), resulting in positively skewed weights for other groups. Although the ABS undertakes adjustments to the Household Expenditure Survey statistics, it is difficult to accurately determine the statistical significance of such effects and, consequently, of measures aimed at their minimisation.

3. Core or Underlying Measures of Consumer Inflation

By tracking changes in the prices of goods and services consumed by households, the CPI acts as an estimator of changes in household utility. On that basis, CPI statistics have been used to motivate bargaining arrangements and wage indexation levels. Consumer inflation statistics, however, are primarily used by the Reserve Bank of Australia (RBA) in undertaking monetary policy aimed at keeping inflation levels within predetermined target bands. To this effect, the RBA (and most central banks) rely on core or underlying measures of consumer inflation in evaluating consumer inflation trends (see Bryan and Cecchetti 1993).[6]

Although there is no universally accepted definition of a core or underlying measure of inflation, such measures are aimed at capturing inflationary trends and reducing the volatility inherent in headline measures of inflation. The core or underlying inflation measure may be understood in the context of the following decomposition of the inflation rate i at time t:

$$i_t = \hat{i}_t + e_t \tag{3}$$

The variable $\hat{i}_t$ may be interpreted as a measure of core or underlying inflation, given the absence of the noise e_t inherent in the headline inflation level. Essentially, the estimation of $\hat{i}_t$ involves the removal of noise from a noisy

signal for the purpose of providing economic regulators with a trend indicator of consumer inflation.

Notwithstanding the numerous methods available for extracting a clear inflationary signal (Harvey and Koopman 2000), popular measures of core or underlying inflation rely on the recalculation of inflation levels subject to the imposition of straightforward methods aimed at reducing volatility. These methods reduce volatility by explicitly removing items that are known a priori to be highly volatile or by reducing the impact of prices at the tail ends of the pricing distribution curve. By doing so, a purportedly better indicator of inflationary trends is obtained. The measures also reduce the impact of classification or statistical practices that may not be reflective of underlying consumer inflation. A pertinent example is the transfer of responsibility for the Child Care Tax Rebate (CCTR) from the Australian Taxation Office to the Family Assistance Office.[7] The new administrative arrangement placed the CCTR within the scope of the CPI in accordance with the ABS criteria for the treatment of subsidies and rebates and resulted in child care costs falling from an otherwise −4.9 per cent to −33.4 per cent.

Two simple publicly available measures of core or underlying inflation used by the RBA are the weighted median and trimmed mean measures of inflation (Figure 1 plots the headline CPI and the two measures of core or underlying consumer inflation). The trimmed mean measure of inflation is computed as the price movement deduced after removal of price classes at the tails of the price distribution for a given period. The RBA currently removes the top and bottom 15 per cent of prices, and computes a symmetric trimmed mean by reweighting the remaining items so that the weighting vector sums to unity. The weighted median is computed as the price change associated with the median element in the vector of weighted price classes. Both measures appear to consistently capture similar trend behaviour in consumer inflation levels. The volatile shifts observed in the headline CPI are also noticeably absent from the trimmed mean and weighted median measures.

4. Other Measures of Inflation

CPI measures of inflation are restricted to prices encountered by the household sector of the economy. To obtain an economy wide perspective of inflation, prices for other sectors of the economy also need to be measured. The natural complement to the CPI is the Producer Price Index (PPI), an index measuring prices received by the production sector (see ABS 2006). In contrast to the 1960 introduction of the CPI, a formal measure of producer prices was not introduced in Australia until 1998. The basic difference between the CPI and PPI measures of inflation is that the latter index is computed by reference to prices received by producers whereas the former depends on retail prices. The derivation of the PPI does not, therefore, depend on retailer imposed margins or consumption taxes such as the Goods and Services Tax (GST). Consequently, the significant impact of taxes and margins may result in weak co-movement between consumer and producer inflation. Figure 2 presents a time series plot of the CPI and PPI quarterly growth rates. The deviation between the two measures appears most pronounced in September 2000 following the introduction of the GST.

In addition to consumer and producer inflation, several other measures of inflation are available for the Australian economy. The measures, of varying broadness, are aimed at capturing particular subsets of price activity. The labour price index, for example, estimates changes in the price of labour supplied by Australian workers (ABS 2004). The index is constructed using sub-indexes of wage and non-wage price levels. The wage price indices measure changes in ordinary time hourly pay (excluding bonuses) for fixed job specifications, whereas the non-wage indices measure additional (net of wage) prices faced by employers in Australia such as superannuation, leave, payroll tax and workers' compensation.

