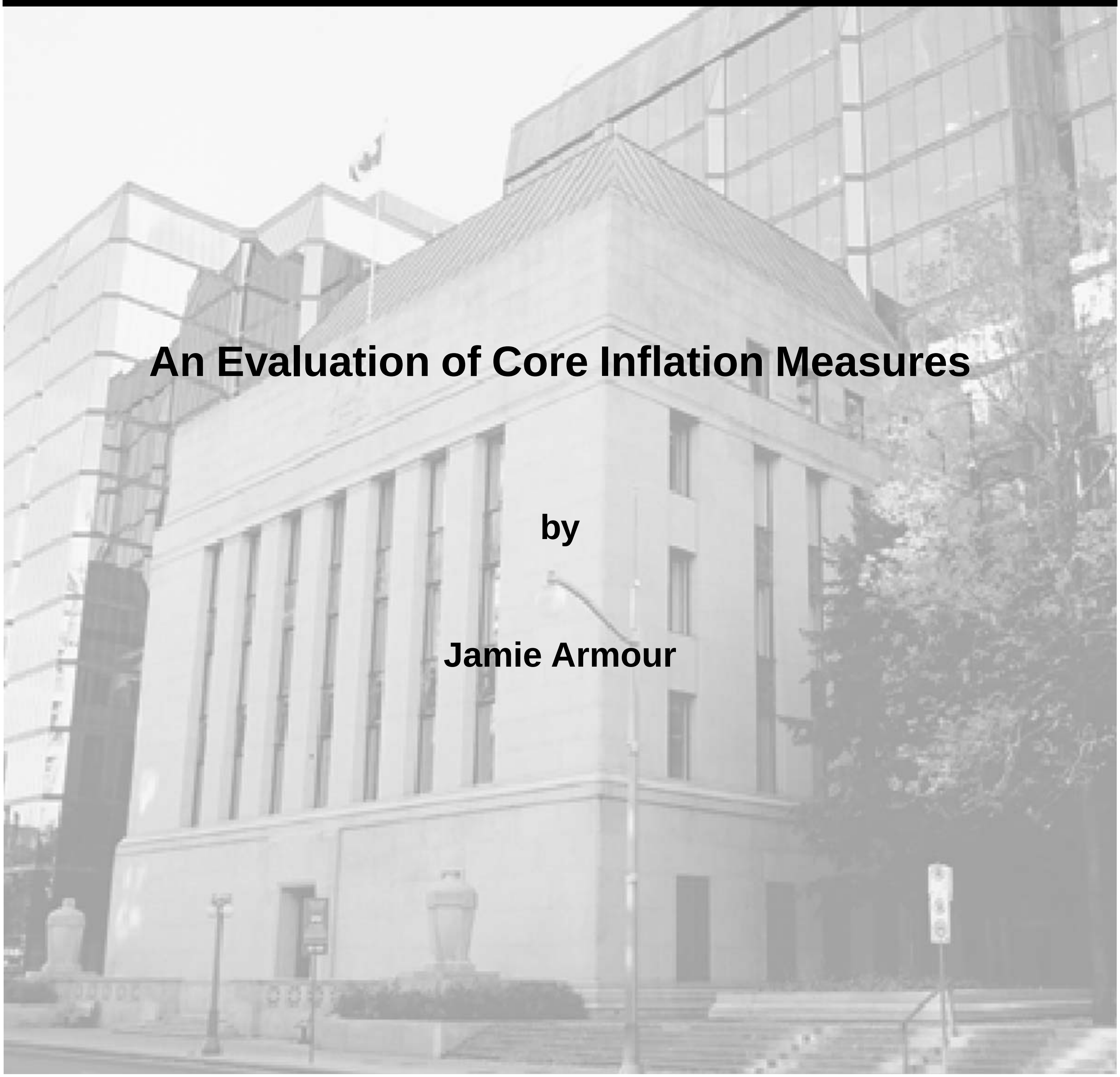
Bank of Canada Banque du Canada

Working Paper 2006-10 / Document de travail 2006-10



An Evaluation of Core Inflation Measures

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ISSN 1192-5434

Printed in Canada on recycled paper

Bank of Canada Working Paper 2006-10

March 2006

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Acknowledgements

I would like to thank Bob Amano, Don Coletti, Allan Crawford, Fred Demers, Richard Dion, Pierre Duguay, Marianne Johnson, Thérèse Laflèche, Dave Longworth, and Tiff Macklem for interesting and helpful discussions and comments. Marianne Johnson also provided me with the programs from her earlier paper. Finally, I would like to thank Jamie McKinnon for his editorial assistance and Annie De Champlain for her research assistance.

Abstract

The author provides a statistical evaluation of various measures of core inflation for Canada. The criteria used to evaluate the measures are lack of bias, low variability relative to total CPI inflation, and ability to forecast actual and trend total CPI inflation. The author uses the same methodology as Hogan, Johnson, and Laflèche (2001) and thus provides updated empirical results. The findings are that most traditional measures of core inflation are unbiased and all continue to be less volatile than total inflation. They nevertheless display some volatility and have limited predictive ability. Overall, CPIW seems to have a slight advantage over the other measures, but the differences across measures are not large. (CPIW uses all components of total CPI but adjusts the weight of each component by a factor that is inversely proportional to the component's variability.) Compared with the results of Hogan, Johnson, and Laflèche, CPIW's relative performance has improved. The distribution of price changes for 54 CPI subcomponents is also examined, and substantial increases in both the skewness and kurtosis of this distribution since 1998 are found.

JEL classification: E31
Bank classification: Inflation and prices

Résumé

L'auteure évalue statistiquement diverses mesures de l'inflation fondamentale au Canada au regard de trois critères : absence de biais, faible variabilité par rapport à l'inflation globale (mesurée par l'indice des prix à la consommation [IPC] global) et capacité de prévision de l'évolution effective et tendancielle de l'inflation globale. Elle a recours à la méthode de Hogan, Johnson et Laflèche (2001) et met à jour leurs résultats empiriques. L'auteure conclut que les mesures usuelles de l'inflation fondamentale ne comportent pour la plupart pas de biais et demeurent toutes moins volatiles que celle de l'inflation globale. Elles affichent néanmoins une certaine volatilité, et leur capacité de prévision est limitée. La mesure IPCP semble l'emporter de peu sur les autres, mais les différences entre elles ne sont pas très marquées. (La mesure IPCP englobe toutes les composantes de l'IPC global, mais la pondération de chacune d'elles est multipliée par un coefficient qui est inversement proportionnel à la variabilité de la composante.) La performance relative d'IPCP s'est améliorée depuis l'étude de Hogan, Johnson et Laflèche. La distribution des variations de prix de 54 sous-composantes de l'IPC est également examinée. Son asymétrie et son aplatissement se sont nettement accentués depuis 1998.

Classification JEL : E31
Classification de la Banque : Inflation et prix

1. Introduction

Many central banks around the world, including the Bank of Canada, have adopted an explicit inflation target. The main goal of having the target is to promote a well-functioning economy. Protecting the value of money by maintaining inflation at low and stable rates should stabilize inflation expectations and enable effective investment decision-making, thereby increasing productivity. It also helps to dampen economic cycles.

While the explicit inflation target is frequently specified in terms of total consumer price index (CPI) inflation, a "core" measure of inflation is often used as a shorter-term operational guide. Given that interest rates affect aggregate demand and inflation with a lag, it is important that central banks do not change interest rates in response to temporary shocks to inflation that will be reversed without intervention. Thus it is useful for central banks to have a measure of inflation that behaves similarly to total CPI inflation, but in a less volatile manner. And given that the monetary authority should act pre-emptively by reacting to forecasts of total inflation rather than to its current value, it is useful to have a measure of inflation that is a good predictor of trend total CPI inflation. An effective measure of core inflation would not only remove transient changes in inflation but would also indicate the fundamental trend of inflation, thus proving a useful guide to monetary policy.

Over the past 10 years, there has been a good deal of research on measures of core inflation from theoretical and statistical perspectives. In 2001, for example, Hogan, Johnson, and Laflèche (HJL) conducted a detailed statistical evaluation of various measures of core inflation for Canada. They concluded that the core measures, particularly CPIX and CPIW, had desirable properties, but that the differences across the measures were not large. Furthermore, they noted the importance of understanding the differences in the behaviour of the various measures of core inflation for identifying temporary or idiosyncratic shocks.

Although inflation targeting can motivate the use of core inflation, it can also provide some challenges. In particular, it is possible that the introduction of inflation targeting fundamentally changed the behaviour of inflation. Also, the economy is always faced with new shocks that may alter the behaviour of inflation. Therefore, periodic re-examination of the core measures is warranted. Consequently, this paper updates the HJL research, employing the same methodology. It covers five additional years, and thus new shocks, as well as a significantly longer period of experience with inflation targets. Since these additional data almost double the inflation-targeting part of the sample that was used in HJL, this paper focuses its analysis on the post-1991 period. It also examines two new measures of core inflation.

The key findings, discussed in greater detail below, are:

- The five main measures of core inflation continue to be less volatile than total CPI inflation and are able to provide some information about the current and future trend of inflation. However, these core measures are fairly volatile and have limited predictive ability.

- Overall, CPIW ranks best among the core inflation measures, and its relative performance seems to have improved relative to the results of HJL, particularly its ability to predict future inflation. The relative performance of CPIX has fallen, likely because it was more affected by shocks to insurance prices in recent years. However, differences in performance among the traditional core measures are not large.

- Throughout the inflation-targeting period, the most volatile components of total CPI remained unchanged; however, a few of the middle rankings have changed substantially, owing in large part to the specific nature of recent shocks.

- Skewness and kurtosis in the cross-sectional distribution of the price changes have become more pronounced since 1998, perhaps owing to large shocks to energy, insurance, and tobacco prices. This seems to have caused slight bias in both the Wmedian and Meanstd measures. Even so, it is important to continue to monitor these measures, since they are better able to filter certain types of shocks.

- Two variations of a measure of core inflation developed by Cutler (2001), based on the persistence of the component prices of CPI using U.K. data, are tested for the first time on Canadian data and do not perform well.

The rest of the paper is organized as follows. The next section provides a brief review of how core inflation is conceived and measured. Section 3 briefly discusses some recent shocks to Canadian inflation. Section 4 describes the measures of core inflation used most frequently in Canada. Section 5 introduces two new measures of core inflation based on the work of Cutler (2001) in the United Kingdom. Section 6 provides a statistical evaluation of the measures of core inflation. Section 7 briefly discusses the usefulness of core inflation measures during two recent episodes. Section 8 suggests implications of the findings. Statistics for the evolution of the moments of the distribution of the Canadian data as well as for the 54 subcomponents are provided in the appendixes.

2. The Concept and Measurement of Core Inflation

The goal of inflation targeting is to promote a well-functioning economy by protecting the value of money. Unfortunately, central banks are not able to stabilize all prices at all times. Therefore, effective monetary policy requires an understanding of which prices are the most appropriate focus for monetary policy in both the long and short run. Many central banks define their inflation target in terms of the growth of total CPI, but use measures of core inflation as a shorter-term operational guide.

Despite the widespread use of this inflation-targeting framework, there is no unique concept or measurement of core inflation. Index number theory is well developed and is appropriate for measuring the cost of living, but there is an understanding that the cost of living is not the most appropriate concept for core inflation. Instead, core inflation is conceived in three main fashions. First is the concept that core inflation is the persistent part of inflation, a view supported by Eckstein (1981) and Blinder (1997). A second concept, used by Bryan and Cecchetti (1993a), defines it as the widespread or generalized aspect of inflation. A third concept links it to demand or expectational pressures. Understanding the link between these concepts of core inflation and determining which one is the most appropriate requires an understanding of how economies function and, particularly, how prices are determined. Unfortunately, there is much uncertainty about this.

Because of this uncertainty over the exact functioning of the economy, the earliest measures of core inflation were not tied to a specific model but were built using statistical methods, often by examining the statistical properties of the various subcomponents of inflation.[1] Nevertheless, "the choice of technical methods used to identify the core and non-core components has been guided by a general model of price determination."[2] The most popular statistical measures of core inflation are often referred to as "exclusion measures" because they simply exclude a small number of subcomponents from total CPI. The components excluded are held constant across time. One example is CPI excluding food and energy. The advantages of these measures are that they are less sensitive to the restrictions or assumptions of a specific model; they are seldom revised, even when additional data are available; and they are easy to calculate and explain to the public. A disadvantage is that they are only loosely tied to a conceptual definition of core inflation. Furthermore, they may not be robust to changes in economic behaviour. Nevertheless, these measures continue to be widely used by many central banks.

1. This section only briefly discusses these statistical measures of core inflation. The discussion here is meant to facilitate a comparison of these measures with those discussed in the broader literature. Section 4 provides a more detailed discussion of these measures, since they are the focus of the empirical evaluation provided in section 6.
2. Hogan, Johnson, and Laflèche (2001, 8).

To address the possibility that the appropriate subcomponents chosen for exclusion may change over time, “order statistics” or “limited-influence” measures were developed. These measures include weighted-median or trimmed-mean measures. The weighted median, for example, is the inflation rate of the subcomponent for which 50 per cent of the CPI basket is both above and below.

Ball and Mankiw (1994) analyze models of price determination and the distribution of price changes, providing some theoretical support for limited-influence measures of core inflation. Their work is based on the observation that the cross-sectional distribution of price changes is non-normal. Using a static model with menu costs, they show that idiosyncratic supply shocks will lead to temporary increases in the mean of inflation. Their work suggests that the distribution of price changes will be skewed and supports the idea that the values in the tails of the cross-sectional distribution represent *temporary* inflation shocks. Bryan and Cecchetti (1993b) use this model of inflation to suggest that core inflation could be reasonably measured by looking at the order statistics like the median or the trimmed mean.

The Ball and Mankiw approach concentrates on supply shocks as the sole source of relative price shocks. Using similar models, Roger (1995) and Bakhshi and Yates (1999) provide another explanation for a non-normal distribution of price changes that calls into question the use of trimmed measures. They argue that if only a fraction of price setters are allowed to adjust prices each period, then demand shocks will change relative prices. However, once all prices in their model are allowed to adjust to the demand shock, the underlying mean of inflation will have changed. Therefore, demand shocks can also cause temporary skewness in the distribution of price changes. Moreover, an increase of skewness in the distribution of price changes could be thought of as a leading indicator of *persistent* future inflation and should not be ignored. Therefore, while they do not reject Ball and Mankiw’s explanation that supply shocks can cause skewness, they suggest other causes that have different implications for the persistence of inflation changes. This implies that care should be exercised in interpreting measures of core inflation that are based on trimming the distribution of price changes.

To tie core inflation more closely to economic theory, measures based on structural vector autoregressions (VARs), dynamic factor indexes, and unobserved components were developed. However, the theoretical structure of these models is still limited. Also, despite differences across these methodologies, they share the disadvantage that, as new data available are used in the estimation, these measures are generally revised, making them especially problematic for central banks to use as communication tools.

The recent literature using dynamic general-equilibrium (DGE) models, particularly the New Keynesian Phillips curve literature, supports the use of inflation targets, and provides insight into measures of inflation that central banks should target. This literature also provides much promise for defining and measuring core inflation. The two most relevant papers for core inflation from this literature are Mankiw and Reis (2003) and Aoki (2001). Mankiw and Reis (2003) build a DGE model assuming that the central bank wants to target inflation and then construct the measure of inflation that, if targeted, would maximize the stability of economic output. They term this the "stability price index" and show that the central bank should target a very broad price index, for which the appropriate weights may not be the expenditure weights used in cost-of-living indexes. Their model includes many prices that can differ according to four characteristics. They find that, generally, the more sensitive a sectoral price is to the business cycle, the higher the weight that it should receive in the stability index. Also, the larger the idiosyncratic shocks to the sector, the smaller the weight that price should receive. As wages are very procyclical and have a low variance, wages should receive a large weight in the stability price index. They also find that the stickier a price is, the larger a weight it should receive. And, interestingly, they find that the optimal weight is inversely proportional to its expenditure share. This is so because changes in prices with high expenditure weights are the most disruptive to the rest of the economy and, therefore, attempts to reverse shocks to these prices would cause additional disruption to the economy. Overall, while their model provides some theoretical support for traditional measures of core inflation, it also suggests concerns with these measures.

Aoki (2001) uses a similar DGE model, which includes two sectors of the economy, characterized by flexible and sticky prices, and indicates that optimal monetary policy should target prices in the sticky-price sector. In fact, this result is a special case of the Mankiw and Reis results. The reason for this result is the absence of trade-off between reducing the variance of output and the variance of sticky prices, whereas there is a trade-off between the variances of total inflation and output. Aoki points out that his results support measures of core inflation that exclude volatile food and energy prices. As well, like Roger (1995) and Bakhshi and Yates (1999), he cautions against the use of measures that trim the tails of the distribution, like the weighted median. Because changes in sticky prices tend to be large, owing to their infrequent changes, trimmed measures remove those price changes to which the central bank should in fact respond.

These two New Keynesian models, and the DGE literature more generally, provide important insights into the appropriate target for optimal monetary policy. As these models develop further, they will provide more information regarding appropriate measures of core inflation. One important area for further work in these two models is how central banks would have to adjust interest rates to maintain inflation at the optimal target. Introducing additional frictions associated with the costs of inflation, particularly distortionary taxes, in these models would also be an important area for future work.

In summary, there is no clear concept for defining and measuring core inflation because, ideally, it requires full understanding of the pricing structure of the economy and, unfortunately, much uncertainty remains on this subject.[3] Statistical measures are widely used, and since they are only loosely tied to economic theory, they are likely to be robust to small theoretical changes.

3. Some Recent Shocks to Inflation Components

As context for the construction and evaluation of measures that use disaggregate inflation, this section discusses the behaviour of some of the components of inflation in Canada since HJL's 1998 data. There have been a few noticeable shocks to Canadian prices in the past few years. This section highlights the increased volatility of a number of prices, particularly electricity and automobile insurance prices.

Oil prices have exhibited episodes of extreme volatility, which has affected other Canadian energy prices, namely, natural gas, gasoline, and fuel oil. Following several years of relative tranquillity, energy markets have had very volatile prices since 2001. Even for prices generally characterized as volatile, these recent movements are noteworthy. A similar argument can be made for the recent behaviour of tobacco prices, which have also experienced sustained increases since 2001, largely reflecting changes in indirect tax rates.

The recent behaviour of electricity prices and insurance prices can be seen as even more unusual. Historically, volatility in world energy markets did not affect domestic electricity prices. However, recent deregulation of the electricity market, particularly the temporary regulatory changes in Ontario's electricity market, allowed volatility from other energy markets to spill over to electricity prices, resulting in an important price shock. Another important shock is the extremely large increases in automobile insurance premiums between early 2002 and late 2003. Several factors, including investment losses experienced by insurance companies and increased settlement costs, contributed to the increases. As the principal motivation for developing measures of core inflation is to help policy-makers see through temporary price movements, shocks to electricity prices and insurance prices provide excellent tests of core measures, and therefore, the effect of these shocks on the various measures will be discussed throughout the paper.

