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How Well Does "Core" CPI Capture Permanent Price Changes?

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Abstract: We decompose core CPI and the food and energy CPI measures into permanent and transitory components using a correlated unobserved components model, to examine the behavior of core CPI when subject to shocks and to examine the claim that core CPI captures the persistent part of headline CPI. We find that the permanent component of core CPI is more volatile than core CPI, or that the permanent and transitory components are highly correlated. We find that the excluded food and energy components have important permanent components, and that core CPI has an important transitory component. We examine impulse response functions and find that headline CPI inflation responds more sharply to shocks than core CPI inflation, and after the first year the impact of shocks on headline inflation is less than the impact on core inflation.

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A. Introduction

Economic agents, both in the private sector and in public policy, make important economic decisions in an uncertain macroeconomic environment. An important variable characterizing that environment is inflation, and agents take inflation into account when making a host of economic decisions. Moreover, agents' decisions often depend on whether price changes are considered to be long-lasting or transitory.

Currently observable or "headline" inflation is a noisy signal about price level movements. In order to determine if observed price level changes are long-lasting or transitory, agents must decompose the observed price level changes into permanent and temporary parts. [1] One widely used approach for this decomposition, both for policy makers and private sector agents, is identification of the "core" rate of inflation.[2] Core inflation measures are constructed to identify and eliminate temporary, volatile, movements from the overall measure of the price level.

The most widely used measure of core inflation is a price index that excludes food and energy prices. This measure of core inflation is considered to be a better measure of permanent price level movements than headline inflation. The elimination of the 'volatile' food and energy components is thought to provide a less volatile series, and one that is more indicative of long run movements in prices. However, it is important to recognize that volatility and

[1] For example, Mishkin (2007) states, "By including all items—including particularly volatile items like food and energy—headline inflation measures are inherently noisy and often do not reflect changes in the underlying rate of inflation."

[2] Evidence on the importance of a core inflation measure in private-sector decision making is given by its persistent and widespread discussion in the popular and business press and economics blogs. For examples, see Coy, Peter, "The Great Inflation Debate," BusinessWeek, June 13, 2008, CBC News, "Inflation, Why Do Prices Rise and Fall?" Your Money, July 17, 2009, and "In Core We Trust?" The Capital Spectator, November 29, 2005. Discussions of the use of core inflation by monetary authorities are provided by Mishkin (2007), Bodenstein, Erceg and Guerrieri, (2008) and Yellen (2009.)

impermanence are not necessarily the same thing. It is perfectly possible for permanent price changes to be volatile. If so, the use of core inflation – CPI less food and energy -- as a measure of "long-run" inflation could be problematic. Agents using this measure would have an erroneous perception of permanent price level movements. [3] That is, the perceived permanent price movements from the use of core inflation would be neglecting important permanent movements. In addition, it is possible that core inflation erroneously includes some short-lived price level movements, so that core inflation could be masking the actual permanent price level movements. This too could lead to suboptimal economic decisions.

To be a bit more precise, users of the core inflation measure rely upon a set of key assumptions about price level movements. First, they assume that changes in core inflation reflect permanent or persistent price level movements. Next, they assume that changes in components excluded from the core index, such as food and energy prices, reflect transitory price movements. If some movements in excluded items are permanent then their exclusion is not warranted. Similarly, if the measure of core inflation includes temporary as well as permanent price movement, then the use of core as a measure of "long-run" price movement might need to be re-evaluated. Finally, there is an implicit assumption that the 'volatile' food and energy components are less persistent than the core measure of prices. This assumption is that a volatile series is not a persistent series, and vice versa.

In this paper, we empirically evaluate these assumptions. We investigate the features of core and headline CPI, paying particular attention to the permanent and transitory components of these and related series, and the implications for the inflation rates constructed from these series. We investigate the traditional core CPI, which excludes food and energy prices, as well as the

[3] This is highlighted in the area of monetary policy by Mishkin (2007): "Of course, if a particular shock to noncore prices is not temporary but, rather, turns out to be more persistent, then the higher costs are likely to put some upward pressure on core prices. Central bankers must always be aware of this risk."

food CPI and the energy CPI. We decompose each series into permanent and transitory components, and allow the permanent and transitory components to be correlated both within and across the series. The model we use is a multivariate extension of the correlated unobserved components model developed by Morley, Nelson and Zivot (2003). One of the key aspects of the correlated unobserved components model is that the permanent component may be more variable than the series itself, due to offsetting transitory components correlated with the permanent component. The model does not force this to be true, but it is a possibility, and it has been found to be the case for a number of series including US headline CPI (Morley and Sinclair, 2009).

An unobserved components model is a natural framework for such an investigation because it simultaneously decomposes price level movements into their permanent and transitory parts. We specifically use Morley, Nelson, and Zivot's (2003) correlated unobserved components model because this model provides the most general decomposition with the fewest *a priori* assumptions about the relative role of the permanent versus transitory components. One advantage of our approach is that we can focus on permanent shocks to the series without making the assumptions needed for a Blanchard and Quah (1989) type identification in a VAR. In addition, our model is more general than a VAR, because the reduced form of our model is a VARMA, not a VAR.

We estimate a three-series unobserved components model in which we jointly decompose the core CPI measure (which excludes food and energy prices), the CPI for food, and the CPI for energy into permanent and transitory components. Our multivariate model has the advantage that it allows investigation of each series but also accounts for contemporaneous shocks to each series and correlations among these shocks. These shocks can be permanent, transitory, or both.

Investigation of the relationship among these shocks provides insight into possible co-movements in the three major parts of the CPI.

We find that the core CPI does not capture permanent price changes very well. The smoothness of the core CPI series arises in part due to temporary movements which offset the more volatile permanent component of core CPI. That is, the permanent component of core CPI is much more volatile than core CPI. We further find that there are also important permanent movements in the "neglected" food and energy series. This suggests that ignoring food and energy makes the traditional core CPI inflation a biased measure of long-run inflation.

In the next section of the paper we present the unobserved components model and discuss its structure. This is followed by the data, estimation results, and interpretations of those results.

B. A Multivariate Unobserved Components Model

We use an unobserved components (UC) model to investigate movements in the key price subseries through time. An unobserved components model starts by dividing (the log of) an observable variable (p_{it}) into its unobservable permanent (τ_{it}) and transitory components (c_{it}). The model has the following form (where $i = C$ (Core CPI), F (Food CPI), and E (Energy CPI):

$$p_{it} = \tau_{it} + c_{it}.$$

The stochastic trend component, τ_{it}, is a random walk, and the formulation permits testing for and including breaks in the drift term (μ):

$$\tau_{it} = \mu_i + \tau_{it-1} + \eta_{it}.$$

The transitory component is modeled as a stationary AR(2) process:[4]

$$c_{it} \;=\; \phi_{i1}\, c_{it-1} \;+\; \phi_{i2}\, c_{it-2} \;+\; \varepsilon_{it}\,.$$

Finally, the model not only permits estimation of the permanent and transitory portions of each variable but also permits correlation between the innovations in the two components, following Sinclair's (2009) multivariate extension of Morley, Nelson, and Zivot (2003). The variance-covariance matrix is thus:

$$\begin{bmatrix} \eta_{Ct} \\ \eta_{Ft} \\ \eta_{Et} \\ \varepsilon_{Ct} \\ \varepsilon_{Ft} \\ \varepsilon_{Et} \end{bmatrix} \sim N(0,\Sigma_1), \quad \Sigma_1 = \begin{bmatrix} \sigma^2_{\eta C} & \sigma_{\eta C\eta F} & \sigma_{\eta C\eta E} & \sigma_{\eta C\varepsilon C} & \sigma_{\eta C\varepsilon F} & \sigma_{\eta C\varepsilon E} \\ \sigma_{\eta C\eta F} & \sigma^2_{\eta F} & \sigma_{\eta F\eta E} & \sigma_{\eta F\varepsilon C} & \sigma_{\eta F\varepsilon F} & \sigma_{\eta F\varepsilon E} \\ \sigma_{\eta C\eta E} & \sigma_{\eta F\eta E} & \sigma^2_{\eta E} & \sigma_{\eta E\varepsilon C} & \sigma_{\eta E\varepsilon F} & \sigma_{\eta E\varepsilon E} \\ \sigma_{\eta C\varepsilon C} & \sigma_{\eta F\varepsilon C} & \sigma_{\eta E\varepsilon C} & \sigma^2_{\varepsilon C} & \sigma_{\varepsilon C\varepsilon F} & \sigma_{\varepsilon C\varepsilon E} \\ \sigma_{\eta C\varepsilon F} & \sigma_{\eta F\varepsilon F} & \sigma_{\eta E\varepsilon F} & \sigma_{\varepsilon C\varepsilon F} & \sigma^2_{\varepsilon F} & \sigma_{\varepsilon F\varepsilon E} \\ \sigma_{\eta C\varepsilon E} & \sigma_{\eta F\varepsilon E} & \sigma_{\eta E\varepsilon E} & \sigma_{\varepsilon C\varepsilon E} & \sigma_{\varepsilon F\varepsilon E} & \sigma^2_{\varepsilon E} \end{bmatrix}$$

We thus estimate a trivariate unobserved components model, in nine equations with the three variables being the (natural logs of the) core CPI series, the food CPI series and the energy CPI series. Estimation of the model includes estimation of correlations among the permanent and transitory innovations in all three variables where we assume the innovations are jointly normally distributed. We cast the model into state-space form (available from the authors upon request) and apply the Kalman filter for maximum likelihood estimation (MLE) of the parameters using prediction error decomposition and to estimate the permanent and transitory components.