International trade price indices are also estimated by the ABS to capture price changes in tradeable items (ABS 2006). The trade price indices are classified as import or export indices depending on the origin of items used to estimate price changes. A tradeables inflation

Figure 1 Time Series Plots of the Year-End Percentage Changes in the Headline, Trimmed Mean and Weighted Median Measures of Consumer Inflation

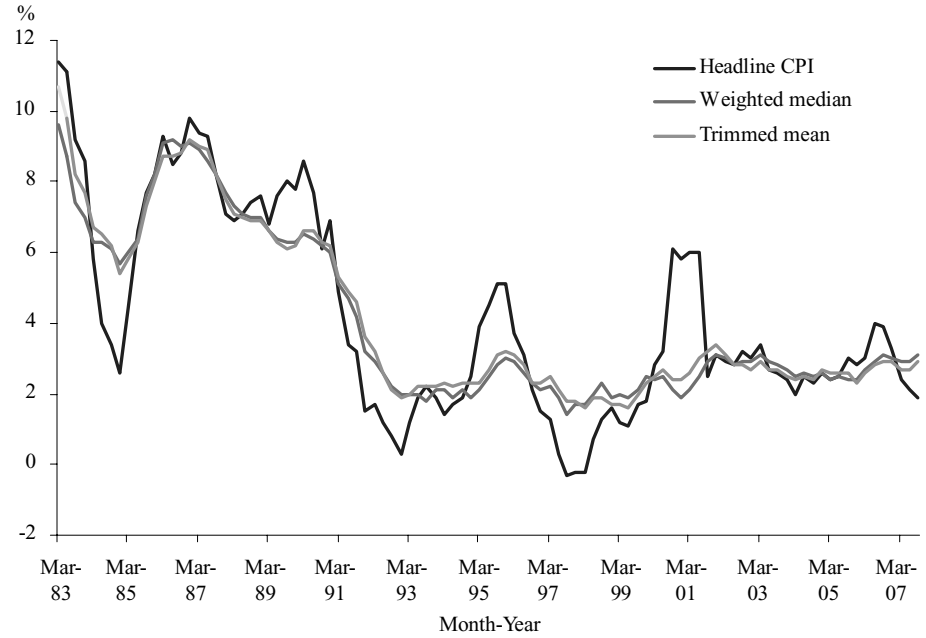
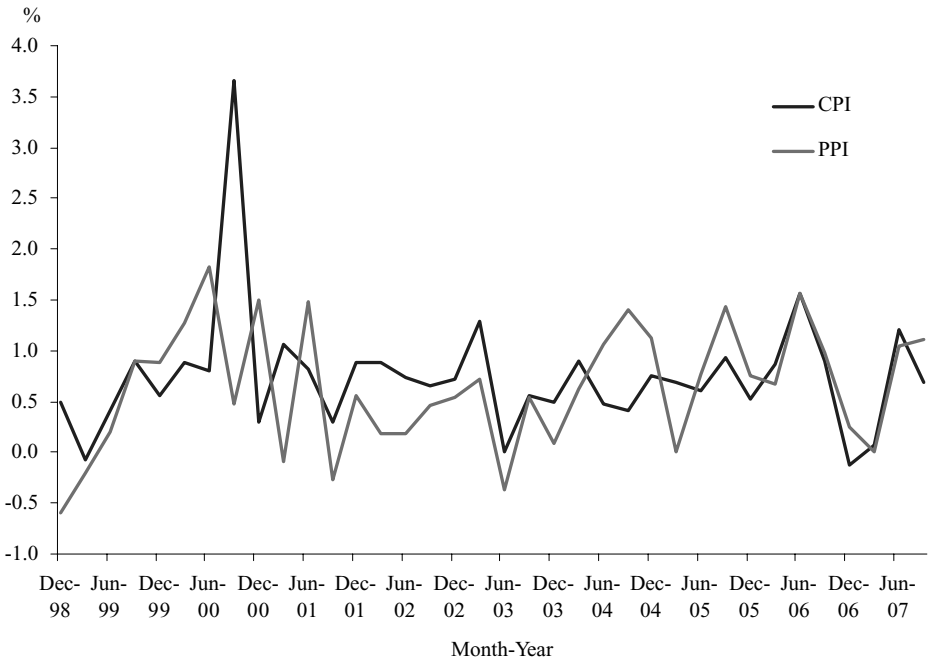


Figure 2 Time Series Plots of the CPI and PPI Measures of Consumer and Producer Prices[a]



Note: (a) The time series are computed as 100-fold the log difference of the index value.

