Underlying Inflation in Australia: Are the Existing Measures Satisfactory?[*]

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ABSTRACT

Along with a number of other central banks around the world the Reserve Bank of Australia has quite explicitly adopted an inflation target. Both the Bank and the Australian Government's statistical agency (the Australian Bureau of Statistics) report various measures of the underlying rate of inflation. The aim of this paper is to formulate criteria which an acceptable underlying rate must satisfy and then test to see whether either individually or in combination any of the current (CPI Excluding volatile items; CPI Market prices excluding volatile items; Weighted median and; Trimmed mean) or recently discarded (the Treasury underlying rate) measures of underlying inflation satisfy these criteria. We find that for the period since inflation targeting began (in 1993) none of these underlying series satisfy all of the criteria we propose but that one series (the RBA's Trimmed mean series) does satisfy the sub-set which we refer to as our 'necessary criteria'. We then examine the results of an 'Unobserved Components' decomposition and argue that it provides useful information on underlying inflation in Australia.

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I Introduction

Along with a number of other central banks around the world the Reserve Bank of Australia has quite explicitly adopted an inflation target. This target is nowadays couched in terms of the headline rate whilst taking into account evidence on the 'underlying' inflation rate. Both the Bank and the Australian Government's statistical agency (the Australian Bureau of Statistics) report various measures of the underlying rate of inflation. The aim of this paper is to formulate criteria which an acceptable underlying rate must satisfy and then test to see whether either individually or in combination any of the current (CPI Excluding volatile items; CPI Market prices excluding volatile items; Weighted median and; Trimmed mean) or recently discarded (the Treasury underlying rate) measures of underlying inflation satisfy these criteria. We then examine the results of an Un-restricted Unobserved Components decomposition to see what information it provides on underlying inflation in Australia. The final section concludes.

II Monetary Policy in Australia Since the Early 1990's

The Reserve Bank of Australia (RBA) is responsible for formulating and implementing monetary policy in Australia. The Reserve Bank Act 1959 requires the RBA Board to conduct monetary policy in a way that will best contribute, inter alia, to the stability of the currency which, in practice, is taken to mean price stability. Commencing in 1993 (according to some,[1] or 1994 according to others[2]) the Bank adopted an explicit inflation target.[3] In 1996 this was formally set out in a *Statement on the Conduct of Monetary Policy*, issued by the Federal Treasurer and the Governor of the Reserve Bank in August of that year. That *Statement* reads, in part: "In pursuing the goal of medium term price stability the Reserve Bank has adopted the objective of keeping underlying inflation between 2 and 3 per cent, on average, over the cycle" (RBA Bulletin, September 1996, p 2).

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[1] The RBA is of the view that 1993 is an appropriate start date. On this see Macfarlane (1998) and Stevens (1999, 2003). In this paper we follow Debelle (1997, p. 5) and date the first period of targeting as 1993:2.

[2] Bernanke et al (1999, p 220) date the introduction of targeting not in 1993 but in 1994 claiming that this is the first time the Governor uses the word "target" in this context. Indeed, prior to 1994 the Governor of the RBA (Fraser) indicates that although "if the rate of inflation in underlying terms could be held to an average of 2 to 3 per cent over a period of years, that would be a good outcome" (Fraser, 1993a, p 2) he goes on to say that he is "wary" of inflation targets (Fraser, 1993a, p 3; see also Fraser, 1992, p 8). However in August 1993 he again expresses a desire for the "average rate of underlying inflation [to] be held to 2 to 3 per cent over time" (Fraser, 1993b, p 3) but this time without qualification (indeed, he goes on to discuss various measures of inflation that are useful for "monetary policy purposes" (ibid, p 4) and by mid 1994 it is clear that Fraser was committed to an inflation target. He writes, for example, "*we would like to hold* the underlying rate to around 2 to 3 per cent over the medium term" (Fraser, 1994, p 4 – our emphasis) and he indicates quite clearly that monetary policy will be used to bring this about.

[3] Brief overviews of the RBA's adoption of inflation targeting and the evolution of this policy over time may be found in Grenville (1997), Macfarlane (1998), Stevens (1999) and Bernanke et al (1999, pp 218-35).

The 1996 *Statement* referred to "underlying inflation" but did not define this term. In practice it would appear that until mid-1998 the Treasury's series was used as 'the' underlying rate. Cockerell writes: "Although no explicit reference was made in [the] Statement, the assessment of the inflation target became closely associated with the Treasury measure of 'underlying' or 'core' inflation" (Cockerell, 1999, p 1n). The ABS, at the time they first published the Treasury underlying rate (in 1994) wrote: "Treasury and the RBA have agreed that the Treasury series provides the best guide to 'underlying' inflation for macroeconomic policy purposes" (ABS, 6401.0, September 1994, p 16).[4] The RBA in 1998 reported that: "it has become customary over recent years for the evaluation of monetary policy to be in terms of the so-called 'Treasury measure of underlying inflation devised by the Commonwealth Treasury in the mid 1970s'" (RBA Bulletin, 1998a, p 2)[5] and, perhaps most authoritatively, (then) Assistant now Deputy Governor Stevens reported that "until late in 1998, the usual metric was the Treasury underlying series …" (Stevens, 1999, p 50) and that: "For practical purposes, the underlying series devised by the Commonwealth Treasury was used as the yardstick" (Stevens, 2003, p 21, n9).

Following changes to the construction of the CPI in October 1998 (and in particular the removal of interest rates from the calculation of the index) the RBA decided that "the inflation target – 2-3 per cent on average over the medium term – could in future be seen as referring to the published CPI, rather than a particular underlying series. The Treasurer has agreed that such an approach is consistent with the intent of the *Statement on the Conduct of Monetary Policy* of August 1996" and so "the target for monetary policy can now be presented simply as maintaining an average rate of inflation, as measured by *the* CPI, of 2–3 per cent over the medium term" (RBA Bulletin, October 1998, p 5, emphasis in original). For future reference we note that the CPI now (i.e. post-1998) includes a component representing house purchases.

Although, as we have seen, the 1998 reworking of the policy led to the statement that "the target for monetary policy can now be presented simply as maintaining an average rate of inflation, *as measured by the CPI*, of 2–3 per cent over the medium term" (RBA Bulletin, October 1998, p 5, our emphasis), this did not mean that measures of underlying inflation no longer had a role in policy formulation. Readers of the 1998 piece were cautioned that: "The published CPI is still likely to be somewhat more volatile than various measures of core or underlying inflation, over short periods. The Bank will still analyse underlying inflation measures, for the purposes of assessing the overall trend in inflation, and will refer to such

[4] This statement is also to be found in the Treasury's *Round Up*, Summer 1995, p 22.
[5] This statement was repeated in the following issue of the RBA Bulletin (RBA,1998b, p 47).

measures in its regular reports on the economy and monetary policy. It will make clear, wherever feasible, the extent to which it judges the CPI as being affected by temporary fluctuations in prices, or factors such as tax and administrative decisions of government, and will also state the way in which monetary policy decisions are treating such impacts" (RBA Bulletin, October 1998, p 5). More recently the RBA has described its approach as follows: "Although the Bank targets [headline] CPI inflation, quarter-to-quarter volatility in the series (in particular 'once-off' price movements in specific components) means that it is useful to look at measures of the underlying trend in inflation" (RBA Bulletin, May 2002, p 56).

III The Headline CPI and the Various Underlying Rates Reported in Australia

The Consumer Price Index (CPI) provides a measure of 'average' or 'overall' changes in the prices of consumer goods and services purchased by households in metropolitan areas of Australia. CPI figures are produced by the Australian Bureau of Statistics (ABS) for each quarter and appear in the publication *Consumer Price Index, Australia* (Cat. no. 6401.0). The "headline CPI" is the figure for the proportionate rate of change in the Index between the latest quarter and the same quarter in the year before for all consumer goods and services (the ABS describes this as "the All groups CPI") and is the weighted average for all eight "capital cities" taken together. Data for the headline CPI is available from September 1970. However, from time to time there have been marked changes in the coverage of the CPI. For example in March 1974 wine & spirits, take-away food and photographic goods & services were included for the first time. In December 1976 holiday travel & accommodation in Australia, restaurant meals, fresh fruit and vegetables, fresh and frozen fish, books, toys, games & sporting equipment were included for the first time. In March 1987 mortgage interest charges and consumer credit charges were included while house purchase, which had previously been included, was excluded. In September 1998 the changes introduced in March 1987 were reversed and mortgage interest charges and consumer credit charges were excluded while house purchase was included. We will need to take these changes into account in our empirical work and so we will return to these data issues in a later section of the paper.

Although Australia's inflation target is now expressed in terms of the "headline" CPI, as noted above, it can be useful when assessing inflationary trends to focus on underlying measures which abstract from short-run volatility. The CPI is often affected by movements in the prices of component items such as fruit, vegetables and petrol that reflect fluctuations in supply conditions and generally do not persist for more than a quarter or two. Adjustments to government charges and taxes can also sometimes have large 'once-off' effects on the level of prices which do not

lead to a persistent rise in the rate of inflation. A graphic example of the latter is the temporary rise in the rate of inflation which accompanied the introduction of the GST in July (i.e. the September quarter) of 2000. Figure 1 shows two estimates of the rate of inflation for the period 1987:4 – 2002:4. One, the broken line, is what the actual rate of inflation as measured by the headline CPI was over the period. The other, the solid line, shows what the RBA estimates the headline rate of inflation would have been with the effects of the introduction of the GST, towards the end of our sample period, excluded.[6]

[FIGURE 1 NEAR HERE]

Similar considerations apply when we have products which are subject to quite volatile and short-lived fluctuations in price, especially when these are the result of (random) supply shocks and so it is not surprising that, in addition to reporting the headline rate of inflation, both the ABS and the RBA publish a number of series which purport to measure the 'underlying' rate of inflation.[7]

One measure of underlying inflation is based on the 'All groups CPI' but excludes movements in the prices of (the deemed to be volatile items) Fresh fruit & vegetables and Automotive fuel. (Prior to September 1998 this series also excluded mortgage interest charges and consumer credit charges which, until September 1998, had been included in the headline CPI.) This series is described as "All groups excluding volatile items" and covers around 90% of the CPI basket.[8] Data for this series is available from 1987:4. We label this series X_1 in what follows.

