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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

BANK FOR INTERNATIONAL SETTLEMENTS
Monetary and Economic Department
Basel, Switzerland

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Foreword

On 18 and 19 February 1999 model builders from central banks met in Basel to discuss the issues of how best to measure underlying, or core, inflation and the implications of the use of alternative measures of core inflation for the conduct of monetary policy.

The concept of underlying inflation has always been central to the monetary policy strategies of central banks; the recent sharper focus on price stability, of which the growing number of countries adopting inflation targeting strategies is only one indication, has made it increasingly important to have an accurate and reliable measure of core inflation. This need arises from the notion that central banks should only resist persistent sources of inflationary pressures and not be concerned with short-term and reversible movements in prices and the inflation rate.

Yet there is no consensus on how to extract a solid measure of long-term price movements from headline inflation.

The nine papers presented at the conference follow three different approaches to this signal extraction problem.

According to the first one – which one can call the behavioural approach – estimates of core inflation are obtained by excluding from the headline measures the prices of certain items that are thought to be volatile enough to obscure long-term movements of inflation. The price index "excluding food and energy" is one well-known example. Several countries compute such indices and consider them in the setting of policy.

Another approach – the statistical approach – attempts to eliminate temporary fluctuations of inflation, or one-off changes in the price levels, by computing limited influence estimators, such as the median and/or the trimmed means. These measures are thought to have desirable properties to the extent they avoid the subjective decision to exclude particular prices from the aggregate price index and because they efficiently estimate long-term movements when the data are drawn from a leptocurtic distribution. The papers by Wynne, Apel and Jansson, and Bryan, Cecchetti and Wiggins discuss this approach.

However, despite the potential superiority of the "statistical" measures, central banks might find it difficult to use them primarily because they are not easy to explain to the public and because they are difficult to replicate. The papers by Johnson, Cockerell and Álvarez and Matea discuss such measurement issues and illustrate what central banks do in practice.

The final approach – the economic approach – tries to derive a measure of core inflation using the long-run neutrality assumption of monetary theory and to explore to what extent alternative measures of core inflation, once they are entered in a given feedback rule for monetary policy, produce different economic outcomes in terms of variability of real output and inflation and instrument instability. The papers by Aucremanne and Wouters, Fase and Folkertsma, and Cassino, Drew and McCaw explore these issues.

EUROPEAN CENTRAL BANK

CORE INFLATION: A REVIEW OF SOME CONCEPTUAL ISSUES[*]

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April 1999

Core Inflation: A Review of Some Conceptual Issues

Abstract: This paper reviews various approaches to the measurement of core inflation that have been proposed in recent years. The objective is to determine whether the ECB should pay special attention to one or other of these measures in assessing inflation developments in the euro area. I put particular emphasis on the conceptual and practical problems that arise in the measurement of core inflation, and propose some criteria that could be used by the ECB to choose a core inflation measure.

[*] I thank Vítor Gaspar, David Lebow, Fabio Scacciavillani and seminar participants at the ECB for comments. This paper is part of a larger project on the measurement of core inflation in the euro area. The views expressed in this paper are those of the author and do not necessarily reflect the views of the European Central Bank or the European System of Central Banks.

1. INTRODUCTION

The notion of core inflation has played an important role in the deliberations of monetary policymakers for the past twenty-five years. However, despite the central role of this concept, there is still no consensus on how best to go about measuring core inflation. The most elementary approach, and the one that is probably the most widely used, consists of simply excluding certain categories of prices from the overall inflation rate. This is the so-called “Ex. food and energy” approach to core inflation measurement, and it reflects the origin of the concept of core inflation in the turbulent decade of the 1970’s. More recently, however, there have been a variety of attempts to put the measurement of core inflation on a more solid footing. The newer approaches have two key features in common. First, they adopt a more statistical rather than behavioural approach to the problem of price measurement. And second, they invoke an alternative, monetary, concept of inflation, as opposed to the traditional microeconomic cost of living concept, as the guiding theory.

This paper critically reviews various approaches to measuring core inflation. I do so by linking these approaches in a single theoretical framework, the so-called stochastic approach to index numbers. I evaluate the competing merits of the different approaches, and argue that a common shortcoming is the absence of a well-formulated theory of what these measures of inflation are supposed to be capturing. The notion that they somehow better capture the “monetary” component of inflation, or the component of inflation that ought to be of primary concern to central bankers, is of questionable validity.

2. THE CONCEPT OF CORE INFLATION

Implicit in all discussions of core inflation is the idea that this type of inflation is fundamentally different to changes in the cost of living. The theory of the cost of living index is by far the most well developed and coherent framework for inflation measurement that currently exists. The basic theory takes as its point of departure the expenditure or cost function of a representative household at a given point in time. The change in the cost of living between some base period, *0*, and some subsequent comparison period, *1*, is then defined as the change in the minimum cost of attaining the reference utility level u between the two periods. This theory, appropriately elaborated, forms the framework for the design of the Consumer Price Index in the United States. However, the theory of the cost of living index is not the theoretical framework for the Harmonised Index of Consumer Prices (HICP) that is used to assess inflation developments in the euro area: at the time of writing there is no fully articulated theoretical framework for the HICPs, although there is a relatively well-defined price concept, namely “final household monetary consumption.” By eschewing the use of the cost of living concept, Eurostat can legitimately motivate the exclusion of certain categories of prices from the HICP. The category that has attracted the most attention by it omission is the costs of owner occupied housing.

One measure of core inflation that is often constructed is one that seeks to exclude the effects of changes in indirect taxes from the overall inflation rate. Donkers et. al. (1983-4) discuss how this is done in a number of European countries. This is potentially of interest from a monetary policy perspective, as arguably an acceleration in headline inflation that is in some sense attributable to an increase in indirect taxes ought not to be of concern to the central bank. Current practice, as reviewed by Donkers et al, is to employ various ad hoc methods to derive an estimate of the inflation rate net of indirect taxes. The exact methods employed differ from country to country. One approach is to simply assume that all of the observed price change reflects the change in the tax and calculate an alternative CPI on the basis of this assumption.[1] The problem with this approach is that the implicit assumption about supply elasticities (perfectly elastic) is unlikely to be a good approximation to reality for many products. A more sophisticated approach might allow for the effects of a change in indirect tax rates

[1] For details see, for example, Diewert and Bossons (1987).

on the structure of production prices, but the variant analysed by Diewert and Bossons (1987) still requires restrictive assumptions about the invariance of the input-output structure of the economy to changes in indirect tax rates.

These calculations raise the question of what it is we want a core inflation statistic to measure. If the object we are pursuing is a true cost of living index, then it is not clear that we should be eliminating the effects of tax increases from our price measure. Furthermore, the reasoning above is only partial equilibrium. A proper treatment of the effects of indirect taxes on a measure of the price level would require a detailed general equilibrium analysis of the effects of the tax increase that would go well beyond current practice.[2] Diewert and Fox (1998) suggest a method for handling tax changes for the purposes of using inflation measures to make welfare comparisons.[3] Note also that in principle the distortionary effect of large infrequent changes in indirect taxes on the inflation signal may be adequately handled by some or all of the approaches reviewed below. Indirect tax changes that apply to some commodities but not others would be reflected in large price changes for the commodities in question. Limited influence estimators of core inflation of the sort proposed by Bryan and Pike (1991) and Bryan and Cecchetti (1994) would omit these observations from the calculation of inflation. However large changes in relative prices induced by changes in indirect taxes are arguably different from large changes due to other possibly more difficult to identify factors, since the indirect tax rates are (presumably) directly observable and therefore it ought in principle be easier to filter out their effects on the overall inflation rate.

The common point of departure for almost all analyses of core inflation is the idea that there is a well-defined concept of monetary inflation that ought to be of concern to monetary policy makers and that this type of inflation, being conceptually different to the cost of living, is not adequately captured by the standard price statistics.[4] Thus it is argued that central banks ought to target a price index whose rate of increase corresponds to the inflation that generates the costs that central banks are seeking to avoid by focusing on an inflation-control objective. Inflation is costly to society because it disrupts the co-ordination of economic activity and discourages the use of fiat money in market transactions. While it is possible that some of the costs of inflation are captured by changes in the cost of living, some of them may require a much broader measure of market transactions. One conclusion from this line of reasoning is that for the purposes of monetary policy what is needed is not a microeconomic theory of the cost of living, but a macroeconomic theory of the cost of inflation. Thus we can interpret various measures of core inflation as attempts to better measure this more appropriate measure of inflation for monetary policy purposes.