Table 4 Descriptive Statistics for the Measures of Australian Consumer Inflation

	CPI	*Trimmed mean*	*Weighted median*
Mean	1.044	1.022	1.039
Standard deviation	0.873	0.619	0.636
Skewness	0.735	0.873	0.974
Kurtosis	3.090	2.514	2.847
Autocorrelation			
Lag 1	0.564	0.892	0.883
Lag 2	0.497	0.839	0.817
Lag 3	0.430	0.781	0.745
Lag 4	0.389	0.751	0.705
LB(4) statistic	86.666	269.218	246.876
Cross-correlation			
CPI	1	–	–
Trimmed mean	−0.112	1	–
Weighted median	0.245	0.784**	1

Notes: The statistics are estimated using quarterly percentage changes over the period June 1982 to September 2007. *LB(4)* is the Ljung-Box Q statistic of the null hypothesis of no autocorrelation at the first four lags (the 99 per cent critical value for the test is 13.3). Cross-correlation coefficients significant at the 5 per cent level are denoted using $**$.

figure is also estimated for the CPI measure. An association, at the theoretic level, can be asserted between the tradeables component in the CPI and import prices on the basis that the price of imported goods is reflected in the prices faced by consumers for such items. Any such association is distorted, however, by differing methods used to measure prices for trade indices. In contrast to the prices identified for the purposes of the CPI, trade price indices measure price changes without reference to regulatory surcharges, such as import duties and taxes, or price additives that may be passed on to consumers, such as the cost of freight.[8]

5. The Statistical Properties of the CPI and Other Inflationary Indicators

Descriptive statistics for the three measures of consumer inflation officially reported in Australia are provided in Table 4. The underlying measures of inflation exhibit a lower level of unconditional volatility than the headline measure. This is expected given that volatile items are implicitly or explicitly removed for the calculation of the trimmed mean and weighted median measures. The underlying measures also exhibit greater levels of positive skewness than the headline measure; this suggests that, in practice, the trimmed mean and weighted median approaches tend to dampen the effects of significant negative pricing shocks. Both underlying measures also exhibit lower levels of kurtosis than their headline counterpart. The lower kurtosis is expected since the underlying measures reduce the weight associated with price items at the tail ends of the pricing distribution, thereby resulting in a less peaked price distribution.

Autocorrelation levels are significantly different to zero for both the headline and underlying inflation measures of inflation. The trimmed mean and weighted median measures, however, exhibit significantly higher levels of autocorrelation than their headline counterpart. Although this is expected, given the trending characteristics of the underlying measures, the autocorrelation statistic of the underlying indicators is an interesting quantity in its own right for two primary reasons. First, the autocorrelation statistic acts as a measure of the statistical impact of the trimmed mean and weighted median procedures. Second, the statistic measures the persistence of medium-term pricing characteristics for the Australian economy (see Fuhrer and Moore 1995; Cogley and Sargent 2001; Dossche and Everaert 2005). Autocorrelation levels for both underlying measures suggest a high level of positive persistence in the price trend encountered by Australian consumers.

The correlation between the headline and underlying measures of inflation is insignificant. The lack of correlation is partially anticipated given the smoothing inherent in the application of the trimmed mean or weighted median methods of estimating the inflationary trend $\hat{i}_t$. In contrast, a significant positive correlation exists between the trimmed mean and weighted median measures of underlying inflation. Although the skewness and kurtosis statistics for the underlying measures suggest that the weighted median measure removes a greater portion of the lower price tail, the

Table 5 Contemporaneous Cross-Correlation between CPI and Non-CPI Price Measures

	PPI	*Import*	*Export*	*WPI*
CPI	0.247	0.147	0.073	0.086
Trimmed mean	−0.226	−0.004	−0.093	0.040
Weighted median	0.001	0.041	−0.098	0.052

Note: The coefficients are estimates using the quarterly percentage change over the period September 1999 to September 2007.

correlation coefficient indicates that the trends captured by the two measures, although not identical, are similar.

Table 5 presents the contemporaneous correlation between the three popular CPI measures and four measures of non-consumer price levels. In the unconditional sense, the correlation between the headline CPI and the PPI, although positive, is not significant. Although sampling error is responsible for some of the deviation observed between the CPI and PPI measures, their weak correlation suggests that the effects of factors such as retail margins, which are not present in the PPI, are significant. Import prices are also positively, albeit not significantly, correlated with headline CPI. The higher correlation observed between the CPI and import prices, relative to export prices, is associated with the positive relationship between the tradeables component of the CPI and import prices. The correlation between the underlying measures of consumer inflation and the measures of non-consumer inflation is weak, suggesting little contemporaneous association between consumer inflation trends and non-consumer inflation.

6. Conclusion

The ABS CPI measures headline inflation in the household sector, while the trimmed mean and weighted median measures attempt to capture underlying (or core) consumer inflation. Statistically, the underlying measures exhibit lower volatility and higher autocorrelation levels than their headline counterpart. These properties are useful for capturing inflationary trends, and the RBA relies heavily on the underlying measures for assessing medium-term inflation levels and benchmarking the effects of monetary policy. There are several other measures of inflation for the Australian economy. The PPI measures inflation in the production sector, the labour price index measures the price of labour and the trade price indices measure import and export prices. Although the consumption and non-consumption measures capture prices for the same economy, their unconditional contemporaneous correlation is insignificant.