3. An important literature is developing that studies the behaviour of disaggregated prices. This research should contribute significant knowledge of pricing behaviour that can be applied to the issues of core inflation. Three examples of this work include Altissimo, Mojon, and Zaffaroni (2004); Bilke (2004); and Cecchetti and Debelle (2004).

Figure 1 shows the recent price movements for piped gas, electricity, other expenses related to motor vehicle operation (including auto insurance), and tobacco. As well, Table B1 in Appendix B shows the mean and standard deviation for each of the 54 components for two subperiods. As suggested by Figure 1, the mean and volatility of many of these components have increased substantially. In particular, Table B1 shows the increased means and standard deviations of the prices of electricity and other motor vehicle operating expenses (components 16 and 37). Based on these criteria, fruit, vegetables, gasoline, natural gas, fuel oil, intercity transportation, and tobacco products remain some of the most volatile components. In contrast, the volatility of mortgage interest costs seems to have diminished in recent years.

4. Traditional Statistical Measures of Core Inflation

This section describes statistical measures of core inflation that are used most frequently in Canada and are evaluated in the next section. The section draws heavily on the detailed discussion of these measures provided in HJL. All measures considered here are built by exploiting the cross-sectional behaviour of the year-over-year inflation rates for 54 subcomponents of total CPI.[4] This approach acknowledges the seasonal fluctuations that affect many components, fluctuations that are largely eliminated in annual rates.

4.1 Exclusion measures

The most commonly used core inflation measures are those that exclude pre-specified components. One example is the Bank of Canada's current measure of core inflation, CPIX. This measure excludes eight of the most volatile components as well as the effect of changes in indirect taxes.[5] The components excluded are fruit, vegetables, gasoline, natural gas, fuel oil, mortgage interest costs, intercity transportation, and tobacco products. Economic theory motivates excluding these components, since they are likely to be more affected by supply shocks. The volatility of these components supports this interpretation. The exclusion of mortgage interest costs and tobacco prices is also motivated by the fact that these are heavily influenced by

4. This level of disaggregation was chosen to get a consistent series back to the mid-1980s. Analysis for the 1990s could use more disaggregated data, if desired.

5. All of the inflation rates of the subcomponents used to build up the cross-sectional measures have only been adjusted for the effects of the Goods and Services Tax (GST) and the 1994 tobacco tax, the two largest indirect tax effects. However, other changes in indirect taxes that generate large swings in relative prices will be eliminated or down-weighted, depending on the construction of each measure. Therefore, total CPI excluding indirect taxes will be used as the main benchmark in the paper. The weighted mean (Wmean) of the 54 components adjusted for these two main tax shifts is also used as a comparison.

monetary and fiscal policy. CPIX excludes 19 per cent of the consumer basket based on the 2001 expenditure weights.[6]

Another exclusion measure of core inflation, and the Bank of Canada's former official measure, is CPIxFET. This measure excludes all components for food and energy (which amounts to 24 per cent of the basket based on the 2001 expenditure weights) and the effects of changes in indirect taxes. One reason this measure is no longer the official measure of core inflation is that, based on the historical volatility of individual components, it unnecessarily excludes some components of food (such as meals at restaurants and bakery products) and energy (electricity) that historically were not volatile.

One important weakness of exclusion measures is that the appropriate components to exclude may change over time. One way to address this concern is to periodically re-evaluate the behaviour of various prices, as is done in this paper. A second solution is to track additional core inflation measures that may be more robust to these changes, such as order statistics.

4.2 Order statistics

Order statistics for inflation are measures that exclude various components based on each time period's cross-sectional distribution of changes in the prices of CPI subcomponents. These measures are potentially better at adapting to certain changes in economic behaviour. Furthermore, as the non-normality of the cross-sectional distribution of price changes can be seen in several countries, including Canada, there are still strong statistical reasons for looking at measures that take into account this non-normality, and these are discussed in Appendix A. Appendix A also documents the recent behaviour of the higher moments of the distribution of price changes and shows that skewness and kurtosis have increased substantially in recent years.

The weighted median (Wmedian) is an order statistic defined as the 50th percentile of the weighted cross-sectional distribution of price changes in any given month. Order statistics such as the Wmedian should be more robust to persistent kurtosis of the price distribution. On the other hand, persistent skewness in the distribution can make order statistics biased relative to the mean. Although Canadian price data exhibit both skewness and kurtosis, the degree of non-normality in the distribution is not constant over time. Moreover, the degree of non-normality seems to have increased substantially since 1998, making it interesting to see how the Wmedian's performance has changed relative to other measures.

6. The basket weights were updated in July 2004, owing to a mistake in the weight of mortgage interest costs, and the weights for CPIX and CPIxFET are now 17 and 26 per cent, respectively. However, this paper uses data up to only early 2004.

Meanstd, another order statistic, also uses the cross-sectional distribution of year-over-year price changes in each month. On a month-to-month basis, it excludes price components whose rate of change is over or under 1.5 standard deviations from average inflation. If the cross-sectional distribution has persistent kurtosis or fat tails, there is statistical support for using a trimmed mean. It is interesting to track which components are excluded from Meanstd most frequently, and this is shown in Tables B2 and B3 in Appendix B. Table B2 shows that the eight components excluded from CPIX continue to be among the nine most excluded from Meanstd over the 1986 to 2004 sample.[7] Comparing the two tables shows the effect of the recent electricity and insurance price shocks on the exclusion rankings. Electricity is ranked 23rd over the longer sample but just 9th since 1998. “Other motor vehicle operating expenses” is now ranked 10th for the longer sample and 6th for the most recent sample. Nevertheless, 7 of the components excluded from CPIX are among the 11 most excluded. In contrast, mortgage interest costs are now rarely excluded from Meanstd, perhaps owing to more stable monetary policy.

There are two main disadvantages associated with Wmedian and Meanstd. First, it is more difficult to explain changes in these inflation rates over time compared with measures that include the same components each month. To understand monthly changes in these measures, it is necessary to keep track of which subcomponent or subcomponents are included in the measure that month. This is particularly difficult for Meanstd. Furthermore, the compositional changes may make forecasting more difficult. The second, and perhaps related, concern is that these measures may be sensitive to changes in the degree of non-normality of the cross-sectional distribution of price changes. If changes in economic behaviour can be characterized as a re-ordering of price changes of subcomponents, keeping the shape of the cross-sectional distribution of price changes constant over time, then these measures should be less volatile than total inflation and perhaps even than other measures of core inflation. However, these measures may not be less volatile if there are substantial changes to the shape of the distribution each month. This is a fairly complicated idea, but the sharp movements between February and April 2001 in Meanstd, and, to a lesser extent, in Wmedian, demonstrate this point. These movements coincide with substantial increases in both the skewness and kurtosis of the cross-sectional distribution of price changes.

4.3 Re-weighted measures

A measure often reported in the Bank of Canada’s *Monetary Policy Report* is CPIW, which does not assign a zero weight to any component in total CPI. Instead, each component of CPI is

7. Tuition is also frequently excluded from this measure. However, this is not generally attributed to volatility but instead to the fact that this price has increased, on average, at more than twice the rate of average inflation.

"double weighted," first by its expenditure share, and second by a measure inversely proportional to its variability. The second weight is defined as the reciprocal of the standard deviation of the change in relative prices, where the change in the relative price is measured by the difference between the price change of a component and the total inflation rate.[8] These two weights are then multiplied. This measure includes all subcomponents at each period, thus reducing the possibility of excluding valuable information, but it is more difficult to compute and to explain to the public.

4.4 Overall behaviour of these measures

Figures 2 to 6 show graphs of these five measures and suggest reduced volatility of core measures relative to the total. Over the past five years, total CPI inflation has been very volatile, leaving the target bands on both the up and down sides. As hoped, measures of core inflation have been less volatile. While measures of core inflation have left the target bands, these departures have been far less significant than for total CPI inflation. CPIxFET and CPIX exhibit the largest spikes in inflation in 2002 and 2003. These specific exclusion measures, and to a lesser extent CPIW, were less able to filter the shocks to electricity and insurance prices. The two order-statistic measures show some increase during 2000, but none of the increase in 2003.

The graphs also suggest that all measures of inflation shown appear stationary after 1991. While standard unit-root tests on all measures over 1985 to 2004 cannot reject a unit root, the introduction of inflation targeting provides theoretical support for the fact that inflation should be stationary. Figures 2 to 6 show that the introduction of inflation targeting in 1991 coincides with a substantial shift in the level of total inflation as well as in the core measures. Therefore, unit-root tests that include an exogenous structural break in 1991m1 were conducted on the data for total CPI inflation and for each traditional measure of core inflation. For each series, one is able to reject a unit root in inflation, given this exogenous structural break in the mean. The rejection of the unit root is also supported by the work of Levin and Piger (2002), Benati and Kapetanios (2002), and Demers (2003). They too conclude that there was a structural break in the mean of Canadian inflation in 1991.

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8. The sample period for calculating the volatility measure was extended to 2004, and CPIW was recalculated. This resulted in historical revisions to the entire series, but in fact it caused very little change to the measure. Therefore, this paper continues to use the volatility measure from the original sample period, January 1986 to April 1997. However, the issue of choosing the sample period for calculating the measure of volatility is one drawback for this measure.

5. Cutler Measures of Inflation

Motivated by the idea of measuring trend inflation by its persistence, Cutler developed a new measure of core inflation in 2001 using U.K. data. This measure uses the same 80 components that are used in RPIX, but weights each component by its inflation persistence. Using monthly data for year-over-year inflation, she measures the persistence of each component's rate of inflation by its autoregressive (AR) coefficient on the 12-month lag of inflation. The weights are updated on an annual basis using rolling regressions. Price components whose rate of change has a negative AR coefficient are excluded with a zero weight, and the remaining weights are rescaled to sum to one. Cutler finds that this measure is a good predictor of future inflation 6 and 12 months ahead. This ability to forecast inflation reinforces the belief that this measure captures trend inflation in the United Kingdom. Furthermore, the theoretical results of Mankiw and Reis (2003) and Aoki (2001) that suggest central banks should target sticky prices may provide support for this measure.

It seemed worthwhile to construct a version of the Cutler measure using Canadian data. Owing to differences in the Canadian data, a few modifications were required. First, while detailed mean-break unit-root tests were not done on each subcomponent, each subcomponent is assumed to be similar to total inflation and therefore stationary, given an exogenous mean shift. Accordingly, autoregressive coefficients were estimated with the 12-month lag of inflation, a mean-shift dummy, and four lags of the change in inflation.[9] Consequently, there are not enough data points to do reliable rolling regressions. Therefore, the first Cutler measure calculated for Canada uses the autoregressive coefficient as a fixed weight throughout the entire sample.

Table B1 shows the expenditure weights used for total CPI as well as the weights based on the persistence measures. Note that 10 components are given a zero weight, and five of these components are also excluded from CPIX. Some of the additional components that are given zero weight in this new measure are furniture, household textiles, and household equipment. Of the eight components excluded from CPIX, only mortgage interest costs, intercity transportation, and tobacco have non-zero weights in this measure. Interestingly, home owners' insurance premiums and electricity, two components that have been subject to recent shocks, are given more weight in this measure than in CPI. As will be discussed in more detail below, this new measure does not rank well among the measures of core inflation. Therefore, a variant was calculated. This second measure combines the fixed autoregressive coefficient from the whole sample with the time-varying expenditure weights. This is similar to CPIW, which uses a double weighting of the time-

9. These equations were estimated over 1986m1 to 2004m1.

varying expenditure weights and the inverse of the standard deviation from (almost) the whole sample for each component. Again, based on the analysis presented below, this measure provides no improvement on existing measures of core inflation. Interestingly, Smith (2003b) and Clark (2001) examine this type of measure for the United States and also find poor results.

In addition to the poor results based on the empirical evaluation, there are three additional shortcomings with this measure. First, there are empirical difficulties involved in estimating persistence parameters, particularly for near unit roots. Therefore, there may not be a consensus on the appropriate weights. Second, the practice of assigning zero weight to components with negative autocorrelation may bias the persistence of this measure of inflation upwards. Third, as shown by Granger (1980), aggregating stationary AR processes creates series with very different statistical behaviour. While this is a potential problem for many aggregate inflation series, putting most weight on those series with more persistence may aggravate this problem. One way to examine these potential problems is to examine the order of integration of these new measures. Using tests which include an exogenous mean structural break, unit roots for these Cutler measures could not be rejected. This highlights the possible difficulties caused by these last two issues. Figure 7 shows a graph of these two measures. The Cutler measures show a clear upward trend between 1998 and 2003, and only recently do they show any moderation.

6. Evaluation of Core Inflation Measures

There is a very large literature on the evaluation of core inflation measures.[10] Criteria used for the evaluation of measures of core inflation can be characterized as theoretical, practical, or empirical. Practical criteria include timeliness and non-revision of the measures, as well as ease of computation and explanation. The main empirical criteria are lack of bias, reduced volatility relative to total inflation, and the ability to forecast total inflation.[11] These three empirical criteria are employed in this section.

6.1 Bias

One important issue for an inflation-targeting central bank that uses a measure of core inflation as a short-term operational guide is bias between total and core inflation. Bias between two measures

10. Roger (1998), Wynne (1999), and Mankikar and Paisely (2004) provide excellent critical reviews of this literature.
11. Notable papers that examine these empirical criteria include Bryan and Cecchetti (1993a), Roger (1995), Freeman (1998), Hogan, Johnson, and Laflèche (2001), Clark (2001), Cogley (2002), and Vega and Wynne (2002).

of inflation implies different long-run average inflation levels. The long-run average for a core inflation measure needs to be very close to that of total inflation.

One simple way to examine the bias is to compare the unconditional means of the various core measures with that of total inflation excluding the effects of changes in indirect taxes (CPIxT). This is done in Tables 1, 2, and 3. Because of the assumption regarding the shift in the mean, the pre- and inflation-targeting samples are examined separately.

Table 1 shows that all measures have higher means than CPIxT in the pre-inflation-targeting sample, with the Cutler measures having the highest means. To determine if these deviations are significant, we use the standard error of the sample mean for the deviation of each measure from CPIxT. For the earliest sample period, all core inflation measures are significantly different from total inflation at the 95 per cent level.[12]

Table 2 shows that the mean of CPIxT is in the middle of the pack of measures for the post-1991 sample. For the inflation-targeting regime, CPIxFET, CPIX, CPIW, CPIX excluding electricity, and Cutler2 are not biased. Although shocks can lead to persistent gaps between trend and total inflation measures (witness the 1998 to 2004 sample) these gaps are not significant over a longer horizon. In contrast, Meanstd, Wmedian, Cutler1, and CPIX excluding auto insurance are significantly biased. The lower means of Meanstd and Wmedian are likely related to the skewness in the distribution of price changes (discussed in Appendix A). The Cutler1 measure, on the other hand, is biased upwards, indicating, perhaps, that the assumption that both Cutler1 and CPIxT shifted simultaneously is false. This interpretation is intuitive, since Cutler1 puts more weight on rates of inflation that may have been slower to fall at the beginning of the inflation-targeting period.

Table 3 reports statistics for the second part of the inflation-targeting regime (1998m8 to 2004m1). All measures of core inflation, except Cutler1, have means substantially below that of CPIxT. Furthermore, Meanstd and Wmedian have the lowest means. This is likely owing to high energy prices over this period. Care must be taken not to overstate conclusions from this short sample.

In summary, four main measures of core inflation are not biased if one considers the entire inflation-targeting period. In contrast, skewness creates concern for bias in order statistics.

12. The bias for CPIW, Meanstd, and Wmedian in this earlier time could be related to indirect tax changes, since Wmean has a mean of 4.52 over this period, the same as the mean of total CPI. In comparison with CPIxT, which has been adjusted for all indirect tax changes, Wmean has only been adjusted for the effects of the GST and the 1994 tobacco tax. Differences between CPIxT and Wmean are very small after 1992.

6.2 Volatility

As noted above, an effective measure of core inflation exhibits low volatility. One measure of the volatility of a series is its dispersion around its own sample mean. Tables 1, 2, and 3, discussed above, also report the standard deviation and coefficient of variation for each measure.[13] These statistics can be considered gauges of the efficiency of various measures of core inflation.[14] For the pre-inflation-targeting sample, CPIW and Cutler1 have coefficients of variability substantially below CPIxT. Several measures, including CPIX, have coefficients of variability only slightly below that of CPIxT.

For the inflation-targeting sample, all traditional measures have coefficients of variation substantially lower than for CPIxT, with CPIX having the lowest value. As in the HJL results covering 1992 to 1998, Wmedian, Meanstd, and CPIxFET are the three most volatile of the traditional measures over the period 1992 to 2004. This result for the order statistics supports the idea that shocks to the cross-sectional distribution of price changes may result in higher volatility, compared with other core measures.

Comparison of Tables 2 and 3 shows that the volatility of CPIX increases in the second half of the inflation-targeting period, whereas the volatility of the other measures declines. Furthermore, the volatility measures of Wmedian and Meanstd are below that of CPIX over the 1998 to 2004 sample. This suggests that the criticism that order statistics would be more volatile is not robust to all subsamples.

Although it is difficult to pinpoint the exact cause of the relative increase in the volatility of CPIX, it seems to be mostly owing to the large movements in auto insurance premiums, as CPIX excluding auto insurance has a much smaller increase in volatility. Auto insurance prices affect the other core measures less, either because these prices have a smaller weight in the measures (i.e., in CPIW) or are eliminated from these measures in certain months (Meanstd). Electricity is unlikely to be the cause, as electricity's weight is actually scaled up in CPIW, owing to its historically low volatility. Also, volatility is largely unaffected when electricity is excluded from CPIX.

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13. Given the assumption of stationarity with a mean shift, these statistics should be statistically well behaved within each subperiod.
14. The coefficient of variation is the standard deviation divided by the mean. If the means of these series are similar, the ranking of the coefficient of variation should not be much different than that of the standard deviation. However, given some evidence in the literature that the variance of inflation increases with the mean, the coefficient of variation may be the more appropriate measure, especially for comparing across time periods.

To examine the robustness of the above results, Tables 1, 2, and 3 also report the mean of the absolute change in year-over-year inflation each month. This alternative measure of volatility depends less directly on the persistence of inflation.[15] For the pre-inflation-targeting period, all but Meanstd have lower values than CPIxT. Looking at the 1991 to 2004 sample, CPIX and CPIW and the Cutler measures do well, with measures of variability about half that of CPIxT. On the other hand, Meanstd and Wmedian have the highest volatility of the core measures, confirming the view that these order statistics are made more volatile by the changing coverage of price components each month. Looking at the most recent sample, the Cutler measures have the lowest values of all. The traditional measures with the lowest values are CPIxFET and CPIW. Thus, while this alternative measure of volatility confirms that all measures of core inflation are less volatile than total inflation, some of the relative rankings of the core measures change.