But just how much guidance does the concept of monetary inflation provide when it comes to measurement? Consider a very standard money market equilibrium condition:

$$\frac{M^S}{P} = L(Y, R)$$

where the notation is the usual. What is the effect of a supply shock (e.g. a hike in oil prices or tax rates) on the price level?[5] An adverse supply shock that lowers the level of output would, under standard assumptions about the nature of the demand for money, also lower the demand for real balances. Absent any action on the part of the central bank to alter the stock of money outstanding,

[2] Diewert (1997) notes that "...there is no unambiguous, completely accurate method for removing all indirect commodity taxes...any attempt to do this will be a complex exercise in applied general-equilibrium modelling rather than in economic measurement. Moreover, the fact that the government has caused consumer prices to increase rather than some other economic phenomenon seems somewhat immaterial: In either case, households are facing higher prices, and we may want to measure this fact!"(Diewert, 1997, 134)

[3] See also Diewert and Bossons (1987).

[4] See, for example, Howitt (1997).

[5] Bryan and Cecchetti (1994) argue "During periods of poor weather, for example, food prices may rise to reflect decreased supply, thereby producing transitory increases in the aggregate index. Because these price changes do not constitute underlying monetary inflation, the monetary authorities should avoid basing their decisions on them."(Bryan and Cecchetti, 1994, 195).

M^S, the price level must rise to clear the market for real balances. Is this increase in the price level "monetary" inflation or not? It does not constitute monetary inflation in the sense that its proximate cause is something other than an action on the part of the central bank. It does constitute monetary inflation to the extent that, in principle, an appropriate response on the part of the central bank (cut the stock of base money to match the decline in the demand for base money) could have prevented it from occurring. More generally, the inflation rate is determined by the rate of growth of the stock of money relative to the demand for it. The inflation rate is not uniquely determined by the monetary authorities but by the monetary authorities and the private sector jointly.

3. THE BASIC FRAMEWORK

The approach to price measurement that has (implicitly or explicitly) formed the basis of many recent attempts to improve upon existing core inflation measures is the stochastic approach to index numbers. In the academic literature this approach is exemplified by the papers by Clements and Izan (1981, 1987) as well as a book by Selvanathan and Prasada Rao (1994). The research of Bryan and Pike (1991), Bryan and Cecchetti (1993, 1994) and Cecchetti (1997) has brought this approach to inflation measurement to the attention of monetary policy makers in the United States, while the work of Quah and Vahey (1995), Blix (1995) and Fase and Folkertsma (1996) indicates that this alternative way of thinking about inflation is also influential among the NCBs in the EU. Diewert (1995) provides a critique of this literature from the perspective of the traditional economic approach to price measurement, and some additional discussion is to be found in Wynne (1997).

The point of departure for all attempts to measure core inflation is the observation that the changes in the prices of individual goods and services between two periods contain a common component that constitutes core inflation and an idiosyncratic component that primarily reflects developments in local markets. The problem of core inflation measurement is then to isolate these two components of observed price changes. This idea is formalised by writing

$$\pi_{i,t} = \Pi_t + x_{i,t}$$

This expression defines the rate of change of the price of an individual commodity, $\pi_{i,t} = \ln(p_{i,t}) - \ln(p_{i,t-1})$, as consisting of an aggregate inflation component, $\Pi_t \equiv \ln(P_t) - \ln(P_{t-1})$ and a relative price change component, $x_{i,t}$. The object we are interested in is P_t - the common component of all prices and what we might interpret as the purchasing power of money. Different approaches to the measurement of core inflation can be characterised by how they go about achieving identification.

Table 1 presents a simple schema of how many of the approaches fit together. The presumption in all of these approaches is that the "headline" rate, which is some weighted average of the individual price changes, $\sum_{i=1}^{N} w_{i,t}\pi_{i,t}$, with weights chosen on the basis of expenditure shares, is a poor or second best approximation to Π_t. What differentiates the various approaches to core inflation measurement is the information that is used to arrive at the core measure. One approach is to simply re-combine the price changes of individual goods and services at each point in time to derive a core measure. This is the "Ex. food and energy" approach, and also the essence of the limited influence measures (such as the trimmed mean and weighted median) advocated by Bryan and Cecchetti. Alternatively, we might choose to ignore the information in the cross-section distribution of individual price changes and instead derive a measure of core inflation by smoothing current and previous headline inflation rates. Thus some have advocated constructing a measure of core inflation by taking a moving average of past inflation rates, or applying a Hodrick-Prescott filter to headline rates. Intermediate to these two extremes is the Dynamic Factor Index proposed by Bryan and Cecchetti

(1993) which combines information on both the time series and cross section characteristics of individual price changes.

4. ESTIMATING CORE INFLATION USING ONLY CONTEMPORANEOUS PRICE DATA

There is some intuitive appeal to the idea that we can somehow isolate the monetary component of price changes by simply averaging the changes in the prices of individual goods and services. This approach to inflation measurement has a long history, and was perhaps first fully articulated by Jevons (1865). Jevons argued for the use of the geometric mean of price changes in calculating inflation

> "... as it seems likely to give in the most accurate manner such general change in prices as is due to a change on the part of gold. For any change in gold will affect all prices in an equal ratio; and if other disturbing causes may be considered proportional to the ratio of change of price they produce in one or more commodities, then all the individual variations of prices will be correctly balanced off against each other in the geometric mean, and the true variation of the value of gold will be detected." (Jevons, 1865, 296).

If we interpret the relative price term, $x_{i,t}$, in the equation above as an error term that is normally distributed, with mean and variance given by $E(x_t) = 0$, $E(x_t x_t') = \sigma_t^2 I_N$, where $x_t = [x_{1,t}, x_{2,t},..., x_{N,t}]'$, it is straightforward to show that the maximum likelihood estimator of the inflation rate, $\hat{\Pi}_t$, is given by a simple unweighted average of the rates of change of the individual price series:[6]

$$\hat{\Pi}_t = \frac{1}{N}\sum_{i=1}^{N} \pi_{i,t}$$

Note that we identify core inflation in this model by defining it as the component of price changes that is orthogonal to relative price changes. By construction, the estimated relative price changes, $\hat{x}_{i,t}$, have the property

$$\sum_{i=1}^{N} \hat{x}_{i,t} = 0$$

That is, the implied relative price changes average to zero.

Exponentiating both sides of the proposed measure of inflation we obtain the geometric mean price index proposed by Jevons (1865) as a way of computing the change in the purchasing power of money over time:

$$\exp(\hat{\Pi}_t) = \prod_{i=1}^{N}\left(\frac{p_{i,t}}{p_{i,t-1}}\right)^{1/N}$$

This measure of inflation has a number of appealing properties, not the least of which is the ease with which it can be calculated. Unlike a simple arithmetic mean of price relatives $(p_{i,t} / p_{i,t-1})$ (the so-called Carli index), this index satisfies the time reversal property. Fase and Folkertsma (1996) argue

[6] See Diewert (1995).

for the use of simple averages of price changes to isolate core inflation in an SVAR framework (discussed below). However, this measure of inflation also has a number of serious shortcomings, all of which ultimately relate to the strong assumptions made about the behavior of the relative price terms, $x_{i,t}$.

Note that so far nothing has been said about which prices to include in the calculations. The prices to be averaged in arriving at a measure of inflation could be just consumer prices, or could include the prices of all GDP transactions or the prices of all transactions (including intermediate transactions) or could even include the prices of assets. Fisher (1920) argued that when it comes to constructing a measure of the purchasing power of money we ought to look at as many prices as possible:

> "Perhaps the best and most practical scheme [for the construction of an index number] is that which has been used in the explanation of P in our equation of exchange, an index number in which every article and service is weighted according to the value of it exchanged at base prices in the year whose level of prices it is desired to find. By this means, goods bought for immediate consumption are included in the weighting, as are also all durable capital goods exchanged during the period covered by the index number. What is repaid in contracts so measured is the same general purchasing power. This includes purchasing power over everything purchased and purchasable, including real estate, securities, labor, other services, such as the services rendered by corporations, and commodities." (Fisher, 1920, 217-218).

It is interesting to note that the preamble to the European Council Regulation governing the calculation of the HICP which will form the basis for assessing inflation developments in the euro area notes that "…it is recognised that inflation is a phenomenon manifesting itself in all forms of market transactions including capital purchases, government purchases, payments to labour as well as purchases by consumers." (European Commission, 1998) Once we have abandoned the cost of living as the guiding concept for inflation measurement for monetary policy purposes there is no reason for confining our attention to changes in the prices of final consumer goods. Changes in the prices received by producers, changes in the prices of intermediate goods and changes in the prices of existing assets all carry information about monetary inflation.

5. ARE ALL PRICES EQUALLY INFORMATIVE?

One possible problem with this approach to estimating inflation is that it treats all prices as being equally informative about inflation and thus equally important.[7] Arguably a more appropriate approach would be to weight the price changes of individual products in terms of their importance, somehow defined.[8] That is, an estimate of inflation of the form

$$\hat{\Pi}_t = \sum_{i=1}^{N} w_{i,t}\pi_{i,t}$$

[7] Diewert (1997) sees this property of the Jevons index number as a "fatal flaw."