A second measure of underlying inflation is based on the 'All groups excluding volatile items' series but includes only those goods and services remaining for which there are 'market prices' and is named "Market goods and services excluding 'volatile items'" (formerly titled 'Private-sector goods ands services').[9] In other words this series excludes not only Fresh fruit & vegetables and Automotive fuel but also items whose 'prices' are not market determined but are rather administered and determined by various government agencies at Commonwealth, State and Local government levels. This series excludes from the 'All groups CPI' the following items: Fresh fruit & vegetables, Automotive fuel, Utilities,[10] Property rates and charges,

[6] We are grateful to the RBA for this data. See Graph 64 RBA Bulletin, November 2002, p 51.
[7] For further information on the various measures of underlying consumer price inflation, refer to 'Measuring "Underlying" Inflation', *RBA Bulletin*, August 1994, and 'Box D: Underlying Inflation', *Statement on Monetary Policy*, May 2002, p 55f.
[8] RBA Bulletin, May 2002, p 55.
[9] Separate series for goods and services are also published. Here we will only be concerned with the series for goods and services taken together.
[10] Electricity, Gas and other household fuels, Water and sewerage.

Health,[11] Other motoring charges, Urban transport fares, Postal & telephone services, Education[12] and Child care. (Prior to September 1998 this series also excluded mortgage interest charges and consumer credit charges which, until September 1998, had been included in the headline CPI.) This series covers around 80% of the CPI basket.[13] This series was introduced by the RBA in 1992 (RBA, 1992). Data for this series is available from 1987:4. We label this series X_2 in what follows.

Figure 2 shows the series for the headline CPI (excluding the impact of the introduction of the GST) and the two underlying series described above. It seems fairly clear that the underlying series are less volatile than the headline rate. (More on this shortly.)

[FIGURE 2 NEAR HERE]

In addition to the two underlying measures mentioned above another series was compiled by the Federal Treasury for many years. The 'Treasury underlying inflation series' excluded all those items excluded from the "CPI: All groups excluding volatile items" and also those excluded from the "Market goods and services excluding volatile items" but, in addition, it also excluded other items that the Treasury judged to be volatile or have a seasonal pattern such as Meat and seafoods, Clothing, Holiday travel & accommodation and also items whose prices are directly influenced by policy factors such as Alcohol & tobacco, Mortgage interest charges and consumer credit charges.[14] It retains only about 51 per cent of the CPI basket.[15] Published data for this series is available only for the period 1972:2 – 1998:2.[16] We label this series X_3 in what follows.

Figure 3 shows the series for the headline CPI (adjusted for the impact of the introduction of the GST) and the Treasury underlying series for the period 1987:4-1998:2. The Treasury series also appears to be less volatile than the headline CPI series. We have already noted that over the period 1993:2 – 1998:2 (inclusive) the Treasury rate was being used as the 'underlying rate'. Clearly, the Treasury series is much smoother (less volatile) than the headline CPI series over that period and is either within or not far away from the 2-3% band, unlike the headline CPI series.

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[11] Hospital and medical services, Optical services, Dental services, Pharmaceuticals.

[12] Preschool and primary education, Secondary education, Tertiary education.

[13] RBA Bulletin, May 2002, p 55.

[14] While it excludes mortgage interest rates it does not include 'house purchases', unlike the adjusted CPI series (Y) used in this paper. Detailed description of the Treasury 'underlying' inflation rate were published in an Appendix to the September quarter 1994 issue of 6401.0 and, most comprehensively, in the Summer 1995 issue of the Commonwealth Treasury's *Economic Roundup*.

[15] ABS, *Consumer Price Index, Australia* (Cat. no. 6401.0), June 1998, p 22.

[16] Strictly speaking the ABS continued to publish this series until 1999:3. However, observations for the few quarters from which we have data after 1998:2 contain a house price component which was not in the series prior to 1998:3.

Fortunately we have been able to obtain from the RBA a series for the CPI which excludes interest rates over the period March 1987 – September 1998 – we label this series *Y* in what follows. This series together with the headline CPI (which includes interest rates over the period represented in the figure) and the Treasury underlying rate are depicted in Figure 3. It would seem that much of the reduced volatility in the Treasury series vis a vis the published CPI series results almost entirely from the fact that the Treasury series excluded interest rates. (More on this shortly.)

[FIGURE 3 NEAR HERE]

The three underlying measures described above are known as 'exclusion measures' because they are based on the *ex ante* exclusion of previously nominated goods or services from the CPI basket. There are a number of alternative ways to arrive at a series for underlying inflation. One alternative is to derive an underlying series by excluding *ex post* all extreme individual price movements, from whatever source and thus without nominating the particular products to be excluded for any (or even for all) period(s) in advance. The RBA also publishes two of these so-called 'statistical' series which are based on an examination of the size of price movements for individual components of the CPI which are "ranked by size of price movement and weighted by their importance in the CPI regimen" (RBA Bulletin August 1994, p 4).[17] These are the 'Weighted median' and the 'Trimmed mean'. The 'Weighted median' is the inflation rate for that item or group of items which is in the middle of the total distribution for each quarter. The 'Trimmed mean' is the weighted mean of the central 70 per cent of the price change distribution of all CPI components. In other words, the top and bottom 15% of the distribution are excluded (trimmed) from the data used to calculate the mean. (Prior to September 1998 both series also excluded mortgage interest charges and consumer credit charges which, from 1987:1 until September 1998, had been included in the headline CPI.[18]) Data for both the Weighted median and Trimmed mean series is available from 1977:3.

It would appear that these two series, and especially the weighted median are given a special place by the RBA.[19] According to Deputy Governor Stevens, "the median CPI is the measure often used by the Bank's professional staff" (Stevens, 2003, p 21). In a recent 'Statement on Monetary Policy', readers of the *RBA Bulletin* were told that "the Bank's assessment is that the statistical measures are currently providing the more accurate reading on

[17] Descriptions of the 'statistical' measures used in Australia are to be found in RBA (1994) and Kearns (1998).
[18] RBA, 1994, p 4.
[19] The ABS has said, with reference to the first two exclusion based series, that "the Reserve Bank of Australia does not accord any special policy status to these series" (ABS, *Consumer Price Index*, Cat No 6401.0, September 2000, p 28).

underlying inflation" RBA (2002, p 50). Cockerell claims that "the statistically-based measures of core inflation, based on trimmed mean and weighted median price changes, have superior properties [to exclusion based measures such as the Treasury underlying rate] (1999, p 14). We label the Weighted median X_4 and the Trimmed mean X_5 in what follows. One aim of the present study is to evaluate the claim that the trimmed mean and weighted median are superior to the other underlying measures. Figure 5 shows the series for the headline CPI (adjusted for the impact of the introduction of the GST) and both the Weighted median and Trimmed mean series for the period 1987:4-2002:4. Again, the two underlying series are less volatile than the headline series.

[FIGURE 4 NEAR HERE]

For future reference we note that none of the underlying series have ever included interest rates but that since September 1998 (and only since September 1998) they have included a house purchase component. On the other hand the headline CPI included interest rates between 1987:4 and 1998:2 and has included a house purchase component since September 1998.

IV The Criteria an "Underlying" Series Should Satisfy

We will take it that the headline CPI or the headline CPI excluding interest rates is the 'target' and that the underlying series are being used to track the 'permanent' component of that and to forecast the (expected value of the) headline rate.

We have seen that 'underlyingness' is defined by the central bank itself in terms that readily lend themselves to statistical testing, they use terms such as "temporary fluctuations", "temporary factors" (RBA *Bulletin* Nov 1998, p 48) and "volatility from quarter to quarter" (RBA Bulletin October 1998, p 2). Given that the focus is on avoiding "short term volatility" (RBA Bulletin October 1998, p 1) and that the aim is to distinguish "between once-off changes to the price level and on-going movements in prices" (RBA, 1994, p 6) and, to this end, for the "underlying series [to] give a more reliable signal, over periods of up to a year or two, of the overall inflationary trend than does the [headline] CPI" (RBA *Bulletin* October 1998, p 3), it seems reasonable to evaluate the adequacy of the measures of underlying inflation used by the RBA using accepted statistical tests and econometric techniques which distinguish between a permanent (underlying) component of a time series and a transitory component.[20]

[20] This is not to say that there are no other criteria that might be thought to be important, in addition to those we mention. Examples would be that the data be available in a timely fashion, that the underlying measure be 'transparent' publicly available information and that the construction of the series be understandable by the public.

We begin with the assumption that the actual (i.e. the headline) rate of inflation (p) over any period can be decomposed into two additive components, one is a permanent, persistent, predictable or underlying component (p^U) and the other is a transitory component (p^T), so that:

$$p_t = p_t^U + p_t^T \tag{1}$$

We assume that the true transitory component is stationary with a zero mean and finite variance, so that $\boldsymbol{E}[p_t] = \boldsymbol{E}[p_t^u]$, where $\boldsymbol{E}$ is the expectation operator.

