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Component-smoothed Inflation: Estimating the Persistent Component of Inflation in Real Time

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Abstract

This paper presents a new measure of underlying inflation: component-smoothed inflation. It approaches the problem of determining underlying inflation from a different direction than previous methods. Rather than excluding or trimming out volatile CPI items, it smoothes components of the CPI based on their volatility – CPI expenditure weights are maintained for all items. Items such as rent are smoothed a little, if at all, while volatile series such as fruit, vegetables and automotive fuel are smoothed a lot. This removes much of the temporary volatility in the CPI while retaining most of the persistent signal. Because our underlying inflation measure includes all CPI items at all times, it is robust to sustained relative price changes and is unbiased in the long run. A potential cost of this approach is that, unlike other measures, it places weight on lagged as well as contemporaneous prices for volatile series. An evaluation of the balance between the costs and benefits of this approach remains an open question.

JEL Classification Numbers: E31, E52

Keywords: CPI, core inflation, underlying inflation, Australia, United States

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1. Introduction

Headline inflation is almost always the target for inflation-targeting central banks. But there is considerable interest in the use of underlying measures that are designed to reduce or remove transitory influences from the headline figure. The most commonly used measures of underlying inflation are those that exclude a few highly volatile items – typically fuel and food – from the headline measure. Other measures based on various statistical criteria, such as the trimmed mean or the weighted median of prices, have also been used in recent years.

This paper investigates an alternative measure of underlying inflation that addresses the problem of separating temporary from permanent shocks in a different way than existing measures. This measure, which we call component-smoothed inflation, estimates the separation between permanent and temporary shocks by using the information contained in the historical behaviour of individual price series. It is implemented by smoothing the historically noisy components of inflation while leaving the historically persistent components relatively untouched. This method has the advantage of allowing all items in the price index to retain expenditure weights in the underlying measure. It is designed to be sensitive to sustained relative price shifts and, consequently, to be unbiased with respect to headline inflation. It is also designed to be calculated in real time so that it can be used as a timely indicator of persistent inflation. A potential disadvantage is that when there are permanent shocks to series that have been historically volatile it will be slow to react to the shocks. These properties are discussed in more detail below. We calculate this measure for both Australia and the US to demonstrate its performance and highlight its characteristics.

2. Literature Review

Reflecting the rise in the number of inflation-targeting central banks, there has also been an expansion in the number of articles on measuring underlying inflation since the 1990s. Wynne (1999) provides a useful summary of the various approaches to underlying inflation that have been adopted.

An important step in considering underlying inflation is defining what is meant by the term. One widespread view of underlying inflation is that it is the common component of inflation that is present in each individual price series and which monetary policy-makers 'ought' to be concerned about.[1] That is, some component π^* where:

$$\pi_{it} = \pi_t^* + \varepsilon_{it} \tag{1}$$

and i indexes individual components of the CPI. Diewert (1995) discusses this view and shows that a 'neo-Edgeworthian' measure which weights movements in each price series by their volatility would provide the optimal estimate of π^*. This approach, however, is at odds with the fact that headline CPIs, which are almost always the target of policy, are expenditure weighted. To address this concern, Laflèche (1997) proposes a 'double weighted' measure that multiplies the neo-Edgeworthian weights by expenditure weights as used in the CPI. In a similar vein, Cutler (2001) implements a persistence-weighted measure of core inflation following an idea first suggested by Blinder (1997). In this approach each component of the price index is weighted by its persistence rather than by its expenditure share.

Bryan and Cecchetti (1993), while still viewing underlying inflation as the common component of individual price series, approach the problem of extracting π^* by focusing on the possibility that ε_{it} may not be normally distributed. They show that, in such circumstances, trimmed means (of which the weighted median

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1 Some papers consider this to be the purely monetary component of inflation that is unrelated to real factors such as supply shocks. This concept of 'monetary inflation' is expressed in the quantity theory of money. The paper by Quah and Vahey (1995), discussed below, provides a clear example of a focus on this concept of inflation.

is a specific example) are a robust method of identifying the central tendency in headline inflation.

Although proceeding from the assumption of a common 'monetary' component of inflation, Quah and Vahey (1995) adopt a very different approach to identifying this component of inflation. They define underlying inflation to be the component of inflation that has no long-run effect on output and then calculate their measure using a bivariate structural VAR model including output growth and inflation growth. They do not make use of the information contained in the component price indices but just use the aggregate headline measure. Their method is subject to revision each period as the estimates of the VAR model are updated with new data.

Other approaches to determining underlying inflation consider it to be the systematic, trend, or otherwise persistent component of inflation. This approach was discussed in Cecchetti (1997) and Blinder (1997). Exclusion measures, for example, observe that price movements in fuel and food are particularly volatile and that a less volatile measure of inflation can be obtained by placing zero weight on movements in these items.

Cogley (2002) suggested smoothing headline inflation using an exponential smoother as a way to extract the trend component of inflation. While his measure had some appealing statistical properties, it has not received much attention. In part this may be because it was applied to aggregate inflation and was conceptually the same as a moving average of inflation or, indeed, year-ended inflation. And these measures typically tend to lag actual inflation by some quarters, which limits their usefulness in a policy-making context.

It is also possible to interpret trimmed means and weighted medians as a method for extracting the persistent components of inflation. The measures are, after all, just robust estimates of the underlying or central tendency in headline inflation that down-weight particularly large movements in individual components – provided one identifies large movements with temporary movements, this approach is analogous to removing temporary volatility while leaving persistent components relatively untouched.[2] Furthermore, trimmed means are robust to relative price changes, provided those changes do not systematically affect the skewness of the price-change distribution.

3. An Alternative Measure of Underlying Inflation

3.1 Why Do We Need Another Measure of Underlying Inflation?

An important feature of the world economy over the past few years has been the emergence of China as a significant influence on world production and prices. Its rapid industrialisation has been pushing up commodity prices. At the same time, this industrialisation combined with its relatively cheap labour force has been driving down the price of manufactured goods. More generally, technological innovation has been driving the price of computers and related items down while services, such as education, medical care and child care have seen significant price rises. The net effect of these changes is that the relative prices of individual components of the CPI have been changing significantly and persistently.

This pattern of changing relative prices sits uncomfortably with the assumptions of a number of existing underlying inflation measures (such as the exclusion or re-weighted measures discussed in Section 2), which assume that there is a common component to inflation in all series around which there is only idiosyncratic noise. It also means that there is the potential for deviations between headline CPI and various underlying measures to emerge. For example, over the three years to March 2006, the average difference between headline CPI and CPI excluding volatile items in Australia was 0.2 per cent per year,[3] in the US it was 0.7 per cent over the three years to October 2006. Of course, whether these differences persist over longer periods will depend on the extent to which the rise in the relative price of fuel over this period proves to be permanent or transitory.

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[2] Because the trimmed mean and weighted median are non-linear functions of headline inflation it is not correct to say that they ignore the effect of all trimmed components. Rather, they limit the influence of outliers. For example, if the median is 2.5 per cent, it is insensitive to whether petrol prices rose by 5 per cent or 15 per cent in a particular period, but is not insensitive to the fact that petrol prices rose by more than the median.

[3] March 2006 is chosen to avoid the 'banana effect' dominating the comparison. Over the three years to September 2006 the average difference is 0.81 per cent per year.

Given these considerations, it is worth considering an approach to measuring underlying inflation that is defined as the low- and medium-frequency component of headline inflation. A problem with using the low and medium frequency component of inflation as a conceptual definition for underlying inflation is that it cannot be assessed in real time; it is only with the benefit of hindsight that one can definitively separate transitory shocks from permanent shocks. Notwithstanding this difficulty, the next section considers a measure that uses the information contained in the historical behaviour of the component price series to provide an estimated separation of the permanent and transitory shocks to the CPI in real time.

3.2 Component-smoothed Inflation

The basic method of constructing our component-smoothed inflation measure is to smooth the individual components of the CPI by an amount that is proportional to the volatility in each series. Thus, fruit and vegetable prices are heavily smoothed, because most movements in these series are temporary, while rent is barely smoothed at all, because most movements in this series are highly persistent. This means that only a small fraction of movements in especially volatile prices are allowed to influence the component-smoothed inflation measure in the period they occur because most of these movements are quickly reversed. Nonetheless, if there are persistent changes in these prices, they will contribute to the measure – albeit with a lag.

This approach is, in a sense, a formalisation of a process many economists already undertake informally in interpreting volatile economic series. With a volatile series, economists will often wait for some periods before being convinced that a given movement is going to be sustained. For example, a large movement in average weekly earnings, a particularly volatile series, rarely leads to a change in economists' estimate of the trend rate of wage growth until it is sustained for some periods. Conversely, a large movement in the wage price index, a particularly stable series, leads economists to change their estimate of trend more quickly. The component-smoothed inflation measure does the same thing for individual price series; an increase in the rent series, a particularly persistent series, is reflected almost immediately in our measure, while an increase in petrol prices, a particularly volatile series, needs to be sustained for a number of periods before it is reflected in our measure. This feature has some influence on how movements in our measure are interpreted. We discuss this further when we present our results below.

From this basic methodological approach, we make a number of choices to ensure some desirable properties of the component-smoothed inflation measure. For example, smoothing is applied to the level of the price series to ensure that the measure is unbiased over time. We also choose a smoothing method from the relatively simple class of exponential smoothers to minimise the computation burden of this measure and maximise its transparency.