[8] The contrary view is taken by Bryan and Pike (1991), who write "...the strength of the inflation signal in goods and services prices is not necessarily related to an item's share of the typical household budget. As a monetary phenomenon, inflation should influence the price of all goods and services equally. The inflationary signal in the price of a new pair of shoes is theoretically the same as that in the price of shoe leather or, for that matter, in the price of cows. There is no reason to expect movements in the price of one to be a clearer indicator of inflation than movements in the prices of others." Likewise Fase and Folkertsma (1996) note "...weighting the price index means that some prices get to determine the general price level thus measured more than others. For an assessment of changes in purchasing power, weighting may certainly be useful but there is no clear reason to gauge inflation by way of weighting."

which assigns weights $w_{i,t}$ to the price changes of individual products in arriving at a measure of overall inflation may be preferable. Diewert (1995) shows that for this expression to be the maximum likelihood estimator of the inflation rate we can retain our original assumption that the relative price changes have zero mean, but need to replace the variance assumption with

$$E(x_t x_t') = \sigma_t^2 W_t^{-1}$$

where $W_t = diag[w_{1,t}, w_{2,t}, ..., w_{N,t}]$. This assumption about the distribution of relative price changes was proposed by Clements and Izan (1981). They motivated it by arguing as follows: "If we think in terms of sampling of the individual prices to form ...[$\pi_{i,t}$]... for each commodity group, then it seems reasonable to postulate that the collection agency invests more resources in sampling the prices of those goods more important in the budget. This implies that ...[$Var(x_{i,t})$]...is inversely proportional to ...[$w_{i,t}$]."(Clements and Izan, 1981, 745) Later Clements and Izan (1987) provided a different justification for this assumption, arguing that the larger an item looms in the budget of consumers, the less scope there is for relative price changes in that item. Neither of these justifications is particularly appealing. However, the theory of the cost of living index provides an alternative rationale for weighting individual price changes by shares in consumer's budgets. A fixed-weight Laspeyres measure of the price level at date *t* with period 0 as the base period can be written

$$P_t^L = \frac{\sum_{i=1}^{N} p_{i,t} q_{i,0}}{\sum_{i=1}^{N} p_{i,0} q_{i,0}} = \sum_{i=1}^{N} w_{i,0} \left(\frac{p_{i,t}}{p_{i,0}} \right) = \sum_{i=1}^{N} w_{i,0} p_{i,t}$$

where we set $p_{i,0} = 1, \ \forall i$. Log differentiating this expression we obtain

$$\frac{dP_t}{P_{t-1}} \equiv \Pi_t = \frac{1}{P_{t-1}} \sum_{i=1}^{N} w_{i,0} dp_{i,t} = \sum_{i=1}^{N} r_{i,t} \pi_{i,t}$$

That is, the standard fixed weight Laspeyres measure of inflation can be written as a weighted average of the rates of change of the prices of individual goods and services. However, note that the weights, $r_{i,t}$, are not the budget share weights of the base period, $w_{i,0}$. Rather they are the "relative importances" of each product, that is, the base period weight adjusted for the extent to which the price of the good in question has grown faster or slower than prices on average. Goods whose prices increase faster than average over time will have an increasing relative importance in a fixed-weight Laspeyres type price index. This is simply another way of expressing the well-known tendency of fixed-weight Laspeyres measures to overstate the true rate of inflation as defined by the cost of living index.[9]

But why do we need to confine ourselves to looking to budget shares for weights? The use of budget shares as weights is best motivated by an appeal to the (atemporal) theory of the cost of living index. Yet implicit in the notion of core inflation that ought to be of primary concern to monetary policymakers is the idea that such inflation is inherently different to inflation as measured by the cost of living index. Thus the weighting scheme that is optimal from the perspective of constructing a cost of living index may no longer be optimal from the perspective of measuring inflation for the purposes of monetary policy.

A weighting scheme that might be more appropriate for monetary policy purposes would weight prices by the strength or quality of the inflation "signal" they provide. Indeed this is the

[9] For further details see Blinder (1981).

approach that implicitly underlies the “Ex. food and energy” or “Ex. indirect taxes” approaches to estimating core inflation that are used by many central banks and statistical agencies. In these approaches we attach zero weight to certain prices on the (unstated) grounds that they convey zero information about core inflation. Formally,

$$w_i = 0 \quad \text{if} \quad \sigma_i^2 > \tilde{\sigma}^2$$

where $\tilde{\sigma}^2$ is some “unacceptably high” level of variability in short term price changes. It is worth noting that there is no justification for such a practice from the perspective of the theory of the cost of living index. The rationale for excluding certain prices from an estimate of core inflation must lie other than in the theory of the cost of living index.

One scheme for operationalising the idea of weighting prices in terms of the quality of their inflation signal would be to set the weights as follows:

$$w_i = \frac{\frac{1}{\sigma_i^2}}{\sum_{i=1}^{N} \frac{1}{\sigma_i^2}}$$

That is, choose weights for the various individual prices that are inversely proportional to the volatility of those prices. A weighting scheme along these lines has been investigated by Dow (1994), who termed the resulting measure of inflation a Variance Weighted Price Index, and by Diewert (1995), who termed the resulting measure of inflation Neo-Edgeworthian. Wynne (1997) reports the results of applying a scheme along these lines to US CPI data. The advantage of employing a variance weighting scheme to calculate core inflation is that we do not discard potentially useful information about core inflation that may be contained in food and energy prices, or whatever categories are excluded. The “Ex. food and energy” approach to estimating core inflation is further compromised by the fact that it requires that we make a once and for all judgement about what the least informative categories of prices are for estimating core inflation. A variance weighting scheme such as the above allows weights to change over time as the volatility of different categories of prices changes over time. The speed with which the weights will change in response to changes in volatility will be determined by the choice of the estimation “window” for the variances.

Yet another weighting scheme was proposed informally by Blinder (1997). Starting from a definition of core inflation as the persistent or durable component of inflation, Blinder suggests that when it comes to calculating core inflation, individual price changes should be weighted by their ability to forecast future inflation. Blinder argues that central bankers are a lot more concerned about future inflation than they are about past inflation, and that when thinking about the measurement of core inflation as a signal extraction problem, future inflation is the object about which we are seeking information via current signals. Thus core inflation is defined in terms of its ability to predict future headline inflation. At present there have not been any attempts to operationalize this approach.[10]

6. SOME PROBLEMS

If we think about the problem of core inflation measurement in terms of an estimation problem, we need to ask whether the distribution assumptions that underlie the estimation are borne out by the data. There are two important distributional assumptions that need to be looked at. The first

[10] However note that Bryan and Cecchetti (1994) evaluate various measures of core inflation in terms of their ability to forecast future inflation.

is that individual price changes are normally distributed, and the second is that individual price changes are independent of one another.

The geometric mean of price relatives is the maximum likelihood estimator of core inflation under the assumption that individual price changes are normally distributed. Is this assumption borne out by the data? No. There is an extensive literature documenting the statistical properties of individual price changes, and it is clear that individual $\pi_{i,t}$ are typically not normally distributed. This fact was first noted by Bowley (1928) in a critique of Jevons, and has subsequently been further documented by Vining and Elwertowski (1976), Ball and Mankiw (1995), Cassino (1995), Bryan and Cecchetti (1996), Balke and Wynne (1996) and Wynne (1998). There is evidence of significant skewness and kurtosis in the cross-section distribution of price changes. Skewness in the distribution of price changes may reflect the fact that changes in the money stock do not necessarily affect all prices at the same time,[11] or it may simply reflect skewness in the underlying shocks that causes relative prices to change.[12]

If the distribution of $\pi_{i,t}$ can be characterised in terms of a distribution with a finite number of moments, it may still be possible to estimate core inflation as the solution to a maximum likelihood problem. However, the resulting measure will probably be significantly more complicated than a simple geometric mean of price relatives.

A more constructive response to non-normality in the distribution of $\pi_{i,t}$ is to employ estimators that are robust to departures from normality. This is the approach advocated by Bryan and Pike (1991), Bryan and Cecchetti (1994, 1996) and Cecchetti (1997). Bryan and Pike argue for the use of the median of $\pi_{i,t}$ as an estimate of core inflation on the grounds that the median is a more robust measure of central tendency. Bryan and Cecchetti (1994) examine in more detail alternative approaches to estimating core inflation and conclude that of the various measures they look at the weighted median CPI performs best. More recently Bryan, Cecchetti and Wiggins (1997) investigate the ability of various trimmed means of the cross section distribution of price changes to track trend inflation. To compute the trimmed mean of the cross-section distribution of prices, start by ordering the sample (from largest to smallest price change, say). Then define the cumulative weight from 1 to i as $W_{i,t} = \sum_{j=1}^{i} w_{(j),t}$, where $w_{(j),t}$ denotes the sorted *j*'th weight. This allows us to define the index set $I_\alpha = \{i : \frac{\alpha}{100} < W_{i,t} < 1 - \frac{\alpha}{100}\}$. The α % trimmed mean inflation rate is then defined as

$$\overline{\Pi}_t^k(\alpha) = \frac{1}{1 - 2\frac{\alpha}{100}} \sum_{i \in I_\alpha} w_{(i),t} \pi_{(i),t}^k$$

where $\pi_{(j),t}$ is the sorted *j*'th price change. If $\alpha = 0$ we obtain the weighted sample mean. For $\alpha = 50$ we obtain the weighted sample median.