In summary, the variability of core inflation measures is indeed lower than that of total inflation. This relative stability of core measures is important and helps analysts to gauge the underlying trend in inflation. Unfortunately, core measures still show considerable variability. The mean absolute change in inflation for the inflation-targeting regime shows that even the best measures change, on average, by 0.15 percentage points each month. Changes between months can be substantially higher than this average.

6.3 Predictive ability

This section examines whether core inflation is able to provide information on the future dynamic behaviour of total inflation or, in other words, if it is a good predictor of persistent or future inflation. Many researchers stress the importance of ranking core measures by their predictive power, including Bryan and Cecchetti (1993a), Blinder (1997), Cutler (2001), and Cogley (2002). Despite its widespread use, the ability of core inflation measures to forecast total or trend inflation is a more controversial evaluation criterion than either bias or volatility.

One argument that has been used against the criterion of predictive ability is that it is difficult to forecast a volatile series with a smoother one. Marques, Neves, and Sarmento (2003) argue that a good forecast of total inflation needs to capture its transitory movements, and since these types of changes are stripped from core measures of inflation, these measures are unlikely to be very good forecasters of future total inflation. However, this is not a strong criticism, since an independent and identically distributed variable is best forecasted by its mean. Therefore, while a smooth series will never forecast all the volatility, it may still be the best forecast available.

15. Note that this measure of volatility can still be calculated if inflation is characterized by a unit root.

Nevertheless, this argument has been used to make a distinction between forecasting the trend of total inflation and its future actual value. Many authors argue that evaluating core measures of inflation by their ability to forecast a smoothed or filtered version of total inflation is more reasonable since, as discussed above, monetary policy is not generally geared towards responding to temporary changes in inflation. Notwithstanding the problem with the empirical motivation, this criterion is still worth examining.

Tables 4, 5, and 6 show the root-mean-squared-error (RMSE) and mean-absolute-deviation (MAD) of the core inflation measures relative to a trend measure of total inflation. Cecchetti (1997a) proposed a 36-month centred moving average of total inflation (Wmean) as a benchmark for trend inflation. Although this is an easy and intuitive benchmark of trend inflation, there is no theoretical support for this measure. Nevertheless, it is widely used. Figure 8 shows this series for Canada. Table 4 reports the forecast errors for the entire sample (trimmed on either side because of the two-sided moving average). It shows that all traditional measures are more efficient than Wmean at forecasting trend total inflation. Consistent with the results of HJL, CPIW has the lowest RMSE; and MAD, CPIxFET, and Wmedian are in the middle. CPIX and Meanstd have the highest deviations. Cutler's measures do not perform well, and are in fact worse than Wmean.

Tables 5 and 6 show results for two inflation-targeting subsamples and indicate that CPIW is again the best measure. While all traditional measures continue to beat Wmean, there is very little difference between these measures. Also, the Cutler2 measure still does very badly even though the Cutler1 measure improves relative to the earlier sample.

A second reason why predictive ability of core measures is a controversial criterion is the increasing evidence that, in an inflation-targeting regime, inflation is best predicted by a simple historical average or by the target itself.[16] A simple way to test this is to estimate the following regression:

$$\pi_{t+h} = \alpha + \beta\pi_t^{Core} + \delta\pi_t + u_t, \quad (1)$$

where the variable π_t is total inflation, π_t^{Core} is a core inflation measure, and u_t is the error term. However, a large literature has emerged on the difficulty of out-of-sample forecasting, and the in-sample RMSE has been shown to be a poor measure of out-of-sample forecasting ability. Clements and Hendry (2002) have written that "unmodeled shifts in the deterministic components of models, however these arise, are the primary cause of forecast failure." The fact that total

16. The results from Demers (2003), for example, support this proposition.

inflation may be best forecasted by either its historical mean or by the target is a testament to the effectiveness of past monetary policy, but provides little advice on how to interpret a large jump in headline inflation. In other words, should interest rates be increased to lower total inflation, or is this a temporary mean-reverting shock? Therefore, it may be more informative to examine whether core inflation measures are able to proxy the mean.

There are many different ways of testing this hypothesis. Cogley (2002) provides an intuitive regression of the form shown in equation (2):

$$(\pi_{t+h} - \pi_t) = \alpha + \beta(\pi_t^{Core} - \pi_t) + u_t, \qquad (2)$$

where the variable $\pi_{t+h} - \pi_t$ is the change in total inflation, π_t^{Core} is a core inflation measure, and u_t is the error term.[17] The intuition for this equation is that if core inflation is above total inflation, this likely means that total CPI has been hit by a *temporary* negative shock that will be reversed. Therefore, one may expect total CPI inflation to increase in the future. In contrast, a simultaneous shift in both core and total inflation would be better interpreted as a shift in the mean of the series and therefore a permanent shock. The value of β indicates whether the current deviation of core from total inflation over- or underestimates the transitory movements in inflation. If β is less than one in absolute value, then the current deviation overstates the transitory movements, and vice versa. The coefficient α captures the systematic bias in the measure.

Cutler (2001) rearranges Cogley's equation, and this version provides a slightly different interpretation:

$$\pi_{t+h} = \alpha + \beta\pi_t^{Core} + (1 - \beta)\pi_t + u_t. \qquad (3)$$

Using this version, Cutler focuses on the relative explanatory power of total inflation and the measure of core inflation. In particular she interprets a $\beta > 0.5$ as indicating that core inflation is more important for explaining future total inflation than for the more volatile total inflation. Another way to rearrange the equation is:

$$\pi_{t+h} - \pi_t^{Core} = \alpha + (1 - \beta)(\pi_t - \pi_t^{Core}) + u_t. \qquad (4)$$

17. Note that this is a restricted version of equation (1) with $\beta + \delta = 1$. Relaxing the restriction that the coefficients on core and total sum to one does affect the results. Similar to other papers, the mean is found to be a good predictor; however, as noted above, the usefulness of this for policy decisions is limited.

This version highlights any persistence in the deviations between core and total inflation. Regardless of which version of the equation is used, if the restrictions suggested by Cogley ($\alpha = 0$ and $\beta = 1$) are imposed, all versions of the equation collapse to:

$$\pi_{t+h} = \pi_t^{Core} + u_t . \quad (5)$$

This equation indicates that core inflation is an unbiased predictor of total inflation. Recalling the discussion of the independent and identically distributed variable, this forecasting equation will never capture all the transitory movements; nevertheless, if core measures are the best "real-time" indicator of the mean, and if inflation is mean-reverting, then this equation should be helpful.

Before discussing the regression results, it is interesting to quickly examine the deviations of core from total inflation over time as well as the correlations between core and total inflation at various horizons. The deviations are shown in Figure 9. While obviously not identical, the traditional measures show similarities. After the introduction of inflation targeting, the absolute size of the deviation falls and remains fairly small until around 1998, at which time energy prices became volatile.

Table 7 shows correlations between various measures of core inflation and *future* CPIxT.[18] It is not obvious *a priori* what pattern of correlation to expect. Correlations may be expected to be high at very short horizons, but should fall to zero at longer horizons.[19] The pattern of negative correlations at 6- and 12-month horizons suggests, as in HJL, that shocks excluded from core measures do reverse themselves over these horizons. This observation provides preliminary support for Cogley's formulation and suggests that core measures at any point in time may be good predictors of total inflation in 6 to 12 months.

Tables 8 to 10 show the regression results based on Cogley's equation estimated over the period 1992 to 2004.[20] Cogley examines many horizons, but Table 7 indicates that focusing on the horizons of 6, 12, and 18 months would be appropriate for Canada. At the 6-month horizon one cannot reject H_0 that β=1 and α=0 at the 5 per cent level for CPIxFET, CPIX, and CPIW, suggesting that these core measures are unbiased predictors of total inflation. However, the

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18. As highlighted by HJL, all measures of core inflation will have high correlations with total inflation if the sample period includes the shift in the mean of inflation, which occurred in 1991. To avoid this misleading effect, correlation calculations will use only post-1991 data.
19. As Rowe and Yetman (2000) show using a simple model, if monetary policy is perfectly successful, inflation beyond the lag at which the policy instrument is effective should have zero correlation with the information available when the policy instrument was set.
20. The Cogley equation was used to estimate all the results, since Clark (2001) suggests that estimating Cogley's equation avoids the difficulties that a near unit root would cause for inference.

p-values for Wmedian and Meanstd are 0.04 and 0.06, suggesting that these measures are not unbiased. Taking a closer look at the unbiased measures, CPIW has the highest $\bar{R}^2$, and CPIX has one of the lowest. But although the hypotheses that β=1 and α=0 cannot be statistically rejected, many of the β coefficients are actually close to 0.5, suggesting that core and total inflation are equally important for forecasting future total inflation at this horizon. For the Cutler measures, the hypothesis that β=1 and α=0 is easily rejected, and the $\bar{R}^2$ s are very low.

For the 12-month horizon (Table 9), the hypothesis of an unbiased predictor is not rejected for any of the traditional measures. This is an improvement on HJL's finding that unbiasedness was rejected for all measures over the authors' shorter inflation-targeting sample. This suggests that deviations between core and total inflation are not persistent and that total inflation moves towards core inflation. The estimated β coefficients are also consistent with core inflation being a more important factor than total inflation itself in forecasting future total inflation. Interestingly, the constant for Wmedian is the largest, although it is not significant.[21] At this horizon, CPIW continues to score the highest in terms of $\bar{R}^2$, and CPIX nearly the lowest among the traditional measures. Also, the $\bar{R}^2$s have risen relative to the 6-month horizon and are now closer to 0.3, even though the standard error of the dependent variable has risen to 1.2 from 0.87, indicating that there is now more volatility to explain. This suggests that deviations between core and total inflation are better characterized as taking a year to reverse. However, the $\bar{R}^2$s are all substantially below those reported in HJL for the 1992 to 1997 sample. While not significantly biased, the Cutler measures again rank poorly, based on their $\bar{R}^2$s.

One-year ahead RMSEs from equations with the restrictions $\alpha = 0$ and $\beta = 1$ were calculated but are not shown. All traditional measures have values close to one percentage point, which is slightly below the value calculated if one uses current total inflation as its predicted value 12 months ahead. However, using the Diebold and Mariano (1995) statistic, one cannot reject the possibility that forecast performance of the core inflation measures is equivalent to that of total inflation.[22] As discussed above, it is not surprising that the RMSEs are so large. Furthermore, if one considers the 1996 to 2004 sample period, a moving average of total inflation over the previous three years has better forecasting ability than core measures.

Table 10 suggests that even at the 18-month horizon many traditional core measures provide unbiased forecasts of total inflation. The exception is CPIX, whose β coefficient is significantly below 1. For all measures, the α coefficients have increased, although they are still

21. Another point to note about the estimated constants for all the measures at all horizons is that they are positive, in contrast to the results for HJL, where they are negative. While they are not significant, it points to the potential issue of time-varying bias discussed in Appendix A.
22. The same analysis was done for the 6- and 18-month horizons, and the results are similar.

not significant. Interestingly, the $\bar{R}^2$s for all traditional measures do not fall much from the 12-month horizon. The Cutler measures again perform poorly.

Compared with the results reported in HJL and Macklem (2001), who both use shorter inflation-targeting samples, CPIX's relative forecasting performance has fallen. This could be in part owing to the large shocks to electricity and insurance prices. Comparing CPIX's performance with that of CPIX excluding electricity changes the overall results little. The forecasting improvement when auto insurance is excluded suggests that the recent shock to this subcomponent has adversely affected the predictive performance of CPIX. On the other hand, as discussed in section 6.1, there is evidence that the average level of core inflation measured by CPIX excluding auto insurance is significantly lower than total CPI inflation over the inflation-targeting period. Furthermore, the inclusion of auto insurance in both CPIxFET and CPIW, albeit with smaller weights, further complicates the issue, since the performance of these measures has not deteriorated.

To sum up, although core measures of inflation do provide unbiased forecasts for future total inflation, it is important not to overemphasize their forecasting ability. However, despite their weak forecasting ability, they remain useful indicators.

6.4 Reversing the Cogley equation

This paper has shown that deviations between core and total inflation contain some information about future total inflation. However, as mentioned earlier, these deviations may also have information about future core inflation, which could happen if menu costs cause different components to have an asynchronous reaction to a shock to desired future prices. For example, if agents are able to change prices each period only in certain sectors, then a demand shock can cause changes in relative prices. This was the point of Aoki (2001), Bakhshi and Yates (1999), and Roger (1995). Therefore, it is interesting to see if deviations between core and total inflation can predict future core inflation. To test this idea, a variation of the Cogley equation is run, in which the dependent variable is the change in core inflation. While detailed tables of the results are not provided, some results are worth reporting. At the 6- and 12-month horizons, the $\bar{R}^2$s of all the equations are very low, and the coefficient of the deviation is not statistically significant in any regression. At the 18-month horizon, the deviation becomes significant in several of the measures, and the $\bar{R}^2$ rises to about 0.15. Although still not large, these values are higher than those found by Macklem (2001).

Overall, these results suggest that there is little evidence that these deviations predict core inflation at short horizons.

7. A Brief Case Study

Another way of evaluating core measures is to examine their behaviour during specific time periods. This section briefly discusses an episode between late 2002 and late 2003 that is worth highlighting. Between September 2002 and February 2003, total CPI excluding indirect taxes increased from 1.7 to 4.1 per cent. This was largely owing to shocks to energy and insurance prices. CPIX, CPIxFET, and CPIW all showed increases over this period. While these increases were generally more muted than that of CPIxT, they were still substantial. In November 2002 alone these three measures increased 0.6 of a percentage point. The two order statistics showed no acceleration in this period, suggesting they were better able to filter these shocks. The April 2003 *Monetary Policy Report* attributed the strong core inflation to two factors: insurance prices and capacity pressures. These capacity pressures contributed to the Bank's decision to raise interest rates. However, between February and July 2003, CPIxT inflation fell from over 4 per cent to around 2 per cent. Furthermore, core inflation decelerated rapidly in the summer of 2003. The October 2003 *Monetary Policy Report* attributes this deceleration in core inflation to weaker than expected capacity pressures and lower than expected import prices owing to the appreciation of the Canadian dollar, leading the Bank to lower interest rates.

Overall, this episode shows that while core inflation measures are less volatile than total CPI, they are still subject to important shocks and periods of volatility. This episode also highlights the limited forecasting abilities of these measures. Acceleration in these core inflation measures occurred shortly before inflationary pressures diminished substantially.

8. Conclusions

This paper has examined the statistical properties and forecasting ability of several measures of core inflation, focusing on the inflation-targeting period from 1992 to 2003. The main results are:

- The measures of core inflation generally continue to satisfy the criteria that they are less volatile than total CPI inflation and that they provide some information about current trend and future total inflation 6 to 12 months ahead.

- Overall, CPIW ranks best among the core inflation measures, and its relative performance seems to have improved relative to the results of HJL, particularly its ability to predict future inflation. The relative performance of CPIX has fallen because it was more affected by shocks to insurance prices in recent years. However, differences in performance among the traditional core measures are not large.

- For the entire inflation-targeting sample, the most volatile components of the CPI remain unchanged; however, there has been some reshuffling among components in the middle rankings. This highlights the importance of some recent unusual shocks to various subcomponents of CPI.

- Skewness and kurtosis have become more of an issue since 1998, perhaps owing to the volatility of energy, insurance, and tobacco prices. This seems to have caused slight bias in both the Wmedian and Meanstd measures. Although evidence of kurtosis supports the use of the order statistics, evidence of skewness raises concerns of bias. Even so, it is important to continue to monitor these measures, since they can more easily filter unanticipated shocks.

- Two variations of a measure of core inflation developed by Cutler for the United Kingdom (based on the persistence of the component prices) are tested for the first time on Canadian data and do not perform well. This paper shows that these measures are not less volatile than total CPI inflation and do a poor job at tracking the moving average or future values of total inflation. Therefore, the Cutler measures would not perform well as operational measures of core inflation when the ultimate target is specified in terms of expenditure-weighted CPI.

Together, these results suggest that although the traditional statistical measures of core inflation do satisfy properties useful for an operational measure of target inflation, their usefulness is nevertheless limited. These measures are less volatile than total CPI and provide limited information to help predict total CPI inflation. However, these measures are not immune to temporary relative price shocks. That said, monitoring several different measures of core inflation should help economists to understand the various shocks hitting the economy. Therefore, the central bank should continue to use these measures as part of its analysis, but their limitations need to be acknowledged.

Going forward, continued research on core inflation from both theoretical and statistical perspectives is needed. Specifically, two areas seem particularly important. First, further research on optimal measures of core inflation using DGE models with many frictions is important. This will bring these measures closer to being operational while they continue to help researchers understand the strengths and weaknesses of the statistical measures of core inflation. Second, continued research on disaggregated and micro price data is important. Further research in this area will help to explain shocks to the cross-sectional distribution of price changes.

References

Altissimo, F., B. Mojon, and P. Zaffaroni. 2004. "Fast Micro and Slow Macro: Can Aggregation Explain the Persistence of Inflation?" Presented at the European Central Bank conference, "Inflation Persistence in the Euro Area," Frankfurt am Main, 10–11 December 2004.

Aoki, K. 2001. "Optimal Monetary Policy Responses to Relative-Price Changes." *Journal of Monetary Economics* 48(1): 55–80.

Apel, M., M. Nessén, U. Söderström, and A. Vredin. 1999. "Different Ways of Conducting Inflation Targeting—Theory and Practice." *Sveriges Riksbank Quarterly Review* 4: 13–42.

Aucremanne, L. 2000. "The Use of Robust Estimators as Measures of Core Inflation." National Bank of Belgium Working Paper No. 2.

Aucremanne, L. and R. Wouters. 1999. "A Structural VAR Approach to Core Inflation and Its Relevance for Monetary Policy." In *Measures of Underlying Inflation and Their Role in the Conduct of Monetary Policy*. Proceedings of the workshop of Central Bank Model Builders held at the BIS on 18–19 February 1999.

Bakhshi, H. and T. Yates. 1999. "To Trim or Not to Trim?: An Application of a Trimmed Mean Inflation Estimator to the United Kingdom." Bank of England Working Paper No. 97.

Balke, N. and M. Wynne. 1996. "Supply Shocks and the Distribution of Price Changes." Federal Reserve Bank of Dallas. *Economic Review* Q1: 10–18.