This approach, smoothing volatile series a lot while leaving persistent series relatively untouched, is analogous to an optimal signal extraction strategy for each series. The Kalman filter, which is often used to identify underlying trends in series, displays just this behaviour.[4] It reflects the fact that movements in persistent series are informative about the underlying trend – and so one's estimate of the underlying trend should be strongly influenced by new observations – while movements in noisy series are relatively uninformative about the underlying trend – and so one's estimate of the underlying trend should be updated relatively little in light of new observations.

In one sense, this approach can be considered an extension of the idea behind exclusion-based measures. Exclusion-based measures derive from the observation that food and fuel prices are volatile and that movements in these series are more likely to be noise than signal. On this basis, these components – and only these components – are ignored in the calculation of the core measures of inflation. The data, however, are not so black and white. In reality, there are a number of items in the CPI that have similar volatility to food and fuel. For example, some clothing and holiday travel costs are approximately as volatile as food and fuel. Thus, a consistent application of the exclusion principle underlying the core measures could also argue for the exclusion of these categories. However, a choice between

4 The exponential smoother can be viewed as an approximation to the theoretically more appropriate Kalman filter (see Hamilton 1994 for details of the Kalman filter). In practice, the Kalman filter gain quickly converges to a constant in the case of the data we use in this paper and, as such, the use of a time-invariant gain is not significantly inferior to the time-varying gain of the Kalman filter.

complete exclusion or full inclusion is not required. The component-smoothed inflation measure allows a continuum of possible treatments for price series between complete exclusion and full inclusion. No series are completely excluded in the long run, and sustained relative price shifts will be reflected in the component-smoothed inflation measure for even the most volatile components. In another sense, however, component-smoothed inflation differs from other underlying measures because it introduces exponential smoothing, whereas most other measures are calculated entirely from contemporaneous information.

Component-smoothed inflation is calculated using two equations to smooth the price level of each CPI component series. The first equation is just an exponential smoother (with an adjustment to allow for trends in the price level – which is needed because of positive inflation) while the second equation updates the estimate of the trend:

$$\begin{aligned} P_{it}^{*} &= \left(P_{it-1}^{*} + \mu_{it-1}\right) + \alpha_{it}\left(P_{it} - \left(P_{it-1}^{*} + \mu_{it-1}\right)\right) \\ \mu_{it} &= \mu_{it-1} + \gamma(\Delta P_{it}^{*} - \mu_{it-1}) \end{aligned} \qquad (2)$$

where P_{it}^{*} is the smoothed price level in logs of series i at time t, P_{it} is the published price level in logs and μ_{it} is the trend rate of growth of the price level. There are two parameters, α and γ, that control the speed of updating or, equivalently, the amount of smoothing. These parameters are restricted to lie between 0 and 1. Our implementation links α and γ so, in practice, only one parameter needs to be chosen.[5]

The parameter α determines how quickly changes in a series' price level are reflected in the smoothed series. A high value of α means that changes will be reflected almost immediately, while a low value of α passes through very little of the change. There are a variety of ways to choose α, but, based on our objective to remove transitory volatility, we choose α based on the signal-to-noise ratio of the

5 This method is sometimes called 'double exponential smoothing'. The double refers to the second equation which ensures that the smoother follows trends whereas 'exponential smoothing' cannot be guaranteed to be unbiased with respect to the original series.

price series.[6] Thus, a highly persistent series would have $\alpha = 1$, and there would be no smoothing, while a series dominated by temporary shocks would have a small value for α and a high degree of smoothing. This has the effect of smoothing transitory shocks while leaving persistent movements relatively unaffected. In a similar manner, the parameter γ controls the speed with which the estimate of trend is updated. If $\gamma = 0$ there is no updating and the trend remains constant throughout the sample.

The basic formula for α is:

$$\alpha_{it} = \frac{Q}{Q + R_{it}} \qquad (3)$$

where Q is a parameter that controls the smoothness of the component-smoothed inflation measure and R_{it} is the variance of the noise in the raw price series. R_{it} is calibrated for each series as the variance of deviations of the observed price series P_{it} from its Henderson trend based on data up to time t. A series with little noise will have small deviations from its Henderson trend, so that R_{it} will be small and, consequently, α_{it} will be close to unity. A series containing a lot of noise will deviate substantially from its Henderson trend, and have a low value for α_{it}. In practice, the values of R_{it} do not appear to matter as much as the ranking between the CPI series that they provide.

While Q needs to be in the same units as R, the precise value for Q is somewhat arbitrary and can be thought of as the 'target' for how smooth the researcher would like the underlying measure to be. A higher value for Q will lead to a more volatile underlying series while a lower value will have the opposite effect. At the limits, if $Q = 0$ all the α parameters would be zero and the resulting series would be a constant, while α approaches 1 for large Q and, in the limit, the resulting series

6 This is also consistent with our method's interpretation as an approximation to the Kalman filter. A superficially appealing alternative to using the signal-to-noise ratio for a series to calibrate α would be to use the autoregressive parameter for the price series. A problem with this approach, however, is that it is not robust to medium-term shifts in the rate of inflation for a series. For example, many Australian inflation series, including ones that are highly volatile, have a high autoregressive parameter when calculated over any period incorporating the decline in inflation in the early 1990s. Nonetheless, we consider this alternative in Section 4.3 when we test the robustness of our measure.

would be the headline CPI. Our particular choice is guided by the desire to capture enough medium-term movements to allow policy-relevant inference about inflationary pressures to be made. We discuss the exact values chosen in Sections 4.1 and 4.2.

When comparing the results based on Equation (3) to those of the Kalman filter we find that highly volatile series are smoothed too much and so the lag before sustained price changes were reflected in the index was judged to be too long. Thus, we adopt one small modification to the formula for α to limit the extent of smoothing. We modify Equation (3) and set α_{it} as:

$$\alpha_{it} = (1-\beta)\frac{Q}{Q+R_{it}} + \beta \qquad (4)$$

where β sets a lower bound for α_{it}, which ensures that even very volatile series still make some contribution to the final index. Because only data up to time t are used to calculate R_{it}, the smoothing process can be performed in real time.

In keeping with our approximation to the Kalman filter we choose $\gamma_{it} = \alpha_{it}^2$. This specification updates the estimate of the trend quickly for series with little noise, and more slowly for series that contain more noise – something that also has obvious intuitive appeal.

As the smoothing process is recursive, the initial values need to be set. We set P_{i0}^* equal to P_{i0}, μ_{i0} equal to the growth rate of the CPI in the period before the algorithm is started and $\alpha_{it} = \hat{\alpha}$, a constant, for an initial three-year period. After three years the estimates for α_{it} are updated and the first three years of data are used to calculate the first value of α_{it}, and the sample used to calculate α_{it} is lengthened recursively with the release of each new observation.[7]

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7 Occasionally new series are added to the CPI. When this occurs, we set the α parameter for the new series to that of the most similar series already in the index for the first three years of its inclusion. For example, in Australia the education fees price series was replaced with three series (primary, secondary and tertiary education) with the introduction of the 14th series CPI. For the first three years we set the α for these three series based on the α for the older aggregate education series.

3.3 Features of Component-smoothed Inflation

The component-smoothed inflation measure can be thought of as an implementation of the idea expressed in Blinder (1997), whereby underlying inflation is the persistent component of inflation. However, rather than down-weighting volatile series, our measure maintains the CPI weights and removes the noise from the series through exponential smoothing. While the maintenance of CPI weighting has obvious intuitive attractions, an additional advantage of maintaining expenditure weights is that it helps to ensure that the measure is unbiased in the long run with respect to headline inflation. As discussed above, sustained relative price shifts have been a particular feature of CPIs around the world over recent years. Our measure is robust in the long run to persistent relative price changes of this sort.

While smoothing each individual CPI component requires more calculation than just smoothing aggregate inflation, a significant advantage is that identification and removal of transitory shocks is much easier at the disaggregated level. To see this most clearly consider a trivial example where the CPI is made up of two series, where one is very noisy and contains no long-term trend (white noise for example), while the other is highly persistent (say, a random walk). At the aggregate level it would not be possible to separate the temporary from the persistent shocks in real time. At the component level, separating the temporary shocks from the persistent shocks is trivial. While the distinction is not quite so easy in the real world, there are still series that are historically highly persistent, such as rent, while others, such as fruit, have historically been characterised by frequent temporary price shocks.

Another feature of the measure is that some lag relative to the headline CPI can arise in circumstances where history has shown that the movements are quickly reversed. If a historically volatile item experiences a persistent change in price, the measure will lag, though to some degree recognition lags are probably inevitable with any measure in these circumstances. There is little problem with temporary shocks to persistent series as they only serve to add a little extra volatility to the series.

Another property of the component-smoothed inflation measure is that a number of existing measures of inflation can be thought of as special cases. For example, headline inflation is equivalent to setting all $\alpha_i = 1$ and the exclusion measures are equivalent to setting $\alpha_i = 0$ for the excluded components and $\alpha_i = 1$ for the rest. This relationship will be discussed further below when this paper's measure is compared with existing measures of inflation.