Yet a further objection to the use of the geometric mean is that changes in relative prices are not independent of each other. Thus if we continue to think about core inflation measurement as an estimation problem, the assumption that $E(x_t x_t') = \sigma_t^2 I_N$ needs to be replaced with the more realistic assumption $E(x_t x_t') = \sigma_t^2 \Omega$. In this case the core inflation rate can in principle be estimated as

$$\hat{\Pi}_t = (\iota_N' \Omega^{-1} \iota_N)^{-1} \iota_N' \Omega^{-1} \pi_t$$

[11] Indeed Ball and Mankiw (1995) argue that this property of the distribution of price changes is important evidence favouring sticky-price or menu-cost models of real-nominal interactions.
[12] This interpretation is proposed by Balke and Wynne (1998).

where ι_N is an $N \times 1$ vector of 1's. In practice, however, operationalising this approach would require making strong assumptions about the precise nature of the interaction between relative prices (*i.e.* specification of Ω) and to date there do not appear to have been any attempts to construct estimates of core inflation along these lines.

A more fundamental objection to the use of the geometric mean is that it requires the systematic component of each price change to be the same, thereby precluding any long-term changes in relative prices. Casual empiricism suggests that this restriction is seriously at odds with reality. This criticism of the geometric mean of individual price changes as an estimate of inflation was first made by Keynes (1930).

Clements and Izan (1987) proposed a way around this problem. They start by writing

$$\pi_{i,t} = \Pi_t + x_{i,t} = \Pi_t + r_i + \varepsilon_{i,t}$$

where the relative price term, $x_{i,t}$, now contains a non-zero component, r_i, as well as a mean-zero stochastic component, $\varepsilon_{i,t}$. Assume

$$E(\varepsilon_t) = 0 \,,\; E(\varepsilon_t \varepsilon_t') = \sigma_t^2 W_t^{-1}$$

where $W_t = diag[w_{1,t}, w_{2,t}, ..., w_{N,t}]$. To identify Π_t and r_i, add the identifying assumption

$$\sum_{i=1}^{N} w_{i,t} r_i = 0$$

The maximum likelihood estimator of the inflation rate is the same as in the basic model (i.e. a simple weighted average of the individual price changes), but now the expected change in the *i*'th relative price is $E(\pi_{i,t} - \Pi_t) = r_i$. While this model is an advance over the simple framework, it is not obvious that the assumption of constant rates of relative price changes is any more palatable than the assumption of no systematic changes in relative prices. For many products, their relative prices tend to follow a U-shaped pattern over their lifetimes, with rapid relative price declines following the introduction of a product, followed by relative price stability as the product reaches maturity, followed by relative price increases as the product is displaced by newer products before finally disappearing from the market.

7. COMBINING CONTEMPORANEOUS AND TIME SERIES INFORMATION TO ESTIMATE CORE INFLATION

Perhaps a more serious shortcoming of these models is that they fail to take account of persistence in both individual price changes and the inflation rate. Some of the dynamic models that have been proposed in recent years seek to remedy this problem, and succeed to varying degrees. We will start by looking at the Dynamic Factor Index (DFI) model proposed by Bryan and Cecchetti (1993) and Cecchetti (1997). This model is of interest for many reasons, not least of which is the fact that it is the only model that attempts to combine information on both the cross-section and time series characteristics of individual price changes in deriving a core inflation measure.

The DFI model starts with the equation

$$\pi_t = \Pi_t + x_t$$

where as before $\pi_t = [\pi_{1,t}, \pi_{2,t}, ..., \pi_{N,t}]'$ and $x_t = [x_{1,t}, x_{2,t}, ..., x_{N,t}]'$. Identification of the common inflation component in all price changes (core inflation) is accomplished by positing time series processes for inflation and the relative price change components of individual price changes as follows:

$$\Psi(L)\Pi_t = \delta + \xi_t$$

$$\Theta(L)x_t = \eta_t$$

where $\Psi(L)$ and $\Theta(L)$ are matrix polynomials in the lag operator L and ξ_t and η_t are scalar and vector *i.i.d.* processes respectively. If $\Psi(L) = 1$ and $\Theta(L) = 1$, we obtain the static model discussed at length above. Another special case of this model where $\Psi(L) = 1 - \psi_1 L$ and $\Theta(L) = 1$ has been studied by Dow (1994). Bryan and Cecchetti (1993) and Cecchetti (1997) estimate versions of this model assuming that $\Psi(L) = 1 - \psi_1 L - \psi_2 L^2$ and $\Theta(L) = 1 - \theta_1 L - \theta_2 L^2$.

In the DFI model the common element in all price changes, Π_t, is identified by assuming that it is uncorrelated with the relative price disturbances at *all* leads and lags instead of just contemporaneously. This is clearly a much stronger identifying assumption than is used in the simple static factor models discussed above (where inflation is defined as the component or price changes that is uncorrelated with relative price changes contemporaneously). It is not clear what is obtained by employing this stronger assumption. The DFI model is also susceptible to the criticism that it only allows for constant trends in relative prices. But perhaps the biggest shortcoming of the DFI approach to measuring core inflation is that history changes each time a new observation is obtained and the model is re-estimated. This problem is common to all measures of core inflation constructed using econometric procedures. While this is not usually ranked as a major concern in choosing and constructing a measure of core inflation, it is of great importance to a central bank that plans to use a core measure as an integral part of its communications with the general public about monetary policy decisions.

8. DYNAMIC MODELS II: BRINGING SOME MONETARY THEORY TO BEAR ON THE DEFINITION OF CORE INFLATION

Core inflation as identified by the static and dynamic factor models above is essentially a statistical concept that it is difficult to attach much economic meaning to. Unlike the economic or cost of living approach to inflation measurement, no substantive economic theory is used to derive these estimates of core inflation. The motivation is usually some simple variant of the quantity theory of money, whereby a given change in the stock of base money is presumed to affect all prices equiproportionately (see the quote from Jevons above). Thus the best estimate of monetary inflation is whatever best estimates this average or common component in price changes. Bryan and Cecchetti (1994) do evaluate their measures of core inflation using basic propositions from monetary theory (core inflation should be caused by but not cause money growth; and core inflation should help to forecast future headline inflation). However these ex post evaluations of the performance of various proposed measures are not quite the same thing as using monetary theory to construct a measure of inflation. If there is a meaningful distinction between the cost of living and monetary inflation that is of concern to central bankers, then presumably we should be able to draw on monetary theory to help us measure this alternative concept of inflation.

This is the approach adopted by Quah and Vahey (1995), who adopt a more monetary-theoretic approach to the measurement of core inflation. They define core inflation as the component of measured inflation that has no impact on real output in the long run, and motivate this definition on the basis of a vertical long run Phillips Curve. Their measure is constructed by placing long-run restrictions on a bivariate VAR system for output and inflation. Quah and Vahey assume that both output and inflation have stochastic trends, but are not cointegrated. Thus they write their system in terms of output growth and the change in the inflation rate:

$$\mathbf{Z}_t = \begin{bmatrix} \Delta Y_t \\ \Delta \Pi_t \end{bmatrix} = \sum_{j=0}^{\infty} D(j)\eta(t-j)$$

where $\eta = [\eta_1, \eta_2]'$ with the disturbances assumed to be pairwise orthogonal and $Var(\eta) = I$. Here Π_t denotes inflation at date t as measured by a conventional price index such as the CPI or RPI. Note that Quah and Vahey do not use any information on the cross-section distribution of individual price changes to construct their core inflation measure. The long-run output neutrality restriction is $\sum_{j=0}^{\infty} d_{11}(j) = 0$. The inflation process can be written

$$\Delta \Pi_t = \sum_{j=0}^{\infty} d_{21}(j)\eta_1(t-j) + \sum_{j=0}^{\infty} d_{22}(j)\eta_2(t-j) .$$

Quah and Vahey's candidate measure of *changes* in core inflation is simply $\sum_{j=0}^{\infty} d_{21}(j)\eta_1(t-j)$.

The Quah and Vahey approach to measuring core inflation has also been implemented by Fase and Folkertsma (1996), Claus (1997), Jacquinot (1998), Gartner and Wehinger (1998), and Alvarez and Matea (forthcoming). Fase and Folkertsma relate this measure of inflation to Carl Menger's concept of the inner value of money. However rather than measuring the inflation rate using the CPI, the take as their measure the *unweighted* average rate of change of the component series, calculated on the basis of 200 component price series for the Netherlands, arguing that "…weighting may certainly be useful but there is no clear reason to gauge inflation [as a monetary phenomenon] by way of weighting." Fase and Folkertsma also calculate a core inflation measure for the EU by aggregating price and output data for Austria, Belgium, France, Germany, Italy, the Netherlands, Spain, Sweden and the UK.