[4] At least AR(2) dynamics are necessary for identification (see discussion in Morley, Nelson and Zivot, 2003, at Sinclair, 2009). Additional lags did not change the key results; therefore we selected the most parsimonious model. An additional benefit of the AR(2) specification is that it makes it much easier to ensure the global maximum using the constraint described in Morley (2009).

C. The Data

We estimate the UC model on monthly US CPI data (consumer price index for all urban consumers) from January of 1983 through December of 2007. The model includes three series (all seasonally adjusted): 1) All Items Less Food and Energy (or Core) CPI, 2) Food CPI, and 3) Energy CPI. Seasonal adjustment factors are recalculated each January for the previous year, so our data end in December, 2007.[5] Our data begin in 1983 to avoid the definitional change regarding shelter in the CPI. Before 1983, mortgage interest rates which were included in the CPI as a part of homeowner's costs, whereas since 1983 a rental equivalence measure has been used (see Smith, 2005).[6] We specifically chose to work with the "regular" CPI (as compared to a chained index) because we want to be able to easily aggregate the three series back to a measure of headline CPI.

D. Testing For Stationarity in Inflation

The first step in estimating the unobserved components model is to determine whether the model should be estimated for the inflation rates of or the price levels for the three series. The unobserved components model specifies a random walk for the permanent component, so it is not appropriate for a stationary series. If the inflation process is I(1) we can estimate its components directly in the UC model. In contrast, if inflation is I(0) then the UC model should be estimated for the (natural logs of) the price levels, and the implications for inflation can then be calculated from the implied changes in the price indexes.

There is debate about whether or not US inflation is stationary. For example, Privetta and Reis (2007) find that data from 1965 to 2001 do not reject a unit root in inflation and argue that

[5] The data were obtained from the Federal Reserve Bank of St. Louis at http://research.stlouisfed.org/fred2. The data are from the August 29, 2008 vintage of data from the Bureau of Labor Statistics (BLS).
[6] The 1983 start date also allows us to avoid issues of different monetary policy regimes as discussed in Murray, Papell, and Nikolosko-Rzhevskyy (2009).

inflation persistence has remained high and relatively unchanged over their sample. Similarly, Stock and Watson (2007) find a unit root in inflation for both 1970-1983 and 1984-2004. On the other hand, Leybourne, Kim, Smith, and Newbold (2003) and Murray, Papell, and Nikolosko-Rzhevskyy (2009) find that inflation is stationary starting in the early 1980s. We follow this literature in two ways. First, we test for stationarity specifically for our sample which begins in 1983. For this sample, the KPSS stationarity test (Kwiatkowski et al. 1992) rejects trend stationarity for all three (log) price level series but does not reject stationarity for all three inflation series. Second, following Levin and Piger (2002), we allow for structural breaks in each of these series.[7] In sum, because we find that the inflation rates are stationary over our sample period, it is appropriate to estimate the unobserved components model for the price levels.

E. Model Estimation

The estimated model includes three structural breaks in the drift term for each series. We determined the break dates by estimating a univariate correlated UC model for each series and then testing for a drift break. We found a significant drift break for all three series. We then estimated two different models, one which allowed for only the single break for each series, and another allowing all three series to break jointly at all the dates determined by the univariate structural break tests. Based on a likelihood ratio test, we rejected the restricted model in favor of the model allowing all three series to break at all three dates. The break dates are June 1991

[7] Other papers have modeled US inflation as an unobserved components model, but generally these models have been applied to the annualized quarterly percentage change in the GDP deflator (where we look at CPI components) and for longer samples. Examples include Dossche and Everaert (2007) and Kang et. al (2009).

(from the results for the food CPI), April 1993 (from the results for the core CPI), and February 2002 (from the results for the energy CPI).[8]

Using these breaks, the multivariate correlated UC model was estimated. The resulting parameter estimates are presented in Table 1 and the estimated components are presented in Figure 1. The key findings of Table 1 and Figure 1 are that the core CPI series is not correctly characterized as having only permanent movements, and the food and energy series are not correctly characterized as having just temporary movements. Furthermore, the temporary movements in core CPI regularly offset permanent movements, so the permanent component of core CPI is actually more variable than the observed series.

While the estimated parameters for the three series share some similarities, the three price series have important differences. First, the size of the drift term for core CPI has been monotonically decreasing over the sample from 0.37 down to 0.18. In contrast, the energy CPI had a monotonically increasing drift over the sample, switching from negative to positive in April 1993. Finally, the drift in the food CPI decreased with a clear structural break in June 1991 from 0.36 to 0.07, but then increased again in 2003 to 0.23.

Our estimates allow us to say something about the standard deviation of the permanent component of each series, and we find that the core CPI series has the lowest standard deviation, followed by the food series and then the (quite volatile) energy series. Thus we find that the permanent component of the energy CPI series is much more volatile – has a much higher standard error of shocks to the permanent component – than either the permanent component of the core CPI or the permanent component of the food CPI series.

[8] Levin and Piger (2006) find a structural break in the intercept of an AR model of quarterly US headline CPI inflation in 1991Q1 and for core in 1991Q2. Their sample was 1984Q3 through 2005Q2.

In terms of the transitory components, the energy series has negative AR parameters indicating its dynamics follow a damped sinusoidal pattern, possibly reflecting overshooting and undershooting. The core series has positive AR parameters. Although the second AR parameter for the food series is negative, the first AR parameter for food is positive and their sum is positive. Both the core and food series demonstrate a high degree of persistence in their transitory components, with sums of the AR coefficients being 0.937 and 0.953 respectively. The disturbances to the transitory components have a standard deviation that is smallest for food, followed by core, and with the highest standard deviation for energy.

If we compare the core and food series, we find that these series have somewhat similar estimated standard deviations of disturbance terms to both their permanent and transitory components. In contrast, the energy series has standard deviations of the permanent and the transitory shocks that are much larger than for either the core series or the food series. Overall this suggests that the volatility in the food series may not in itself be sufficiently large to justify its exclusion from core CPI.

Our results show that there are important permanent components in both the food and energy series, contradicting the assumption that these series have movements which are wholly or largely transitory. This can be seen examining Figure 1 which presents the permanent and transitory components of our three series. It is clear that the permanent components are the main determinants of the overall levels of each of the three series.

Another way to look at this issue is to compare the movement in the estimated permanent component with the movement in the overall index. This is done in Figure 1, which shows that the permanent component is very important for all three series. In fact, close inspection of the figure shows that the permanent component may be least important for the core series. Such a conclusion is further supported by comparing the ratio of the variance of the permanent component to the variance of the transitory component for each of the three series. This comparison shows that the relative size of the variance of the permanent shocks is smallest for the core series. This stands in contradiction to the assumption that the core series contains permanent price movements while the two excluded series contain mostly temporary price movements.

Ratio of the Variance of the Permanent Shocks to the Variance of the Transitory Shocks

Core	0.613
Food	1.934
Energy	6.275

Important information is also contained in the contemporaneous correlation of the shocks. First, the correlations between the permanent and transitory shocks for an individual series provide insight into the pattern of arrival of shocks to the series. For both the core series and the energy series, permanent and transitory within-series shocks are highly negatively correlated. In unobserved component models, this correlation is often interpreted to imply that the full effects of permanent shocks are partially mitigated in the short run (as discussed in Morley, Nelson, and Zivot, 2003; Sinclair, 2009; and Mitra and Sinclair, 2009). If the adjustment to a permanent shock is somewhat gradual, the actual value in the period of incidence will be below the permanent value, giving rise to a temporary negative shock in the opposite direction. In contrast, there is a relatively small positive correlation between permanent and transitory shocks to the food series. In this instance, the temporary shock is reinforcing the permanent shock, leading to a form of overshooting in the period in which the permanent shock occurs.