Papers by Roger (1998) and Wynne (1999) have proposed a number of properties for underlying inflation measures which they see as desirable. The component-smoothed inflation measure is designed, wherever possible, to have these properties. Thus, it is timely as it can be calculated in real time, it is unbiased by construction, and we have also endeavoured to make it easy for the public to understand and verify by choosing to use exponential smoothing and opting towards simpler formulations wherever possible.[8] As argued for by Wynne, the component-smoothed inflation measure is non-revisionary and, as is shown below, because it focuses on the persistent component of inflation, has some predictive power for future inflation.

Finally, while we calculate the component-smoothed inflation measure based on headline inflation in this paper, it would be a simple matter to base the construction on any other inflation measure. This would result in a measure that is unbiased with respect to that measure of inflation, but smoother. This would seem to be of most relevance in countries where some other measure of inflation is the legislated, or otherwise chosen, target of policy.

A more detailed evaluation of the performance of the component-smoothed inflation measure is contained in the next section which presents the measure for Australia and the US and compares these results with commonly used measures of underlying inflation in each country.

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[8] Exponential smoothing and the other steps required to calculate component-smoothed inflation can all be implemented in a spreadsheet while other methods may require more specialised software.

4. Results

4.1 Australia

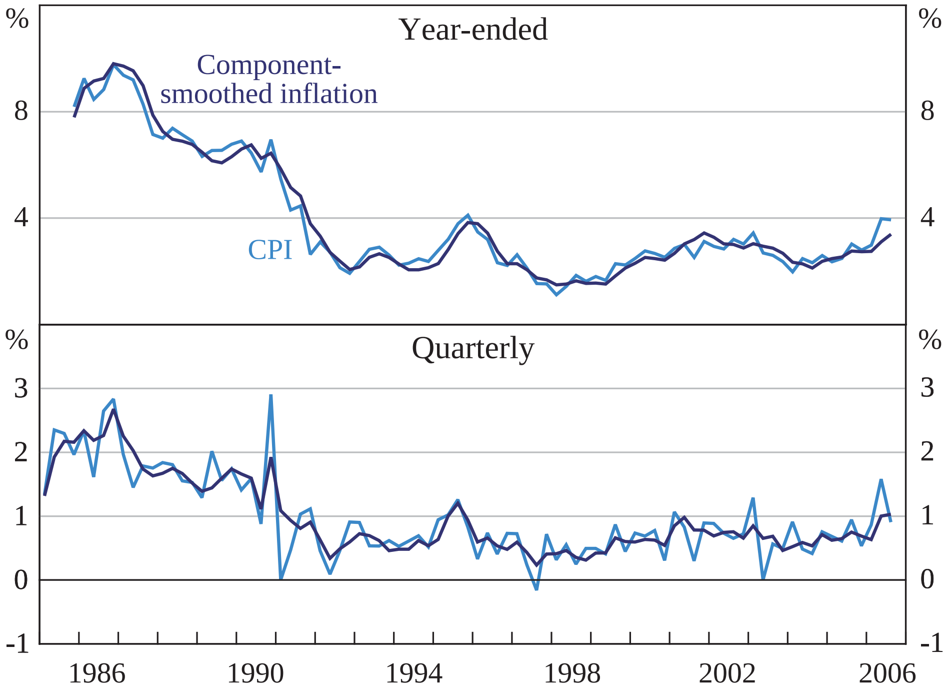
Reflecting the fact that Australia has a quarterly CPI, we calibrate R_{it} for each series as the variance of its deviations from a 5-quarter Henderson trend. In general, a 5-term Henderson trend removes at least 80 per cent of cycles less than 2.4 periods, so that deviations of a series from its 5-term Henderson trend should be a good measure of the amount of high-frequency volatility that we wish to smooth out (ABS 2006). Q is chosen to be 0.5 percentage points, which gives a relatively smooth profile to our measure of underlying inflation. The parameter β is set equal to 0.15, ensuring that shocks to even the most volatile series have a half-life no greater than 5 periods, and the parameter $\hat{\alpha}$ is set equal to 0.3. We start our sample in 1982, when the ABS introduced the 10th series of the CPI, so that the first readings for our underlying inflation measure are in 1985. We also use seasonally adjusted price series where appropriate.[9]

The component-smoothed inflation measure of underlying inflation is shown in Figure 1.[10] It clearly removes much of the volatility in CPI inflation, while still capturing its medium-term trends. Furthermore, despite the smoothing, the peak correlation between component-smoothed inflation and CPI inflation is contemporaneous and many of the peaks and troughs in the measure line up with those of the CPI.

9 We use the same seasonal adjustment as is used for the 15 per cent trimmed mean measure used by the Reserve Bank of Australia (RBA). The seasonal adjustment process is discussed in more detail in Roberts (2005).

10 The temporary shock to banana prices in Australia in the June and September quarters of 2006 is having some effect on the level of underlying inflation shown by our component-smoothed inflation measure. Because we know this shock will be temporary, we can use this knowledge to set $\alpha = 0$ for the fruit price series in the June and September quarters 2006, ensuring that our measure does not update in response to the surge in banana prices. Adjusting for banana prices in this way has the effect of reducing the inflation rate for the component-smoothed inflation measure from 3.4 to 3.2 per cent over the year to the September quarter 2006.

Figure 1: CPI and Component-smoothed Inflation Measures of Inflation – Australia



Note: Both series exclude interest charges, major health policy changes and the tax changes of 1999–2000.

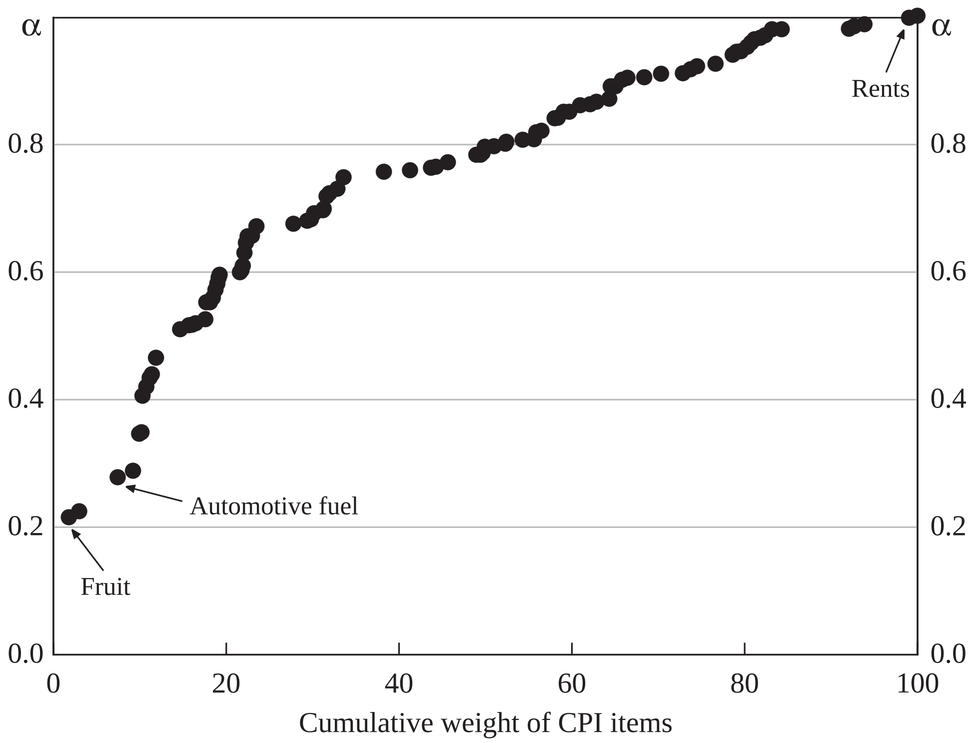
The amount of smoothing applied to each CPI series by our measure can be seen in Figure 2. Our method imposes small α coefficients for the most volatile series, such as fruit, vegetables and automotive fuel, but as Figure 2 indicates, the majority of series have high α coefficients, ensuring that price changes in series with relatively low volatility are quickly incorporated into our measure of underlying inflation. For example, rent has an α coefficient very close to unity, so that price changes in this series are almost immediately incorporated into our component-smoothed inflation measure. Appendix A contains a table reporting the CPI items with the highest and lowest dozen α coefficients.

Table 1 indicates how the component-smoothed inflation measure, and a number of commonly used underlying inflation measures, perform on several of the metrics by which underlying inflation series are typically assessed.[11] We present results for the full sample of data, which includes a significant mean shift, as well

[11] We use the 15 per cent trimmed mean for comparison because that trim is the one currently published by the RBA. Work by Brischetto and Richards (2006) examines the full range of possible trimmed means and finds that the performance of trimmed means are very similar for trims greater than, approximately, 5–10 per cent.

as over the low-inflation period beginning in 1993. By construction, our measure has a high autocorrelation, especially compared to existing underlying inflation measures over the low-inflation period. Consistent with this, the mean absolute difference of quarterly inflation based on our measure is low, and its standard deviation is lower than that for the headline and exclusion-based measures, and comparable to that for the statistical measures. The component-smoothed inflation measure also tracks trend inflation more closely than the other inflation measures. The measure of trend inflation we have used to assess this is the inflation rate calculated from a centred 9-term Henderson trend of the CPI. Unlike the other measures of underlying inflation, the component-smoothed inflation measure is exactly unbiased relative to the CPI by construction but, as shown in Table 1, unbiasedness is not ensured over any finite sample. Nevertheless, over the full sample of data, the bias is negligible and compares favourably with the exclusion-based and statistical measures. For the low-inflation period since 1993, the point estimate of the bias is slightly smaller than for the trimmed mean, though neither is statistically significant.