The implications of all this and the way in which we intend to go about our task may perhaps best be glimpsed in passing by assuming that the underlying and actual inflation series are both I(1), in which case we can think of the two being cointegrated and with an error-correction mechanism linking the actual rate of inflation (p) and its permanent or underlying component (p^U) such that:

$$\Delta p_t = \lambda\left(p_{t-1} - \alpha - \beta p_{t-1}^U\right) + \sum_j \phi_j \Delta p_{t-j} + \sum_j \theta_j \Delta p_{t-j}^U + \varepsilon_t \tag{2}$$

and with $\alpha = 0,\ \beta = 1$

Given the above, we summarise the criteria to be met by a satisfactory underlying series as follows:[21]

1. For an underlying series to be satisfactory, we would require any discarded data (i.e. p_t^T, which is to say, data on inflation rates or components of inflation rates which are present in p_t but not present in p_t^U) to contain no useful permanent information, i.e., we would want them to be stationary.

2. The underlying rate p_t^U and headline (target) rate (p_t) to be integrated of the same order.

3. If the series are I(1) then we would want:

   (a) The underlying rate (p_t^U) to be cointegrated with the headline or 'target' rate (p_t) so that the residuals are stationary with zero mean. If this were not the case the two series will diverge over time and movements in the underlying series will not be a useful indicator of the target series.

   (b) In the relationship between the headline rate and the underlying rate we want the error correction parameter to have a sign such that the relationship is stable and that adjustment is speedy. In other words we want the error-correction model

[21] Appropriate criteria are also discussed in Freeman (1998), Johnson (1999), Marques et al (2000 and 2002), Cogley (2002) and in Mankikar & Paisley (2002). We have both expanded and consolidated the lists provided in these papers.

(ECM) to be such that the short run error correction coefficient (λ in equation (2) above) is $-1 < \lambda < 0$ and ideally that λ is close to -1.

(c) The cointegrating relationship to be such that (in the ECM) the long-run (equilibrium) relationship displays a constant (α) which is not significantly different from zero and a long run (slope) coefficient of p on p^U (β) which is not significantly different from unity. In other words we want the cointegrating vector to be (1, -1).

(d) In the relationship between the headline rate and the underlying rate we want the direction of causality to show that the headline is "caused" by the underlying rate and not the other way round. This is especially important if the underlying rate is intended to inform us about future levels of the target rate.

Condition 1 is a general condition which should hold regardless of the time-series properties of the inflation series. However, since inflation series tend to be I(1) variables, then in our view conditions 2 and 3(a)-(d) are necessary criteria that any underlying series should satisfy. One way to assess whether or not any particular underlying series (X_1 ,…,X_5 and another of our own construction we shall introduce later) is "satisfactory" is to substitute it for p^U in the ECM representation given above, and to then test whether it satisfies conditions 2 and 3(a)-(d) once the headline (target) rate of inflation is substituted for p. But before we do any econometric work we need to describe the data we are using and examine certain descriptive statistics.

V The Data[22]

In relation to the data two issues confront us at this point. One is how to deal with the disturbances to prices caused by the introduction of the GST. A second is how to deal with interest rates which were a component of the headline CPI between 1987 and 1998 but, as we have seen, have always been excluded from all of the underlying measures mentioned in the previous section.

With respect to the first, it is clearly desirable to purge the data for the CPI and all of the underlying series of the disturbances to prices caused by the introduction of the GST. As

[22] For the convenience of the reader, the definitions and sources of all the data used in the paper is contained in the Appendix.

mentioned earlier, the RBA has supplied us with data series for the headline and underlying rates which achieve this.[23]

With respect to interest rates we have decided that we should remove interest rates (as well as the effects of the GST) from all of the series we use in our econometric work because they have been purged from all of the underlying series (both 'exclusion' based and so-called 'statistical'), because the rate which was 'targeted in the 1993-8 period was a rate excluding interest rates, and because the RBA is now using a CPI which excludes interest rates as the target. Since interest rates have never been included in any of the underlying series compiled in Australia the only data set that needs adjustment is that for the headline CPI which does include interest rates over the period 1987:4 – 1998:2. Fortunately, as mentioned earlier, we have been able to obtain from the RBA a series for the CPI which excludes interest rates over the period March 1987 – September 1998: we label this series as *Y* in what follows. Because the *Y* series excludes interest rates up to and including 1998:2 (and includes house prices beyond that date), the *Y* series and our various underlying series (X_1 ,…, X_5) are compiled on a consistent, and thus comparable, basis.

Our series for *Y* and the CPI as originally reported by the ABS over the period 1987:4 – 2002:4 are shown in Figure 5. The two series are identical after 1998:2 as after that date the CPI no longer included interest rates.

[FIGURE 5 NEAR HERE]

VI Historical Evaluation of the Various Underlying Series Published in Australia

In this section of the paper we undertake an evaluation of the various underlying series used in the past in Australia. We will look at the relationship between the series for the CPI excluding interest rates and various underlying series[24] (all of which excluded interest rates) over the period 1987:4 – 2002:4 but with some attention given to two sub-periods. First, the sub-period 1993:2 – 2002:4 is worthy of study as in that period targeting was in place. Second, the sub-period 1993:2 – 1998:2 is worthy of study as in that period the Treasury underlying rate and it alone appears to have been used as the underlying series and we are keen to see if it

[23] This is the data which lies behind their charts in RBA Bulletin Feb 2003, p 45 Graph 61 and p 46 Graph 62.

[24] Issues arise with respect to the Treasury series. As noted earlier, until the end of 1998 the RBA used this rate as 'the' underlying rate. Earlier we noted that published data for this series is available only for the period 1972:2 – 1999:2 as publication of the series ceased in June 1999. We have for the purposes of this paper updated the Treasury series to 2002:4. We did this two ways. First, the Treasury series is very highly correlated with the market prices series and so we used a regression model fitted for the period 1998:2 - 1999:2 to predict the values of the treasury series for the period where we know the market prices series (excluding GST) but don't have a direct measure of the Treasury series (1999:3-2002:4). A second method, which proved inferior to the first because it does not allow us to take the GST influence out of the Treasury series, is the construct a Treasury series using the data for expenditure groups provided in each CPI release.

outperformed the other series in any sense. (Although familiarity may have dictated its adoption, *cet par*.)

To assist the reader in what follows we set out in Table 1A some elementary information about the various series in the two major periods of interest. The means and standard deviations for that sub-period are given in Table 1B. We see that over this sub-period the Treasury underlying rate (X_3) is markedly less volatile than the headline CPI and that it is also less volatile than the target series (Y) and that the mean for the Treasury series is below the mean for the target series.

[TABLES 1A AND 1B NEAR HERE]

We will now look at the various underlying series in relation to the three criteria mentioned above. All inflation rates are measured as the percentage change for the quarter on the same quarter in the year before. This has an advantage over quarterly rates or annualised values of quarterly rates as seasonality will not be a problem.

(i) Criterion 1

The first of the criteria we said that we would expect to be met by a satisfactory underlying series was that any discarded data (i.e., data on inflation rates which are present in p_t but not present in p_t^U) should not contain useful permanent information. Many researchers[25] evaluate this by seeing if the 'gaps' between the target series and each of our (five) underlying series are stationary based on the argument that the 'gaps' should reflect variations over time in the transitory elements in the series (i.e. p_t^T in equation (1) above) and should, inter alia, be stationary. Tables 2A and 2B show ADF statistics for the 'gaps' between the target series and each of our (five) underlying series, where by the word 'gaps' we mean the values of $\left(Y_t - X_{it}\right)$ for each underlying series, X_i , $i=1,\ldots,5$.

Table 2A reports the ADF statistics for these 'gaps' over the whole sample period and over the sub-sample period of inflation targeting. The ADF test for each series was performed with and without an intercept. If the intercept proved to be significantly different from zero at the 5% level it was retained and an entry appears under the appropriate heading in the table below. If the intercept proved not to be significantly different from zero it was dropped and the test conducted without a constant. The reason for allowing for the possible presence of a significant intercept is that we saw earlier that there are slight differences in the means of the target and underlying series. We see that for the whole of our sample period (1987:4 – 2002:4)

[25] See for example, Cockerell (1999), Johnson (1999), Marques et al (2000 & 2002) and Mankikar & Paisley (2002).

we can reject the null of non-stationarity in favour of stationarity in all of the 'gap' series at the 1% level.[26] However, for the sub-period over which inflation targeting has been in operation we can reject the null of non-stationarity at the 1% level for only one of the series (X_2) and for only two others (X_1 and X_4) at the 5% level. It is of interest to check our finding of non-stationarity for the Treasury underlying series for the specific period over which the RBA was using the Treasury rate as 'the' underlying rate (1993:2 – 1998:2). ADF statistics for the gap between our Y series and the Treasury underlying rate ($Y - X_3$) for that period are set out in Table 2B. It would appear that over this sub-period that the 'gap' associated with the Treasury underlying rate was non-stationary and so it was not a satisfactory estimate of the true p^U as valuable non-transitory information was not included in X_3.[27]

[TABLES 2A AND 2B NEAR HERE]

However this approach, where researchers investigate the properties of the 'gaps', assumes that variability over time in the arithmetic difference between Y and X_i is solely a reflection of the variability in p_t^T in equation (1). There are two comments that can be made about this. First, instead of looking at the time series properties of what we have called the 'gaps', it may be preferable to fit a cointegrating regression to each pair of Y and X_i (recall that each X_i can be regarded as an estimate of p_t^U) and test to see if the residuals from that regression are stationary. We will examine these residuals in the next section of the paper.

A second comment which can be made is that the difference between Y and each X_i may (especially, but not only, in a small sample) in part be capturing the influence of the underlying component as well as the excluded (hypothesized transitory) component.[28] This may be seen as follows: The series for Y may be thought of as being the weighted sum of two rates of inflation, one being the rate of inflation associated with the underlying component (X_i) and the other being the rate of inflation associated with the excluded component (E_i), so that:

$$Y_t = w_i X_{it} + (1 - w_i) E_{it}$$

where w_i is the appropriate weight.[29]

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[26] However, we only have hard data on the Treasury series for the period 1987:4 – 1998:2 and it may be that the finding that this series is stationary over the period 1987:4-2002:4 may result from our attempt to find a proxy series over the period 1999-2002. If we look only at the period where we have hard data on X_3 (i.e. 1987:4 – 1998:2), we find that it is stationary.