Cross-series correlations also yield interesting information about the relationship among the shocks to the three series. First, permanent shocks to the core series are correlated with permanent shocks to both the food series and the energy series despite the fact that permanent shocks to the food and energy series themselves do not appear to be correlated. We interpret this as suggesting that there may be underlying structural shocks to the food and energy series with permanent components that can affect the permanent movement in the core series. In addition, permanent shocks to both the energy and food series are negatively correlated with the temporary core shock, mimicking the relationship between the permanent core shock and the temporary core shock. This also suggests that the dynamic behavior of the core series may be influenced by innovations in food and energy prices.

Another useful way of interpreting the results of the unobserved components model is to estimate its implications for the bifurcation of the overall or "headline" price level into its permanent and transitory components. Movements in the permanent or "long-run" component of the headline price level can be thought of as an estimate of the conceptual definition of inflation as a sustained increase in the overall price level. Calculation of the permanent part of the headline price level thus can be used to produce a measure of the long-run inflation rate. In addition, this measure can be compared to movement in the core price index to see how well the core index approximates permanent changes in the overall price level.

For these reasons, we use our estimated components to calculate the permanent and transitory components of the headline price level and then the resulting inflation rate. The headline CPI, as calculated by the Bureau of Labor Statistics, is the weighted combination of the three component indexes, where the weights are functions of what the BLS calls the "relative importance" of each of the series in the base year.[9]

We thus use the relative importance (δ_i) for each series from the base year to aggregate the permanent portions of the three component series:[10]

$$\tau_{cpi,t} \quad = \quad \delta_{xfe}\, e^{\tau_{xfe,t}} \quad + \quad \delta_f\, e^{\tau_{f,t}} \quad + \quad \delta_e\, e^{\tau_{e,t}}$$

The headline CPI price index is the sum of the permanent and transitory values for the price level in each period and is therefore made up of all six the individual series listed above. The permanent or long-run price level is measured by the three permanent components as specified in the above equation. We start our comparison by comparing the permanent or "long run" CPI against the headline CPI by plotting them together in Figure 2. While the two measures of the price level generally move together, there are significant periods of time during which the headline price level is persistently above or below its long run value. The figure also reveals the permanent movements in the price level dominate its determination.

More insight can be gained by comparing the headline inflation rate with the permanent or long-run inflation rate. These inflation rates are calculated as the year-over-year changes in the respective price levels. The headline and long-run inflation rates are presented in Figure 3.[11] That figure shows that headline inflation is somewhat smoother than permanent or long run

[9] See Wynne (2008) for a discussion of this formula. The formula holds only in close approximation because, as explained by Clark (2002) "The Bureau of Labor Statistics computes these indexes using a different, although conceptually equivalent, formula." This issue is also discussed by Wynn (2008). We should note that this is the best approximation that can be made with publicly available data. To ensure accurate comparisons between our long-run measure and reported headline inflation, we recompute the headline CPI using the reported relative importance for each component series. This ensures that there are no differences in computational algorithm leading to differences in the series. The recomputed CPI is extremely close, but not identical to the reported CPI. Note that we use the "adjusted relative importances" which are adjusted for seasonal factors (since we are working with the seasonally adjusted data) and renormalized. These weights are available upon request from the authors.

[10] We use 1986 as the base year for the aggregation so that the sum is multiplied by the headline CPI number in December 1986 and then each sub-series is multiplied by the relevant relative importance and divided by the sub-series value in December 1986. Thus, our estimates of "long-run" CPI begin in December of 1986.

[11] We construct inflation throughout as the year over year percentage change, i.e. $(p_{it} - p_{it-12})/p_{it-12} * 100\%$.

inflation reflecting the fact that headline inflation includes offsetting cyclical or transitory price movements. In other words, in contrast to previous assumptions, the unobserved components model suggests that the headline CPI is actually smoother than its permanent component. This occurs because transitory movements tend to be offsetting, not reinforcing nor orthogonal to, the permanent innovations to the series. This also suggests that concern about volatility in short run movements of headline inflation may be misplaced. This point is reinforced by the fact that the long-run rate of inflation tends to be above the headline rate when inflation is rising, but below the long run rate when inflation is falling. We also note that the long run rate can be materially above the headline rate, by as much as two percentage points.

Another interesting comparison is between the long-run price level and the "core" measure that is often discussed and used in monetary policy formulations. This comparison is presented in Figure 4. Theoretically, the core measure is supposed to strip out volatile, temporary movements in prices that do not contribute to long run inflation. However, the figure shows that there are important permanent movements in the price level that the core index does not capture. For most periods, the core CPI lies well above the long run value for the index. This suggests that not only does the core index exclude important long run movements in food and energy but it also includes transitory price level movements.

We also compare the permanent or long-run inflation rate and the core inflation rate in Figure 5. It shows that core inflation appears to be a relatively poor proxy for long-run or permanent inflation, and suggests that there are important permanent components to food and energy (about 25% of the CPI – based on the relative importance weights from the BLS.) that should not be ignored when considering long run inflation. It is true that the core rate is significantly smoother than headline, but this reflects the fact that the core also includes offsetting short run price movements.[12] This figure also shows that focusing on core inflation could provide the monetary authority with misleading signals. In particular, long-run inflation exceeded core inflation rates by more than 1% over the period mid-2003 through end of 2005. During this period the Federal Funds Rate reached a local minimum of 1%, staying at this level from mid-2003 through mid-2004, and some have criticized the Federal Reserve System for having such low interest rates over this period. Levels of the Federal Funds Rate that look reasonable based on a (core) inflation rate of 1% to 2% per year might appear less reasonable based on a (long-run) inflation rate of 2.5% to 4% per year. Thus the fact that the Federal Funds Rate was kept low over this period may indicate a problem with focusing on core inflation.

Finally, we note that the long run behaviors of core, food, and energy inflation are governed, in part, by their estimated drift terms. The drift terms for the individual series are presented as annualized values for each of the sub-periods in Table 2. For example, absent shocks, core inflation will asymptotically equal the drift in the permanent component of core CPI, estimated to be 4.49% annually for the 1983-1991 period. The table shows that the structural shocks to food inflation have followed the general pattern of the structural shocks to core inflation, with the exception of the second subperiod. The drift in the permanent component of energy inflation, meanwhile, has increased monotonically. Together these drift terms can be used to calculate the changes in drift for overall inflation. The overall drift term ranges from 4.04% per year in 1986-1991 subperiod to 3.05%, 2.43%, and 3.05% per year in the successive subperiods. Comparing this pattern with the individual drift terms for the components, we see that the drift term for the permanent component of overall inflation are most closely similar to the drift terms in the long run core inflation rate, whereas food and energy

[12] This is confirmed by a comparison of long run core inflation with headline core inflation. The latter is much smoother than the former.

have periods with long run inflation rates showing large departures from the long run headline inflation rate. This could be interpreted as evidence in support of the core CPI as a measure of long-run inflation. However, as shown in the following section, the dynamic responses to shocks suggest that there are key aspects of long-run inflation that are not captured by the core series.

F. Shocks and Dynamic Responses

Even though we find important permanent movements in both the food and energy series, these movements could be correlated with movements in the core inflation series in such a way that tracking just core inflation would be sufficient for capturing the permanent movements in inflation. In the extreme, these series could be "perfectly" connected in the sense that the permanent movements in the core CPI completely capture the permanent movements of the food and energy series. To explore this possibility, we examine the response of both headline CPI and core CPI to permanent core, food, and energy shocks, using generalized impulse response functions. We focus on permanent shocks for two reasons. First, our identification assumption is that permanent shocks to the CPI series cause resulting transitory shocks, but transitory shocks do not cause permanent shocks. Second, and partly due to our identification assumptions, transitory shocks have a limited, small impact on inflation rates.

We use the generalized impulse response functions suggested by Pesaran and Shin (1998). This allows us to incorporate the impact of contemporaneous correlation among the shocks without taking a stand on the complete underlying structure. While we are comfortable assuming that transitory shocks do not cause permanent shocks (almost by definition), we are less willing to specify the causality among the permanent shocks to the different CPI subcomponents.

Figures 6 plots the impulse response functions for the headline CPI and core CPI to shocks to each of the three components of the CPI. Figure 7 plots the impulse response functions for headline CPI and core CPI inflation rates. The generalized impulse responses are calculated for a two standard error shock to the permanent component of each component. Looking first at Figure 6, we see in the top panel that the headline or overall CPI reacts more quickly and more strongly than the core CPI to a permanent shock originating in the core CPI. The shock to core CPI causes headline CPI to spike rather dramatically in the first few months, and it is only at about 20 months that the increase in the core CPI matches the increase in the headline CPI.