Figure 2: Ordered α Coefficients of CPI Items – Australia



Note: α coefficients and effective weights are for 2006:Q3.

Table 1: Inflation Measures Summary Statistics

Quarterly percentage changes[(a)]

	Component-smoothed inflation[(b,c)]	CPI[(b)]	CPI ex volatiles	15 per cent trimmed mean[(c)]	Weighted median[(c)]
1985:Q1–2006:Q3					
AR(1) coefficient	0.92	0.61	0.83	0.89	0.91
Standard deviation	0.59	0.66	0.63	0.57	0.58
Mean absolute difference	0.16	0.39	0.24	0.18	0.18
Deviation from trend[(d)]	0.15	0.32	0.22	0.16	0.17
Bias[(e)]	–0.03	–	–0.08	–0.12	–0.15
1993:Q1–2006:Q3					
AR(1) coefficient	0.71	0.08	0.42	0.36	0.32
Standard deviation	0.19	0.30	0.23	0.16	0.17
Mean absolute difference	0.11	0.31	0.18	0.14	0.16
Deviation from trend[(d)]	0.10	0.22	0.17	0.13	0.17
Bias[(e)]	–0.07	–	–0.19	–0.10	–0.13

Notes: (a) Excluding interest charges and adjusted for the tax changes of 1999–2000.
(b) Excluding major health policy changes.
(c) Based on prices seasonally adjusted at the component level where appropriate.
(d) Root-mean-squared error (RMSE) of difference in inflation rates from a centred 9-term Henderson trend, in percentage points.
(e) Relative to the CPI, except for component-smoothed inflation which is relative to the CPI excluding major health policy changes.

Another common benchmark used to assess measures of underlying inflation is their ability to forecast changes in headline inflation. While the component-smoothed inflation measure is not primarily intended to be used for forecasting, the removal of variability in headline inflation that is likely to be quickly reversed should allow it to perform well as a predictor of headline inflation over short horizons. To assess this, Table 2 reports RMSE statistics when the most recent quarterly inflation rate is used to forecast quarterly headline inflation rates at horizons out to one year. Clearly, all the measures of underlying inflation reported in Table 2 are better predictors of headline inflation at short horizons than headline inflation itself, with the component-smoothed inflation measure performing comparatively well on this criterion.

Table 2: Root-mean Squared CPI Forecast Errors

Forecasts of quarterly CPI inflation using the most recent quarterly inflation rate for each candidate series[(a)]

Forecast horizon	Component-smoothed inflation[(b,c)]	CPI[(b)]	CPI ex volatiles	15 per cent trimmed mean[(c)]	Weighted median[(c)]
			1985:Q1–2006:Q3		
1Q	0.47	0.58	0.50	0.43	0.42
2Q	0.44	0.56	0.48	0.43	0.41
4Q	0.47	0.52	0.49	0.44	0.44
			1993:Q1–2006:Q3		
1Q	0.33	0.41	0.37	0.32	0.33
2Q	0.32	0.40	0.38	0.34	0.33
4Q	0.35	0.38	0.39	0.34	0.35

Notes: (a) Excluding interest charges and adjusted for the tax changes of 1999–2000.
(b) Excluding major health policy changes.
(c) Based on prices seasonally adjusted at the component level where appropriate.

A corollary of good forecasting performance is that divergences between headline inflation and the component-smoothed inflation measure are closed by headline inflation moving towards component-smoothed inflation, rather than the reverse. To test this, we performed pair-wise Granger causality tests between the CPI and the component-smoothed inflation measure, as well as the other underlying inflation measures.[12] The results presented in Table 3 indicate that over the full sample of data, divergences between CPI and underlying inflation are closed by CPI inflation moving towards underlying inflation, and not the reverse (except for the trimmed mean measure). Over the low-inflation period beginning in 1993, there is no statistically significant Granger causality between CPI inflation and any of the underlying inflation measures. This is consistent with the finding in Heath, Roberts and Bulman (2004) that inflation in Australia has become harder to forecast in the low-inflation period.[13]

12 Roberts (2005) outlines a number of other tests that address this property.

13 Brischetto and Richards (2006) discuss the use of Granger causality tests in more detail and suggest some caution when interpreting the results.

Table 3: Pair-wise Granger Causality Tests

F-statistics: one-quarter-ahead causation between CPI and candidate series

	1985:Q1–2006:Q3 Null hypothesis		**1993:Q1–2006:Q3 Null hypothesis**	
	CPI does not Granger cause candidate series	Candidate series does not Granger cause CPI	CPI does not Granger cause candidate series	Candidate series does not Granger cause CPI
Component-smoothed inflation[a,b,c]	0.46 (0.50)	24.23 (0.00)***	1.25 (0.27)	0.98 (0.33)
CPI ex volatiles[a]	0.41 (0.52)	20.95 (0.00)***	0.33 (0.57)	0.53 (0.47)
15 per cent trimmed mean[a,c]	10.36 (0.00)***	53.01 (0.00)***	0.02 (0.89)	2.53 (0.12)
Weighted median[a,c]	2.42 (0.12)	56.34 (0.00)***	0.28 (0.60)	1.14 (0.29)

Notes: ***, ** and * denote rejection of the null hypothesis at the 1, 5 and 10 per cent levels of significance; p-values in parentheses below F-statistics.

(a) Excluding interest charges and adjusted for the tax changes of 1999–2000.

(b) Excluding major health policy changes.

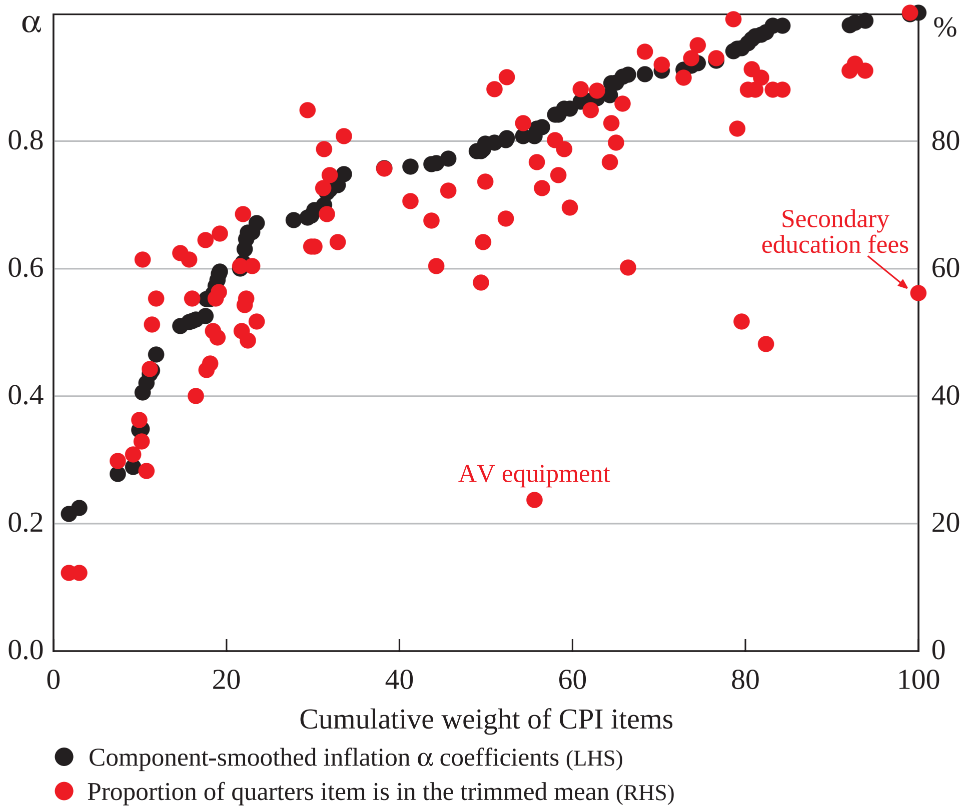
(c) Based on prices seasonally adjusted at the component level where appropriate.

4.1.1 Relation to other underlying inflation measures

In order to better understand differences between component-smoothed inflation and other measures of underlying inflation, it is helpful to consider the effective smoothing that is applied to each CPI component under the alternative measures. As noted earlier, our measure would be the same as the CPI if $\alpha_{it} = 1$ for all components. Similarly, the CPI ex volatiles is equivalent to a measure with $\alpha_{it} = 1$ for all the included components and $\alpha_{it} = 0$ for the excluded components (fruit, vegetables and automotive fuel). The items included in the trimmed mean vary from quarter to quarter, but we can get a sense of the amount of volatility in each CPI component, as assessed by the trimmed mean, by calculating the proportion of time each item is included in the trimmed mean. In general, we would expect that series with low α coefficients (those containing a lot of temporary shocks) would be frequently excluded from the trimmed mean, and vice versa.

To show this graphically, Figure 3 updates Figure 2 to include the proportion of time each CPI item has been included in the trimmed mean over the history of each price series.