[27] The same is true if we regard the 'gap' as the difference between the headline CPI as reported by the ABS over the period (this included interest rates, unlike our Y series) and the Treasury underlying rate. The 'gap' here is also I(1) on the basis of an ADF test.

[28] This issue is also addressed by Marques (et al), 2002.

[29] We are assuming that the weights are (roughly) constant, at least relative to the other component(s).

Notice that this expression implies that

$$Y_t - X_{it} = (w_i - 1) X_{it} + (1 - w_i) E_{it} = (1 - w_i)(E_{it} - X_{it})$$

and so the time series properties of the gap between Y and X_i depend not only upon the properties of E_i but also of X_i.

This suggests that, instead of looking at the 'gaps' (i.e., $Y_t - X_{it}$), it may be more appropriate to attempt to extract the implied values of E_i for each underlying series and evaluate these.[30] We do this using the weights reported in an earlier section of the paper (the proportion of the expenditure covered by the CPI which remains in each of the underlying series[31]) and assuming they are constant, we combine this information together with the series for Y and each X_i to generate E_i as:

$$E_{it} = \left[(Y_t - X_{it}) / (1 - w_i) \right] + X_{it} \tag{3}$$

Table 2C shows ADF statistics for the rates of inflation excluded from the underlying series (E_i's) over the whole period and for the sub-period over which targeting has been in place. Given that there are slight differences in the means of the target and underlying series we again perform the ADF test for each series with and without an intercept. If the intercept proved to be significantly different from zero at the 5% level it was retained and an entry appears under the appropriate heading in the table below. If the intercept proved not to be significantly different from zero it was dropped and the test conducted without a constant. We see in Table 2C that for the whole of our sample period we can reject the null of non-stationarity in favour of stationarity at the 1% level for only one of the series (E_1) and at the 5% level for only one other series (E_2).[32] The other three excluded series (inflation rates) appear to be I(1).[33] This implies that those three underlying rates (the Weighted Median, the Trimmed Mean and the Treasury underlying rate[34]) are not satisfactory estimates of the true p^U as information was being discarded from those underlying series (i.e., information which is in Y but not X_i) which is of value as it has a permanent component. For the sub-period over which targeting has been in operation none of the excluded series are stationary at the 1% level, one of the excluded series (E_1) is stationary at the 5% level and one other (E_2) is stationary at the 10% level. The other three excluded series

[30] An alternative would be to look at the time series properties of the rate of change in prices for individual expenditure groups (products) excluded from the various series (Johnson, 1999).

[31] It is not clear what weight should be used for the weighted median series (X_4). Based on the diagrams in RBA (1994, p 4) we have selected a weight of 0.35.

[32] The underlying series X_1 and X_2 are the two which exclude the least from the headline CPI.

[33] ADF test results for the first differences confirm that these three series are I(1) in the levels.

[34] However, as noted earlier, we only have hard data on the Treasury series for the period 1987:4 – 1998:2. If we look only at the period where we have hard data on X_3 (i.e. 1987:4 – 1998:2), we find that we also cannot reject the null that the excluded series (E_3) for that period is non-stationary.

(E_3, E_4 and E_5) are non-stationary.[35] It is also of interest to check the relevant excluded series (E_5) for the period when the Treasury underlying rate was being used as 'the' underlying series (1993:2 – 1998:2). This is done in Table 2D below. We conclude that for this sub-period (over which we have reliable data) the Treasury underlying series excluded relevant information in that the implied inflation rate for the expenditure groups not included in the Treasury series are not stationary.

[TABLES 2C AND 2D NEAR HERE]

In our view this second approach, where we look at the time series properties of the excluded series, is preferable to looking at the properties of the 'gaps' if our aim is to assess whether or not the underlying series is 'efficient' in the sense that any discarded data (i.e. data on inflation rates which are present in p_t but not present in p_t^U) should be stationary. Our conclusions, based on Tables 2C and 2D, are that the majority of the underlying series are not satisfactory in that they are excluding useful permanent information. Amongst other things this means that the series now preferred by the RBA (X_4 and X_5) are not superior to any of the other series on this criterion. It would also appear that the Treasury series was unsatisfactory on this criterion over the period it was being used as 'the' underlying series as well as in other periods.[36]

(ii) Criterion 2

The second of the criteria we said that we would expect to be met by a satisfactory underlying series was that the underlying rate (X_i) and the target rate (which for us is the headline rate with interest rates excluded - Y) be integrated of the same order. Table 3A below sets out ADF statistics for each of the series for the whole of our sample period and also for the sub-period over which targeting has been in place.[37] For the whole of the period 1987:4 – 2002:4 all of the series appear to be I(1) at the 5% level on the basis of the ADF test.[38] For the sub-period where targeting has been in place all except X_2 appear to be I(1) at the 5% level on the basis of the ADF test and all, including X_2, are I(1) at the 1% level. In what follows we will assume that the target series (Y) and all of the underlying series are I(1) and integrated of the same order.[39]

Again, it is of interest to look at the period when the Treasury underlying rate was being used as 'the' underlying series (1993:2 – 1998:2). This is done in Table 3B below. We see that

[35] ADF test results for the first differences confirm that these three series are I(1) in the levels.
[36] In a sense this result is not surprising, given that the Treasury series excludes for more than any of the other series.
[37] Structural change is not an issue because we are comparing series which are subjected to the same permanent shocks.
[38] For the period where we have hard data on X_3 (i.e. 1987:4 – 1998:2), we find that we also cannot reject the null that the series is non-stationary.
[39] ADF test results for the first differences confirm in each case that the series are all I(1) in the levels.

over this sub-period the Treasury rate and the target series (Y) are both I(1) and so, in what follows, we will assume that these two are both I(1) and integrated of the same order not only over the periods 1987:4 – 2002:4 and 1993:2 – 2002:4 but also over the sub-period 1993:2 – 1998:2.

[TABLES 3A AND 3B NEAR HERE]

(iii) Criterion 3

The third of the criteria was that the underlying rate (X_i) and headline (target) rate (Y) be co-integrated and that the relationship between the two series satisfy certain conditions. To test for cointegration we regressed Y on each of the underlying series, with and without a constant and then examined the residuals to see if they are stationary.[40] The results for the regressions are reported in Table 4A. We maintain the hypothesis that there is no significant difference in the means between the target and underlying series in each case as we shall see this is supported by the VECM results presented later in the paper. For each set of regressions we used two sample periods. One is for the whole of our period (1987:4 – 2002:4) and the other for the period over which targeting has been in force (1993:2 – 2002:4).

We find that for the whole of our sample period the target series (Y) and all of the underlying series are co-integrated at the 1% level.[41] However if we restrict our attention to the sub-period over which targeting has been in force we conclude that only one of the underlying series, X_2, is cointegrated with the target series at the 1% level, the Treasury series, is cointegrated with the target series at the 5% level while X_1 and X_5 are cointegrated with the target series at the 10% level. Another of the series favoured by the RBA (X_4) narrowly misses out on being cointegrated with the target series at the 10% level.

It is of interest to test for cointegration between the target series (Y) and the Treasury series over the sub-period when that series was used as the underlying series (i.e. the period 1993:2 – 1998:2). The results are given in Table 4B. Our finding is that these two series were not cointegrated at the 5% level but that they are cointegrated at the 10% level.

[TABLES 4A AND 4B NEAR HERE]

As a result of the cointegration tests and using 10% as the critical value, we judge that our target series Y and all of the underlying series are cointegrated over the period 1987:4 –

[40] Phillips-Ouliaris critical values (Phillips and Ouliaris,1990, p 190) are used in Tables 4A and 4B to test for stationarity in the residuals.
[41] We also find that over the period where we have hard data on X_3 (1987:4 – 1998:2), that it is cointegrated with Y.

2002:4,[42] that Y and the Treasury series (X_3) are cointegrated over the period it was used as 'the' underlying series and that Y is cointegrated with X_1, X_2, X_3 and X_5 over the period targeting has been in operation. We next examine these relationships in an error correction framework, utilizing the Granger representation theorem to consider directions of causation.[43]

Table 4C reports the results obtained using EVIEWS 4.1 to estimate a Vector Error Correction model of Y on each of the underlying series using the Schwarz information criterion for determining the number of lagged difference terms to include. The sample period is 1987:4 – 2002:4. In all cases reported below the intercept in the unrestricted regression proved not to be significantly different from zero and so it was dropped and the equation re-estimated without a constant. With respect to causation, only one of the series (X_4) appears to be exogenous (at least at the 10% level). The series X_2, where the causation appears to run in both directions, X_1, the Treasury series (X_3) and one of the measures favoured by the RBA (X_5) do not meet this criterion.[44] Can we reject the restriction that $\alpha = 0$ and $\beta = 1$ for each underlying series? Using a Likelihood Ratio (LR) test we reject the restriction for two of the series, X_3 and X_5.[45]

Table 4D reports the results obtained using EVIEWS 4.1 to estimate a Vector Error Correction model of Y on the Treasury series for the (short) sample period during which the RBA used the Treasury series as 'the' underlying rate. Clearly the Treasury series was not a satisfactory underlying series over that period. The causation is in the wrong direction and the null that β is 1 is rejected.

[TABLES 4C AND 4D NEAR HERE]

Of most interest is the performance of the various series over the period since inflation targeting was introduced in 1993. Relevant information is reported in Table 4E. The results indicate that only one series (X_5 – the RBA's Trimmed mean series) satisfies our conditions relating to causality and the restrictions we require on the coefficients over the period since inflation targeting was introduced.

[TABLE 4E NEAR HERE]

[42] And also the finding of cointegration between our target series Y and the Treasury underlying series over the period 1987:4 – 1998:2.