———. 2000. "An Equilibrium Analysis of Relative Price Changes and Aggregate Inflation." *Journal of Monetary Economics* (45)2: 269–92.

———. 2003. "The Relative Price Effects of Monetary Shocks." Federal Reserve Bank of Dallas Working Paper No. 0306.

Ball, L. and N. Mankiw. 1994. "Asymmetric Price Adjustment and Economic Fluctuations." *Economic Journal* 104(423): 247–61.

———. 1995. "Relative-Price Changes as Aggregate Supply Shocks." *Quarterly Journal of Economics* 110(1): 161–93.

Bank of Canada. 1991a. "Targets for Reducing Inflation: Announcements and Background Material." *Bank of Canada Review* (March): 3–21.

Bank of Canada. 1991b. "Targets for Reducing Inflation: Further Operational and Measurement Considerations." *Bank of Canada Review* (September): 3–23.

———. 2001. "Renewal of the Inflation-Control Target: Background Information." Bank of Canada Press Release (May).

———. 2003a. *Monetary Policy Report* (April).

———. 2003b. *Monetary Policy Report* (October).

Benati, L. and G. Kapetanios. 2002. "Structural Breaks in Inflation Dynamics." Bank of England. Photocopy.

Bera, A. and C. Jarque. 1981. "An Efficient Large-Sample Test for Normality of Observations and Regression Residuals." Working papers in Economics and Econometrics No. 40, Australian National University.

Bilke, L. 2004. "Break in the Mean and Persistence of Inflation: A Sectoral Analysis of French CPI." Presented at the European Central Bank conference, "Inflation Persistence in the Euro Area," Frankfurt am Main 10–11 December.

Bjørnland, H. 1997. "Estimating Core Inflation: The Role of Oil Price Shocks and Imported Inflation." Discussion Paper No. 200. Research Department, Statistics Norway.

Blinder, A. 1997. "Commentary." Federal Reserve Bank of St. Louis *Review* (May-June): 157–60.

Blix, M. 1995. "Underlying Inflation—A Common Trends Approach." Working Paper No. 23. Sveriges Riksbank.

Bryan, M. 1997. "On the Origin and Evolution of the Word *Inflation*." Federal Reserve Bank of Cleveland *Economic Commentary* (October).

Bryan, M. and S. Cecchetti. 1993a. "The Consumer Price Index as a Measure of Inflation." Federal Reserve Bank of Cleveland *Economic Review* 29(4): 15–24.

———. 1993b. "Measuring Core Inflation." NBER Working Paper No. 4303.

———. 1996. "Inflation and the Distributions of Price Changes." NBER Working Paper No. 5793.

Bryan, M., S. Cecchetti, and R. Wiggins II. 1997. "Efficient Inflation Estimation." NBER Working Paper No. 6183.

Bryan, M. and C. Pike. 1991. "Median Price Changes: An Alternative Approach to Measuring Current Monetary Inflation." Federal Reserve Bank of Cleveland *Economic Commentary (*December).

Cecchetti, S. 1997a. "Measuring Short-Run Inflation for Central Bankers." Federal Reserve Bank of St. Louis *Review* (May-June) 79(3): 143–55.

———. 1997b. "Central Bank Policy Rules: Conceptual Issues and Practical Considerations." NBER Working Paper No. 6306.

Cecchetti, S. and G. Debelle. 2004. "Has the Inflation Process Changed?" Paper prepared for the third BIS annual conference, "Understanding Low Inflation and Deflation," Brunnen Switerland, 18–19 June.

Clark, T. 2001. "Comparing Measures of Core Inflation." Federal Reserve Bank of Kansas City *Economic Review* 86(2): 5–31.

———. 2003 "Disaggregate Evidence on the Persistence of Consumer Price Inflation." Federal Reserve Bank of Kansas City Research Working Paper No. 03–11.

Claus, I. 1997. "A Measure of Underlying Inflation in the United States." Bank of Canada Working Paper No. 97–20.

Clements, M. and D. Hendry (eds.). 2002. *A Companion to Economic Forecasting*. Malden, MA: Blackwell.

Cogley, T. 2002. "A Simple Adaptive Measure of Core Inflation." *Journal of Money, Credit, and Banking* 34(1): 94–113.

Crawford, A., J-F Fillion, and T. Laflèche. 1998. "Is the CPI a Suitable Measure for Defining Price Stability?" In *Price Stability, Inflation Targets, and Monetary Policy.* Proceedings of a conference held by the Bank of Canada, 3–4 May.

Cutler, J. 2001. "Core Inflation in the UK." Bank of England Discussion Paper No. 3.

Demers, F. 2003. "The Canadian Phillips Curve and Regime Shifting." Bank of Canada Working Paper No. 32.

Devereux, M. and H. Siu. 2003. "State Dependent Pricing and Business Cycle Asymmetries." University of British Columbia. Photocopy.

Dewachter, H. and H. Lustig. 1997. “A Cross-Country Comparison of CPI as a Measure of Inflation.” Center for Economics Studies, Catholic University of Leuven, Discussion Paper No. 6.

Diebold, F. and R. Mariano. 1995. “Comparing Predictive Accuracy.” *Journal of Business and Economic Statistics* 13(3): 253–63.

Dixon, R. and G. Lim. 2005. “Underlying Inflation in Australia: Are the Existing Measures Satisfactory?” *Economic Record* 80(251): 373–86.

Duguay, P. 2004. “Wrap-up Discussion.” In *The Future of Inflation Targeting*, 284–89, edited by C. Kent and S. Guttmann. Reserve Bank of Australia.

Eckstein, O. 1981. *Core Inflation*. Englewood-Cliffs, NJ: Prentice-Hall.

Eichenbaum, M. and J. Fisher. 2003. “Testing the Calvo Model of Sticky Prices.” Federal Reserve Bank of Chicago *Economic Perspectives* 27(2): 40–53.

Fase, M. and C. Folkertsma. 1997. “Measuring Inflation: An Attempt to Operationalize Carl Menger’s Concept of the Inner Value of Money.” De Nederlandsche Bank Working Paper No. 8.

Folkertsma, C. and K. Hubrich. 2000. “Performance of Core Inflation Measures.” De Nederlandsche Bank Working Paper No. 63.

Freeman, D. 1998. “Do Core Inflation Measures Help Forecast Inflation?” *Economics Letters* 58(2): 143–47.

Friedman, M. 1969. *The Optimum Quantity of Money and Other Essays*. Chicago: Aldine Publishing Company.

Gartner, C. and G. Wehinger. 1998. “Core Inflation in Selected European Union Countries.” In *Topics in Monetary Policy Modelling*. Bank for International Settlements Conference Papers, vol. 6.

Granger, C. 1980. “Long Memory Relationships and the Aggregation of Aggregate Dynamic Models.” *Journal of Econometrics* 14(2): 227–38.

Hansen, L. and R. Hodrick. 1980. “Forward Exchange Rates as Optimal Predictors of Future Spot Rates: An Econometric Analysis.” *Journal of Political Economy* 88(5): 829–53.

Heath, A., I. Roberts, and T. Bulman. 2004. "Inflation in Australia: Measurement and Modelling." In *The Future of Inflation Targeting*, 167–207, edited by C. Kent and S. Guttmann. Sydney: Reserve Bank of Australia.

Hill, R. 2004. "Inflation Measurement for Central Bankers." In *The Future of Inflation Targeting*, 140–60, edited by C. Kent and S. Guttmann. Sydney: Reserve Bank of Australia.

Hogan, S. 1998. "Core Inflation as an Intermediate Target and Indicator." Paper presented at the Centre for Central Banking Studies (CCSB) Bank of England Workshop, Bank of Canada, Ottawa (September).

Hogan, S., M. Johnson, and T. Laflèche. 2001. *Core Inflation*. Technical Report No. 89. Ottawa: Bank of Canada.

Hooker, M. 1999. "Are Oil Shocks Inflationary?: Asymmetric and Nonlinear Specifications versus Changes in Regimes." Federal Reserve Board Working Paper.

Humpage, O. and E. Pelz. 2002. "Do Energy-Price Shocks Affect Core-Price Measures?" Federal Reserve Board of Cleveland Working Paper No. 02-15.

Issing, O. (editor). 2003. *Background Studies for the ECB's Evaluation of Its Monetary Policy Strategy*. Frankfurt: European Central Bank.

Kearns, J. 1998. "The Distribution and Measurement of Inflation." Reserve Bank of Australia Research Discussion Paper No. 9810.

Kozicki, S. and P. Tinsley. 2002 "Alternative Sources of the Lag Dynamics of Inflation." Federal Reserve Bank of Kansas City Working Paper No. 02-12.

Laflèche, T. 1997a. "Mesures du taux d'inflation tendanciel." Bank of Canada Working Paper No. 97-9.

———. 1997b. "Statistical Measures of the Trend Rate of Inflation." *Bank of Canada Review* (Autumn): 29–47.

Laidler, D. and S. Aba. 2000. "It's Time to Ignore Core Inflation." C.D. Howe Institute Backgrounder.

Levin, A. and J. Piger. 2002. "Is Inflation Persistence Intrinsic in Industrial Economics?" Federal Reserve Bank of St. Louis Working Paper No. 2002-23E.

Longworth, D. 2002. “Inflation and the Macroeconomy: Changes from the 1980s to the 1990s.” *Bank of Canada Review* (Spring): 3–18.

Macklem, T. 2001. “A New Measure of Core Inflation.” *Bank of Canada Review* (Autumn): 3–12.

Mankiw, N. and R. Reis. 2003. “What Measure of Inflation Should a Central Bank Target?” *Journal of the European Economic Association* 1(5): 1058–86.

Mankikar, A. and J. Paisley. 2002. “What Do Measures of Core Inflation Really Tell Us?” *Bank of England Quarterly Bulletin* 42(4): 373–83.

———. 2004. “Core Inflation: A Critical Guide.” Bank of England Working Paper No. 242.

Marques, C., P. Neves, and L. Sarmento. 2003. “Evaluating Core Inflation Indicators.” *Economic Modelling* 20: 765–75.

Marques, C., P. Neves, and A. Gonçalves da Silva. 2002. “Why Should Central Banks Avoid the Use of the Underlying Inflation Indicator?” *Economics Letters* 75(1): 17–23.

Nessén, M. and U. Söderström. 2001. “Core Inflation and Monetary Policy.” *International Finance* 4(3): 401–39.

Parkin, M. 1984. “On Core Inflation by Otto Eckstein.” *Journal of Monetary Economics* 14(2): 251–64.

Quah, D. and S. Vahey. 1995. “Measuring Core Inflation.” *The Economic Journal* 105(432): 1130–44.

Ricketts, N. and D. Rose. 1995. “Inflation, Learning and Monetary Policy Regimes in the G-7 Economies.” Bank of Canada Working Paper No. 95-6.

Roger, S. 1995. “Measures of Underlying Inflation in New Zealand, 1981-95.” Discussion Paper No. G95/5. Wellington: Reserve Bank of New Zealand.

———. 1997. “A Robust Measure of Core Inflation in New Zealand, 1949–96.” Discussion Paper No. G97/7. Wellington: Reserve Bank of New Zealand.

———. 1998. “Core Inflation: Concepts, Uses and Measurement.” Discussion Paper No. G98/9. Wellington: Reserve Bank of New Zealand.

———. 2000. “Relative Prices, Inflation and Core Inflation.” International Monetary Fund Working Paper No. 00-58.

Rowe, N. and J. Yetman. 2000. “Identifying Policy-Makers’ Objectives: An Application to the Bank of Canada.” Bank of Canada Working Paper No. 2000-11.

St-Amant, P. and D. Tessier. 1998. “Résultats empiriques multi-pays relatifs à l’impact des cibles d’inflation sur la crédibilité de la politique monétaire.” Bank of Canada Working Paper No. 98-23.

Shiratsuka, S. 1997. “Inflation Measures for Monetary Policy: Measuring the Underlying Inflation Trend and Its Implications for Monetary Policy Implementation.” *Monetary and Economic Studies* 15(2): 1–26.

Smith, J. 2003a. “Monetary Regimes and Core Inflation.” Trinity University. Photocopy.

———. 2003b. “Better Measures of Core Inflation?” Trinity University. Photocopy.

———. 2004. “Weighted Median Inflation: Is This Core Inflation?” *Journal of Money, Credit and Banking* 36(2): 253–63.

Statistics Canada. 1995. *The Consumer Price Index Reference Paper: Update Based on 1992 Expenditures.* Ottawa: Statistics Canada.

Stuber, G. 2001. “The Changing Effects of Energy-Price Shocks on Economic Activity and Inflation.” *Bank of Canada Review* (Summer): 3–14.

Svensson, L. 1997. “Inflation Forecast Targeting: Implementing and Monitoring Inflation Targets.” *European Economic Review* 41(6): 1111–46.

Taylor, J. (ed.) 1999. *Monetary Policy Rules*. Chicago: University of Chicago Press.

Vega, J.-L. and M. Wynne. 2002. “A First Assessment of Some Measures of Core Inflation for the Euro Era.” Federal Reserve Bank of Dallas Working Paper No. 0205.

Wynne, M. 1999. “Core Inflation: A Review of Some Conceptual Issues.” European Central Bank Working Paper No. 5.

Table 1: Core Inflation Measures: Growth over 12 Months (sample 1986m1 to 1991m1)

	Mean	Standard deviation	Variability (stddev/ mean)	Mean absolute change
CPIxT	3.84	0.57	0.15	0.20
CPIxFET	4.27	0.44	0.10	0.18
Wmedian	4.31	0.52	0.12	0.19
CPIX	4.17	0.56	0.14	0.17
CPIW	4.42	0.33	0.07	0.10
Meanstd	4.44	0.64	0.14	0.24
Cutler1	5.49	0.31	0.06	0.15
Cutler2	5.14	0.56	0.11	0.15
CPIX excluding electricity	4.09	0.55	0.13	0.17
CPIX excluding auto insurance	3.90	0.52	0.13	0.17

Table 2: Core Inflation Measures: Growth over 12 Months (sample 1991m2 to 2004m1)

	Mean	Standard deviation	Variability (stddev/ mean)	Mean absolute change
CPIxT	1.89	0.89	0.47	0.28
CPIxFET	1.85	0.67	0.36	0.18
Wmedian	1.70	0.60	0.35	0.21
CPIX	1.91	0.50	0.26	0.17
CPIW	1.88	0.62	0.33	0.14
Meanstd	1.77	0.63	0.36	0.23
Cutler1	2.31	1.07	0.46	0.15
Cutler2	1.93	1.12	0.58	0.16
CPIX excluding electricity	1.89	0.48	0.25	0.15
CPIX excluding auto insurance	1.75	0.45	0.25	0.17

Table 3: Core Inflation Measures: Growth over 12 Months
(sample 1998m8 to 2004m1)

	Mean	Standard deviation	Variability (stddev/ mean)	Mean absolute change
CPIxT	2.13	0.95	0.45	0.37
CPIxFET	1.79	0.55	0.31	0.16
Wmedian	1.65	0.44	0.26	0.19
CPIX	1.80	0.57	0.31	0.19
CPIW	1.87	0.43	0.23	0.17
Meanstd	1.67	0.43	0.26	0.22
Cutler1	2.37	0.69	0.29	0.14
Cutler2	1.99	0.66	0.33	0.15
CPIX excluding electricity	1.81	0.56	0.31	0.15
CPIX excluding auto insurance	1.61	0.45	0.28	0.21

Table 4: Root-Mean-Squared Error and Mean-Absolute Deviation (sample 1987m7 to 2002m7)

Core	RMSE[a]	MAD[b]
Wmean	0.64	0.55
CPIxFET	0.55	0.45
Wmedian	0.55	0.44
CPIX	0.59	0.50
CPIW	0.43	0.36
Meanstd	0.60	0.51
Cutler1	0.81	0.64
Cutler2	0.83	0.66
CPIX excluding electricity	0.64	0.53
CPIX excluding auto insurance	0.59	0.49

a. Root-mean-squared error: $RMSE = \sqrt{\left(\frac{1}{n}\right)\sum_{i=1}^{n}(core_i - ma_i)^2}$

b. Mean-absolute deviation: $MAD = \left(\frac{1}{n}\right)\sum_{i=1}^{n}|core_i - ma_i|$

Table 5: Root-Mean-Squared Error and Mean-Absolute Deviation (sample 1993m6 to 2002m7)

Core	RMSE	MAD
Wmean	0.61	0.51
CPIxFET	0.56	0.45
Wmedian	0.54	0.43
CPIX	0.55	0.46
CPIW	0.43	0.37
Meanstd	0.55	0.47
Cutler1	0.50	0.38
Cutler2	0.74	0.60
CPIX excluding electricity	0.57	0.47
CPIX excluding auto insurance	0.51	0.40

Table 6: Root-Mean-Squared Error and Mean-Absolute Deviation (sample 1998m8 to 2002m7)

Core	RMSE	MAD
Wmean	0.70	0.56
CPIxFET	0.70	0.63
Wmedian	0.69	0.57
CPIX	0.68	0.59
CPIW	0.53	0.47
Meanstd	0.64	0.54
Cutler1	0.30	0.24
Cutler2	0.55	0.51
CPIX excluding electricity	0.69	0.61
CPIX excluding auto insurance	0.68	0.59

Table 7: Correlation of Core Measures with Future CPIxT Inflation (sample 1992m1 to 2004m1)

	CPIxT[t]	CPIxT[t+6]	CPIxT[t+12]	CPIxT[t+18]	CPIxT[t+24]
CPIxT	1.00	0.33	-0.21	0.06	0.09
CPIxFET	0.65	0.18	-0.23	0.02	-0.07
Wmedian	0.42	-0.04	-0.27	0.12	0.23
CPIX	0.46	-0.05	-0.34	-0.06	-0.19
CPIW	0.65	0.10	-0.22	0.10	0.00
Meanstd	0.52	-0.04	-0.38	0.14	0.18
Cutler1	0.33	0.07	-0.09	0.03	-0.06
Cutler2	0.42	0.12	-0.11	0.05	0.00

Table 8: Regressions: Six Months Ahead[a] (sample 1992m1 to 2003m7)

CPI[t+6]	CPIxFET	Wmedian	CPIX	CPIW	Meanstd	Cutler1	Cutler2	CPIX excluding electricity	CPIX excluding auto insurance
$\bar{R}^2$	0.19	0.18	0.14	0.21	0.14	0.11	0.08	0.11	0.17
s.e.e.	0.82	0.83	0.85	0.81	0.85	0.87	0.88	0.87	0.84
α (s.e.)	0.08 (0.10)	0.14 (0.12)	0.01 (0.13)	0.06 (0.11)	0.10 (0.12)	-0.06 (0.15)	0.07 (0.07)	0.01 (0.13)	0.08 (0.12)
β (s.e.)	0.67* (0.37)	0.53** (0.26)	0.48 (0.34)	0.67** (0.33)	0.51* (0.27)	0.35 (0.21)	0.32 (0.25)	0.46 (0.34)	0.51* (0.25)
p-value H_0: (β=1, α=0)	0.60	0.04	0.16	0.59	0.06	0.00	0.02	0.16	0.12

a. * indicates significance at 10 per cent level and ** indicates significance at 5 per cent level. Standard errors are corrected for serial correlation.