Figure 3: Ordered α Coefficients of CPI Items and Proportion of Quarters in the 15 Per Cent Trimmed Mean – Australia

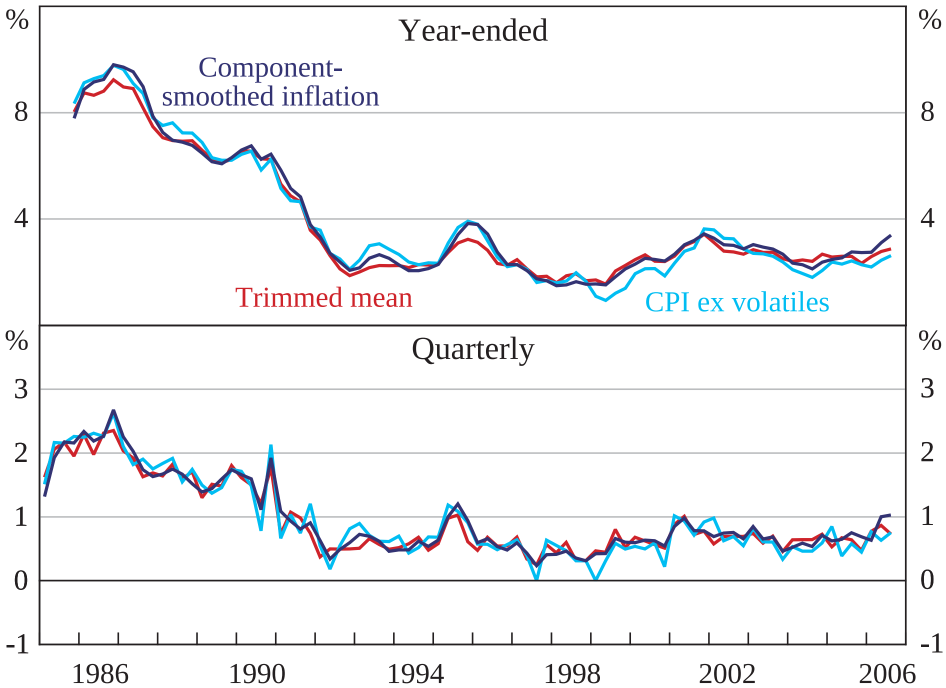


Notes: α coefficients and effective weights are for 2006:Q3. Data for the 15 per cent trimmed mean reflect the proportion of time that items in the 15th series CPI have been in the 15 per cent trimmed mean for each quarter the series has been in existence, except for the deposit & loan facilities and other financial services series, which have only been published since 2005:Q3.

As expected, there is a fairly close correspondence between the α coefficients of each CPI component for our measure and the proportion of time each component has been excluded from the trimmed mean. A notable exception is the series for audio, visual & computing equipment. It is relatively persistent, but is regularly excluded from the trimmed mean. This is because it has experienced a substantial relative price decline. Similarly, secondary education, which is found to be the most persistent series using our method, is regularly excluded from the trimmed mean because it is experiencing a substantial relative price increase, growing at 6.7 per cent per annum on average. At an aggregate level, these offsetting effects seem to cancel out such that the trimmed mean is not significantly biased with respect to headline inflation. Nonetheless, this does suggest some efficiency loss in the trimmed mean compared with the component-smoothed inflation measure as informative movements in audio, visual & computing equipment and secondary education prices are commonly trimmed.

The result of these differences can be seen in Figure 4, which shows year-ended inflation for the component-smoothed inflation measure, the CPI ex volatiles series and the trimmed mean. While these measures all present a broadly similar picture of underlying inflation over our sample, there are some notable differences. In the period between 1995 and 1997 the component-smoothed inflation measure corresponds more closely to the CPI ex volatiles measure than the trimmed mean, which showed a smaller rise in inflation, most likely due to the increase in the positive skewness of CPI inflation over this period. More recently, the component-smoothed inflation measure has diverged from the CPI ex volatiles measure, due in part to the different treatment of automotive fuel. Over the past three years, rises in automotive fuel prices have accounted for around 15 per cent of the rise in the level of our index, and by definition have made no contribution to growth in the CPI ex volatiles measure. Over this same period, automotive fuel prices have only been in the trimmed mean once, though, for reasons mentioned above, they still influence it.

Figure 4: Inflation Measures – Australia



Notes: All series exclude interest charges, and are adjusted for the tax changes of 1999–2000. The component-smoothed inflation measure has also been adjusted for major health policy changes.

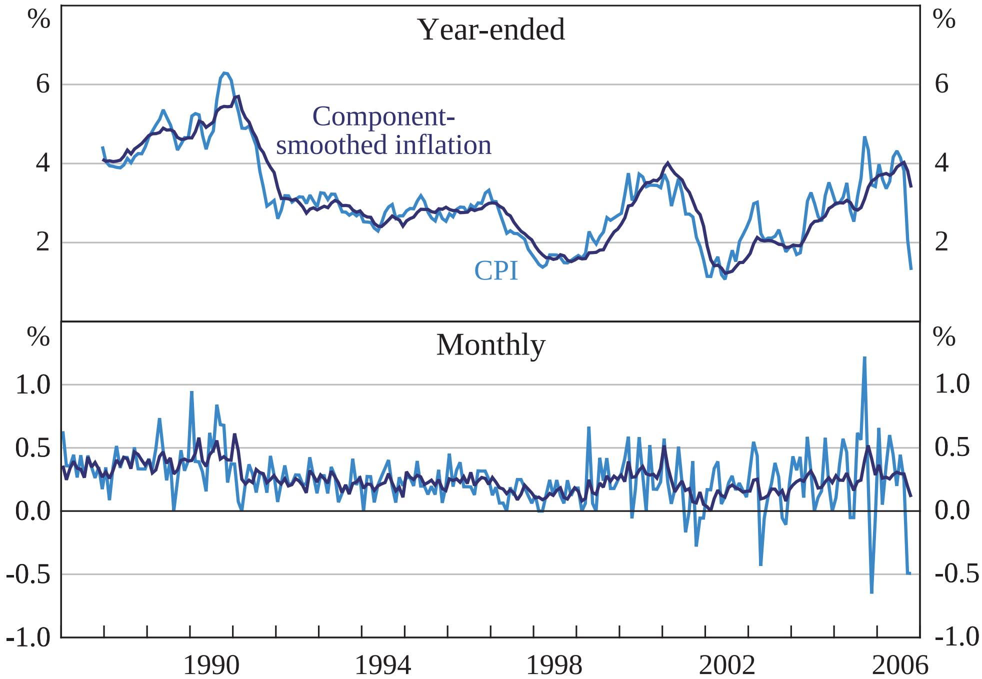
4.2 The United States

Reflecting the monthly frequency of the US CPI, we use different parameters than those used with the quarterly Australian data. We use a 23-month Henderson trend to calibrate R_{it} compared with the 5-quarter Henderson trend used for the Australian data. The 5- and 23-term Henderson trend series remove the majority of variation in data series at frequencies of less than 2.4 and 8 periods respectively, and so are comparable measures of noise when used on quarterly and monthly data (ABS 2006). The parameter Q does not need rescaling because values for R_{it} calculated based on a 23-month Henderson trend are broadly comparable in magnitude to those calculated with a 5-quarter Henderson trend. However, the parameters $\hat{\alpha}$ and β are scaled down by a factor of one-third. With these adjustments, the performance of the component-smoothed inflation measure on US data is similar to that on the Australian data.

Our sample is from 1987:M1 to 2006:M10. Over this period there have been several re-weightings of the US CPI, but only in 1997 were there changes to the items included in the CPI price indices. We use data at the expenditure class level (which currently consists of 70 categories), and are able to obtain data for the bulk of the post-1997 price indices for several years before 1997, allowing us to calculate α coefficients for these series, and so avoiding any break in our underlying inflation measure. For series where data before 1997 are not available, they are assigned the α coefficient of the most similar superseded series for the first three years.

Figure 5 below shows the US CPI and the component-smoothed inflation measure in monthly and year-ended percentage change form. Clearly, our measure of underlying inflation is smoother than headline inflation, particularly in monthly terms. The peak correlation with headline inflation is contemporaneous. As will be seen when this measure is compared with the core measure (CPI ex food & energy) the apparent lag around the turn of the century is induced by large swings in energy prices that turned out to be quite persistent. Of course, at the time this could not be predicted and the delayed response evident in our measure is generally the best one can do in real time.

Figure 5: Inflation Measures – United States



Notes: The CPI series is the seasonally adjusted series published by the Bureau of Labor Statistics (BLS). The component-smoothed inflation series uses component data that have been seasonally adjusted using Census X12 where appropriate.

The properties of the component-smoothed inflation measure that can be seen in Figure 5 are also evident in the statistics presented in Table 4: relative to the CPI, our measure has high persistence, a low standard deviation and small mean-absolute difference of percentage changes. The bias for the component-smoothed inflation measure is also small over our sample period. The component-smoothed inflation measure is also a smoother measure of inflation than the CPI excluding food & energy (which is the most commonly quoted core CPI measure in the US). Our underlying inflation measure also follows trend inflation more closely than the CPI ex food & energy. For the US, we measure trend inflation as the inflation rate calculated from a centred 23-term Henderson trend of the CPI.