[43] Since the variables are clearly cointegrated and structural change is not an issue, we pool information for VECM analysis.

[44] Again, we have to consider the possibility that the result for the Treasury series is being distorted by the proxy used for the 1998:3 – 2002:4 period and so we redid the VECM for X_3 for the period 1987:4 – 1998:2. We find that for this period β is estimated to be 1.136 and here also that there is unidirectional causality running from Y to X_3 at the 1% level.

[45] The restrictions are also rejected for the Treasury series (X_3) for the period 1987:4 – 1998:2.

(iv) Conclusions Regarding the Appropriateness of Existing Underlying Series

In this sub-section we summarise our findings in relation to the five underlying series published in Australia. Particular attention will be given to the Treasury series (X_3) and the two series favored by the RBA (X_4 and X_5).

Tables 5A and 5C below report the performance of each of the underlying series against the criteria we set out at the beginning of this section[46] for the period 1987:4 – 2002:4 and separately for the period over which targeting has been in operation (1993:2 – 2002:4). In addition we summarise in Table 5B the performance of the Treasury series (X_3) in the period over which it would appear to have been the underlying rate used by the RBA.

[TABLES 5A AND 5B NEAR HERE]

If we look at the performance of the various underlying series over the whole of our sample period (this includes some 5 years before inflation targeting was introduced as well as the 9 years since it was introduced) no series satisfies all of the criteria we specify. Only three series satisfy the requirement that that $\alpha = 0$ and $\beta = 1$, but only one of those (X_4) in addition satisfies the direction of causality criterion. Of more interest however is the performance of the Treasury series over which it was being used as 'the' underlying series (Table 5B) and also the performance of all of the underlying series over the period targeting has been in operation (Table 5C). Our findings are that the Treasury series was not appropriate to be used as an underlying series over the period the RBA was using it as such, as it fails most of our criteria for that period.

[TABLE 5C NEAR HERE]

Of most concern is the performance of the various series over the period since inflation targeting was introduced in 1993. Only one series (X_5 – the Trimmed mean) satisfies our necessary conditions but it would appear that this series is not satisfactory in that it does not meet our first criterion that the excluded series be stationary. It should also be noted that X_5 is only weakly cointegrated (10%) with the target series and also that the restrictions that $\alpha = 0$ and $\beta = 1$ are accepted only weakly. However, it does appear to dominate all of the other series, including X_4 – the Weighted median.

[46] Our decision in relation to the item "Relevant information is not excluded?" is based on the results in Tables 2C and 2D above.

In the next section of the paper we consider whether estimated underlying time series (modeled as a latent in the target headline series) perform any better than the current set of underlying series generated and used by the RBA.

VII The Underlying Rate Given by the Unobserved Components Model

Earlier we assumed that the actual rate of inflation (p) over any period can be decomposed into two additive components, one is a permanent or underlying component (p^U) and the other is a transitory component (p^T). We assume that the transitory component is stationary with a zero mean and finite variance. In this section, we shall apply a time-series econometric method (the 'Unrestricted Unobserved Components' (or trend-cycle) decomposition of Morley *et.al.* (2003)) to extract the underlying or permanent component from the raw data (the headline CPI). We will begin however by introducing an additional 'target series'.

Since we are no longer restricted to using underlying series generated by others we are also no longer tied to the CPI series as published by the ABS or simple variants of it such as the *Y* series we have been using thus far. In particular, we note that since 1998:3 the ABS and the RBA have been utilizing a CPI series which not only excludes interest rates but also includes a house purchase component and we consider it useful to generate a new series that mimic the current composition of the CPI. In particular, for econometric purposes it would be useful to have a long run of data for a CPI series which does not only exclude interest rates (like our *Y* series) but which includes house prices (unlike our *Y* series prior to 1998:3). The RBA has also very kindly given us a series for their estimate of an 'Acquisitions CPI' over the period 1987:4 – 1998:2. This series, which was reported in Graph 1 on page 3 of the *RBA Bulletin* for October 1998, excludes interest rates while including house purchases.[47] Combining this with CPI headline series post 1998:2 should give us an approximation to a consistent data set for CPI inflation at an annual rate for the period 1987:4 – 2002:4 and with the series being measured on a basis which is consistent with the make-up of the CPI as it is now (post 1998) and thus as the inflation target is currently specified. We label this series *Z*.

Figure 6 shows how the 'acquisitions' adjusted CPI series (*Z*) compares with the original CPI series over the period 1987:4-1998:2 when interest rates were included in the headline CPI. Clearly the *Z* series (which includes house purchases but not interest rates) is less volatile than the CPI as reported by the ABS which included interest rates but not house purchases (prices). Figure 7 shows how the two adjusted CPI series (*Y* and *Z*) compare with the original CPI series

[47] Readers should note that the "Acquisitions CPI" series was constructed by the RBA, and is not an official ABS series. As such, it is not constructed on a basis that is wholly consistent with the official CPI (as constructed from September 1998 onwards) and can only be considered a rough approximation to the ideal.

over the period 1987:4 – 2002:4. Clearly the *Y* series (which excludes interest rates) and the *Z* series (which includes house purchases but not interest rates) are highly correlated over most of the period.

[FIGURES 6 & 7 NEAR HERE]

In what follows, the 'target series' (*Z*) prior to September 1998 (i.e., for the period 1987:4 – 1998:2 inclusive) is the Headline CPI series as published by the ABS adjusted by excluding mortgage interest charges and consumer credit charges but with house purchases put back in and that post September 1998 it is the Headline CPI adjusted for the introduction of the GST. However, to facilitate comparisons with earlier sections of the paper we will also report results for the '*Y*' series.

(i) The (Unrestricted) Unobserved Components Decomposition

The Unobserved Components decomposition method (Cochrane (1988), Stock & Watson (1988) and Morley et al (2003)) is a univariate method which "provides a convenient way to estimate the permanent and transitory components of an integrated time series" (Morley, 2001, p 123) and is based on the notion that any integrated time series (e.g. an I(1) series) can be decomposed into two additive elements, a pure random walk and a stationary series. This method has all the advantages of the so-called 'statistical' approach the RBA uses to derive its series (the Weighted median and the Trimmed mean) in that there is no prejudgment about particular individual price series to be removed but, in addition, it does not have the major disadvantage of the two RBA series which is that they totally neglect all information which might be in the raw data on the (across period) time series properties in CPI series. The Unobserved Components approach (along with the Beveridge-Nelson (1981) model) has the additional advantage in that, unlike all of the underlying measures currently compiled and reported in Australia, it will, by its very construction, satisfy all of the criteria we set out above. For all of these reasons we believe it is worth investigating as an appropriate method for generating a useful and intellectually defensible underlying inflation series.

The model we propose is an Unrestricted Unobserved Components Model. This is an Unobserved Components model in which the covariance between permanent and transitory shocks is not restricted to be zero. In terms of our application, the model, dubbed 'UC-UR' by

Morley et al (2003), can be written as follows:

$$p_t = p_t^U + p_t^T \tag{1}$$

$$p_t^U = p_{t-1}^U + u_t \tag{4}$$

$$p_t^T = \phi_1 p_{t-1}^T + \phi_2 p_{t-2}^T + e_t \tag{5}$$

$$\begin{pmatrix} u_t \\ e_t \end{pmatrix} \sim N(0, \Sigma); \quad \Sigma = \begin{pmatrix} \sigma_u^2 & \sigma_{ue}^2 \\ \sigma_{ue}^2 & \sigma_e^2 \end{pmatrix}$$

As before, equation (1) says that the observed (target) inflation rate can be decomposed into an underlying or permanent component[48] (p^U) and a volatile transitory component[49] (p^T). The (unobservable) underlying component is assumed to behave like a simple random walk (equation (4)), while the volatile component is assumed to behave like an autoregressive process (equation (5))). We follow Watson (1986), Clark (1987) and others in hypothesizing that this term is an AR(2) process and we constrain the coefficients to ensure a stationary process. The covariance (σ_{ue}^2) between shocks to the underlying component (u_t) and the transitory component (e_t) in the Morley et al UC-UR model is also not restricted to be zero, unlike the original UC model.

Another advantage of the UC-UR model is that it can be put into a cointegration framework. Doing this for our model gives the vector ECM as:

$$\Delta p_t = (-1 + \phi_1 + \phi_2)(p_{t-1} - p_{t-1}^U) - \phi_2 \Delta p_{t-1} + \phi_2 \Delta p_{t-1}^U + [e_t + u_t]$$

$$\Delta p_t^U = u_t$$

where the error correction term is conditioned to satisfy the restriction: $0 < (\phi_1 + \phi_2) < 1$

By construction in this model underlying inflation (p^U) is exogenous (equation (4)) while equation (1) shows the cointegration between the target (p) and underlying (p^U) rates with cointegrating vector {1,-1}. Hence the underlying series satisfies all of our necessary conditions to be a satisfactory underlying series.

The model has been estimated by maximum likelihood utilizing the Kalman filter. Tables 6A and 6B below give information on the estimated values of the parameters in the UC-

[48] Often referred to as the 'trend' component.
[49] Often referred to as the 'cyclical' component, even when it is not periodic.

UR model for the two series we are interested in (*Y* and *Z*). [50] The model has been estimated for the whole of our sample period and for the targeting sub-period alone. [51]

[TABLES 6A AND 6B NEAR HERE]

The estimated values of the underlying (or permanent) component of each series can be recovered and are displayed in Figures 8 and 9 for the period (1988:1-2002:4). The underlying components (our estimate of p^U) are labeled *YUC* (!) and *ZUC*. The close movement of the estimated underlying and the actual series suggests that the transitory component of actual inflation is quite small.