The middle panel shows the response of the core and the headline CPIs to a permanent shock in the food CPI. This shock leads to a large immediate positive response in the headline CPI and a small immediate negative response in the core CPI. Within a few months of the shock, the headline CPI has increased 5% while the core CPI has declined almost 1.5%. The level of the headline CPI remains above the level of the core CPI, although gradually the headline and core CPIs converge.

The third panel shows the response of the core and the headline CPIs to a permanent shock to the energy CPI. Here again the immediate headline CPI response is stronger than the core response, although the core response is positive. The headline CPI is above the core CPI for the first year after the shock, although the two series are roughly the same in the second year after the shock. Overall, Figure 6 paints a picture of the headline CPI responding more quickly than the core CPI to permanent shocks to the core, energy, or food CPIs. Also the overall CPI always responds in the appropriate direction while the core CPI does not. For example, the core CPI initially declines following a permanent positive shock to food CPI, even though the core CPI eventually increases. Given that all three of these permanent shocks increase both the core and the headline CPI over time, it is not clear that the more gradual immediate response of the core CPI to these shocks is support for the core CPI as a measure of permanent price movements.

Figure 7 plots the IRF's for the inflation rates implied by the movements in the headline and the core indexes. The top panel illustrates the response of headline inflation and core inflation to a permanent shock to the core CPI. Here headline inflation is initially higher than core inflation, although their paths cross near the one-year mark when core inflation begins to exceed headline inflation. Thus, headline inflation responds more quickly, and initially more strongly, to the core CPI shock, whereas the response of core inflation builds more gradually over the year and then declines more slowly in the second year.

The middle panel shows the response of core inflation and headline inflation to the permanent shock to the food CPI. Here again we have the strong positive immediate response of headline inflation, a response that builds over the first year and then declines, initially sharply, at about the one year mark. In contrast, core inflation is initially negative, then builds over the first year, crossing the path of headline inflation at roughly the one year mark, and then declines gradually during the second year. During this second year, core inflation's path is above headline inflation's path.

In the third panel we see the response of core and headline inflation to the permanent shock to energy. Again we see that headline inflation initially has the greater response, and that over the first year headline inflation is higher than core inflation. In the second year core inflation and headline inflation both decline, but core inflation remains higher than headline inflation. In summary, the patterns in Figure 7 exhibit some interesting similarities. Headline inflation responds more strongly and more quickly than does core inflation to shocks to core, food, and energy. Headline inflation is above core inflation during the first year after these shocks, and both are rising over time. In the second year, the paths cross, and core inflation is above headline inflation as the two inflation rates decline over time.

These impulse responses show something of the tradeoff in choosing between headline and core inflation as measures of inflation. Headline inflation responds more sharply to shocks to any of the three CPI components (core, food, or energy), and for the first year is higher than core inflation. However, in the second year headline inflation is lower than core inflation as both series decline toward zero. This means that core inflation understates the impact of shocks to headline inflation in the year immediately following the shock, and then overstates the impact in the second year. In this sense core inflation presents a smoother path than headline inflation in response to shocks.

This has implications about how economic agents respond to price information. For example, in terms of monetary policy, responding to core inflation instead of headline inflation would mean, for a given monetary rule with given parameters, that monetary policy would respond more gradually following a shock to any of our three CPI components. It would also mean that monetary policy would respond over a longer period, as core inflation is higher than headline inflation in the second year and continuing as the core and headline inflation series return to baseline.

G. Conclusion

The core CPI -- the CPI less food and energy prices -- is widely used by private sector agents and policymakers as a measure of permanent price changes. This use is based upon a belief that the core measure excludes volatile temporary movements that potentially masks permanent price changes. However, volatility and impermanence are two different characteristics and one does not imply the other. It is important, therefore to investigate if the omitted price movements in food and energy are indeed temporary. In addition, smoothness does not imply permanence, so it is also important to investigate if the core CPI contains material temporary price movements.

We undertake this investigation using a multivariate correlated unobserved components model. The unobserved components model is a natural framework for such an investigation because it simultaneously decomposes price level movements into their permanent and transitory parts. We find evidence suggesting caution in using the core CPI as a measure of permanent inflation. The omitted components – food and energy -- have substantial permanent components which should be included in a measure of permanent price level movements. Their omission suggests that the core CPI is likely to be a biased measure of permanent price movements.

We also find that the core CPI includes material temporary price movements which tend to offset its permanent price movements. The observed smoothness in the core CPI thus reflects two deficiencies of the core CPI as a measure of long-run price movements. First, its smoothness comes in part from its temporary movements partially offsetting the underlying permanent movements. Second, the core CPI is smooth due to its inability to accurately capture the full set of permanent price movements. Finally, we find evidence suggesting that the core inflation rate may be too smooth to serve as a good representation of permanent price level movements.

The dynamic responses of core and the headline CPI to shocks to the core, food, and energy CPIs indicate that the headline CPI inflation responds more sharply to shocks, and that the headline CPI inflation rate is higher than the core CPI inflation rate for the first year after the shock, while in the second year both inflation rates are declining and core inflation exceeds headline inflation. Thus, core inflation more gradually responds to shocks, but in the second year core inflation is slower to return to the baseline.

Table 1: Maximum Likelihood Estimates of the UC Model

Table 1a: Standard Deviations, Drift Terms, and AR Parameter Estimates

Estimated Parameters (Standard Errors in Parentheses)

	St. Dev. Perm. Shocks (σ_η)	**St. Dev. Trans. Shocks (σ_ε)**	**Drift 1983.1-1991.6 (μ_1)**	**Drift 1991.7-1993.4 (μ_2)**	**Drift 1993.5-2002.2 (μ_3)**	**Drift 2002.3-2007.12 (μ_4)**	**AR1 (φ_1)**	**AR2 (φ_2)**
Core	0.155 (0.008)	0.198 (0.009)	0.366 (0.012)	0.281 (0.018)	0.215 (0.010)	0.178 (0.010)	0.922 (0.020)	0.015 (0.019)
Food	0.178 (0.009)	0.128 (0.013)	0.359 (0.022)	0.067 (0.045)	0.234 (0.016)	0.210 (0.022)	1.197 (0.034)	-0.244 (0.033)
Energy	2.485 (0.091)	0.992 (0.056)	-0.089 (0.056)	-0.028 (0.058)	0.297 (0.062)	0.862 (0.067)	-0.370 (0.051)	-0.353 (0.024)

(LLV: -319.410)

Table 1b: Correlation Parameter Estimates

Shock	**Perm – Core**	**Perm – Food**	**Perm – Energy**	**Trans – Core**	**Trans – Food**	**Trans – Energy**
Perm – Core	1					
Perm – Food	0.561 (0.068)	1				
Perm – Energy	0.759 (0.014)	-0.112 (0.083)	1			
Trans – Core	-0.913 (0.012)	-0.618 (0.061)	-0.629 (0.021)	1		
Trans – Food	0.455 (0.097)	0.249 (0.047)	0.305 (0.078)	-0.069 (0.103)	1	
Trans – Energy	-0.674 (0.033)	0.112 (0.090)	-0.901 (0.018)	0.568 (0.034)	-0.249 (0.075)	1

Table 2: Drift Terms By Sub-Period at Annualized Rates

	1983-1991	**1991-1993**	**1993-2002**	**2002-2007**
Core	4.49%	3.43%	2.61%	2.16%
Food	4.40%	0.81%	2.85%	2.55%
Energy	-1.06%	-0.34%	-3.63%	10.90%