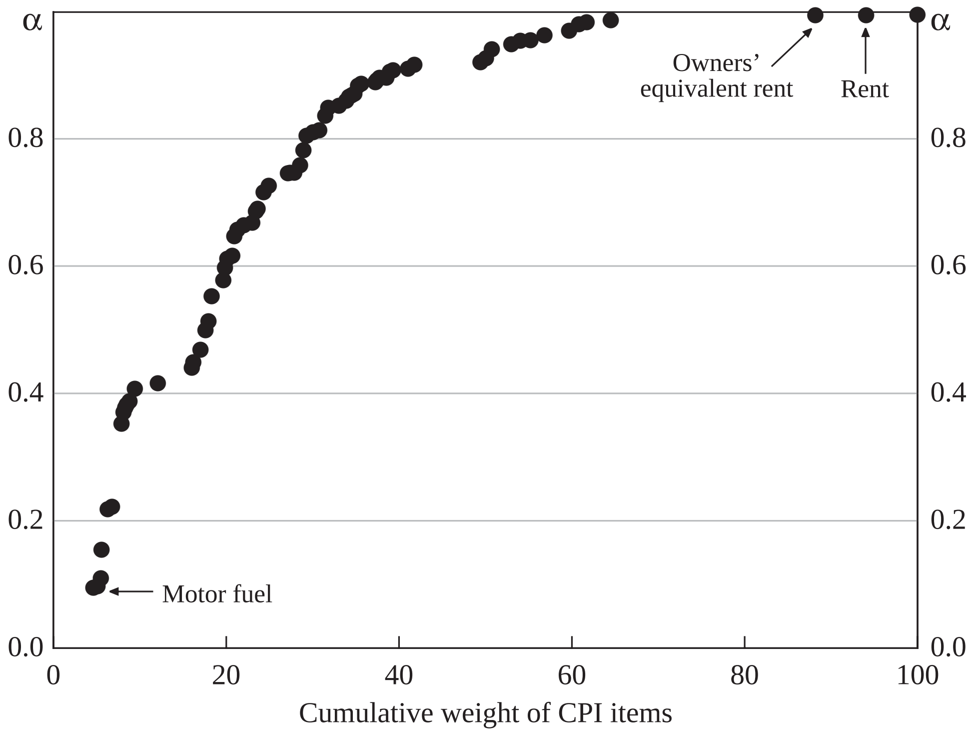
As shown in Figure 6, the distribution of α coefficients for the US is similar to that for Australia. The ranking among CPI item types is also broadly similar. For example, the rent series have α coefficients close to unity, while motor vehicle fuel has a small α coefficient for Australian and US data. Interestingly, even with monthly data, which we might expect to be more noisy than quarterly data, over half the CPI items by weight have an α coefficient of 0.9 or greater, so that price data for at least half the CPI are incorporated rapidly into the component-smoothed inflation measure. See Appendix A for a list of the CPI components with the highest and lowest dozen α coefficients.

Table 4: Inflation Measures Summary Statistics – United States
Monthly percentage changes: 1987:M1–2006:M10

	Component-smoothed inflation[(a)]	CPI[(b)]	CPI ex food & energy[(b)]
AR(1) coefficient	0.78	0.29	0.39
Standard deviation	0.11	0.22	0.12
Mean absolute difference	0.05	0.19	0.11
Deviation from trend[(c)]	0.06	0.18	0.11
Bias[(d)]	0.02	–	–0.07

Notes: (a) Price series have been seasonally adjusted using Census X12 where appropriate.
(b) The seasonally adjusted series produced by the BLS.
(c) RMSE of difference in inflation rates from a centred 23-term Henderson trend, in percentage points.
(d) Relative to the CPI.

Figure 6: Ordered α Coefficients of CPI Items – United States



Note: α coefficients and effective weights are for 2006:M10.

For brevity, we have not reported the results contained in Table 2 for US data, as the same general conclusions made earlier with Australian data also hold with US data. In particular, the current level of monthly component-smoothed inflation is a better predictor of the future level of CPI inflation at short horizons than the current level of the CPI ex food & energy measure. However, we find that while the component-smoothed inflation measure Granger causes the CPI, the CPI also Granger causes the component-smoothed inflation in a test containing at least two lags.[14]

4.2.1 Relation to other underlying inflation measures

Figure 7 shows the component-smoothed inflation measure and the CPI ex food & energy, together with the 25 per cent trimmed mean series calculated by Brischetto and Richards (2006) in year-ended form. The component-smoothed inflation measure and the core CPI (that is, ex food & energy series) have at times presented quite different indications on the pace of underlying inflation.

Of particular note is the recent divergence created by the increase in oil prices – the component-smoothed inflation measure has been rising since 2004 in year-ended terms while the core measure has only recently kicked up above 2.5 per cent. The component-smoothed inflation measure also indicated more strength in underlying inflation in the late 1990s, and suggested that underlying inflation declined more rapidly than the CPI ex food & energy measure in the early 2000s.

Our measure appears to lead the core CPI measure – particularly through the period around the turn of the century – while it appeared to lag headline during this period (Figure 5). This pattern is consistent with the hypothesis that sustained energy price shocks ultimately lead to inflationary pressures. Whether or not this is the case, our measure can provide an indicator of building price pressures associated with sustained energy price movements in a timely fashion while not providing false signals associated with temporary shocks. This different perspective on such shocks seems potentially useful when combined with evaluations based on other underlying inflation measures. Because energy prices are volatile, and so are typically removed from trimmed mean measures of inflation, the 25 per cent trimmed mean shown in Figure 7 appears also to have excluded most of the first-round effect of higher energy prices in recent years.

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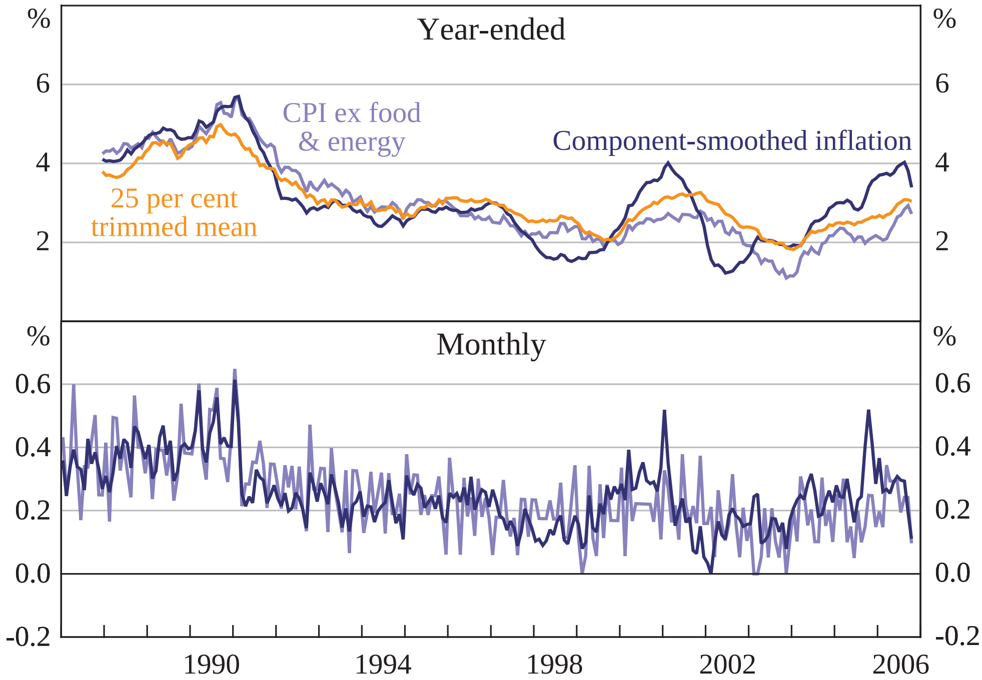
[14] Brischetto and Richards (2006) presents a wider range of Granger causality tests for the US.

Figure 7: Component-smoothed Inflation and Underlying Inflation Measures – United States



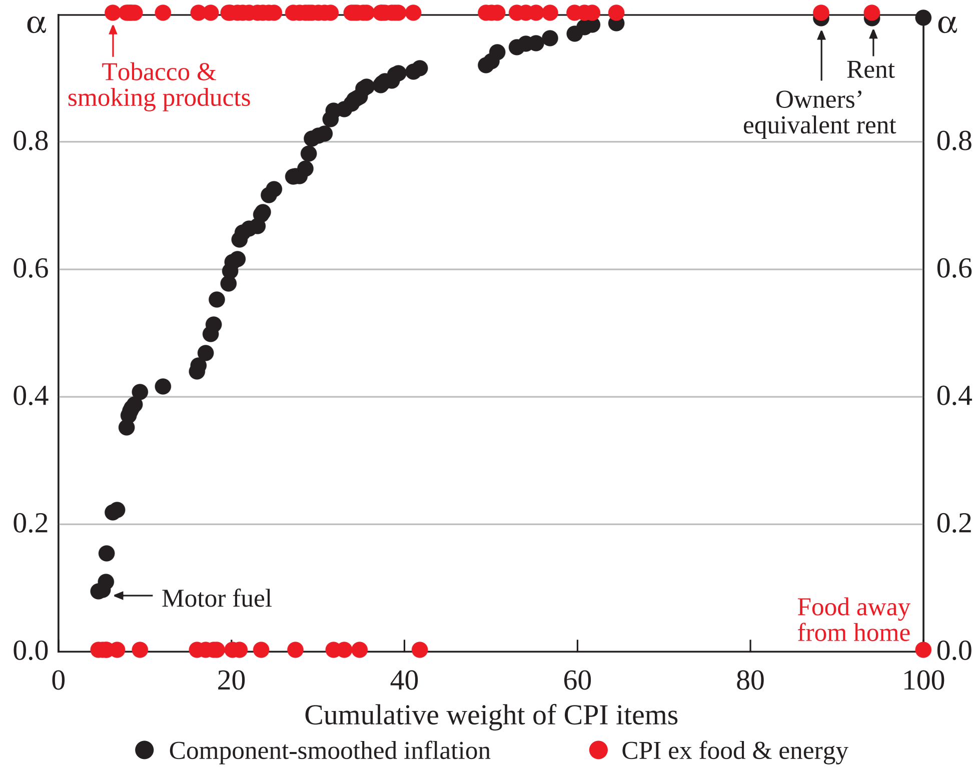
Note: The CPI ex food & energy series is the seasonally adjusted series published by the BLS. The component-smoothed inflation series uses component data that have been seasonally adjusted using Census X12 where appropriate.