[FIGURES 8 & 9 NEAR HERE]

Table 6C below shows the 'mean of the absolute deviations'[52] (MAD) between the target series and the respective underlying series over the whole sample period and over the sub-sample period when the RBA has been engaged in inflation targeting (1993:3 – 2002:4). These figures are an estimate of the average (absolute) size of the 'transitory component of inflation (p^T) over the period. The figures in Table 6C may be compared with the mean values for *Y* and *Z* over the period 1988:1 – 2002:4 of 3.42 and 3.43 respectively and their mean values over the sub-period 1993:3 – 2002:4 of 2.46 and 2.42 respectively. It is clear from the information given in Table 6C and also in Figures 8 & 9 that, according to the UC-UR model, very little of the movement in the target series is transitory (or 'cyclical'). This is in marked contrast to that suggested by comparing values of the target series over the period with each of the other underlying series considered earlier in the paper. Table 6D shows the mean of the absolute deviations (MAD) of the target series (*Y*) from the various underlying series (X_1 ,…,X_5) over the whole sample period and over the sub-period 1993:3 – 2002:4. Clearly, each of these series is suggesting a much larger 'transitory' component, and a correspondingly smaller 'underlying' component to the target series than is indicated by the use of the UC-UR decomposition. Another way of putting this is to say that our results suggest that all of the underlying measures used in Australia, including the 'statistical' series developed by the RBA are excluding too much information from the original series. This finding is consistent with and reinforces our comments along these lines in an earlier section of the paper.

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[50] The small negative values for σ_{ue}^2 implies that the trend component of the UC-UR series will be (slightly) more volatile than the original time series as the negative correlation between the trend and cycle components will act to make the original time series smoother than it would other wise be.

[51] It may be said that independence of shocks to underlying and transitory components should be forced on the data but this hypothesis is rejected by the model we have estimated. We see in both Tables that the σ_{ue}^2 terms are all significantly different from zero (while being 'small'). There is nothing in the model, as we have estimated it, that forces the correlation coefficient to be any particular value (see Morley et al, 2003).

[52] Measured as $(1/N)\sum|Y_t - X_{it}|$, where *N* is the number of periods in the sample.

[TABLES 6C AND 6D NEAR HERE]

VIII Conclusions

The aim of this paper was to formulate criteria which an acceptable underlying inflation rate must satisfy and then to test whether any of the current or recently discarded (the Treasury underlying rate) measures of underlying inflation satisfy these criteria.

We found that for the period since inflation targeting began (in 1993) none of these underlying series satisfy all of the criteria we propose but that one series (the RBA's Trimmed mean series) does satisfy the sub-set which we refer to as our 'necessary criteria'. We also found that the Treasury series was not appropriate to be used as an underlying series over the period the RBA was using it as such, as it fails most of our criteria for that time period. Our finding that 'exclusion based' series are inadequate is in accord with the findings of Cockerell (1999) for the Treasury series in Australia and of Marques et al (2000 & 2002) and Mankikar & Paisley (2002) for the US, the UK and various other European countries.

We also found that the majority of the underlying series are not satisfactory in that they are excluding useful information.[53] This finding was supported by the results of an (Unrestricted) Unobserved Components decomposition which suggests that (a) very little of the movement in the target series was transitory and (b) all of the underlying measures used in Australia, including the 'statistical' series developed by the RBA are excluding too much information from the original series.

Since the measurement of the Unobserved Components series relies only on past data and can be updated quickly each time the CPI is released, the UC-UR procedure (or some other econometric time series decomposition algorithm) has considerable merit.[54]

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[53] This finding is also consistent with those reported by Marques et al (2000 & 2002) for the USA and various continental European countries.

[54] However it also has the drawback that it is usually contended that a necessary attribute for an underlying series is that it be readily understood by non-economists ('the public') and this series is further removed from that than are the 'exclusion based methods', for example.

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TABLE 1A

Means and Standard Deviations for the Whole of the Sample Period (1987:4 – 2002:4) and for the Sub-period Over Which Targeting has Been in Operation (1993:2 – 2002:4).

	1987:4 – 2002:4		1993:2 – 2002:4	
Series	Mean	Std Dev	Mean	Std Dev
CPI	3.29	2.45	2.22	1.29
Y	3.49	1.90	2.46	0.73
X_1	3.51	1.93	2.43	0.79
X_2	3.32	1.92	2.30	0.81
X_3	3.18	1.83	2.13	0.52
X_4	3.28	1.88	2.22	0.47
X_5	3.24	1.75	2.23	0.49

Note: *'CPI'* is the headline CPI reported by the ABS at the time (without any adjustments for interest rates) but with the impact of the introduction of the GST removed; *Y* is the CPI excluding GST and interest rates; X_1 is the "CPI excluding volatile items"; X_2 is the "Market goods and services excluding 'volatile items'"; X_3 is the Treasury underlying rate; X_4 is the Weighted median, and; X_5 is the Trimmed mean.

TABLE 1B

Means and Standard Deviations for the Period when the Treasury Series was Used as the 'Underlying Rate' (1993:2 – 1998:2).

Series	Mean	Std Dev
CPI	2.10	1.64
Y	2.52	0.78
X_3	2.17	0.57

TABLE 2A
ADF Statistics for the 'Gaps' Between the Target and Underlying Series.

Series	1987:4 – 2002:4		1993:2 – 2002:4	
	With intercept	Without intercept	With intercept	Without intercept
$Y_t - X_{1t}$		-4.206		-2.104
$Y_t - X_{2t}$		-3.846	-4.767	
$Y_t - X_{3t}$	-4.581			-1.890
$Y_t - X_{4t}$		-3.260		-2.015
$Y_t - X_{5t}$	-3.902			-1.908
1% Critical Value	-3.544	-2.604	-3.610	-2.626
5% Critical Value	-2.911	-1.946	-2.939	-1.950
10% Critical Value	-2.593	-1.613	-2.608	-1.612

Note: The Schwarz criterion has been used to determine the appropriate lag structure in each case. In each case where we cannot reject the null of non-stationarity in the levels (X_3 and X_5), ADF results for the first differences confirm that each series is I(1) in the levels.

TABLE 2B
ADF Statistics for the 'Gaps' over the Sub-period During which the Treasury Underlying Rate was Used as 'the' Underlying Series.

Series	ADF
$Y_t - X_{3t}$	-1.617
1% Critical Value	-2.680
5% Critical Value	-1.958
10% Critical Value	-1.608

Note: Test is performed without an intercept. When an intercept was included in the test equation it proved to be insignificant and was dropped. ADF results for the first differences confirm that the series is I(1) in the levels.

TABLE 2C

ADF Statistics for the Rate of Inflation of the Series Excluded from the Underlying Series (E_i's).

Series	1987:4 – 2002:4		1993:2 – 2002:4	
	With Intercept	Without Intercept	With Intercept	Without Intercept
E_1	-3.617			-2.014
E_2	-3.305		-2.717	
E_3		-1.351		-0.479
E_4		-1.553		-0.448
E_5		-1.336		-0.714
1% Critical Value	-3.544	-2.604	-3.610	-2.626
5% Critical Value	-2.911	-1.946	-2.939	-1.950
10% Critical Value	-2.593	-1.613	-2.608	-1.612

TABLE 2D

ADF Statistics for the Rate of Inflation of the Series Excluded from the Treasury Underlying Rate for the Sub-period During Which it was Being Used as 'the' Underlying Series.

Series	ADF
E_3	-0.813
1% Critical Value	-2.680
5% Critical Value	-1.958
10% Critical Value	-1.608

Note: Test is performed in the levels without an intercept. ADF results for the first differences confirm that the series is I(1) in the levels.

TABLE 3A
ADF Statistics for Each of the Series in the Levels.

Series	1987:4 – 2002:4	1993:2 – 2002:4
Y	-2.434	-1.654
X_1	-2.376	-2.849
X_2	-2.873	-3.232
X_3	-2.164	-2.377
X_4	-2.484	-1.952
X_5	-2.724	-2.318
1% Critical Values	-3.544	-3.610
5% Critical Values	-2.911	-2.939
10% Critical Values	-2.593	-2.608

Note: There is an intercept (but no trend) in all of the test equations for the levels in tables 3A and 3B.

TABLE 3B
ADF Statistics for the Sub-period During which the Treasury Underlying Rate was Used as 'the' Underlying Series.

Series	ADF
Y	-1.631
X_3	-2.218
1% Critical Values	-3.788
5% Critical Values	-3.012
10% Critical Values	-2.646

Note: ADF results for the first differences confirm that the series for Y and X_3 are I(1) in the levels.

TABLE 4A

ADF Tests of the Residuals from the OLS Regressions $Y_t = \beta X_{it} + u_{it}$

Series	1987:4 – 2002:4	1993:2-2002:4
u_1	-3.978	-2.556
u_2	-4.113	-4.173
u_3	-4.542	-2.863
u_4	-3.592	-2.436
u_5	-4.247	-2.542

Note: Phillips-Ouliaris Critical Values are: 1%, -3.387; 5%, -2.762; 10%, -2.451.

TABLE 4B

ADF Tests of the Residuals from the OLS Regression $Y_t = \beta X_{3t} + u_{3t}$

Series	ADF
u_3	-2.735
5% Critical Value	-2.762
10% Critical Value	-2.451

Note: The intercept in the cointegrating equation proved insignificant and was dropped.

TABLE 4C
Results of VEC Models: Sample Period is 1987:4 – 2002:4.

Series	$\hat{\beta}$	Direction of Causation	LR Test for the null that $\alpha = 0$ and $\beta = 1$
X_1	1.028	[Y to X_1]***	p-value = 0.288
	(0.023)		
X_2	1.044	[X_2 to Y]*	p-value = 0.116
	(0.025)	[Y to X_2]*	
X_3	1.149	[Y to X_3]***	p-value = 0.000
	(0.030)		
X_4	1.090	[X_4 to Y]*	p-value = 0.120
	(0.037)		
X_5	1.134	[Y to X_5]**	p-value = 0.000
	(0.022)		

Notes: Figures in brackets in the second column are the estimated standard errors of the coefficients. *** indicates significant at the 1% level, ** significant at the 5% level and * significant at the 10% level

TABLE 4D
Results of VEC Model for the Period 1993:2 – 1998:2.