As noted, the theoretical justification for the Quah-Vahey approach is the presumption that the Phillips Curve is vertical in the long run. While this might appear to be a relatively innocuous assumption, upon reflection it is clear that it is not without problems. If we accept that the Phillips Curve is indeed vertical in the long run, we are essentially saying that inflation is neutral in its effects on the real economy.[13] It is not obvious that all monetary economists would accept this proposition, still less central bankers charged with the pursuit of price stability. Even fully anticipated constant inflation can have real effects, as documented in the well-known study by Fischer and Modigliani (1978). More generally, insofar as inflation constitutes a tax on holdings of base money, changes in this tax rate may be expected to have implications for agents' decisions about how much money to hold, which will in turn have other real effects (except under limiting assumptions). Another way of thinking about this problem is in terms of the widely held view that the sole objective of monetary policy should be price stability.[14] If we accept that core inflation as measured by Quah and Vahey does in fact correspond to the component of inflation that is under the control of the monetary authority, and also that this component of inflation is in fact neutral with respect to output in the long run, it invites the question of why a central bank would ever want to be concerned about price stability. After all, if all the central bank controls is the price level in the long run, and if the rate at which the price level increases has no implications for the level of real economic activity, then one inflation rate is just as good in welfare terms as another. There is no reason to prefer a steady state inflation rate of 2%

[13] The price level is superneutral.
[14] Although not universally: see for example Aiyagari (1990).

over one of, say, 20%. Price stability or zero inflation ought not to play any particular role in the setting of objectives for monetary policy. Of course nobody seriously believes this. A more realistic assumption might be that the Phillips Curve is not vertical in the long run, but rather upward sloping, from left to right, as proposed by Friedman (1977). Such an assumption would better capture the notion that steady-state or long-run inflation is indeed costly from society's perspective, but would probably be a lot more difficult to operationalise.

Blix (1995) also implements the Quah and Vahey model. However Blix's implementation of the model differs in important respects from Quah and Vahey. To start with, the long run identifying restriction is implemented in a common trends framework rather than a VAR. That is, the model estimated is

$$\begin{pmatrix} Y_t \\ P_t \end{pmatrix} = x_0 + \begin{pmatrix} \alpha_{11} & 0 \\ \alpha_{21} & \alpha_{22} \end{pmatrix} \begin{pmatrix} r_t \\ n_t \end{pmatrix} + \Phi(L) \begin{pmatrix} \varphi_{r,t} \\ \varphi_{n,t} \end{pmatrix}$$

with the growth terms given by the vector random walk process

$$\begin{pmatrix} r_t \\ n_t \end{pmatrix} = \mu + \begin{pmatrix} r_{t-1} \\ n_{t-1} \end{pmatrix} + \begin{pmatrix} \varphi_{r,t} \\ \varphi_{n,t} \end{pmatrix}$$

However, the most substantive difference between this specification and that of Quah and Vahey is the fact that the system is specified in terms of output and the *price level* rather than the inflation rate.[15] Arguably, the proposition that changes in the money stock, and by extension the price level, are neutral in their effects on real economic activity is less controversial than the proposition that changes in the growth rate of the money stack (and by extension the inflation rate) are also neutral in the long run. The distinction is important. Estimating core inflation on the basis of posited neutrality of changes in the price level is surely a lot more appealing from a central banker's perspective than estimation based on the long run neutrality of inflation.

Quah and Vahey express agnosticism about the exact determinants of underlying inflation. However, Blix extends the Quah and Vahey framework to make the role of money even more explicit by estimating the following extended system:

$$\begin{pmatrix} Y_t \\ P_t \\ M_t \end{pmatrix} = x_0 + \Xi_0 \begin{pmatrix} \alpha_{11} & 0 \\ \alpha_{21} & \alpha_{22} \end{pmatrix} \begin{pmatrix} r_t \\ n_t \end{pmatrix} + \Phi(L) \begin{pmatrix} \varphi_{r,t} \\ \varphi_{m,t} \\ \varphi_{p,t} \end{pmatrix}$$

In addition a cointegration restriction is imposed that requires that velocity, i.e. $Y_t + P_t - M_t$, is stationary. The restriction requires that

$$\Xi_0 = \begin{pmatrix} 1 & 0 \\ 0 & 1 \\ 1 & 1 \end{pmatrix}$$

This extension thus brings further hypotheses about real and nominal interactions to bear on the estimation of core inflation. Blix reports that the measures of core inflation obtained in the basic and the extended Quah and Vahey model are quite similar. Unfortunately he does not provide details of the

[15] As justification Blix notes that "Dickey-Fuller tests suggest that the vector $\Delta x_t = (\Delta Y_t, \Delta P_t)'$ is stationary for all countries considered" including the UK. Quah and Vahey claim that "The standard tests confirm that measured *inflation* and output can be treated as I(1)" (emphasis added) using UK data. There is a puzzling inconsistency here.

data used. Monetary theory tells us that, under a fiat monetary standard, the price level is ultimately determined by the stock of base money outstanding relative to the demand for it. Therefore the appropriate measure of M in the system above is a measure of the base money stock. However, the assumption of stationary velocity of base money is probably at odds with the data for several, if not all, industrialised countries.

While Blix's approach to estimating core inflation is more plausible in many respects than the original Quah and Vahey implementation, the fundamental problem of what can be achieved via long run restrictions when we only have a finite sample of data available remains. Faust and Leeper (1997) and Cooley and Dwyer (1998) explore this problem in some detail. The latter provide a series of compelling examples that demonstrate how sensitive inferences from SVAR models are to seemingly innocuous auxiliary assumptions (about whether the data are trend stationary or difference stationary, the number of underlying shocks and so on). So far there has been no attempt to evaluate the sensitivity of core inflation estimates from the SVAR approach of Quah and Vahey to alternative auxiliary assumptions. The SVAR approach to core inflation estimation is also subject to the criticism levied against the DFI, that because it is based on econometric estimates, history will change each time a new observation is added.

9. CRITERIA FOR CHOOSING A MEASURE OF CORE INFLATION

Table 2 presents a set of criteria that could be used to settle on a measure of core inflation, and gives some indication of the extent to which various proposed measures meet these criteria. Note that included in the table are moving average type measures of core inflation, which we have not discussed in any detail. The simplest such measure is a year-on-year inflation rate, which is simply an average of the inflation rate over the past twelve months. The exponential weighted measure of Cogley (1998) could also be included in this category. The major drawback of all such measures is their inherently backward looking nature.

First among the criteria listed is that the measure should be computable in real time. Almost all proposed measures meet this criterion. The only exceptions are measures based on two-sided filters of some sort (such as the band-pass filters proposed by Baxter and King (1995)). Note also that while a measure of core inflation constructed using the well-known Hodrick-Prescott filter is computable in real time, the "end of sample" problems with this filter documented by Baxter and King (1995) make it particularly unappealing as a basis for core inflation measurement.

The second criterion listed is that the measure should be forward looking in some sense. Most of the proposed measures are not inherently forward looking, but they may have some predictive power for future headline inflation. Only the SVAR measures are forward looking by construction. One way in which it is possible to induce an element of forward lookingness into the various measures is to calibrate them to predict future headline inflation or track a trend that is defined in a two-sided manner. Thus Bryan, Cecchetti and Wiggins (1997) calculate the optimal trim on the basis of the ability of the trimmed mean to track a 36-month centred moving average of headline inflation.

The third proposed criterion is that the measure have a track record of some sort. Trivially, all of the measures meet this criterion, but some have been more thoroughly explored than others. The Edgeworth index and the Dynamic Factor index are probably the two least examined measures of core inflation.

The fourth proposed criterion is that the measure be understandable by the public. The inclusion of this criterion is only important insofar as a central bank wishes to compute a measure of core inflation and use it as an integral part of its regular communications with the general public to explain monetary policy decisions. It is questionable whether *any* of the more sophisticated core inflation measures could easily be explained to the general public.

If a core inflation measure is to be used by a central bank to communicate with the general public, it is also important that history not change each time we obtain a new observation. This is the fifth criterion listed, and it essentially rules out (or at least severely compromises the attractiveness of) any core measure that is derived from econometric procedures. It would be worthwhile to discover just how sensitive econometric based estimates of core inflation are to the addition of new information.

Finally it is desirable that the chosen measure have some theoretical basis, ideally in monetary theory. The only measure that really satisfies this criterion is the SVAR measure proposed by Quah and Vahey. However, not all attempts to implement this approach are careful to distinguish between long-run neutrality and long-run superneutrality of money. I have argued that only identification of core inflation based on the neutrality of money should be of interest to a central bank.