Table 9: Regressions: Twelve Months Ahead
(sample 1992m1 to 2003m1)

CPI[t+12]	CPIxFET	Wmedian	CPIX	CPIW	Meanstd	Cutler1	Cutler2	CPIX excluding electricity	CPIX excluding auto insurance
$\bar{R}^2$	0.34	0.33	0.28	0.41	0.25	0.23	0.17	0.26	0.36
s.e.e.	0.98	0.99	1.02	0.93	1.04	1.05	1.10	1.04	0.96
α (s.e.)	0.18 (0.20)	0.26 (0.19)	0.04 (0.25)	0.12 (0.22)	0.17 (0.20)	-0.07 (0.24)	0.18 (0.17)	0.05 (0.24)	0.14 (0.23)
β (s.e.)	1.13** (0.38)	0.99** (0.38)	0.89** (0.41)	1.23** (0.41)	0.98** (0.40)	0.64** (0.29)	0.57* (0.34)	0.90** (0.43)	1.03** (0.38)
p-value H_0 : (β=1, α=0)	0.58	0.40	0.96	0.64	0.68	0.19	0.33	0.96	0.79

Table 10: Regressions: Eighteen Months Ahead
(sample 1992m1 to 2002m7)

CPI[t+18]	CPIxFET	Wmedian	CPIX	CPIW	Meanstd	Cutler1	Cutler2	CPIX excluding electricity	CPIX excluding auto insurance
$\bar{R}^2$	0.30	0.33	0.27	0.37	0.32	0.23	0.18	0.26	0.35
s.e.e.	0.88	0.85	0.89	0.83	0.86	0.92	0.95	0.90	0.84
α (s.e.)	0.22 (0.23)	0.28 (0.19)	0.10 (0.23)	0.17 (0.20)	0.18 (0.20)	0.03 (0.16)	0.24 (0.18)	0.11 (0.24)	0.16 (0.23)
β (s.e.)	0.92** (0.14)	0.91** (0.16)	0.76** (0.08)	1.03** (0.19)	1.04** (0.14)	0.55** (0.19)	0.51** (0.21)	0.78** (0.09)	0.93** (0.10)
p-value H_0 : (β=1, α=0)	0.44	0.17	0.02	0.70	0.64	0.06	0.00	0.04	0.64

Figure 1: Variables Experiencing Large Shocks (sample 1986m1 to 2004m1)
Year-over-Year Growth Rates

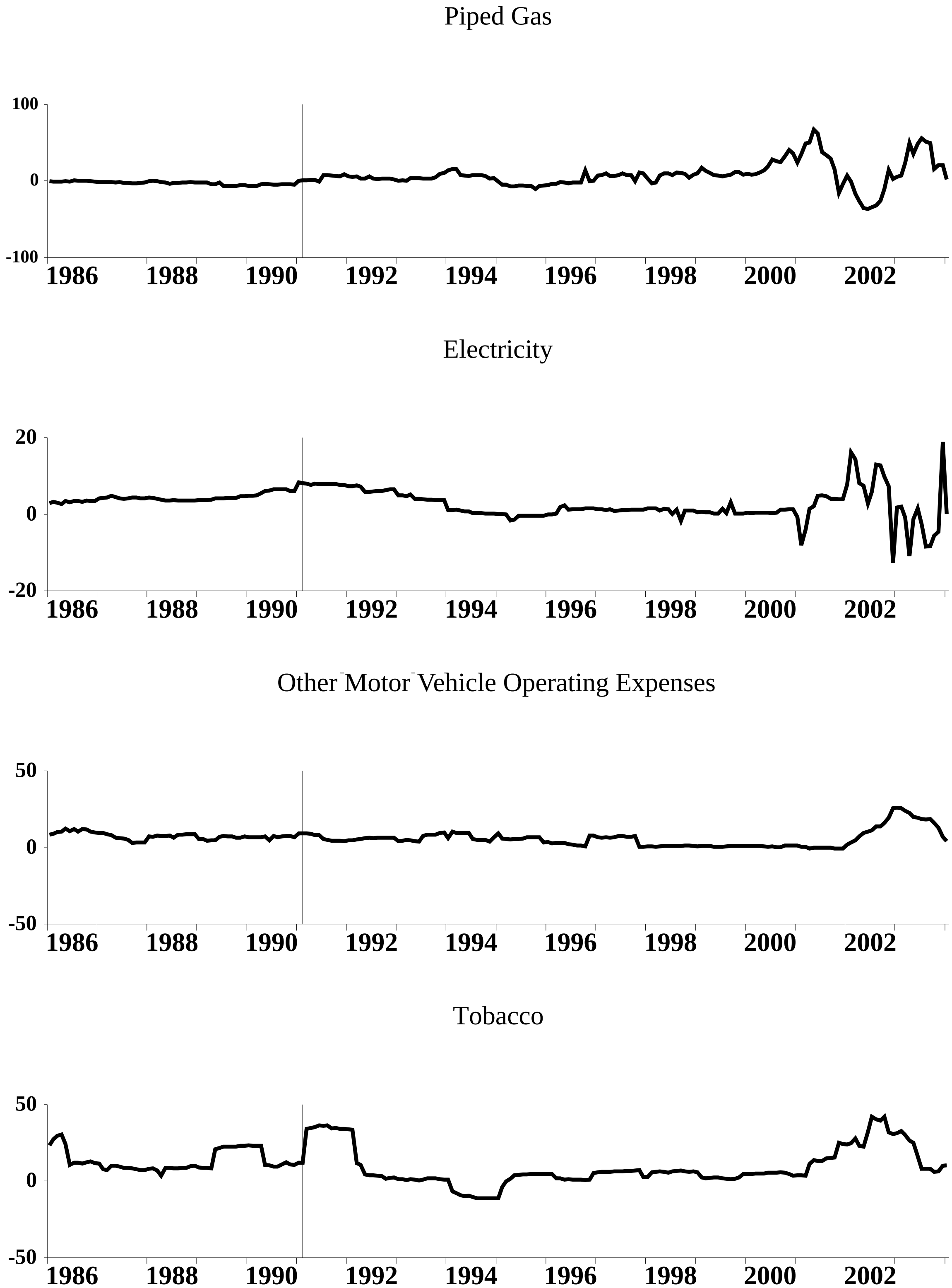


Figure 2: Year-over-Year Growth of CPIXFET and CPIxT (sample 1986m1 to 2004m1)

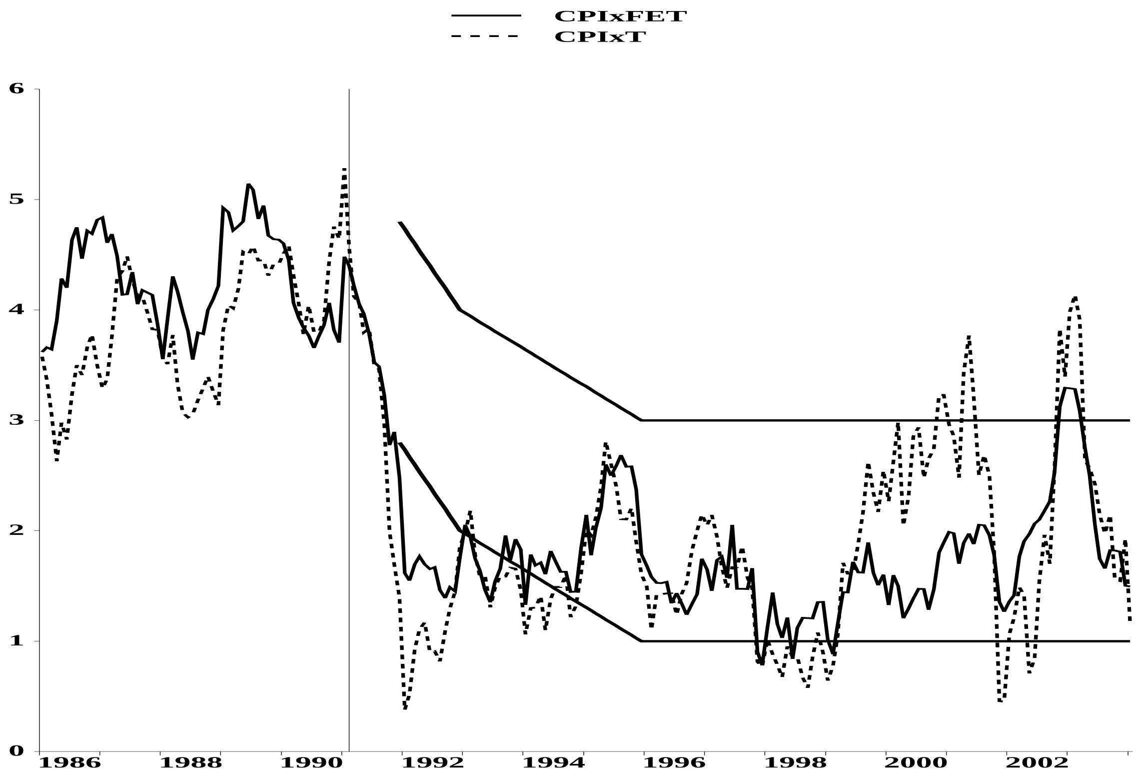


Figure 3: Year-over-Year Growth of CPIX and CPIxT (sample 1986m1 to 2004m1)

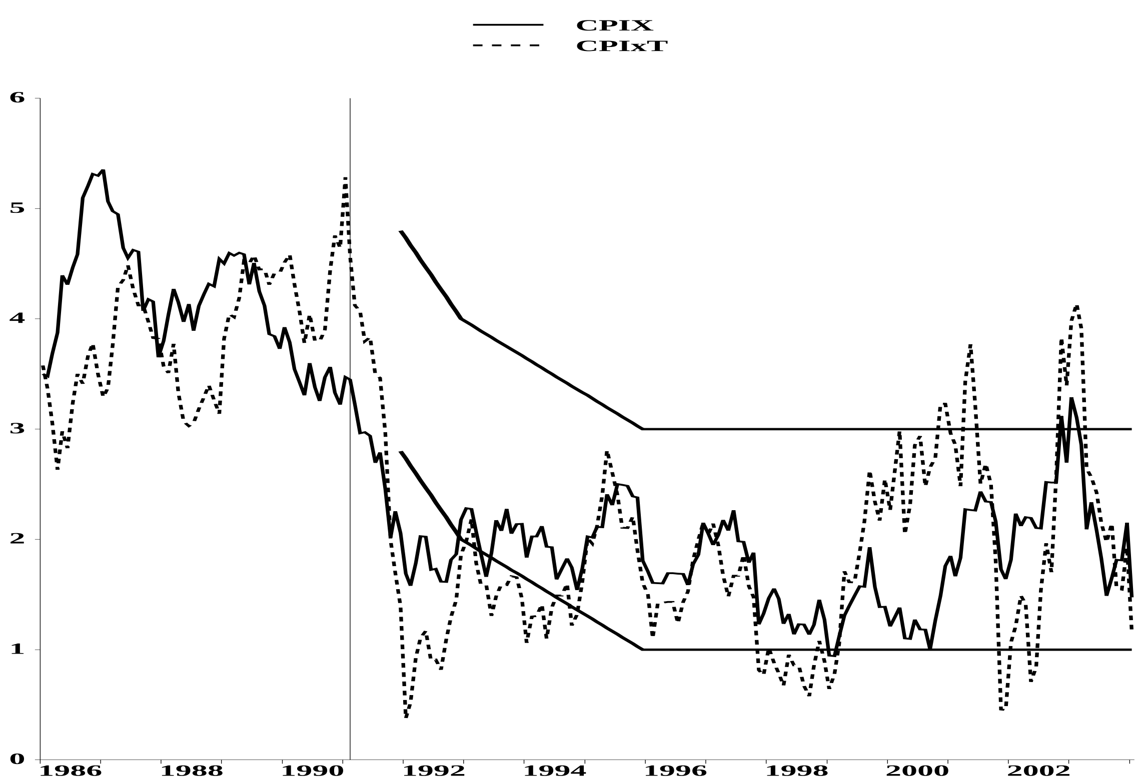


Figure 4: Year-over-Year Growth of CPIW and CPIxT (sample 1986m1 to 2004m1)

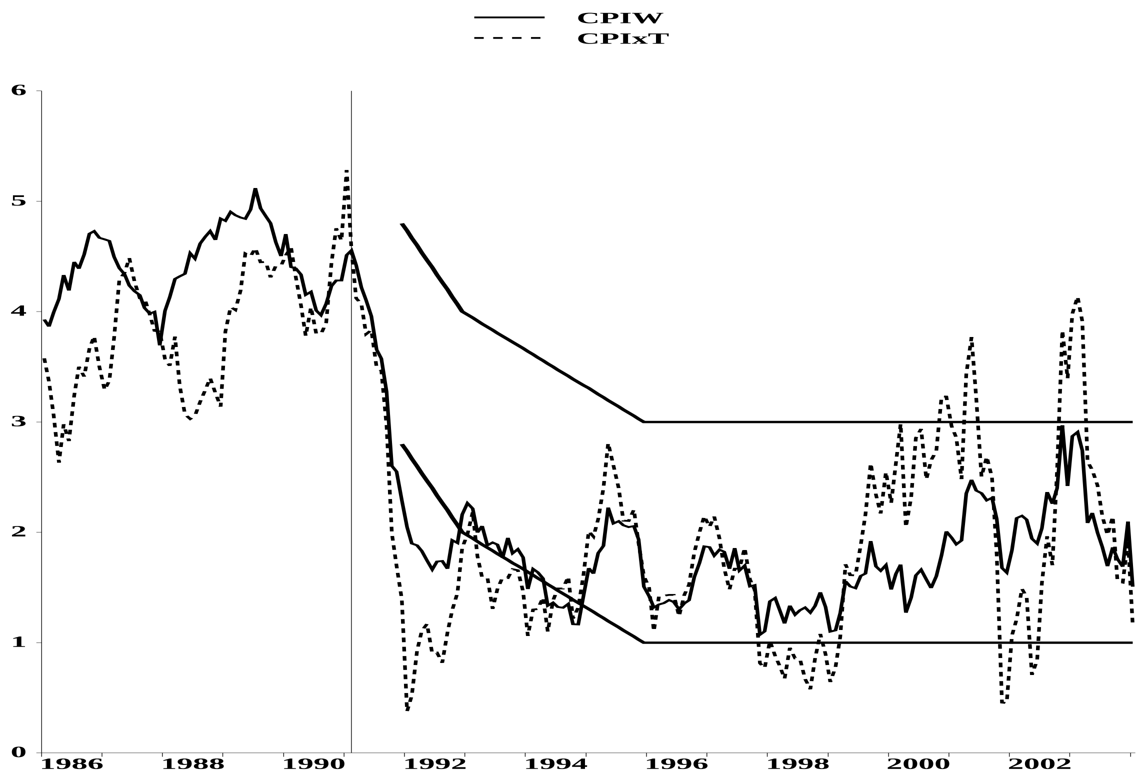


Figure 5: Year-over-Year Growth of Wmedian and CPIxT (sample 1986m1 to 2004m1)

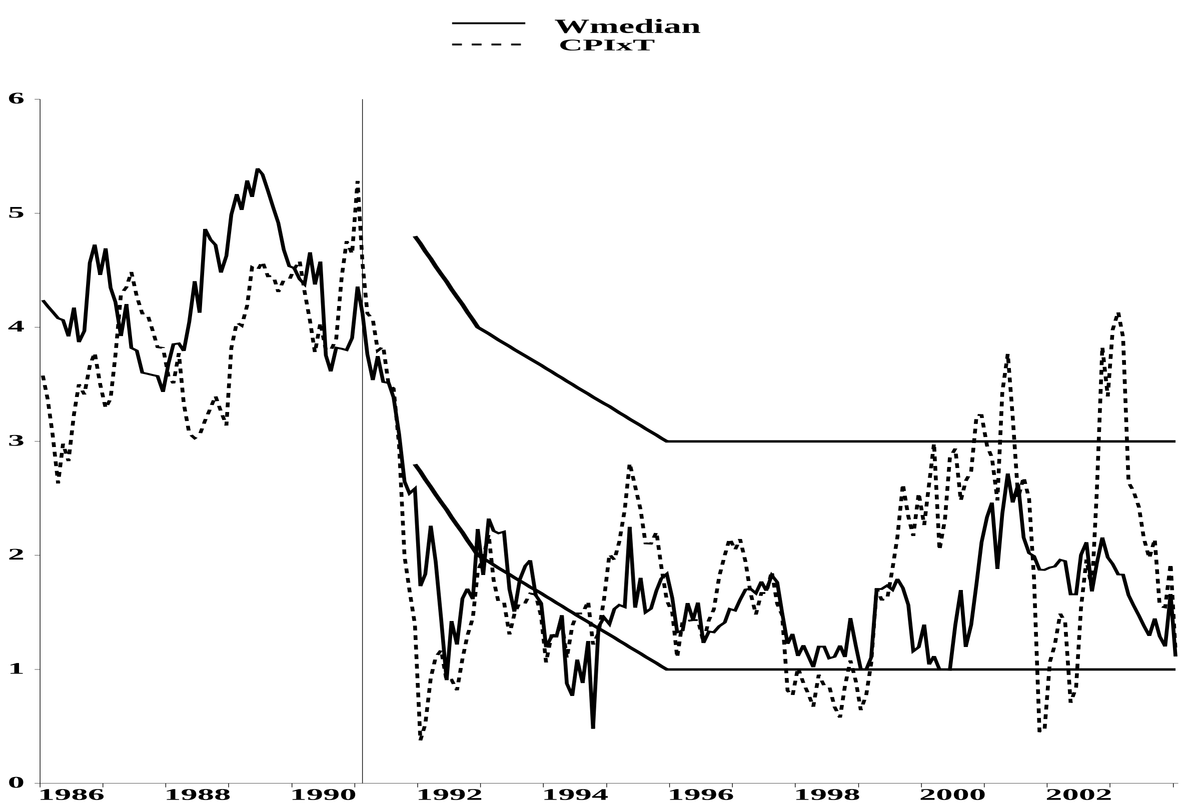


Figure 6: Year-over-Year Growth of Meanstd and CPIxT (sample 1986m1 to 2004m1)