Series	$\hat{\beta}$	Direction of Causation	LR Test for the null that $\alpha = 0$ and $\beta = 1$
X_3	1.185	[Y to X_3]***	p-value = 0.004
	(0.037)		

Notes: Figures in brackets in the second column are the estimated standard errors of the coefficients. The intercept in the unrestricted regression proved not to be significantly different from zero and so it was dropped and the equation re-estimated without a constant. Guided by the SIC no lagged difference terms were included. *** indicates significant at the 1% level

TABLE 4E

Results of VEC Models for the Period over which Targeting has Been in Operation.

Series	$\hat{\beta}$	Direction of Causation	LR Test for the null that $\alpha = 0$ and $\beta = 1$
X_1	1.000	[Y to X_1]**	p-value = 0.999
	(0.051)		
X_2	1.087	[Y to X_2]***	p-value = 0.056
	(0.045)		
X_3	1.162	[Y to X_3]**	p-value = 0.044
	(0.063)		
X_5	1.118	[X_5 to Y]*	p-value = 0.122
	(0.062)		

Notes: Figures in brackets in the second column are the estimated standard errors of the coefficients. In all cases the intercept in the unrestricted regression proved not to be significantly different from zero and so it was dropped and the equation re-estimated without a constant. For X_2 (guided by the SIC) one lagged difference term was included. For all others no lagged difference terms were included.*** significant at the 1% level. ** indicates significant at the 5% level and * significant at the 10% level.

TABLE 5A

Summary of Test Outcomes for all Underlying Series Over the Period 1987:4 – 2002:4.

Series	Relevant information is not excluded?	Same degree of integration as target?	Cointegrated with target?	Accept restriction that $\alpha = 0$ and $\beta = 1$?	Underlying series "cause" target?
X_1	Yes	Yes	Yes	Yes	No
X_2	Yes	Yes	Yes	Yes	No
X_3	No	Yes	Yes	No	No
X_4	No	Yes	Yes	Yes	Yes
X_5	No	Yes	Yes	No	No

TABLE 5B

Summary of Test Outcomes for the Treasury Series Over the Period 1993:2 – 1998:2.

Series	Relevant information is not excluded?	Same degree of integration as target?	Cointegrated with target?	Accept restriction that $\alpha = 0$ and $\beta = 1$?	Underlying series "cause" target?
X_3	No	Yes	Yes	No	No

TABLE 5C

Summary of Test Outcomes for all Underlying Series Over the Period 1993:2 – 2002:4

Series	Relevant information is not excluded?	Same degree of integration as target?	Cointegrated with target?	Accept restriction that $\alpha = 0$ and $\beta = 1$?	Underlying series "cause" target?
X_1	Yes	Yes	Yes	Yes	No
X_2	Yes	Yes	Yes	Yes	No
X_3	No	Yes	Yes	No	No
X_4	No	Yes	No	---	---
X_5	No	Yes	Yes	Yes	Yes

TABLE 6A
Results of Fitting the UC-UR Model to the Two Target Series (Y and Z) over the Period 1988:1 – 2002:4.

	Y *series*		Z *series*	
Parameter	Estimate	p-value	Estimate	p-value
σ_u	0.605	0.000	0.590	0.000
σ_e	0.097	0.019	0.102	0.003
ϕ_1	1.341	0.000	1.313	0.000
ϕ_2	-0.829	0.000	-0.821	0.000
σ_{ue}^2	-0.059	0.037	-0.060	0.009

TABLE 6B
Results of Fitting the UC-UR Model to the Two Target Series (Y and Z) over the Period During which Targeting has been in Operation.

	Y *series*		Z *series*	
Parameter	Estimate	p-value	Estimate	p-value
σ_u	0.404	0.000	0.366	0.000
σ_e	0.500	0.000	0.183	0.009
ϕ_1	0.153	0.000	0.906	0.000
ϕ_2	-0.077	0.000	-0.452	0.000
σ_{ue}^2	-0.182	0.000	-0.021	0.004

TABLE 6C
Mean of the Absolute Deviations (MAD) of the Target Series from the UC-UR Underlying Series.

Series	1988:1-2002:4	1993:3 – 2002:4
Y from *YUC*	0.16	0.10
Z from *ZUC*	0.15	0.10

TABLE 6D
Mean of the Absolute Deviations (MAD) of the Y Series from Various Underlying Series.

Series	1988:1-2002:4	1993:3 – 2002:4
Y from X_1	0.32	0.51
Y from X_2	0.40	0.59
Y from X_3	0.47	0.52
Y from X_4	0.41	0.34
Y from X_5	0.38	0.41

APPENDIX

Definitions of variables and data sources

Variable	Description	Source
CPI	the quarter on same quarter of the year before rate of change in the headline CPI reported by the ABS over the period 1987:4 – 2002:4	ABS Time series Table 6401-09
CPIEXGST	as above but with the impact of the introduction of the GST removed	RBA
Y	as above but excluding the interest rate component (while including a house price component from 1998:3)	RBA
Z	as above but including a house price component over the whole period	RBA
X_1	CPI excluding volatile items	as for CPI
X_2	Market goods and services excluding 'volatile items'	as for CPI
X_3	Treasury underlying rate	as for CPI
X_4	Weighted median	RBA Bulletin database Table G.01
X_5	Trimmed mean	as above

Figures for: Underlying inflation in Australia: Are the existing measures satisfactory?

FIGURE 1

CPI is the inflation rate (given by the "All groups CPI") which includes the effects upon prices of the introduction of the GST in 2000; CPIEXGST is the same inflation rate but excluding the effects upon prices of the introduction of the GST". Sample period is 1987:4 – 2000:4.

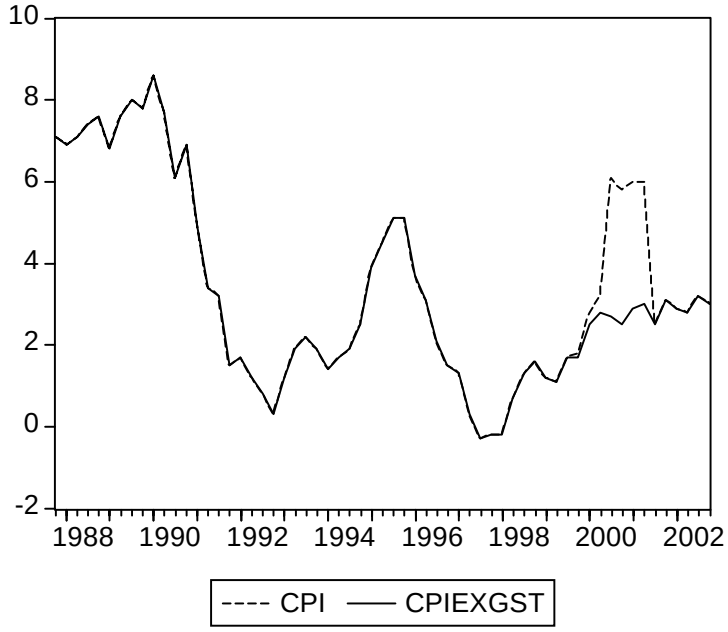

FIGURE 2

CPIEXGST is the inflation rate as given by the headline CPI series (excluding the impact of the introduction of the GST); X_1 is the 'CPI excluding interest rates and volatile items' series and X_2 is the 'Market prices excluding volatile items' series. Sample period is 1987:4 – 2000:4.

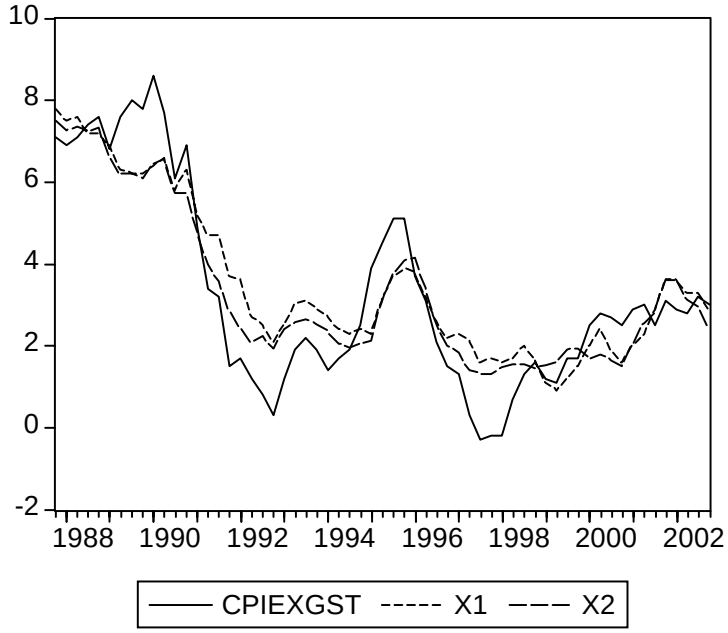

FIGURE 3

CPI is the headline inflation rate; Y is the headline rate excluding interest rates; X_3 is the Treasury underlying rate. Sample period is 1987:4 – 1998:2.