Figure 1

Panel 1: Core CPI and Components

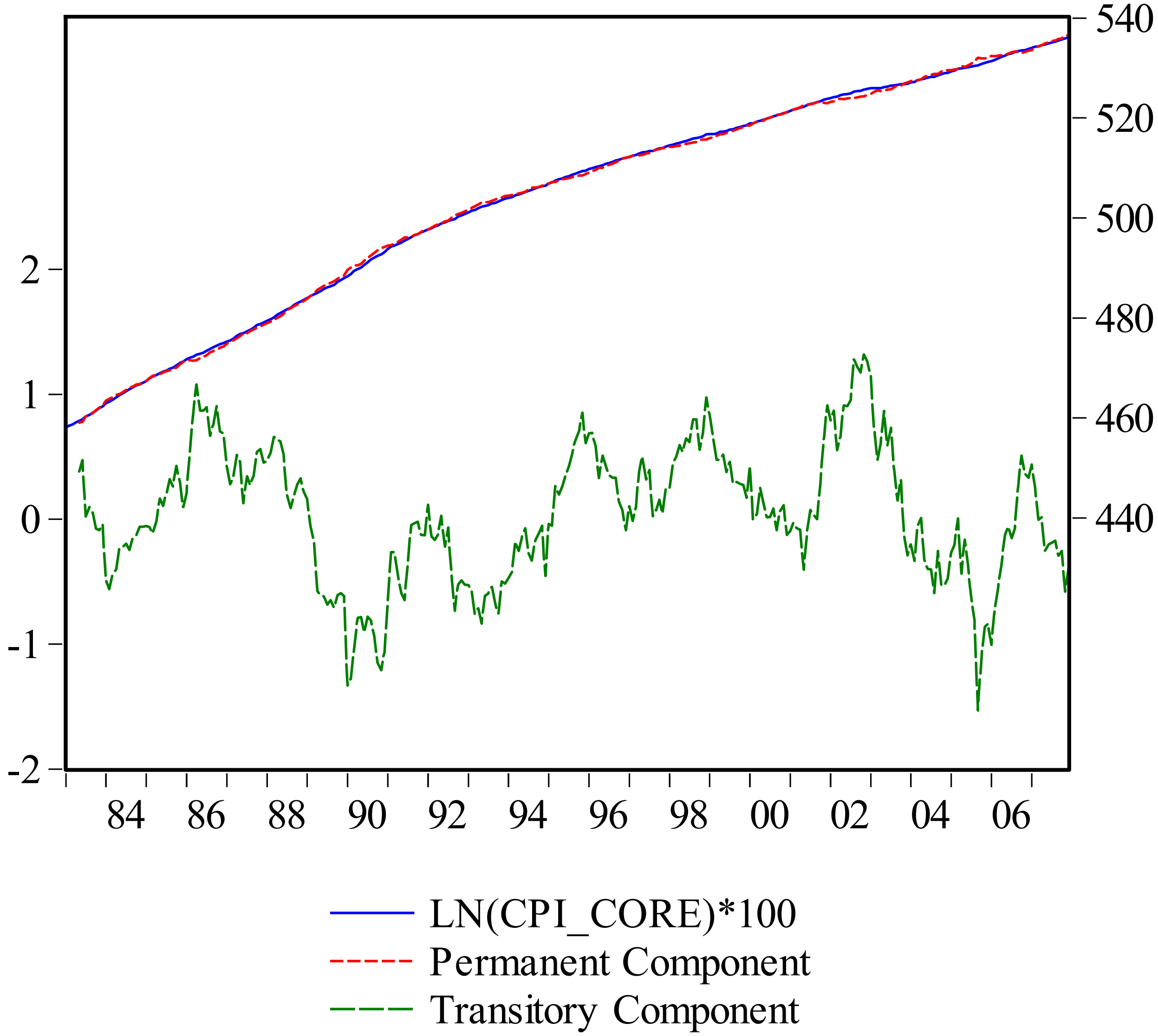


Figure 1

Panel 2: Food CPI and Components

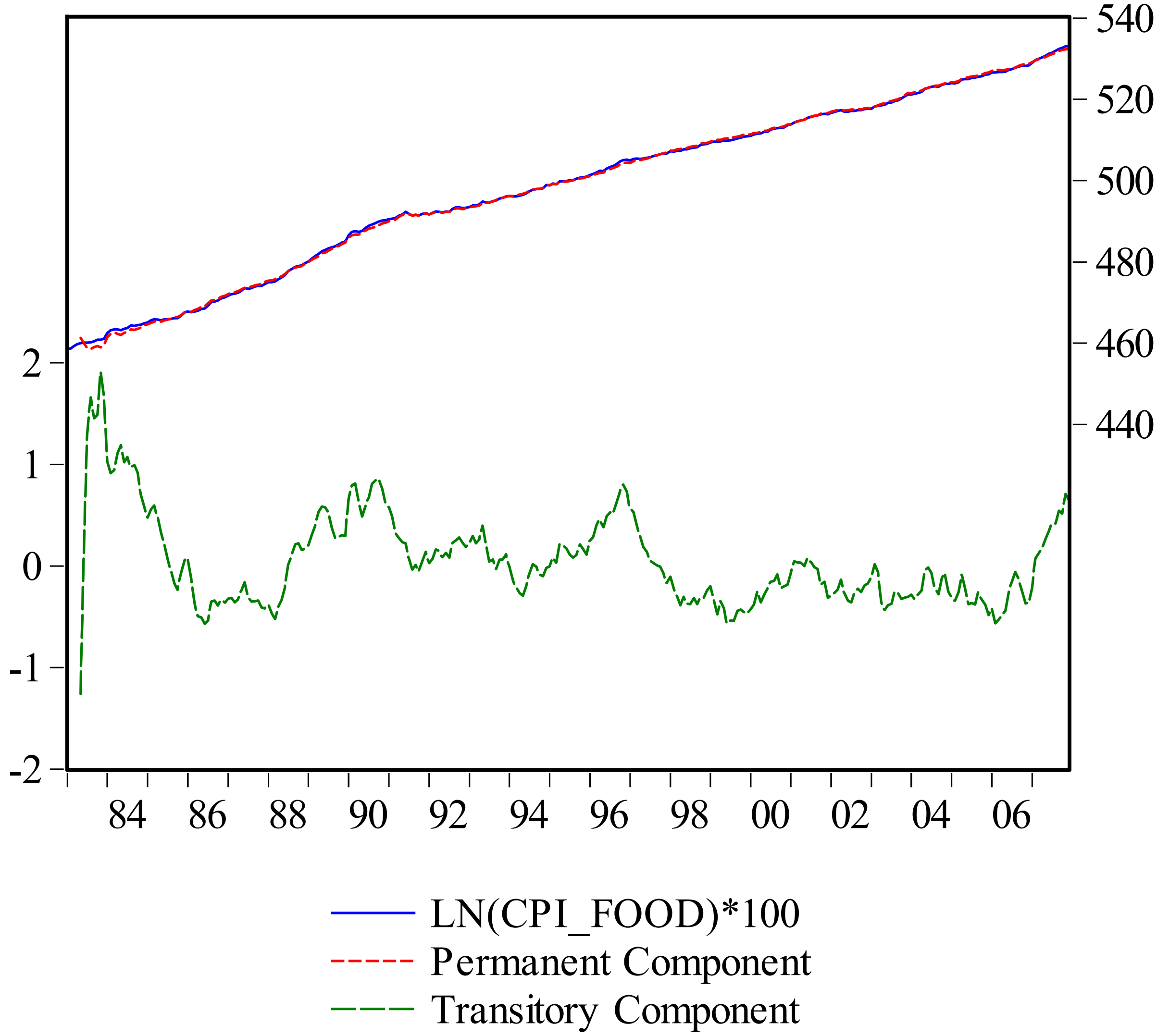


Figure 1

Panel 3: Energy CPI and Components

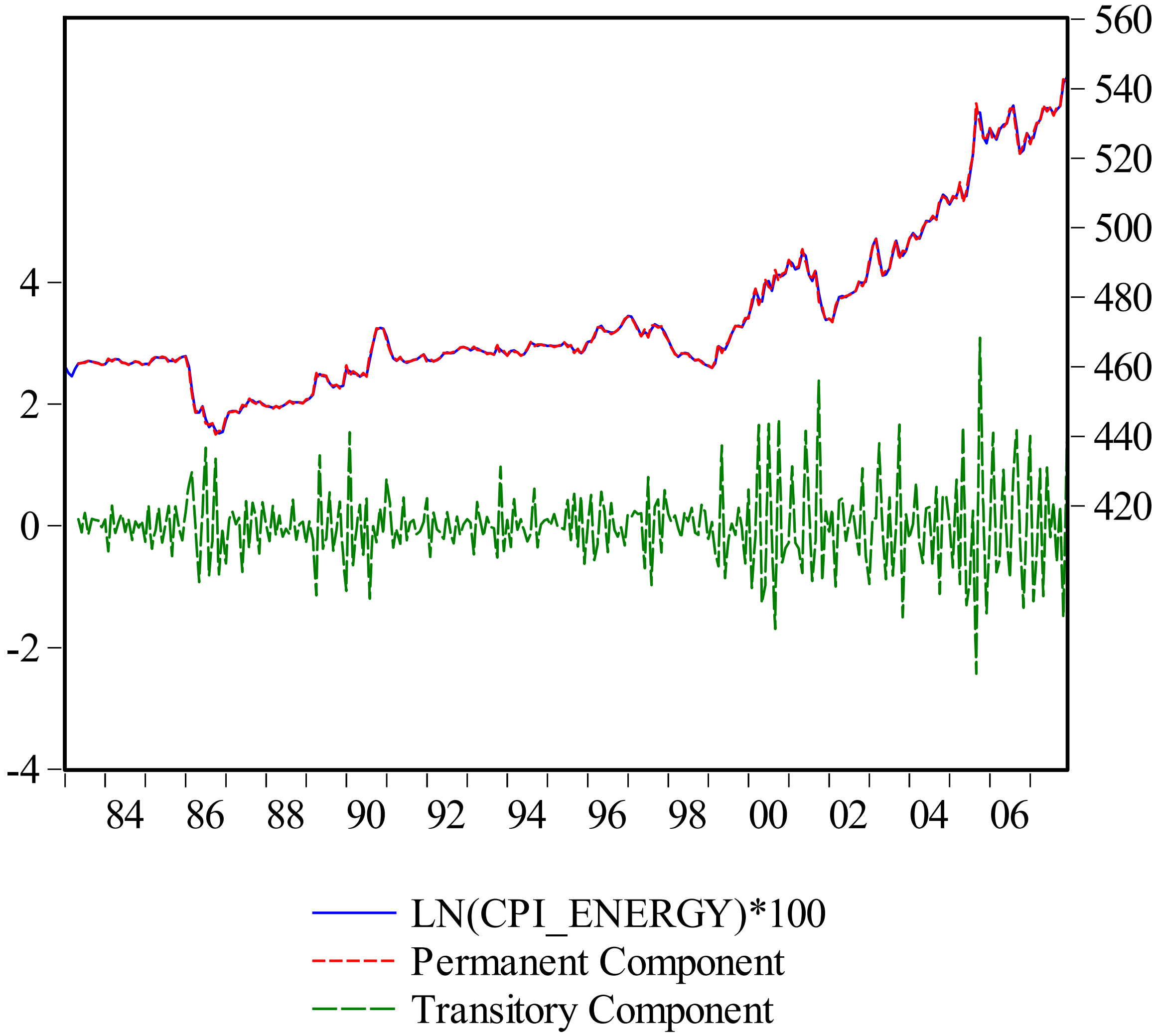
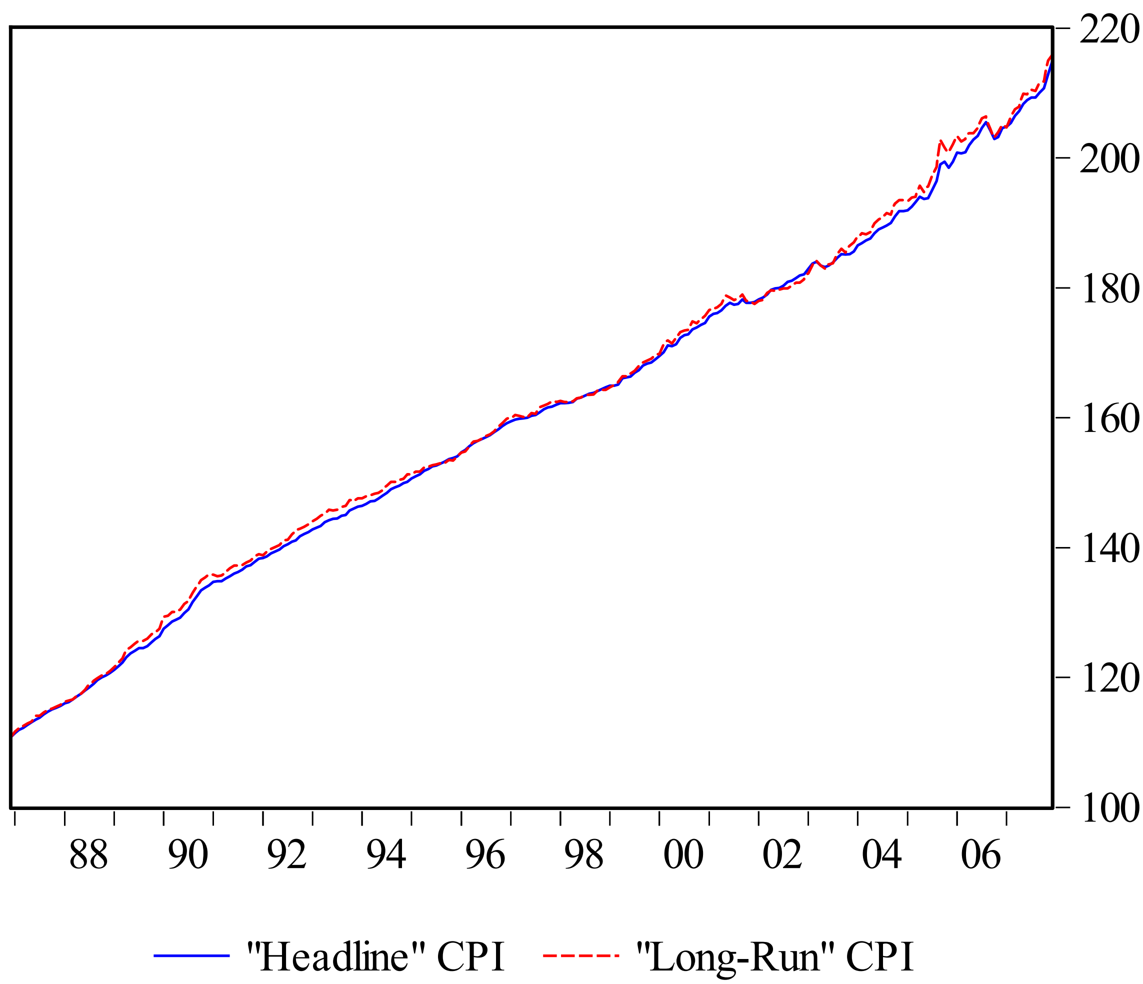


Figure 2: Headline CPI and Long-Run CPI[13]



[13] The headline CPI is slightly different than what is reported by the BLS, but the aggregation of its three parts (core, food, and energy) is consistent with the aggregation used for our long run CPI measure. Long-run CPI is the appropriately weighted sum of the permanent components of core, food, and energy.