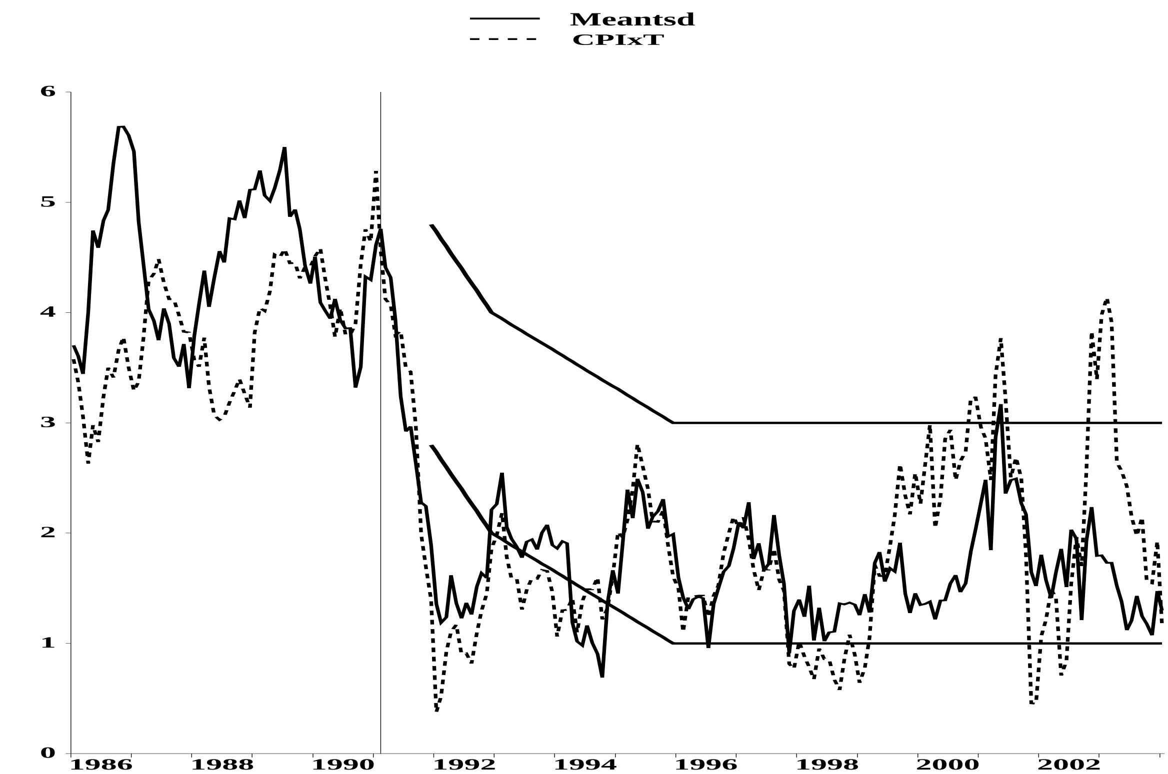


Figure 7: Year-over-Year Growth of Cutler Measures and CPIxT (sample 1986m1 to 2004m1)

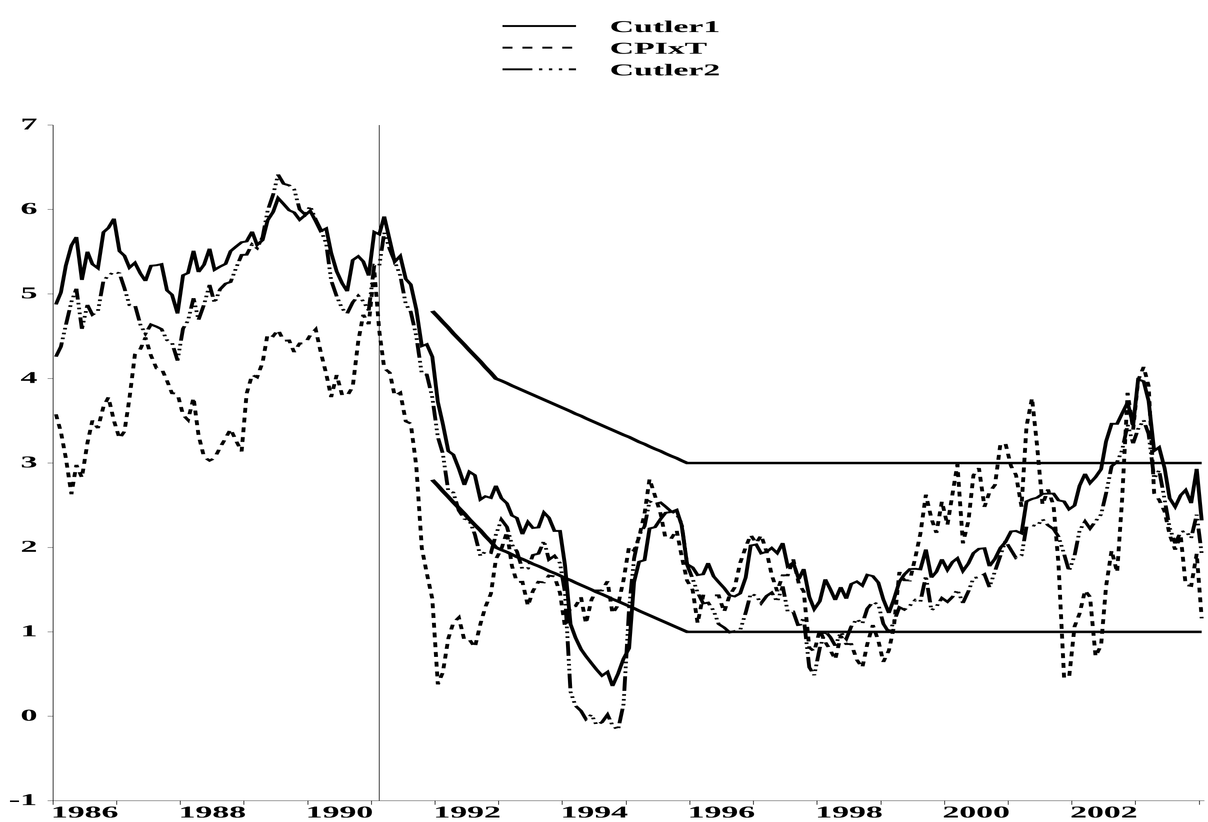


Figure 8: Moving Average of Weighted Mean (sample 1986m1 to 2004m1)

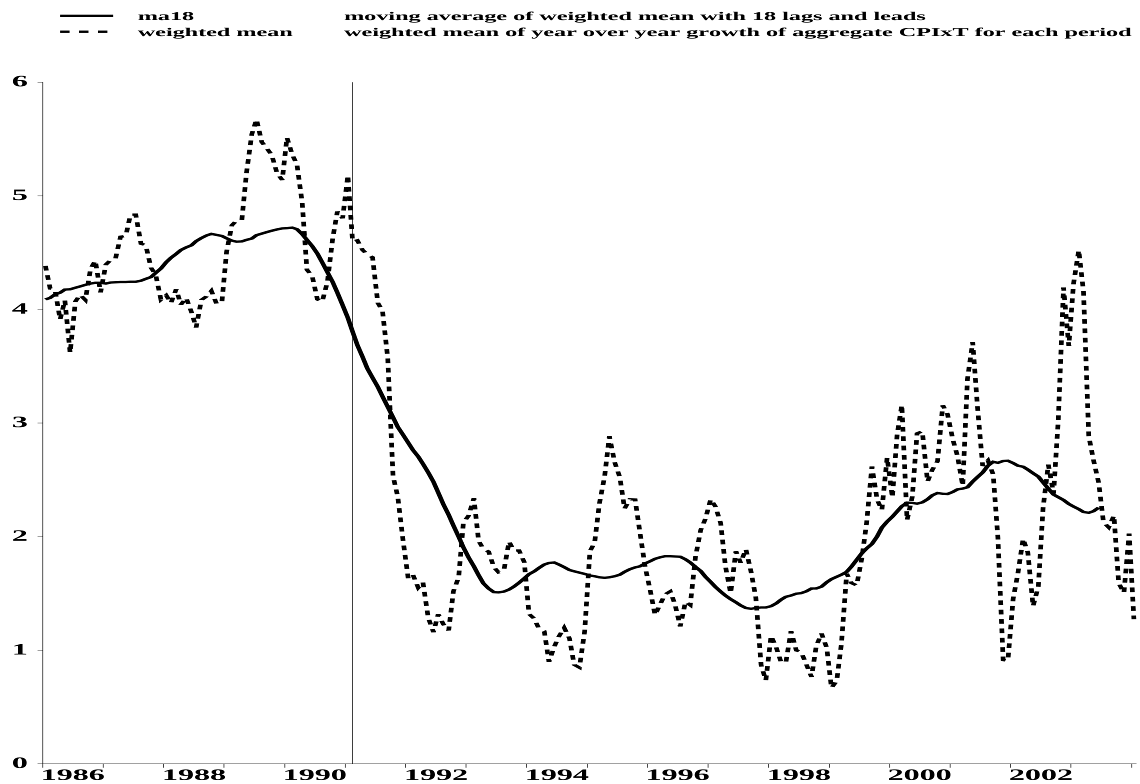
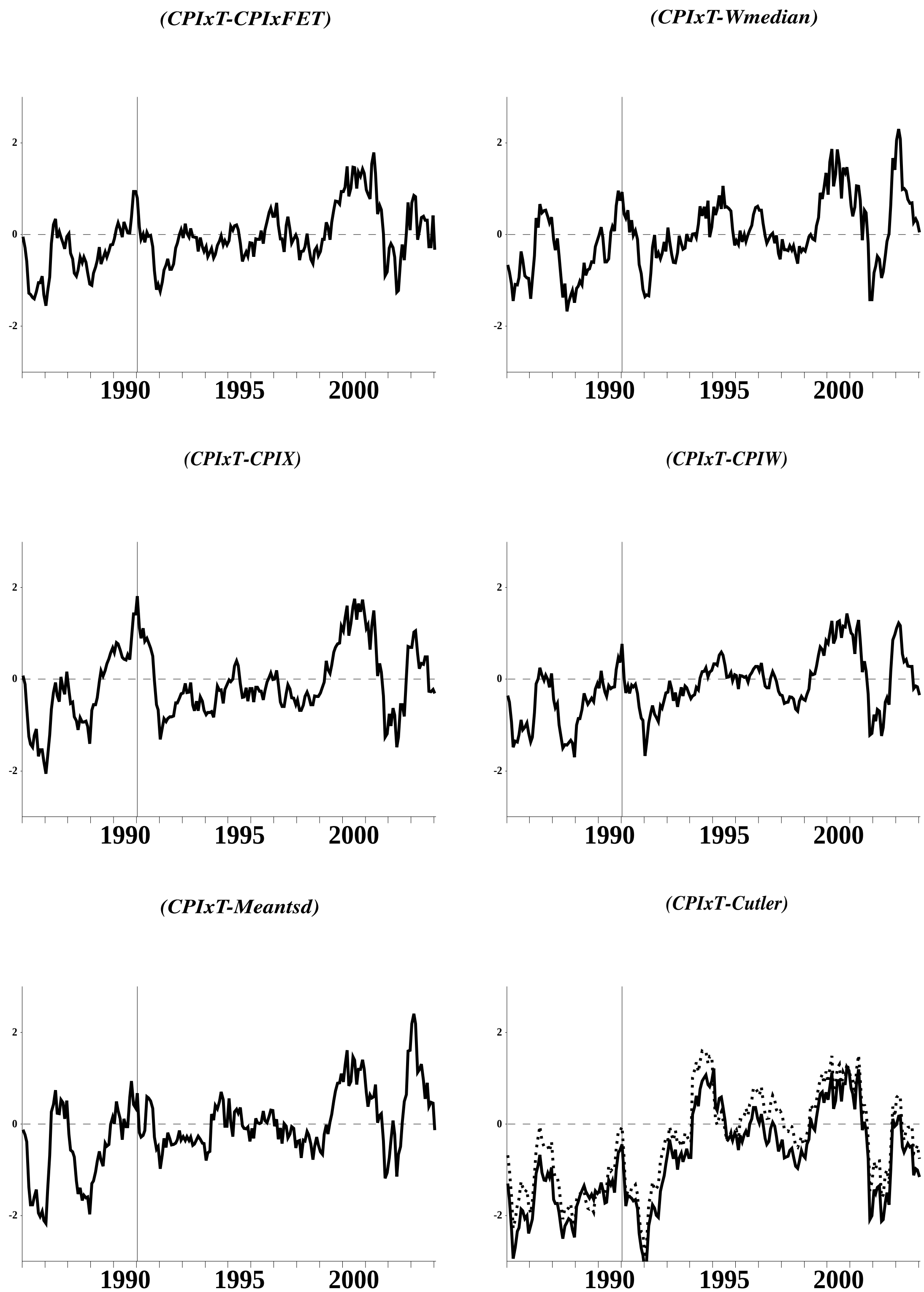


Figure 9: CPIxT minus Core Measure (sample 1986m1 to 2004m1)



Appendix A: Implications and Evidence of Non-Normality

The third and fourth moments of a distribution, measured by the coefficient of skewness and kurtosis, provide information on the shape of this distribution. A non-zero (positive) coefficient of skewness indicates that more of the distribution is on one (the right) side of the distribution. Kurtosis measures the thickness of the tails of the distribution. It has long been known that if a distribution is approximately normal, then the sample mean is an unbiased and efficient estimator of the population mean. However, the efficiency of this estimator, measured by its variance, is sensitive to kurtosis. Leptokurtosis, or fat tails in the distribution, causes the mean to be a less efficient and less robust estimator of the population mean than an order statistic such as the median. On the other hand, skewness causes the median to be a biased measure of the population mean.

Higher moments of the distribution of price changes have implications for both the construction and ranking of core inflation measures. Previous work has found skewness and kurtosis in the distributions of price changes for many countries, including Canada, the United States, New Zealand, and the United Kingdom, as well as the euro area. Therefore, it is important to re-examine the higher moments for Canadian price changes over the more recent sample period. Figures A1 to A5 show the mean and median of inflation as well as the skewness and kurtosis of the cross-sectional distributions of price changes for various inflation horizons. HJL provides a detailed discussion of how these were calculated. Table A1 shows the mean and standard deviation for both skewness and kurtosis for inflation calculated at different horizons.[1] Table A3 also examines the moments for two subsamples. Four main points are worth highlighting:

- Kurtosis at all horizons is over 3, the level for a normal distribution. Therefore, we can consider the weighted median or other order statistics as more efficient estimators of the underlying population mean and, by extension, as prospective measures of core inflation, since they should be less influenced by the many price changes in the tails of the distribution.

1. Although the discussion in this section focuses on the weighted moments, the unweighted moments were also calculated, and they are shown in Table A2. Both methods of calculating skewness and kurtosis suggest similar conclusions.

- There is positive skewness at all horizons. Furthermore, as the horizon lengthens, so does the skewness, and therefore the potential bias, between the weighted mean and the weighted median.[2] At the top of each of Figures A1 to A5, we graph the weighted mean and the weighted median of the Canadian data to emphasize the problem that might be created by skewness. For the month-over-month data, the weighted median seems to capture the central tendency of the data. This also appears to be the case for the 3-month-over-3-month changes in the CPI. However, for the 12-month-over-12-month and the 24-month-over-24-month cases, the weighted median is increasingly below the weighted mean after 1999. In the 36-month-over-36-month case, the weighted median consistently underpredicts the weighted mean. This demonstrates how it might be misleading to focus on a weighted median in the presence of skewness.

- Although skewness and kurtosis for the monthly and quarterly horizons are in general quite high, they show no large increase in recent years. As HJL discussed, seasonality likely plays the most important role at these high frequencies.

- In contrast, for the 12-, 24-, and 36-month horizons, those at which seasonality does not play an important role, both skewness and kurtosis increase substantially after 1998.

The above analysis highlights the importance of bias for various measures of trend inflation relative to total CPI inflation. Examining data for New Zealand, Roger (1997) finds that, although the median is the most robust estimator in the presence of kurtosis, it is also biased. Therefore, he calculated an alternative order statistic (the 57th percentile) that "reliably corrects for the asymmetry of the distribution, while maintaining its efficiency and robustness." The problem with this approach is that the percentile that corrects for the bias will depend on both the kurtosis and the skewness of the distribution and will therefore be time-varying. As shown here, there have been substantial changes to skewness and kurtosis since 1998.

This final point is worth investigating further. An interesting hypothesis is that the increases in higher moments at the longer horizons in recent years have their sources in the behaviour of energy (oil) and tobacco prices. As shown in Figure A6 and Table A4, recalculating the moments for only the 46 components in CPIX results in a cross-sectional distribution of CPIX that is much closer to being a normal distribution, at least at a 12-month frequency, than the

2. There is a trade-off between having larger maximum peaks in skewness and kurtosis at the shorter horizons of price changes, and smaller but more persistent skewness in the distribution at longer horizons of price changes, since shocks take longer to fall out of the price-change horizon.

distribution for total CPI.[3] This is not only true for the most recent period, but also for the early 1990s. These greatly reduced levels of skewness and kurtosis provide support for the present measure of core inflation, since it would be less affected by outlier price movements. There has been a recent increase in the higher moments for only the components in CPIX, but this increase is small compared with that for the entire distribution. This increase may originate from the peculiar behaviour of automobile insurance and electricity prices.

Although the above experiment may point towards the subcomponents that cause the non-normality, further theoretical research is needed to understand the behaviour of these prices. For instance, Ball and Mankiw (1995) argue that asymmetric shocks combined with menu costs can explain this type of behaviour, whereas Balke and Wynne (1996) suggest that asymmetric supply shocks combined with the input/output structure of the economy are the explanation. Another paper by Balke and Wynne (2003) shows that asymmetric responses to monetary policy shocks are another possible explanation. Unfortunately, we do not have a definitive theory for what causes the skewness and kurtosis in the Canadian data. Furthermore, while kurtosis will make order statistics, such as the weighted median, more efficient estimators of the population mean, skewness will cause these order statistics to be biased with respect to the sample mean of total inflation. Therefore, more theoretical and applied research should be done to help examine the causes of the non-normality and understand this trade-off.

3. Note that calculations excluding only four components were also done (i.e., the three energy components and tobacco). The results for the moments of these 50 components were very similar to the ones using only 46 components.