Another way to better understand the divergences between the component-smoothed inflation measure and the CPI ex food & energy measure is shown in Figure 8. Figure 8 adds the equivalent α coefficients for the CPI ex food & energy measure to the α coefficients for the component-smoothed inflation measure shown in Figure 6.

Interestingly, the core CPI (which excludes food & energy) removes many items that have relatively high α coefficients, most notably the item food away from home which, based on our measure, we find to be the CPI item containing the least noise.[15] In contrast, the core CPI includes a number of items that we find to be highly volatile, such as tobacco & smoking products. This suggests some efficiency loss for the CPI ex food & energy series by excluding some potentially informative series while including a number of series with similar volatility to other excluded series.

15 Clark (2001) also finds the CPI item food away from home to be highly persistent.

Figure 8: Ordered α Coefficients of CPI Items and Equivalent α Coefficients of CPI ex Food & Energy Items – United States



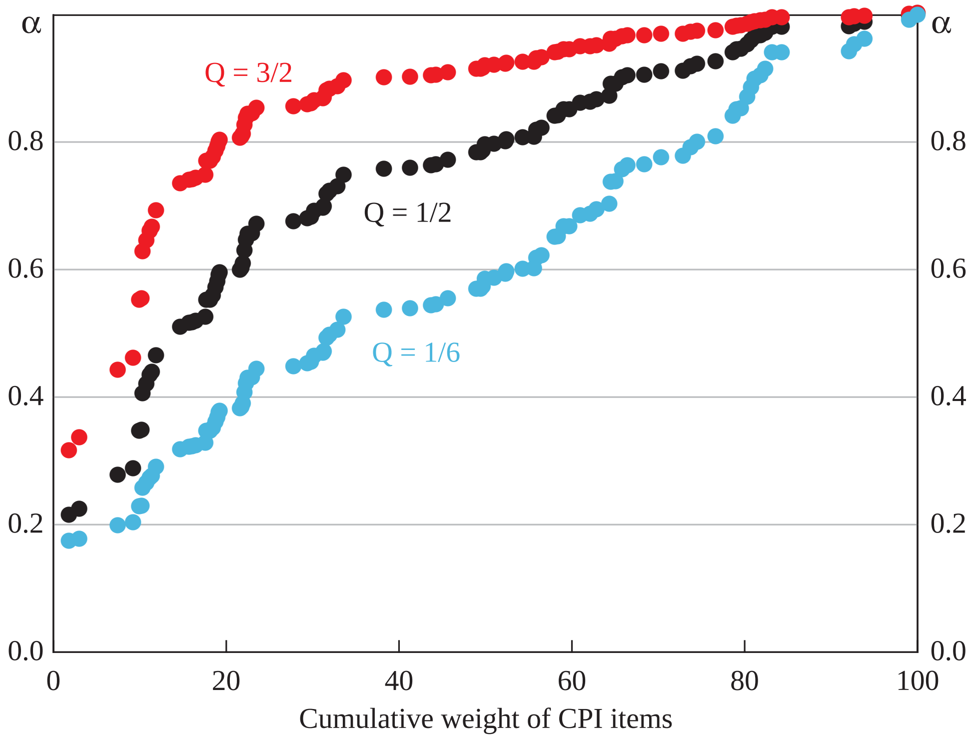
Note: α coefficients and effective weights are for 2006:M10.

4.3 Sensitivity

Along the way, we have chosen a number of parameter values that affect the performance of the component-smoothed inflation measure. In this section, we discuss the effect of varying these parameters on the component-smoothed inflation measure.

The parameter Q, which controls the variance of the smoothed price series, tends to have little effect on the amount of smoothing that is applied to series containing little noise, but has a larger effect on the amount of smoothing applied to more noisy series. This is because series such as rent have values for R_{it} which are much smaller than Q, so that α_{it} is close to unity for a wide range of values for Q, but for noisy series such as automotive fuel, R_{it} is closer to the value of Q we have chosen, so that changing Q has a larger effect on α_{it} for these series. To illustrate this, Figure 9 shows α coefficients for Australian data when Q is three times and one-third the value we have chosen for the component-smoothed inflation measure presented earlier.

Figure 9: Effect on α Coefficients of Varying Q

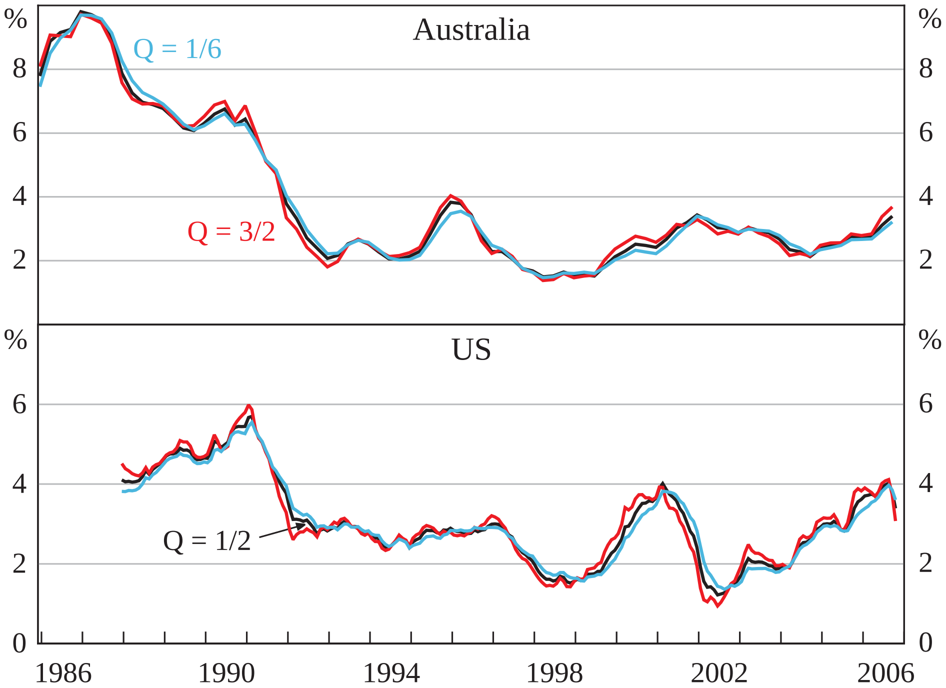


Note: α coefficients and effective weights are for 2006:Q3.

Figure 9 shows that increasing the value of Q has the effect of increasing the α coefficients for each series, but with the largest proportional increase for the most noisy series, and vice versa. In order to gauge the effect of these changes in α parameters on our measure of underling inflation, Figure 10 shows the component-smoothed inflation measure in year-ended percentage change form for Australia and the US when Q is scaled to be one-third and three times the value we have chosen.

As expected, higher values of Q, which reduce the amount of smoothing applied to CPI series, result in a more variable component-smoothed inflation measure, more closely following CPI inflation. However, the differences are not substantial, despite the wide range of parameter values we have shown; for both Australia and the US, the component-smoothed inflation presents a broadly similar picture of underlying inflation for each of the three values of Q shown in Figure 10.

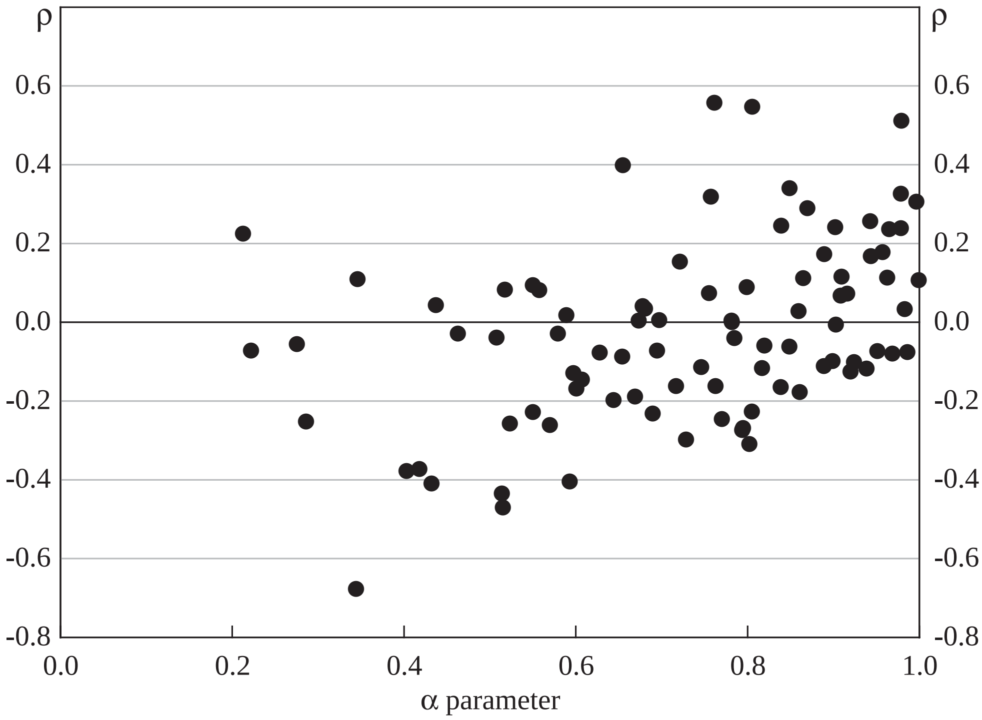
Figure 10: Effect on the Component-smoothed Inflation of Varying *Q*



The method we have chosen to assess the amount of volatility in each price series, namely the variance of deviations of price series from their Henderson trend, can be replaced with a variety of other methods. For example, using the mean-squared difference or variance of percentage changes in each price series produces a similar ranking of relative noise content of CPI items. As mentioned earlier, the magnitude of R_{it} is not important because Q is chosen relative to R_{it} and the resulting component-smoothed inflation measures are similar to the ones presented in this paper.