Figure 3: Headline CPI Inflation and Long Run Inflation

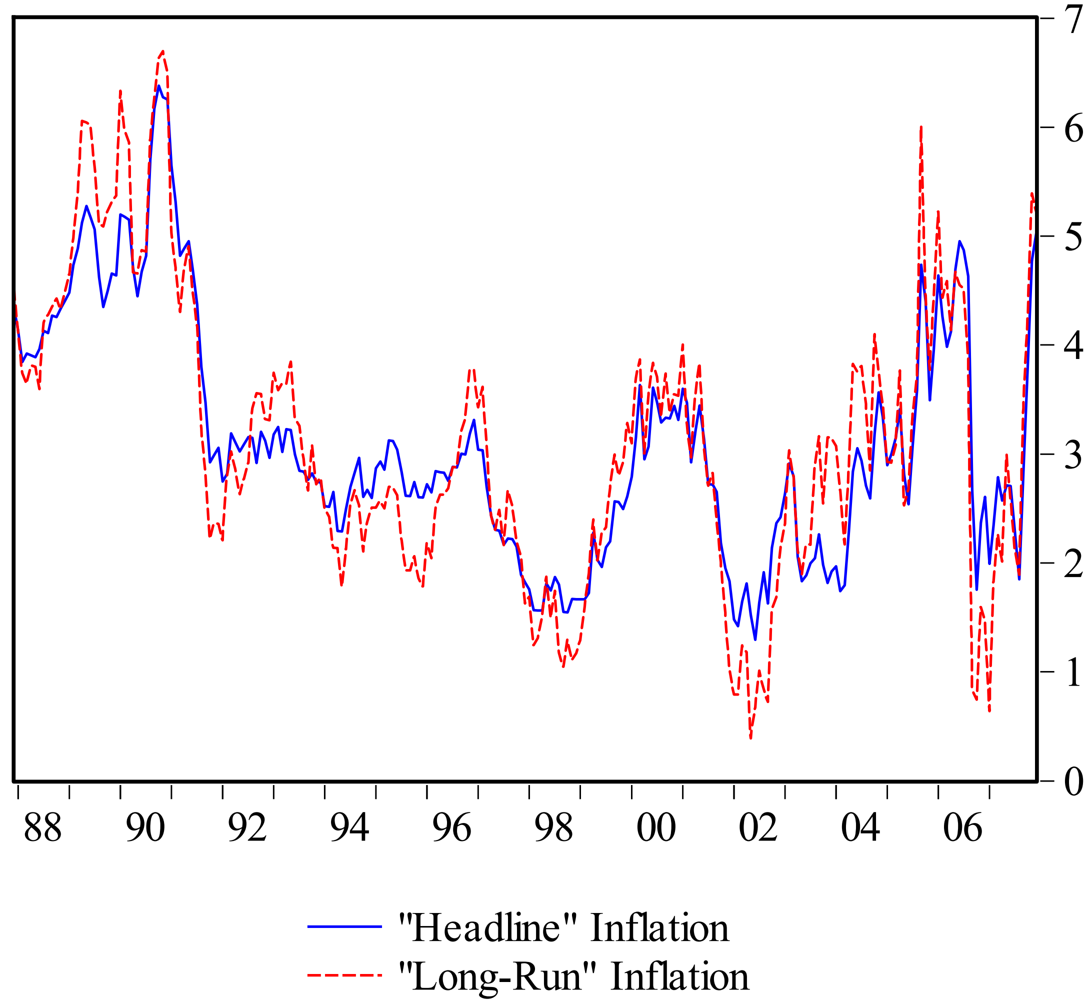


Figure 4: Core CPI and Long Run CPI

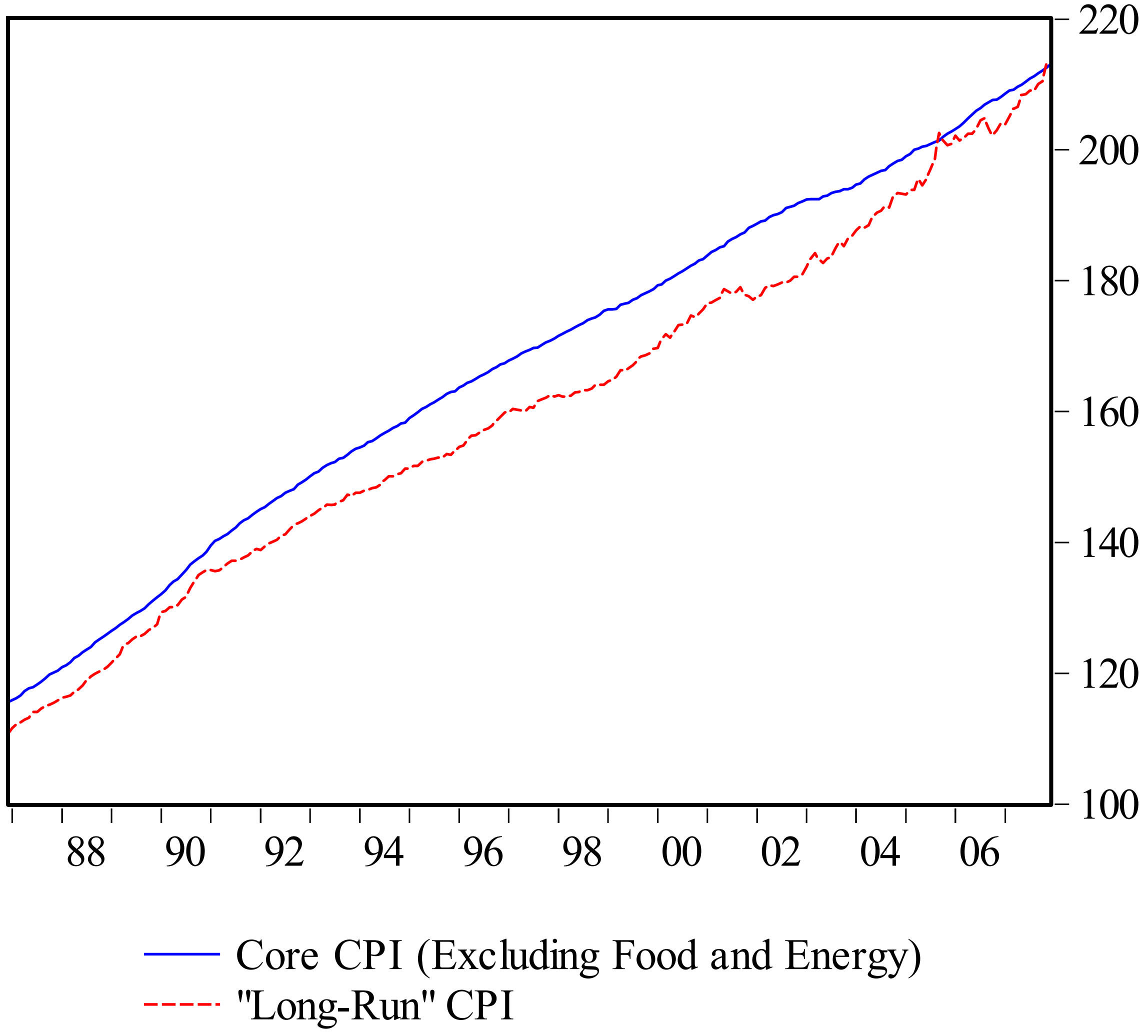


Figure 5: Core CPI Inflation and Long Run Inflation

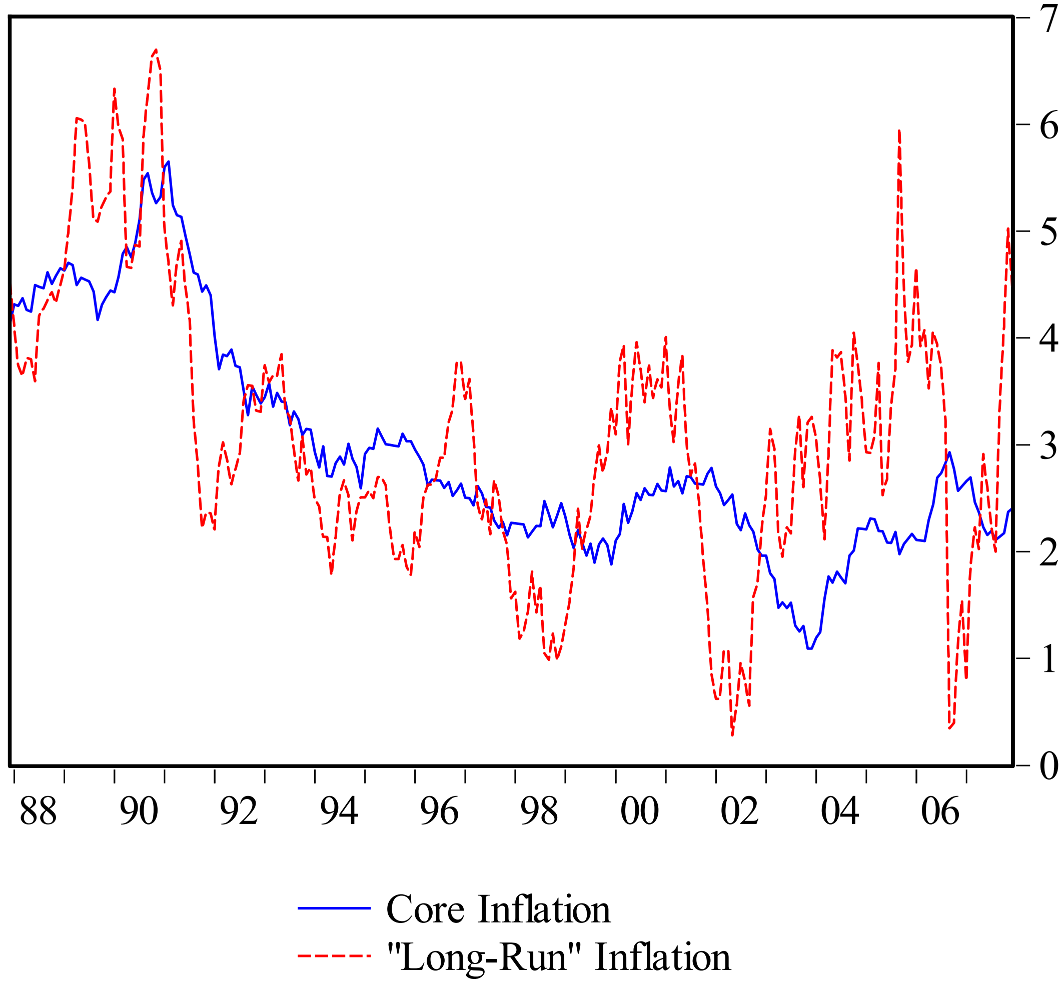
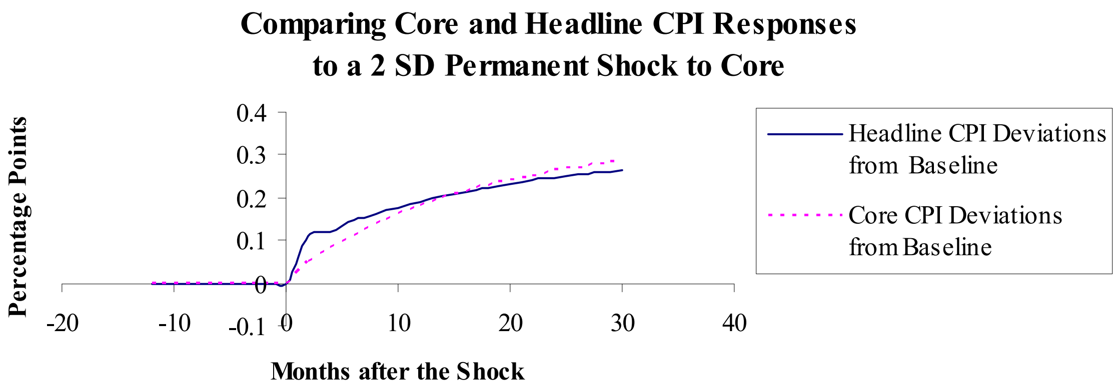
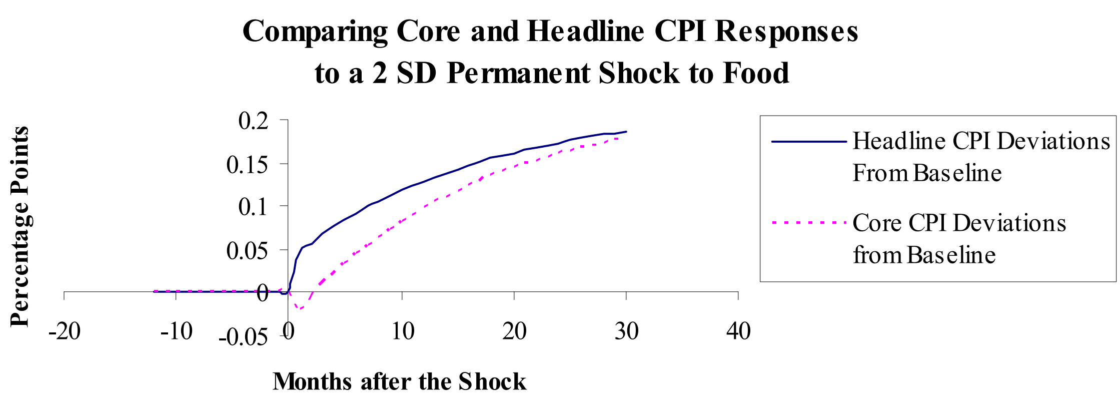