Table A1: Summary Statistics for Price-Change Distributions of Various Horizons (sample 1986m1 to 2004m1)

	M/M	3M/3M	12M/12M	24M/24M	36M/36M
	Weighted skewness				
Average	0.50	0.44	0.76	1.14	1.37
Standard deviation	3.09	2.68	1.95	1.47	1.28
	Weighted kurtosis				
Average	20.91	17.74	10.86	8.90	8.82
Standard deviation	14.34	12.27	8.89	6.86	6.51

Table A2: Summary Statistics for Price-Change Distributions Equally Weighted Price Changes (sample 1986m1 to 2004m1)

	M/M	3M/3M	12M/12M	24M/24M	36M/36M
	Skewness				
Average	0.39	0.35	0.71	1.00	1.21
Standard deviation	2.64	2.26	1.78	1.37	1.18
	Kurtosis				
Average	15.67	13.67	9.69	8.03	7.83
Standard deviation	8.59	6.74	6.39	5.51	5.35

Table A3: Summary Statistics for 12M/12M Price-Change Distributions

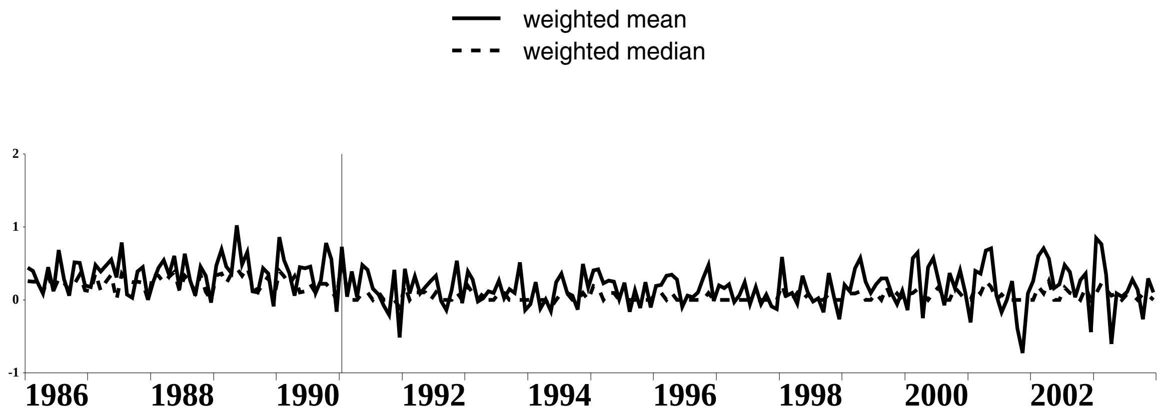
	1986m1 to 1991m1		1991m2 to 2004m1	
	Weighted mean			
Average	4.14		1.60	
Standard deviation	0.63		0.41	
	unweighted	weighted	unweighted	weighted
	Skewness			
Average	-0.23	-0.03	1.08	1.06
Standard deviation	1.69	1.83	1.68	1.91
	Kurtosis			
Average	8.46	8.97	10.17	11.60
Standard deviation	4.14	4.11	7.03	10.09

Table A4: Summary Statistics for Price-Change Distributions for CPIX (sample 1986m1 to 2004m1)

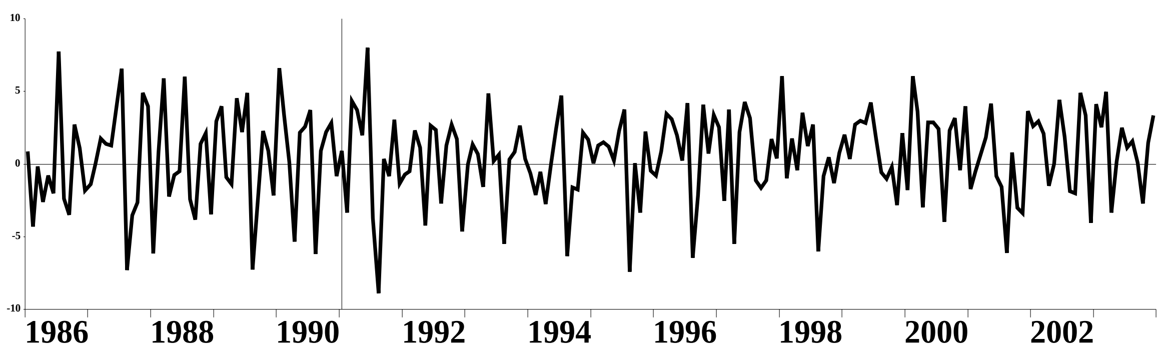
Average	M/M	3M/3M	12M/12M	24M/24M	36M/36M
Weighted skewness	0.90	0.75	0.39	0.40	0.43
Weighted kurtosis	14.03	12.01	5.40	5.13	5.02

Figure A1: Month-over-Month Changes

Weighted mean vs Weighted median
Month-over-month growth of CPI, monthly data
January 1986 to December 2003



Skewness over sample
Month-over-month growth of CPI, monthly data
January 1986 to December 2003



Kurtosis over sample
Month-over-month growth of CPI, monthly data
January 1986 to December 2003

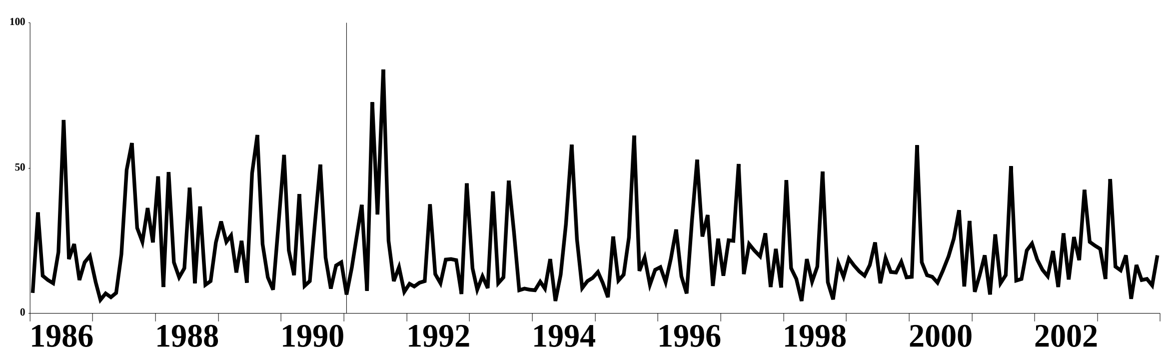
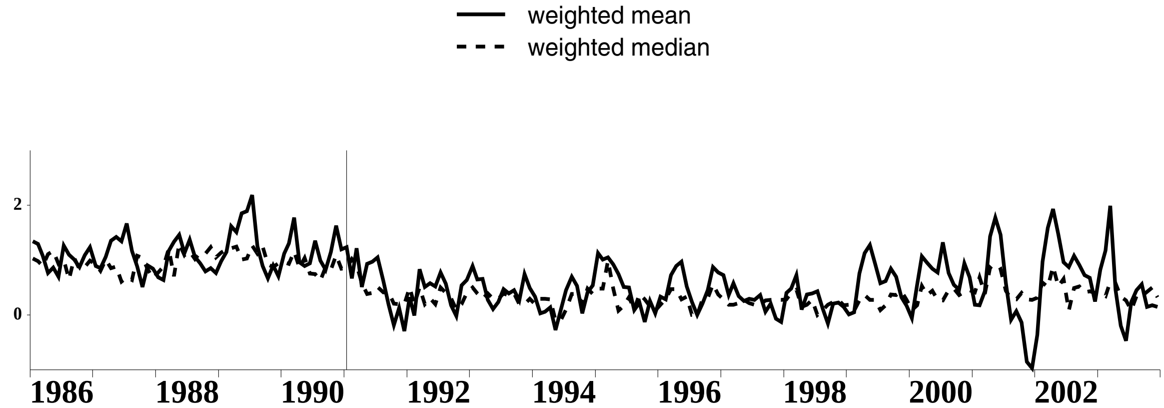
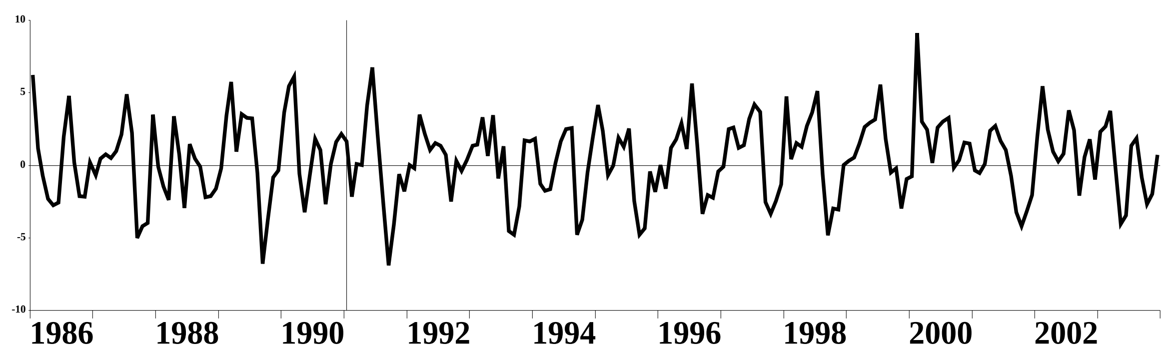


Figure A2: Quarter-over-Quarter Changes

Weighted mean vs Weighted median
Quarter-over-quarter growth of CPI, monthly data
January 1986 to December 2003



Skewness over sample
Quarter-over-quarter growth of CPI, monthly data
January 1986 to December 2003



Kurtosis over sample
Quarter-over-quarter growth of CPI, monthly data
January 1986 to December 2003

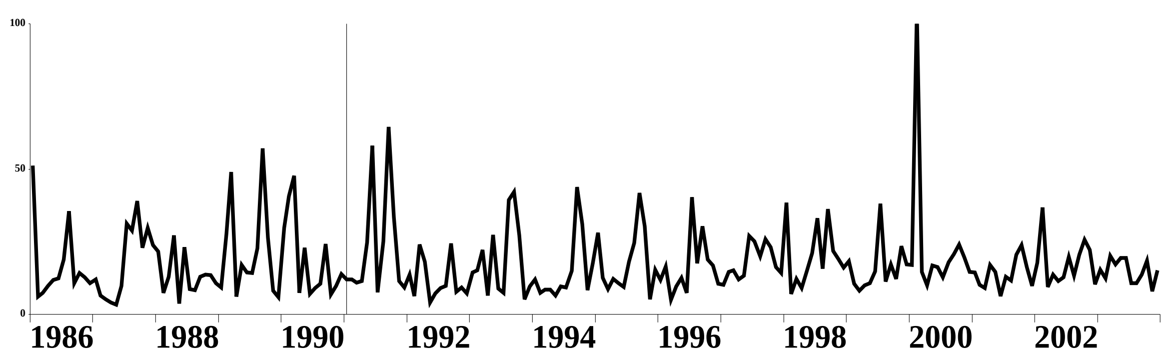
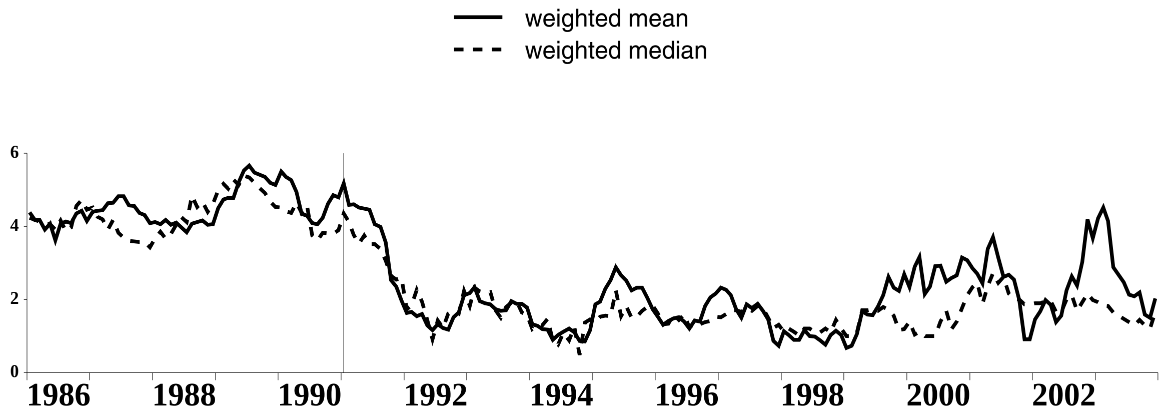
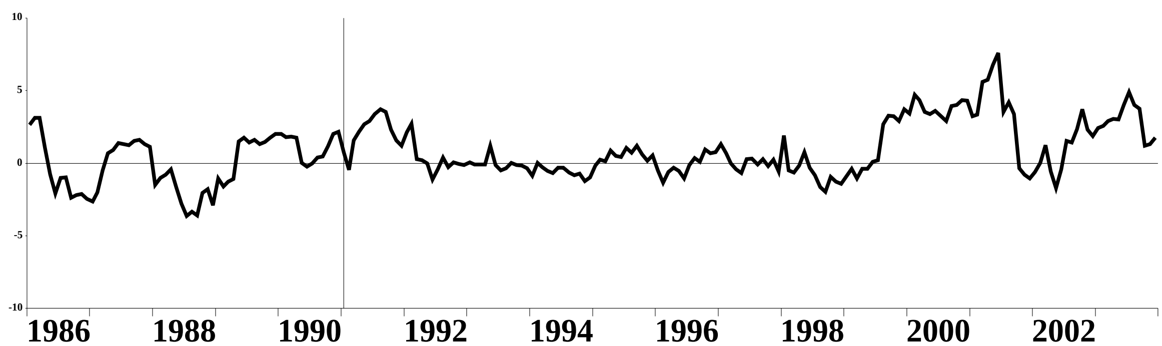


Figure A3: Year-over-Year Changes

Weighted mean vs Weighted median
Year-over-year growth of CPI, monthly data
January 1986 to December 2003



Skewness over sample
Year-over-year growth of CPI, monthly data
January 1986 to December 2003



Kurtosis over sample
Year-over-year growth of CPI, monthly data
January 1986 to December 2003

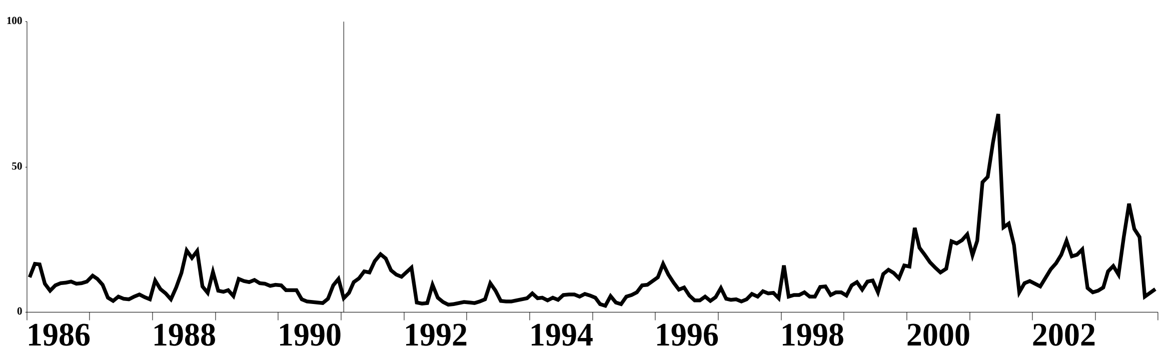
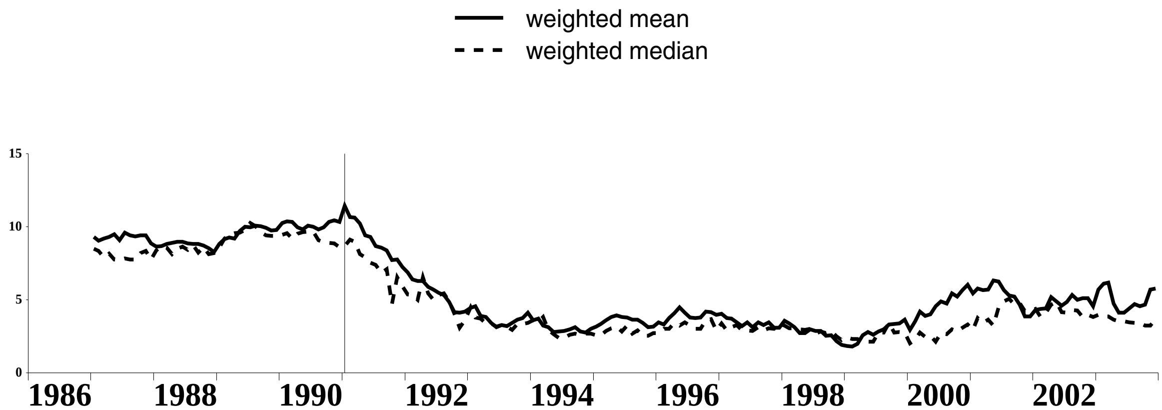
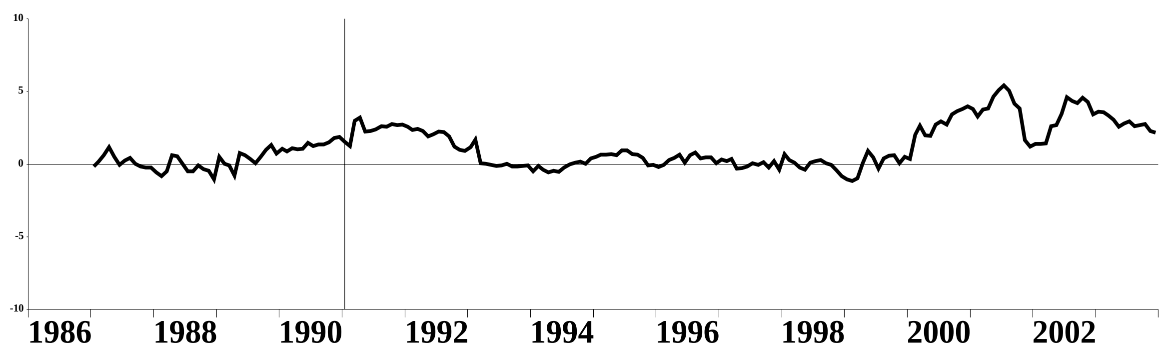


Figure A4: 24-Month-over-24-Month Changes

Weighted mean vs Weighted median
24-month-over-24-month growth of CPI, monthly data
January 1986 to December 2003



Skewness over sample
24-month-over-24-month growth of CPI, monthly data
January 1986 to December 2003



Kurtosis over sample
24-month-over-24-month growth of CPI, monthly data
January 1986 to December 2003