10. CONCLUDING OBSERVATIONS

This paper reviewed various approaches to the measurement of core inflation. A common theme linking many of these approaches is the idea that there is some concept of monetary inflation that is distinct from changes in the cost of living and that is a more appropriate target of monetary policy. Reasoning from a traditional quantity theory perspective, this has motivated several authors to look at alternative estimates of the central tendency of the distribution of prices as the best estimate of core or monetary inflation. Other authors have used dynamic frameworks along with neutrality propositions from monetary theory to try to estimate core inflation. All of these approaches suffer from the fact that there is simply no agreed upon theory of money that can serve as a basis for inflation measurement that could plausibly replace the theory of the cost of living.

I have also addressed (somewhat tangentially) the question of how measures of core inflation ought to be evaluated. Many of the measures of core inflation that have been proposed in recent years eschew the theory of the cost of living index as the basis for measurement. This makes evaluation difficult. The theory of the cost of living index provides a coherent framework for the evaluation of measures of headline inflation such as the CPI or the HICP. Essentially we deem a measure of headline inflation to be reliable by the degree to which it approximates the theoretical ideal. There is no theoretical ideal for a monetary measure of core inflation. Rather they are evaluated by their consistency with various loosely formulated propositions from monetary theory. Thus a measure of core inflation that is designed to capture "monetary" inflation might be evaluated by the extent to which it is (Granger) caused by some measure of the money stock but does not (Granger) cause money. Or a measure might be evaluated by the degree to which it forecasts future inflation. This is an approach suggested by Blinder (1997). The problem with this is we start to leave the area of economic measurement and enter the domain of formal theorising and forecasting. It needs to be asked why we would want a measure of core inflation that forecasts future headline inflation. Surely the central bank would be more interested in forecasting future inflation (and would get better results) using multivariate rather than univariate approaches?

This review of various approaches to core inflation measurement also suggests a large number of questions for future research.

First and foremost before choosing a measure of core inflation we need to specify what it is we want the measure for. Do we want a measure of core inflation to answer the question "What would the inflation rate have been if oil prices (or indirect taxes) had not increased last month?" If so, then none of the approaches reviewed above will help. This question can only be answered in the context of a full general equilibrium model of the economy. Furthermore if the measure of inflation we are interested in is the cost of living, then it is not clear why we would ever want to exclude the effects of oil price increases or indirect taxes. Thus it must be the case that when measuring core inflation we have some other inflation concept in mind. Ideally a central bank would be most interested in a measure of inflation that measured the rate of decline in the purchasing power of money. Unfortunately there is no well developed and generally agreed upon theory that can serve as a guide to constructing such a measure. Thus in practical terms we left with the options of constructing a core inflation measure so as to better track the trend inflation rate (somehow defined) in real time, or what in many circumstances may amount to the same thing, forecast the future headline inflation rate.

To start with it might be useful to take a cue from the recent work of Cecchetti (1997) and Bryan, Cecchetti, and Wiggins (1997) and define the problem of core inflation measurement as that of tracking changes in the trend inflation rate. They define the trend as a simple 36-month centred moving average of headline inflation, and then estimate using Monte Carlo methods how much to trim from the cross-section distribution of price changes so as to best track this trend using a trimmed mean measure of core inflation. Their use of a trimmed mean is motivated by the by now well-documented skewness and kurtosis in the cross-section distribution of changes in consumer and producer prices in the US. Thus a first step in constructing a core measure for the ECB would be to document the statistical characteristics of the cross section distribution of HICP price changes.[16] Assuming (as seems reasonable) that the distribution exhibits similar characteristics to that of the US CPI, it would then be useful to investigate the ability of some of the core measures discussed above to track this trend. Note that in doing so we will rapidly come up against the very binding constraint of the short time series of observations for the HICP. With only four years of data it will not be possible to assess the ability of core measures to track the trend in the actual data. The best that can be hoped for is that the inferences drawn from the Monte Carlo experiments are robust. One way around this data constraint would be to investigate various core measures using national CPI data for which longer time series ought to be available. One problem here is that the characteristics of the national CPI data may reflect a particular type of relative price variability that will disappear after the start of EMU, namely that due to exchange rate changes.

The discussion above was highly critical of the various dynamic approaches to core inflation measurement, such as the DFI and the SVAR approach of Quah and Vahey. I asserted that the major shortcoming of the DFI model is that history changes each time a new observation is added. It would be useful to know before dismissing this approach completely by how much history changes each time the model is re-estimated. This should also be done for the other econometric based measures of core inflation. If it turns out that the amount by which the addition of new information causes previous estimates of core inflation to change is trivial, this criticism might lose a lot of its force. There would also be some merit in further exploring the SVAR approach of Quah and Vahey. The great merit of this approach is that it has some basis in monetary theory, but it only makes sense if it is operationalised on the basis of neutrality of money rather than superneutrality. Here what needs to be done (in addition to assessing the sensitivity of estimates to the addition of new information) is to see how sensitive the measures of core inflation are to violations of the auxiliary assumptions.

[16] Preliminary results are presented in Wynne (1998).

Table 1 Schema of approaches to core inflation measurement			
		Time perspective	
		Cross-section	Time series
Raw data	Individual price changes	"Ex. Food and Energy", Limited influence estimators, Neo-Edgeworthian (variance weighted) Index	Dynamic Factor Index
	Headline inflation rate	NA	Moving averages, filtered series, Exponentially smoothed series
	Price data (either headline or disaggregated) plus other aggregates	NA	SVAR measures

Table 2
Criteria for selecting a measure of core inflation

	"Ex. food and energy"	Moving averages	Trimmed mean	Edgeworth (variance weighted) index	Dynamic factor index	VAR measures
Computable in real time	Yes	Maybe	Yes	Yes	Yes	Yes
Forward looking	No	No (?)	No	No	No	Yes
Track record	Yes	Yes (?)	Yes	Yes (?)	Yes	Yes
Understandable by public	Yes	Yes (?)	Maybe	No	No	No
History does not change	Yes	Maybe	Yes	No	No	No
Theoretical basis	No	No	No	No	No	Yes

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SVERIGES RIKSBANK

A Parametric Approach for Estimating Core Inflation and Interpreting the Inflation Process*

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Abstract
In this paper we propose a new parametric approach for measuring core inflation and analysing the inflation process. In the model, measured inflation may change because of changes in three basic factors: long-run conditions, transitory output, and ”special factors”. The “special factors” include supply shocks and other factors that affect inflation over and above changes in long-run conditions and transitory output. None of the three basic factors can be directly observed, but each factor is econometrically identified. We show that our approach can be used to derive estimates of core inflation that parallel three different views found in the literature -- as long-run inflation, demand-driven inflation, and inflation excluding certain undesired “special factors”. The approach is illustrated using Swedish quarterly data covering the time period 1970:1-1998:1.

Key Words: Core inflation, Kalman filter, structural time-series models, underlying inflation, unobserved-components models.

JEL Classification System Numbers: C32, E31.

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1. Introduction

In the last decade, inflation targeting has become a widely used framework for both theoretical analysis and practical design of monetary policy.[1] In this framework, the primary objective of the central bank is to keep inflation in line with the target, mainly by affecting real economic activity through appropriate adjustments of its instrument rate. This task may seem straightforward but is in practice associated with considerable difficulties.

One problem pertains to the identification and selection of an appropriate target variable. The common view of inflation-targeting central banks seems to be that not all movements in the general price level are equally important from a monetary policy point of view. For example, if an increase or decrease in inflation is perceived to be sufficiently temporary, a policy response may not be regarded as necessary. This suggests that central banks wish to avoid basing their monetary-policy decisions on inflation changes that are not part of the "pure" inflationary process, and rather focus on the underlying, or core, rate of inflation.[2] Unfortunately, underlying inflation is a variable that cannot be directly observed.[3]

Another problem is related to the determination of the component of real economic activity that the central bank can affect through its policy. According to the widely accepted notion of long-run neutrality of money, the central bank can affect real economic activity only temporarily. However, like underlying inflation, the transitory component of output that can be affected by monetary policy is not observable. An interpretation of the task of the central bank is therefore that it has to control an unobservable variable – underlying inflation – mainly through the effects of interest rates on another unobservable variable – a transitory component of output. This is obviously a rather intricate task.

Somewhat surprisingly, and adding to the complexity of the problem, the concept of core inflation appears to have no clear theoretical definition. As indicated above, it is usually interpreted as some more persistent component of measured inflation, but different approaches seem to refer to different parts of persistent inflation. In the literature, it is possible to identify at least three different views on core inflation.

The first, proposed by Eckstein (1981), interprets core inflation as "the rate [of inflation] that would occur on the economy's long-term growth path, provided the path were free of shocks, and the state of demand were neutral in the sense that markets were in long-run equilibrium". (Eckstein, 1981, p. 8.) In what follows we label this view on core inflation "long-run inflation", reflecting the fact that it in this view is seen as a steady-state concept.[4]

A second view, introduced by Quah & Vahey (1995), looks at core inflation as "that component of measured inflation that has no (medium- to) long-run impact on [real] output". (Quah & Vahey, 1995, p. 1130.) An alternative way of putting this is as that component of inflation that is generated by shocks with no (medium- to) long-run effects on real output. Because shocks with no long-run effects on real output are often referred to as demand shocks (Blanchard & Quah, 1989), the Quah-Vahey view on core inflation may alternatively be interpreted as approximately corresponding to the demand-driven component of inflation.