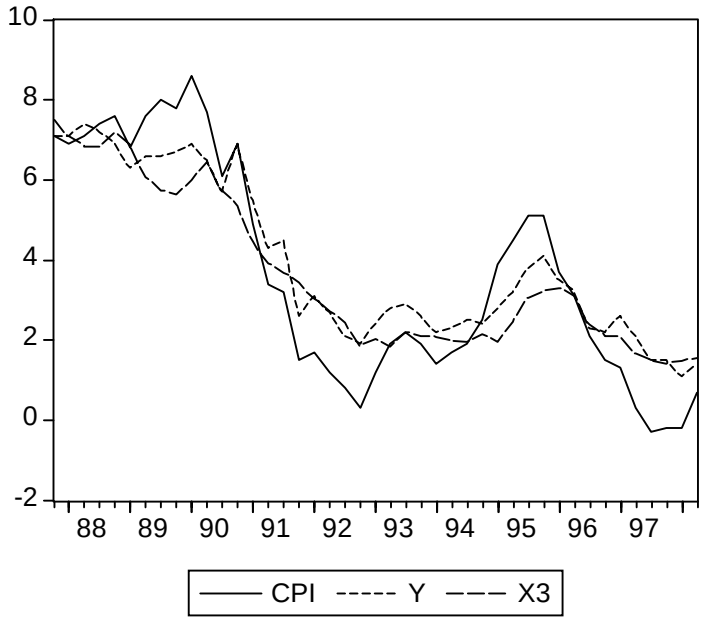

FIGURE 4

CPIEXGST is the headline inflation rate (excluding the impact of the introduction of the GST); X_4 is the 'Weighted median series; X_5 is the 'Trimmed mean series.Sample period is 1987:4 – 2002:4.

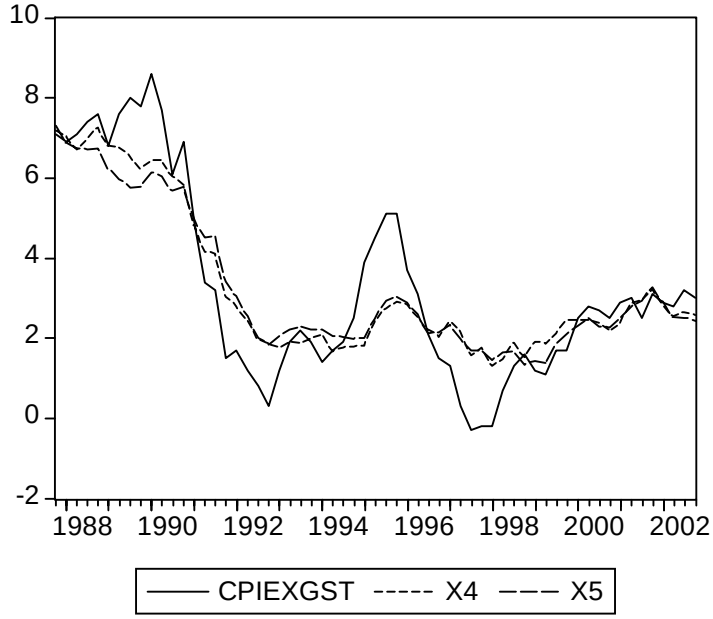

FIGURE 5

CPIEXGST is the headline inflation rate (excluding the impact of the introduction of the GST); Y is the headline rate adjusted for the impact of the introduction of the GST and also excluding interest rates. Sample period is 1987:4 – 2002:4.

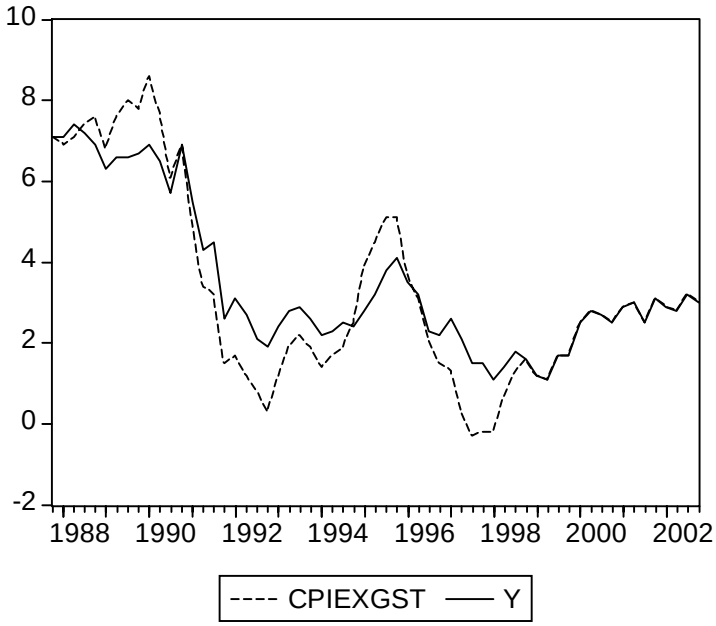

FIGURE 6

Z is the 'Adjusted CPI' series which includes the price index for 'house purchases' over the whole period; CPI is the inflation rate as given by the "All groups CPI" including mortgage interest rates and consumer credit charges. Sample period is 1987:4 – 1998:2.

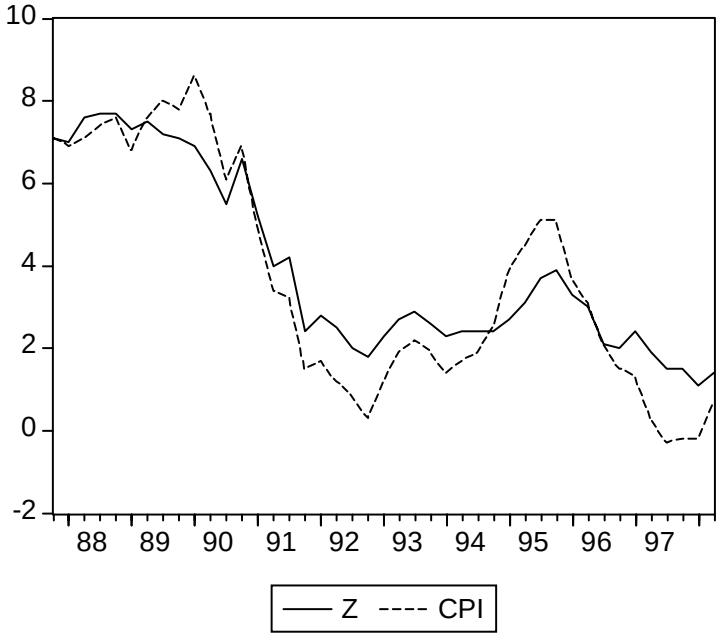

FIGURE 7

Z is the 'Adjusted CPI' series which includes the price index for 'house purchases' over the whole period and excludes the effects of the introduction of the GST; Y is the inflation rate as given by the "All groups CPI excluding the impact of the introduction of the GST" but including mortgage interest rates and consumer credit charges. Sample period 1987:4 – 1998:2

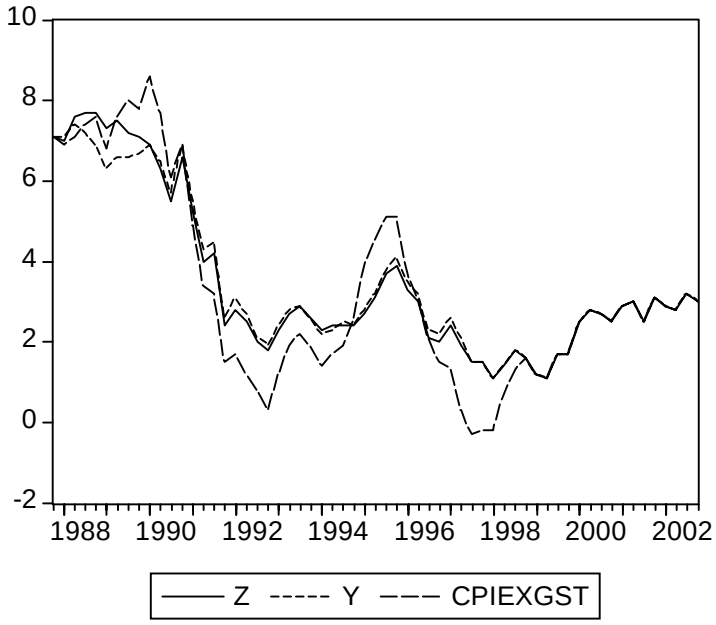

FIGURE 8

Actual and UC-UR underlying rates of inflation for the Y series: 1988:1 - 2002:4

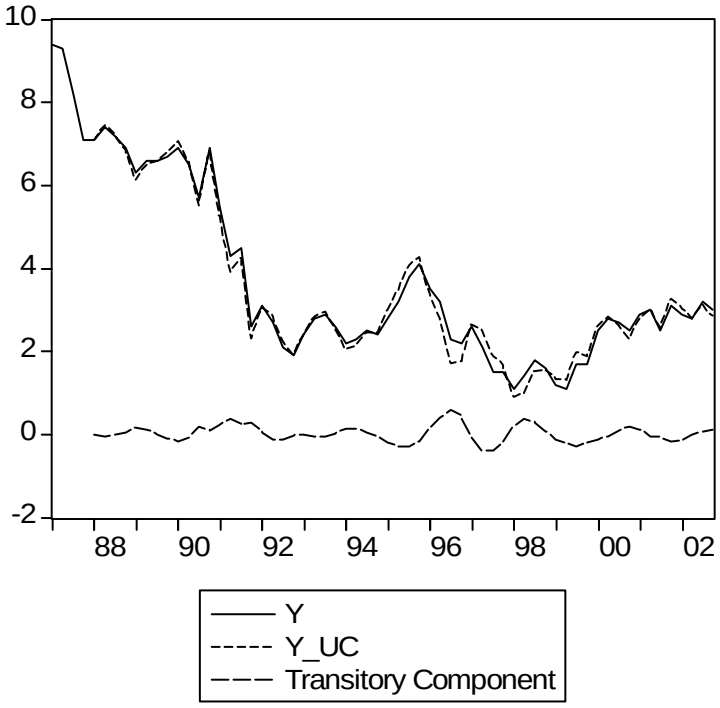

FIGURE 9

Actual and UC-UR underlying rates of inflation for the Z series: 1988:1 - 2002:4