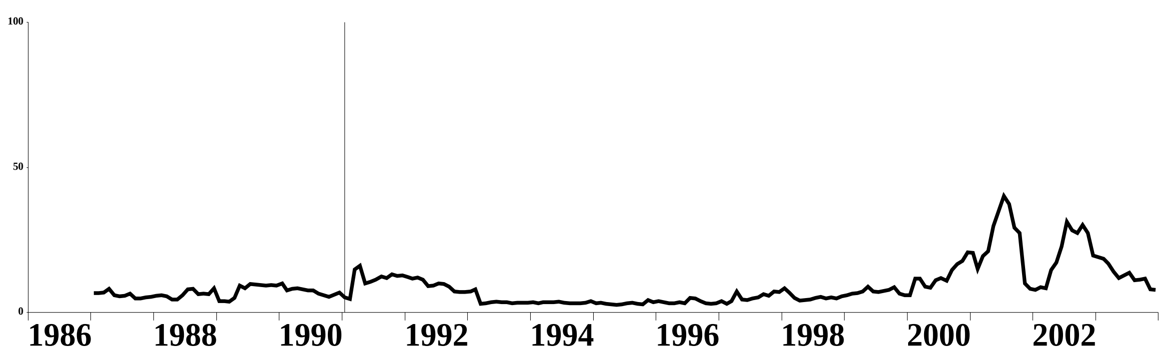
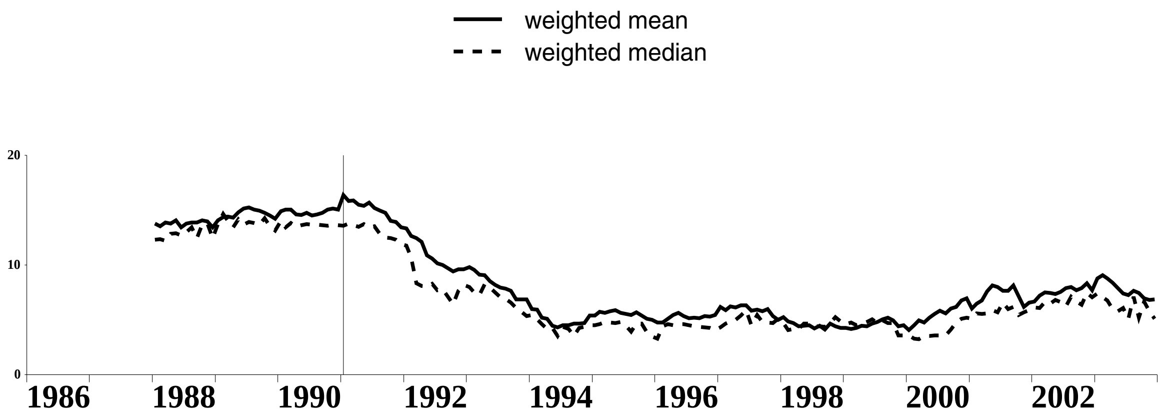
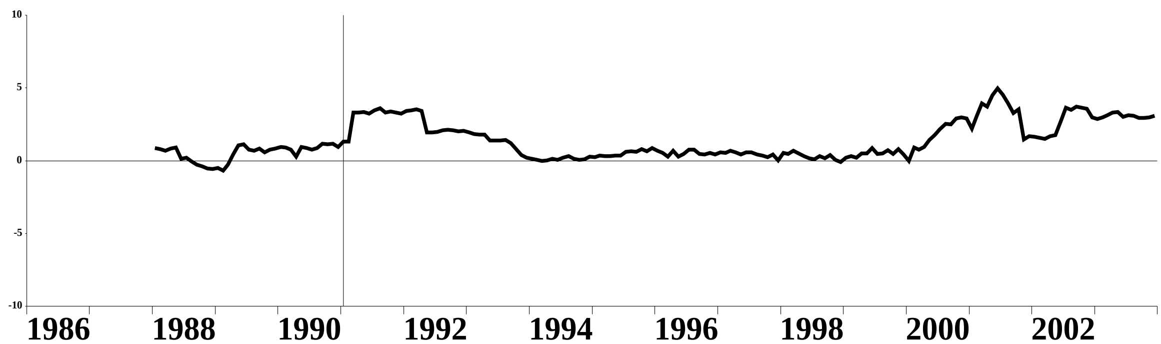


Figure A5: 36-Month-over-36-month Changes

Weighted mean vs Weighted median
36-month-over-36-month growth of CPI, monthly data
January 1986 to December 2003



Skewness over sample
36-month-over-36-month growth of CPI, monthly data
January 1986 to December 2003



Kurtosis over sample
36-month-over-36-month growth of CPI, monthly data
January 1986 to December 2003

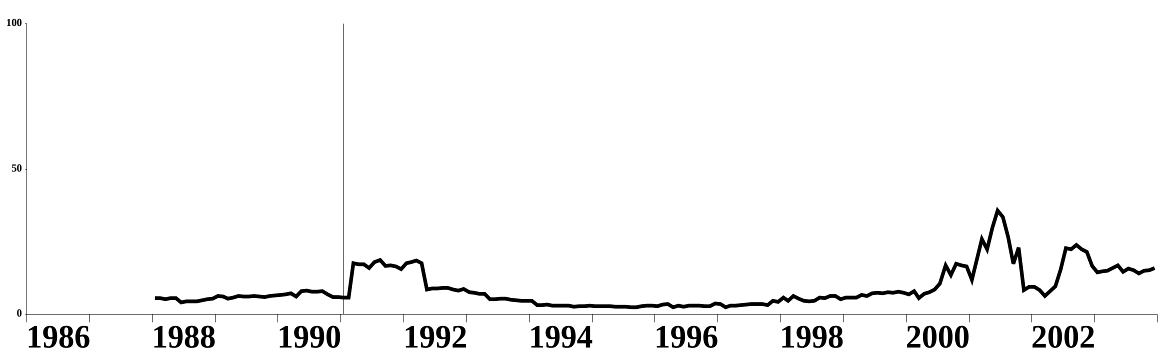
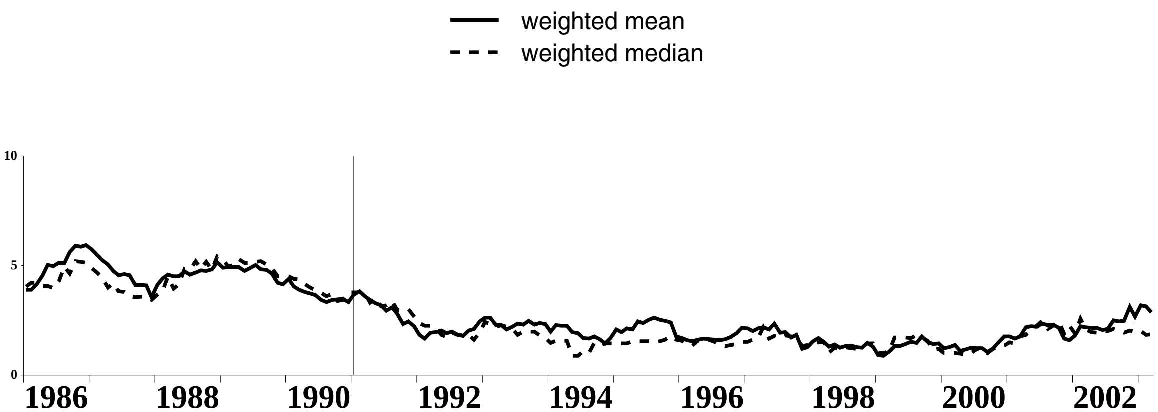
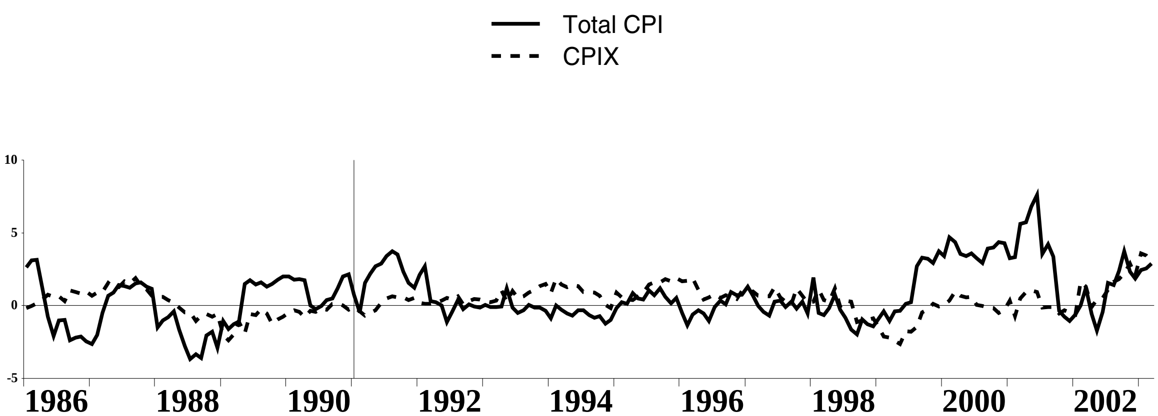


Figure A6: 12-Month-over-12-Month Changes

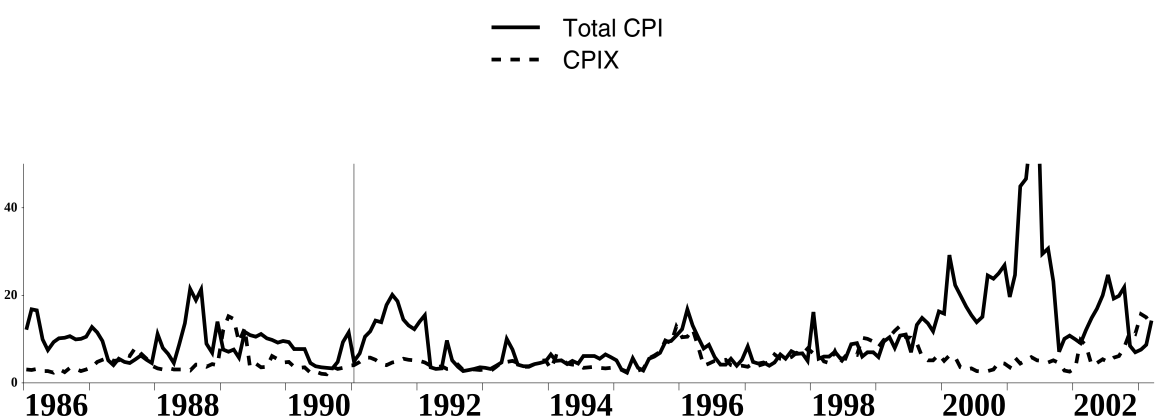
Weighted mean vs Weighted median
Year-over-year growth of CPIX, monthly data
January 1986 to March 2003



Skewness over sample
Year-over-year growth of CPIX, monthly data
January 1986 to March 2003



Kurtosis over sample
Year-over-year growth of CPIX, monthly data
January 1986 to March 2003



Appendix B: Statistics on the Subcomponents of CPI

Table B1: Year-over-year growth of the 54 subcomponents of the CPI

		Subsample 1991m2 to 2004m1		Subsample 1998m8 to 2004m1		Total CPI Weight	Cutler AR(1) Weight
	Component	Mean	Standard Deviation	Mean	Standard Deviation	2003 Weight	1986 to 2003
1	Meat	1.95	3.09	3.00	3.42	2.24	0.31
2	Fish	2.09	2.49	2.18	2.43	0.27	0.84
3	Dairy products and eggs	2.00	1.52	2.43	1.01	1.69	1.46
4	Bakery and other cereal products	2.01	1.77	1.94	1.93	1.72	1.42
5	Fruit, fruit preparations, and nuts	0.90	5.20	1.85	4.61	1.31	0.00
6	Vegetables and vegetable preparations	1.15	8.34	1.65	6.66	1.20	0.00
7	Other food products	1.17	2.59	1.53	1.13	2.89	0.08
8	Food purchased from restaurants	2.19	0.83	2.51	0.64	5.03	2.38
9	Rented accommodation	1.69	0.69	1.41	0.38	6.10	4.69
10	Mortgage interest costs	-0.85	4.14	0.74	2.77	8.37	4.91
11	Replacement cost	1.36	2.83	3.56	2.00	3.03	3.43
12	Property taxes	2.69	2.52	1.32	1.12	3.09	4.12
13	Homeowners' insurance premiums	3.21	3.68	5.75	3.44	1.01	2.73
14	Homeowners' maintenance and repairs	1.92	2.59	3.35	1.32	1.76	1.86
15	Other owned accommodation	1.89	1.55	2.76	1.24	1.10	2.97
16	**Electricity**	2.35	4.32	1.73	5.66	2.13	2.24
17	Water	4.05	2.10	3.10	1.30	0.48	3.99
18	Natural gas	8.11	16.81	15.00	23.36	0.88	0.00
19	Fuel oil and other fuel	4.09	16.18	8.77	22.65	0.43	0.00
20	Communications	1.57	2.48	0.72	2.83	2.65	0.61
21	Child care and domestic services	2.27	2.14	0.70	1.41	0.98	4.11
22	Household chemical products	0.54	2.25	1.27	1.61	0.52	0.00
23	Paper, plastics, and foil supplies	2.07	4.55	2.05	2.06	0.68	0.79
24	Other household goods and services	1.65	1.42	2.30	0.97	1.94	2.20
25	Furniture	1.01	1.65	1.31	1.75	1.50	0.00

(continued)

Table B1: Year-over-year growth of the 54 subcomponents of the CPI (continued)

		Subsample 1991m2 to 2004m1		Subsample 1998m8 to 2004m1		Total CPI Weight	Cutler AR(1) Weight
	Component	**Mean**	**Standard Deviation**	**Mean**	**Standard Deviation**	**2003 Weight**	**1986 to 2003**
26	Household textiles	0.92	2.20	1.73	1.91	0.42	0.00
27	Household equipment	0.03	1.14	-0.10	1.35	1.63	0.00
28	Services related to household furnishings	2.79	1.50	3.23	1.04	0.27	1.91
29	Clothing	0.31	1.54	-0.44	1.75	3.60	2.05
30	Footwear	0.39	1.63	-0.01	1.80	0.86	1.53
31	Clothing accessories and jewellery	0.39	2.00	0.80	1.58	0.55	1.59
32	Clothing materials, notions, and services	2.10	0.19	2.31	0.82	0.44	1.83
33	Purchase of motor vehicles	2.24	2.70	-0.04	1.49	7.07	2.16
34	Leasing and renting of motor vehicles	0.48	4.53	-0.19	3.00	1.42	0.66
35	Gasoline	2.11	10.59	5.82	13.99	3.70	0.00
36	Automobile parts, maintenance, and repairs	1.48	1.54	2.67	1.06	1.82	2.40
37	**Other motor vehicle operating expenses**	5.74	5.73	6.03	8.30	3.40	3.17
38	Local and commuter transportation	4.20	2.88	3.11	0.97	0.59	3.38
39	Intercity transportation	5.84	5.45	4.77	5.21	1.03	0.74
40	Health care goods	1.53	1.53	1.75	1.42	0.93	3.18
41	Health care services	2.59	1.11	2.49	0.31	1.24	4.10
42	Personal care supplies and equipment	0.53	1.63	0.50	1.01	1.31	1.39
43	Personal care services	2.62	1.61	2.25	0.58	0.96	2.96
44	Recreational equipment and services	-2.89	2.53	-4.46	2.19	2.12	2.94
45	Purchase of recreational vehicles	2.63	1.87	1.81	1.90	0.79	1.32
46	Operation of recreational vehicles	2.78	3.21	4.14	4.05	0.52	1.01
47	Home entertainment, equipment, and services	-1.07	1.49	-0.46	0.87	1.32	1.39
48	Travel services	2.35	4.33	1.85	4.70	1.59	1.33
49	Other recreational services	4.01	1.09	4.36	0.88	2.55	1.29
50	Education	6.79	2.92	4.66	1.16	2.30	3.95

(continued)

Table B1: Year-over-year growth of the 54 subcomponents of the CPI (concluded)

		Subsample 1991m2 to 2004m1		Subsample 1998m8 to 2004m1		Total CPI Weight	Cutler AR(1) Weight
	Component	Mean	Standard Deviation	Mean	Standard Deviation	2003 Weight	1986 to 2003
51	Reading materials and other printed matter	3.08	1.93	2.61	1.45	0.65	1.32
52	Served alcoholic beverages	2.41	2.18	2.48	0.90	0.61	2.83
53	Alcoholic beverages from store	2.25	1.43	1.92	0.63	1.10	2.02
54	Tobacco products and supplies	9.00	12.77	13.21	11.93	2.10	2.42

Table B2: Frequency of Elimination of the CPI Components in the Calculation of Meanstd (sample 1986m1 to 2004m1)

Rank	Component	Meanstd	
		#	%
1	Natural gas	127	59
2	Fuel oil and other fuel	122	57
3	Gasoline	112	52
4	Intercity transportation	100	46
5	Vegetables and vegetable preparations	99	46
6	Tobacco products and smokers’ supplies	83	38
7	Education	72	34
8	Mortgage interest costs	61	28
9	Fruit, fruit preparation, and nuts	47	22
10	**Other motor vehicle operating expenses**	40	19
11	Recreational equipment and services	38	18
12	Communications	35	16
13	Rental and leasing of motor vehicles	33	15
14	Homeowners’ insurance premiums	29	13
15	Travel services	27	13
16	Fish and other seafood	24	11
17	Replacement cost	24	11
18	Local and commuter transportation	18	8
19	Paper, plastics, and foil supplies	15	7
20	Water	14	6
21	Home entertainment equipment and services	14	6
22	Property taxes	12	6
23	**Electricity**	12	6
24	Health care goods	12	6
25	Other food products	11	5
26	Homeowners’ maintenance and repairs	10	5
27	Household textiles	8	4

(continued)

Table B2: Frequency of Elimination of the CPI Components in the Calculation of Meanstd (sample 1986m1 to 2004m1) (concluded)

Rank	Component	Meanstd	
		#	%
28	Clothing accessories and jewellery	8	4
29	Household chemical products	7	3
30	Purchase of motor vehicles	7	3
31	Reading material and other printed matter	7	3
32	Other recreational services	6	3
33	Personal care supplies and equipment	5	2
34	Meat	4	2
35	Child care and domestic services	3	1
36	Footwear	2	1
37	Purchase of recreational vehicles	2	1
38	Operation of recreational vehicles	2	1
39	Other owned-accommodation expenses	1	0
40	Served alcoholic beverages	1	0

Table B3: Frequency of Elimination of the CPI Components in the Calculation of Meanstd (sample 1998m9 to 2004m1)

Rank	Component	Meanstd	
		#	%
1	Natural gas	50	78
2	Fuel oil and other fuel	48	75
3	Gasoline	38	59
4	Tobacco products and smokers' supplies	29	45
5	Recreational equipment and services	21	33
6	**Other motor vehicle operating expenses**	16	25
7	Intercity transportation	16	25
8	Vegetables and vegetable preparation	14	22
9	**Electricity**	10	26
10	Travel services	9	14
11	Fruit, fruit preparations, and nuts	7	11
12	Communications	7	11
13	Fish	6	9
14	Education	6	9
15	Homeowners' insurance premiums	5	8
16	Other recreational services	3	5
17	Household textiles	2	3

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