A third view, which in what follows is referred to as the "central-bank view", seeks to capture core inflation by eliminating or reducing the influence of certain factors, typically particularly volatile and erratic components (see for example Blinder, 1982a). Since demand shocks are not in general considered to be among these "undesirable" components, this view on core inflation differs from that of Eckstein, in which the state of demand, as noted above, is required to be neutral at the core rate of inflation.[5] It also seems to differ from the Quah-Vahey interpretation since not only demand shocks are assumed to matter for core inflation.

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[1] Surveys are given in, for example, Leiderman & Svensson (1995), Haldane (1995, 1997), Debelle (1997), and Mishkin & Posen (1997).
[2] In this paper, the terms core inflation and underlying inflation are used synonymously.
[3] In this context it is however important to note that the policy implications from targeting the core or headline rate of inflation not necessarily need to be different. An inflation-targeting central bank usually bases its actions on a forecast of inflation. Only to the extent that the forecast of headline inflation differs from the forecast of core inflation will the policy actions then differ. This will happen if there are foreseeable effects, for example temporary effects, which affect the forecast of headline inflation but not the forecast of core inflation. The difference between the policy actions is hence likely to depend on the central bank's target horizon.
[4] Scadding (1979) suggested a similar interpretation.
[5] See Blinder (1982b).

In this paper we propose a new parametric approach for measuring core inflation and interpreting the inflation process. The approach takes the unobservability of both core inflation and its determinants explicitly into consideration and estimates these unobservable components simultaneously. In the model, measured inflation may change because of changes in three basic factors: long-run conditions, transitory output, and "special factors". The "special factors" include supply shocks and other factors that affect inflation over and above changes in long-run conditions and transitory output. None of the three basic factors can be directly observed, but each factor is econometrically identified and thus possible to estimate.

Our approach has several interesting features. Firstly, because it explicitly identifies the determinants of inflation within a theoretical model, it allows a *decomposition of inflation into economically interpretable components*. This facilitates the understanding and analysis of the inflation process. Secondly, and as a corollary of the above-mentioned aspect, we are able to derive *estimates of core inflation that parallel the above-discussed different views on this variable*. A measure closely related to Eckstein's (1981) approach is obtained by letting core inflation correspond to the part of inflation generated by long-run conditions, that is when the influences of transitory output and "special factors" are eliminated. Given that transitory output is assumed to reflect the state of aggregate demand, which is the common interpretation in this type of model, a measure corresponding to Quah & Vahey's (1995) approach is obtained by letting the part of inflation generated by transitory output represent core inflation. The central-bank measure, finally, is obtained by merely excluding the effects of certain of the "special factors" from the measured inflation rate. Thirdly, because our approach is parametric, *different specifications of the processes of the determinants of inflation (and hence also of core inflation)* may be considered. This may help us to improve our understanding of the inflation process in Sweden (which is the country that we study), but it also may make the approach usable for applications to other countries.

The remainder of the paper is structured as follows. Section 2 gives a brief review of the approaches to estimating core inflation that can be found in the literature. Section 3 presents our parametric model of the inflation process and discusses how it relates to the above-mentioned views on core inflation. The empirical illustrations are presented and discussed in Section 4. Section 5, finally, provides concluding remarks.

2. Different Views on Core Inflation

2.1. Long-Run Inflation

According to the framework in Eckstein (1981), inflation can be divided into three components: core inflation, a component related to aggregate demand, and a "shock" component. Core inflation is interpreted as the inflation rate that would occur on the economy's long-term growth path in the absence of shocks and at a neutral state of demand – that is, as the inflation rate that would occur in long-run equilibrium; long-run inflation for short.[6] Eckstein develops an econometric model of the US economy, which he uses to decompose actual inflation into these three components. Parkin (1984) shows that this concept of core inflation essentially coincides with the expected rate of inflation in a traditional expectations-augmented Phillips (or aggregate supply) curve.[7]

Despite the fact that an immense number of Phillips curves have been estimated in different contexts, Phillips-curve specifications have rarely been used to explicitly estimate core inflation interpreted in this way. A possible explanation is that this steady-state interpretation of core inflation seems to be rarely used outside (and possibly also inside) the academic sphere and is probably not what people in general have in mind when referring to the term.

[6] This long-run interpretation of the core-inflation concept can also be found in macroeconomic textbooks. See, for example, Burda & Wyplosz (1993) and Romer (1996).
[7] See also Scadding (1979, p. 8) who argues that core (underlying) inflation "presumably comes close to the theoretical notion of the perceived rate of inflation".

2.2. The Quah-Vahey Approach

An alternative approach for estimating core inflation was introduced by Quah & Vahey (1995). Like the Eckstein framework, this approach establishes a link between core inflation and other economic variables. Core inflation is seen as the component of measured inflation that has no (medium- to) long-run impact on real output. This restriction is in Quah & Vahey (1995) implemented in a bivariate output-inflation vector-autoregressive (VAR) system by assuming that there exist (permanent) shocks that do not affect real output in the long run. These shocks are then assumed to be the shocks that generate core inflation. In the literature, shocks with no long-run impact on output have often been interpreted as demand shocks. Thus, in the Quah-Vahey framework, core inflation may be interpreted as demand-driven inflation (although Quah & Vahey themselves do not explicitly make this interpretation).

This view of core inflation seems to differ from other views on the concept. Looking at core inflation as the component of measured inflation that has no (medium- to) long-run impact on real output implies that core inflation is associated with transitory movements of real output *out of* long-run equilibrium. This contrasts with the interpretation of Eckstein, who assumes that core inflation is the rate of inflation that would occur when the real economy is *at* its long-run equilibrium. The view also differs from the central-bank view, which does not assume that core inflation only depends on demand shocks.

Although no central bank to our knowledge is currently using an estimate derived from the Quah-Vahey approach as its official estimate of underlying inflation, the approach has certainly gained widespread use among analysts of monetary policy (see for example Blix, 1995, Fase & Folkertsma, 1997, Bjørnland, 1997, Claus, 1997, Dewachter & Lustig, 1997, and Gartner & Wehinger, 1998).

2.3. The Central-Bank View

The approaches for estimating core inflation emanating from the central-bank view may be loosely described as various ways of eliminating or reducing different "undesirable" effects on the measured inflation rate. Typically, measured inflation is adjusted for highly volatile components and price developments considered to be representing one-off shifts in the price level, such as changes in indirect taxes. Sometimes, measured inflation is also adjusted with respect to the direct, more or less definitional, adverse effects of the central bank's own actions. In many countries, components directly related to interest-rate changes are left out of the inflation measure since, for example, a tightening of monetary policy will through these components increase measured inflation autonomously. Clearly, such an adverse short-term effect is hardly an adequate reason for further monetary tightening.[8]

A common feature of the practical implementations of the central-bank approaches is that they, unlike the approaches of Eckstein (1981) and Quah & Vahey (1995), do not establish an explicit link between core inflation and other economic variables. Hence, they tend to have a weaker theoretical under-pinning and may therefore be viewed as more "mechanical". On the other hand, they are less complicated and thus easier for the general public to understand, at least in the sense that the operations made to arrive at the core-inflation estimate are quite straightforward.

Data on the different aggregate price index components (in practice, CPI components) are often used as the starting point for the analysis of core inflation according to the central-bank view. One commonly used approach attempts to make measured inflation reflect the underlying rate more accurately by removing the estimated effects of specific disturbances and events on a *case-by-case basis*.[9] The most common example of this type of correction is adjustment for the effects of changes in indirect taxes. Other events that sometimes are believed to motivate an adjustment are significant changes in the terms of trade or different types of natural disasters causing large price increases on certain items.[10] This procedure requires adequate information regarding the source, magnitude, and timing of the disturbance on the price series concerned, which may often be difficult to obtain.

[8] See, for example, Roger (1994).

[9] See, for example, Roger (1994) and Ravnkilde Erichsen & van Riet (1995).

[10] The escape clauses of the institutional monetary-policy framework of New Zealand (see for example Mishkin & Posen, 1997, p. 38) may be viewed as a type of (implicit) case-by-case adjustment in that they allow the central bank to temporarily disregard certain inflation impulses and to accommodate first-round effects on prices, but not to allow the passing on of these effects to a second round.

Adjustment is primarily made with respect to the first-round effects, which may be less uncertain than the successive feed-through effects of the shocks. In the case of indirect-tax adjustments, first-round effects are often calculated by simply using the change in the tax rate and the weight in the CPI of the items in question. However, even first-round effects may be difficult to determine since they may vary over time, for example due to varying opportunities for firms to absorb price shocks in the profit margins, and it may be unclear exactly which items that are affected. Furthermore, a seemingly temporary price shock may affect inflation expectations and thereby feed through into the more persistent parts of inflation. Hence, case-by-case adjustment necessarily contains a judgmental ad-hoc element and may, as a result, sometimes be viewed as a less transparent method.