Using the autoregressive parameter from a simple regression of a price series on its own lag is, despite its superficial appeal, an inferior approach. The problem is that it does not distinguish between short- and medium- or long-term trends. Thus, over a period of significant disinflation where there is a large change in the mean level of inflation, most series will have a high autoregressive parameter regardless of the amount of temporary volatility in the series. Even absent a mean shift in the general level there are still problems with using the autoregressive parameter. To illustrate this, Figure 11 below plots the autoregressive parameter for each item in the Australian CPI calculated over the low-inflation period against the α we choose based on deviations from the Henderson trend. Significant deviations from a straight line indicate that the measures are not close substitutes. As can be seen, there is little correlation between the measures and many of the autoregressive parameters are actually negative, which complicates interpretation further.

Figure 11: Comparison of Autoregressive Parameter and α Coefficients – Australia



Note: Autoregressive parameters calculated over the low-inflation period 1993:Q1–2006:Q3.

5. Caveats

As with all underlying inflation measures, our component-smoothed inflation measure has strengths and weaknesses. We have highlighted some of its strengths in preceding sections. This section highlights areas where the measure needs to be interpreted with caution.

The measure makes assumptions about the behaviour of individual price series based on their historical behaviour; if that behaviour changes, those assumptions will be inaccurate. This problem is most relevant when evaluating series that are judged to be volatile.

Movements in series which have been persistent in the past are reflected in the measure quickly. As such, temporary shocks to a persistent series will be associated with marginally more volatility in the measure but are unlikely to mislead about the underlying rate of inflation. Notwithstanding this, in such circumstances, a measure like the trimmed mean, which trims away large movements regardless of the series in which they occur, could have lower volatility.

On the other hand, if there is a permanent shock to a volatile series, the component-smoothed measure will be slow to incorporate this. We have discussed the US experience of energy price fluctuations where this is argued to be beneficial. Nonetheless, shocks to other prices may not affect the rest of the economy in the same way as energy prices do and, as such, the component-smoothed inflation measure may be slower to reflect these inflationary pressures than the CPI itself or may reflect shocks whose influence on the economy has already dissipated.

A related issue is whether an optimal measure of current inflation should be affected by movements from previous periods. An argument can be made that, in essence, bygones should be bygones and large inflationary shocks in previous periods should not continue to directly influence a measure of underlying inflation in and of themselves. Our measure, because it is calculated on the level and maintains unbiasedness with respect to the CPI, does not have this property. Rather, the measure will display higher inflation than usual in the immediate aftermath of a large sustained positive price shock to a historically volatile series. Another way of putting this issue is to ask whether an optimal measure of current inflation needs to be unbiased over time. The resolution of that issue is left for other work.

6. Conclusion

The component-smoothed inflation measure of underlying inflation developed in this paper approaches the problem of removing noise from headline inflation in quite a different way than existing measures of underlying inflation. Instead of re-weighting the component price series, we smooth them in proportion to the amount of noise they contain to preferentially remove temporary shocks; volatile series such as fruit and automotive fuel are smoothed heavily while stable series such as rents are smoothed very little, with other CPI items lying on a continuum between these extremes. This leads to a measure that has a number of desirable properties for an underlying measure of inflation: it is unbiased with respect to headline inflation in the long run, it can be calculated in real time and it is much smoother and less noisy than headline inflation. Additionally, as was discussed with respect to the US experience, where the measure does lag headline because of persistent shocks to historically volatile series, this lag may be appropriate.

An additional feature of the component-smoothed inflation measure is that it requires a relatively small number of parameters. Thus, while we have specified certain values for these parameters in this paper, these can easily be respecified by the user, depending on the desired smoothness of the component-smoothed inflation measure. Notwithstanding this, the general framework of component smoothing based on volatility advanced in this paper allows for more advanced smoothing mechanisms to be employed; while we suggest that the exponential smoothing mechanism provides a good trade-off between simplicity and rigour, the use of the Kalman filter to smooth the component series is an easy modification for more technically inclined users.

In addition to having desirable general properties, the results for Australia and the US provide estimates of underlying inflation that offer potentially useful perspectives on inflationary pressures. The component-smoothed inflation measure tracks the medium-term trends in headline inflation that are relevant for monetary policy formulation, while removing – in real time – much of the noise present in headline inflation.

Notwithstanding these positive attributes, as demonstrated in the tables of results comparing the various underlying inflation measures, while exclusion measures are usually dominated, none of the component-smoothed inflation and statistical measures are better than each other in all respects. In these circumstances each can offer a different and valuable perspective on underlying inflationary pressures. Thus, by approaching the problem of measuring underlying inflation in a different way the component-smoothed measure may provide a useful supplement to existing measures. An evaluation of the balance between the costs and benefits of this approach remains an open question.

Appendix A: Smoothing of Selected CPI Components

Table A1: Australia

CPI components with lowest and highest α coefficients

12 items with lowest α coefficients	α [(a)]	**Variance**[(b)]	**CPI weight**[(a)]
Fruit	0.21	150.62	1.80
Vegetables	0.22	65.45	1.20
Automotive fuel	0.28	19.07	4.45
Overseas holiday travel and accommodation	0.29	13.12	1.78
Gas and other household fuels	0.34	6.42	0.71
Lamb and mutton, sa	0.35	9.46	0.26
Children's footwear	0.40	2.84	0.11
Glassware, tableware and household utensils	0.42	5.92	0.45
Children's and infants' clothing	0.43	5.16	0.38
Tea, coffee and food drinks	0.44	5.80	0.25
Childcare	0.46	7.08	0.50
Hospital and medical services[(c)]	0.51	3.42	2.79
12 items with highest α coefficients			
Sports participation	0.95	0.27	0.73
Pet services including veterinary	0.96	0.18	0.44
Newspapers and magazines	0.96	0.43	0.40
Dental services, sa	0.96	0.13	0.69
Preschool and primary education, sa	0.97	0.16	0.55
Water and sewerage, sa	0.98	0.30	0.80
Other recreational activities, sa	0.98	0.30	1.10
House purchase	0.98	0.44	7.79
Other household services	0.98	0.48	0.61
Property rates and charges, sa	0.99	0.19	1.18
Rents	1.00	0.06	5.17
Secondary education, sa	1.00	0.02	0.98

Notes: (a) For 2006:Q3. All data are adjusted for the tax changes of 1999–2000.
(b) Variance in percentage points of quarterly percentage changes over the period 1993:Q1–2006:Q3.
(c) Adjusted for major health policy changes.

Table A2: United States

CPI components with lowest and highest α coefficients

12 items with lowest α coefficients	α [(a)]	**Variance[(b)]**	**CPI weight[(a)]**
Motor fuel	0.09	27.31	4.63
Fresh vegetables	0.09	7.81	0.49
Fuel oil and other fuels	0.11	19.57	0.38
Eggs	0.15	10.42	0.09
Tobacco and smoking products	0.22	7.63	0.71
Fresh fruits	0.22	2.25	0.50
Public transportation	0.35	1.06	1.09
Girls' apparel	0.37	2.27	0.23
Boys' apparel	0.38	1.84	0.19
Infants' and toddlers' apparel	0.38	0.85	0.18
Jewelry and watches	0.38	1.22	0.32
Beef and veal	0.40	1.32	0.63
12 items with highest α coefficients			
Personal care services	0.94	0.05	0.67
Motor vehicle insurance	0.95	0.12	2.26
Prescription drugs and medical supplies	0.95	0.04	1.03
Miscellaneous personal services	0.95	0.02	1.18
Hospital and related services	0.96	0.06	1.62
Tuition, other school fees, and childcare	0.97	0.02	2.84
Motor vehicle maintenance and repair	0.98	0.03	1.14
Water and sewer and trash collection services	0.98	0.03	0.89
Professional services	0.98	0.02	2.80
Owners' equivalent rent of primary residence	0.99	0.01	23.66
Rent of primary residence	0.99	0.01	5.87
Food away from home	0.99	0.01	5.95

Notes: (a) For 2006:M10. CPI components have been seasonally adjusted using Census X12 where appropriate.
(b) Variance in percentage points of monthly percentage changes over the period 1987:M1–2006:M10.

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