December 2007

Endnotes

1. For example, is a household acquiring or using goods or services for consumption or investment purposes? Or is a small business, rather than a household, consuming goods or services?

2. Some products, such as gambling, prostitution or prohibited narcotics, are not tracked on legal and/or ethical grounds. There is also the need to consider the additional difficulty of dealing with changes in the selection of goods and services available to consumers.

3. The US Department of Labor produces a monthly CPI. The official Canadian Statistician, Statistics Canada, also produces a monthly CPI. In Europe, the Office for National Statistics in the United Kingdom and the Federal Statistical Office in Germany, for example, produce monthly CPI statistics.

4. Further information is available at <http://www.melbourneinstitute.com/research/macro/>.

5. The use of barcode scanning information may alter this situation.

6. Officially, the RBA targets the headline CPI published by the ABS. The weight attached to the official target when undertaking monetary policy, however, is questionable. In 2007, for example, the RBA increased its interest rate target in August and November, notwithstanding annual headline inflation of 2.1 per cent and 1.9 per cent (that is, at the lower end of the RBA's target band of 2 to 3 per cent) for the June and September quarters. The annual inflation measured by the weighed median (trimmed mean) was 2.9 per cent (2.7 per cent) and 3.1 per cent (2.9 per cent) respectively during the same period.

7. The CCTR was initiated in 2004 as a potential claim against taxable income for a proportion of child care costs incurred by certain parents. In 2007, responsibility for the CCTR was transferred from the Australian Taxation Office to the Family Assistance Office (FAO). As part of this change, the FAO would make payments to parents at the end of the financial year in which child care costs were incurred regardless of tax liability.

8. This price is deemed the FOB (Free on Board) price. Exchange rate adjustments for prices denominated in foreign currencies also affect trade indices. Although exchange rates also impact on the tradeables component of the CPI, such effects are not always passed on to consumers.

References

Advisory Commission to Study the Consumer Price Index 1996, *Toward a More Accurate Measure of the Cost of Living—Final Report of the Advisory Commission to Study the Consumer Price Index*, U.S. Government Printing Office, Washington, DC.

Australian Bureau of Statistics 2004, *Labour Price Index: Concepts, Sources and Methods*, Cat. no. 6351.0.55.001, ABS, Canberra.

Australian Bureau of Statistics 2005a, *Australian Consumer Price Index: Concepts, Sources and Methods*, Cat. no. 6461.0, ABS, Canberra.

Australian Bureau of Statistics 2005b, *A Guide to the Consumer Price Index: 15th Series*, Cat. no. 6440.0, ABS, Canberra.

Australian Bureau of Statistics 2006, *Producer and International Trade Price Indexes: Concepts, Sources and Methods*, Cat. no. 6429.0, ABS, Canberra.

Braithwait, S. D. 1980, 'The substitution bias of the Laspeyres price index: An analysis using estimated cost-of-living indexes', *American Economic Review*, vol. 70, pp. 64–77.

Bryan, M. F. and Cecchetti, S. G. 1993, 'Measuring core inflation', Cleveland Federal Reserve Working Paper Series, WP 9304.

Bureau of Labor Statistics 2007, *BLS Handbook of Methods*, ch. 17, Washington, DC, viewed December 2007, <http://www.bls.gov/opub/hom/home.htm>.

Cogley, T. and Sargent, T. 2001, 'Evolving post-World War II US inflation dynamics', *NBER Macroeconomics Annual*, vol. 16, pp. 331–73.

Dossche, M. and Everaert, G. 2005, 'Measuring inflation persistence: A structural time series approach', ECB Working Paper Series, WP 495/June 2005.

Fuhrer, J. and Moore, G. 1995, 'Inflation persistence', *Quarterly Journal of Economics*, vol. 110, pp. 127–59.

Grossack, I. M. 1981, 'The weighting bias in the consumer price index', *Business Horizons*, vol. 24, no. 5, pp. 17–22.

Harvey, A. C. and Koopman, S. J. 2000, 'Signal extraction and the formulation of unobserved components models', *Econometrics Journal*, vol. 3, pp. 84–107.

Hill, R. J. 2004, 'Inflation measurement for central bankers', in *The Future of Inflation Targeting: Conference Proceedings*, Reserve Bank of Australia, Canberra.

Lebow, D. E. and Rudd, B. R. 2003, 'Measurement error in the consumer price index: Where do we stand?', *Journal of Economic Literature*, vol. 41, pp. 159–201.

Manser, M. E. and McDonald, R. J. 1988, 'An analysis of substitution bias in measuring inflation, 1959–85', *Econometrica*, vol. 56, pp. 909–30.

Unayama, T. 2004, 'Upward bias in the consumer price index under the zero-inflation economy', *Economics Letters*, vol. 85, pp. 139–44.