Figure 6: Generalized Impulse Response Functions for the Price Indices





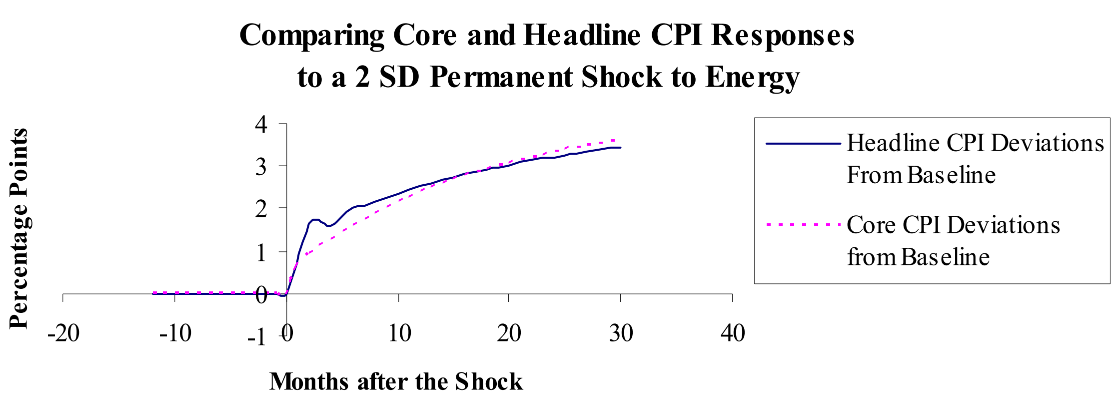
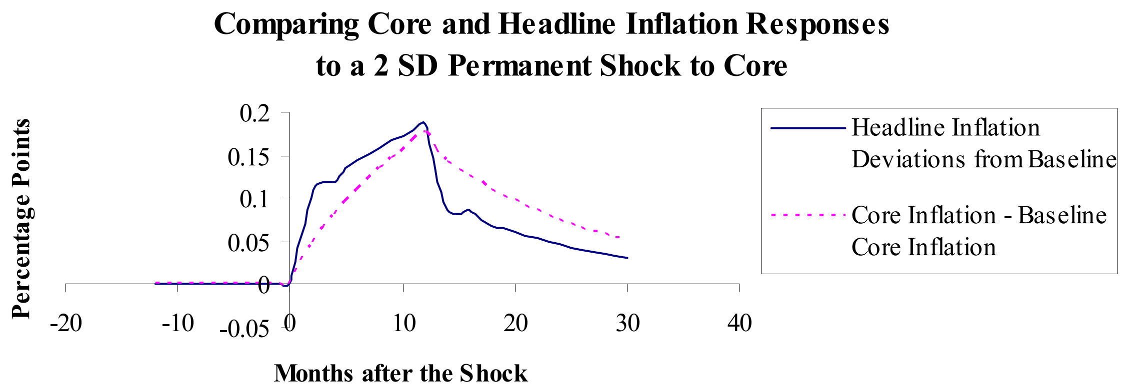
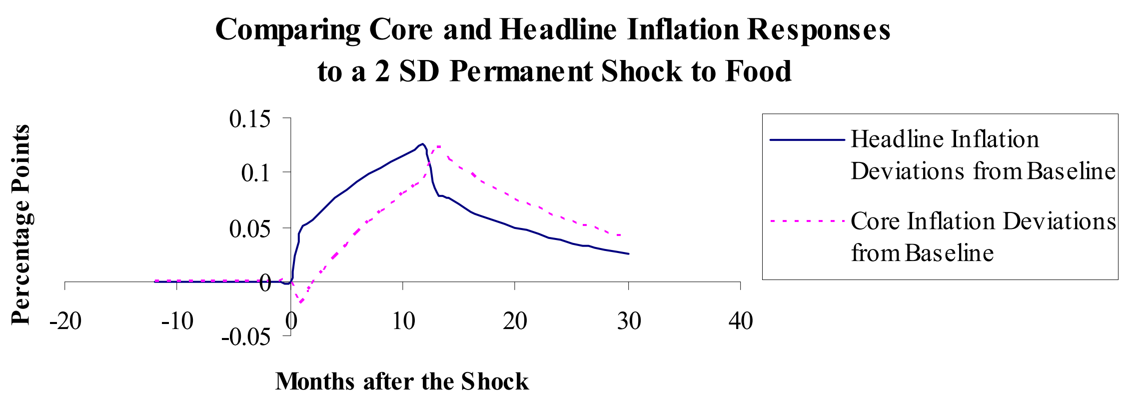
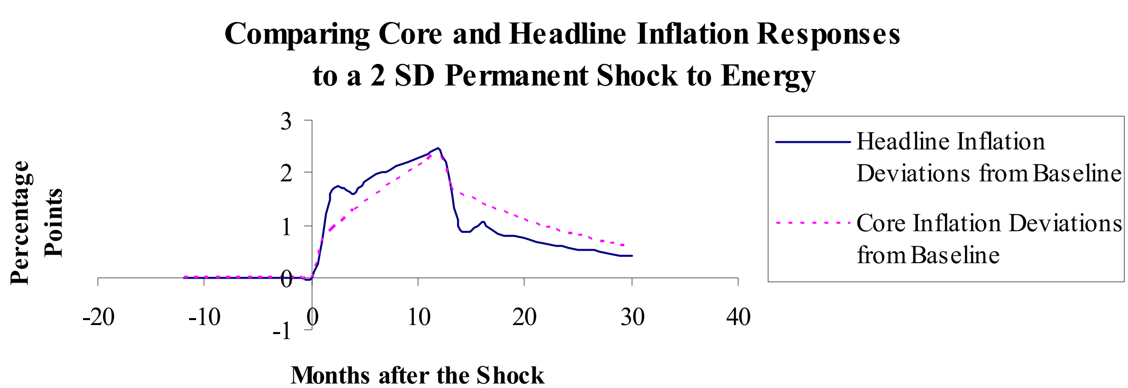


Figure 7: Generalized Impulse Response Functions for the Inflation Rates







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