Another frequently used approach intended to make measured inflation correspond more closely to underlying inflation is the so-called *excluding-food-and-energy approach* which implies that certain price series are completely removed from the aggregate price index. For example, the inflation rate relevant for monetary-policy decisions in the US excludes changes in food and energy prices while the inflation-target variable in the UK is adjusted for mortgage interest payments. Contrary to the case-by-case approach, adjustments are made systematically according to a pre-specified rule and they may therefore be regarded as more transparent.[11] A disadvantage of the excluding-food-and-energy approach is that it requires an ex ante identification of the price series to be excluded, which may not always be an easy task. This is illustrated by the finding in Cecchetti (1997) that the CPI excluding food and energy is, in fact, not less volatile than the CPI itself. Furthermore, one can hardly be certain that the excluded price series *never* contain information on core inflation. Changes in excluded price series may for example at some point in time and under certain circumstances affect inflation expectations and hence feed into the more persistent parts of inflation in the same way as some of the disturbances eliminated in the case-by-case approach. It is also possible that the composition of the group of items whose price behaviour differs from the behaviour of prices in general changes over time. The once-and-for-all choice of the items to be excluded therefore runs the risk of generating an estimate of underlying inflation that over time becomes misleading.

The basic idea in the case-by-case and excluding-food-and-energy approaches is that because the overall price index is calculated as a weighted mean of the prices of individual items, the importance of temporary disturbances will be overstated. This is also the point of departure for an approach using so-called limited-influence estimators (LIEs) to analyse core inflation. One type of LIE, suggested by Bryan & Pike (1991), is the *weighted median* across the number of individual prices.[12] The median will differ from the mean when the distribution of individual price changes is skewed. This may be the case when, for example, a period of poor weather raises the price of certain items temporarily. The skewed distribution generates a transitory increase in the mean whereas the median may not be affected (or, at least, less affected).

Bryan & Cecchetti (1994) provide a theoretical justification for the use of LIEs, based on the framework in Ball & Mankiw (1995). In the absence of shocks, Bryan & Cecchetti assume that firms raise their prices in line with underlying inflation. When a relative price shock (or cost shock) occurs, the firms affected have to decide whether or not to change their prices at a rate differing from the underlying rate. Changing the price is assumed to be associated with an adjustment cost (menu cost), which implies that the shocks have to be sufficiently large to trigger such a price change. If the cost is large enough, then the firms will choose not to react to the shock and we would as a result find a spike in the cross-sectional price-change distribution at the rate of inflation representing core inflation. Furthermore, above and below certain cut-off points determined by the adjustment costs we would find a lower and an upper tail representing firms hit by shocks large enough to induce deviating price changes despite the adjustment costs. If the distribution of the underlying shocks is, for example, skewed to the right, we would in the distribution of realised price changes expect to find an upper tail that is larger than the lower tail. The most common inflation measure – the mean of realised price changes -- would be influenced by both the spike and the tails and would hence over-estimate core inflation. The median, on the other hand, would only regard the spike, which, according to the assumptions, represents core inflation.

[11] It should be noted that the *excluding-food-and-energy approach* is often used as a complement to the *case-by-case approach*. It is for example common to adjust for changes in indirect taxes and at the same time exclude certain volatile price series.

[12] The weighted median is obtained by ordering the individual items in the aggregate index with respect to the magnitude of the price change, accumulating the weights and picking the price increase of the item corresponding to an accumulated weight of half of the total weight.

An advantage of the weighted median compared to the case-by-case and excluding-food-and-energy approaches is that it is completely systematic in the sense that no arbitrary judgement concerning what shocks to adjust for or what price series to disregard from is needed. Furthermore, Bryan & Cecchetti (1994) conclude that among a number of different estimates of core inflation, the weighted median performs best in many respects, for example regarding the ability of the estimate to forecast future price changes.

Another LIE is the *trimmed mean*, suggested by, for example, Bryan & Cecchetti (1994). This estimator is computed by trimming a percentage from the tails of the distribution of individual price changes, and averaging what is left. Thus, the weighted median may be seen as a special case of the trimmed mean where 50 percent has been removed from each tail of the distribution of price changes. Bryan, Cecchetti & Wiggins (1997) and Cecchetti (1997) investigate the efficiency properties of different estimators on US data. They find that the mean with around 10 percent trimmed from each tail is the most efficient estimator of core inflation.[13] The choice of how much to trim from the tails is however not obvious. Shortcomings that the LIEs share with the above-discussed other central-bank estimates are that it is difficult to give the estimates an explicit economic content (for example, how they relate to changes in demand and supply) and that there is a risk of excluding potentially important information.

3. A Parametric Model of the Inflation Process

As mentioned above, the approach that we propose is based on the idea that the link between inflation and other economic variables can be summarised in a model where inflation is a function of three basic factors: long-run conditions, transitory real output, and "special factors".[14] The approach may be regarded as an application of the so-called structural time-series or unobserved-components (STM/UC) methodology.[15] In this section we present the model and discuss some of its properties and implications.

Let π_t be the measured (CPI) inflation rate, π_t^{LR} long-run inflation, y_t^{TRAN} the relevant transitory component of real output, Z_t a vector of "special factors" (to be defined below) normalised so that $E(Z_t) = 0$, and ε_t an IID error with zero mean and constant variance σ_ε^2. The key equation of our model may then be written as:

$$\pi_t - \pi_t^{LR} = \alpha_1(\pi_{t-1} - \pi_{t-1}^{LR}) + ... + \alpha_p(\pi_{t-p} - \pi_{t-p}^{LR}) + \beta_0 y_t^{TRAN} + \beta_1 y_{t-1}^{TRAN} + ... + \beta_q y_{t-q}^{TRAN} + \delta_0 Z_t + \delta_1 Z_{t-1} + ... + \delta_m Z_{t-m} + \varepsilon_t,$$

or, equivalently,

$$\alpha(L)(\pi_t - \pi_t^{LR}) = \beta(L) y_t^{TRAN} + \delta(L) Z_t + \varepsilon_t, \qquad (3.1)$$

where L is the lag operator, $L^i x_t = x_{t-i}$ for any variable x. Thus, the short-run component of measured inflation $(\pi_t - \pi_t^{LR})$ depends on a transitory component of real output (y_t^{TRAN}) and a vector of "special factors" (Z_t), or, equivalently, measured inflation (π_t) depends on long-run inflation (π_t^{LR}), y_t^{TRAN}, and Z_t. A formal justification of our interpretation of π_t^{LR} as the inflation rate that occurs in the long run will be given below.

Equation (3.1) bears a rather close resemblance to traditional Phillips (or aggregate supply) curves (see, for example, Gordon, 1997, and Hall & Mankiw, 1994). In some respects, however, the equation differs from traditional Phillips-curve specifications. One difference is that long-run inflation

[13] A thirty-six month centred moving average of actual inflation is used as a representation of core inflation.
[14] Our framework is hence conceptually similar to that of Eckstein (1981).
[15] See, for example, Harvey (1989) for a general reference. Examples of other applications of the STM/UC methodology are Apel & Jansson (1997, 1998) and Gerlach & Smets (1997).

enters (3.1) as an explicitly identified component which is allowed to vary over time. Usually, the term that we label long-run inflation (which in traditional expectation-augmented Phillips-curve specifications corresponds to expected inflation) is assumed to be constant (captured by the mean rate of inflation) or equal to the inflation rate in the previous period (whereby the *change* of inflation enters the left-hand side of equation (3.1)). The equation thus allows for a separate identification of the dynamics associated with changes in short-run and long-run inflation (the dynamics of long-run inflation will be discussed below). In a specification with no long-run inflation dynamics (a constant π_t^{LR}), the actual persistence of measured inflation has to originate from one or several of the following sources: (1) the autoregressive lags of measured inflation; (2) the transitory output terms; (3) the "special factors" included in the Z_t vector. Equation (3.1) adds to these sources of persistence by allowing for different dynamics of inertia with respect to short- and long-run inflation.

In this type of specification, the Z_t vector is generally regarded as a vector of supply-shock proxies, intended to capture shifts in the Phillips curve (see, for example, Gordon, 1997).[16] Ignoring the influence of supply changes is likely to give rise to mis-specification problems (see Apel & Jansson, 1997, for further discussions of this point). In the present application it will be useful to divide the Z_t vector into two sub-categories. The first category $(Z_{t,1})$ contains the "undesirable" components that the central bank wishes to exclude when making its analysis of core inflation (see the discussion in Section 2.3). The second category $(Z_{t,2})$ includes (other) supply-shock proxies that improve the fit of the equation but that here have no direct implications for the estimates of core inflation.

From the discussion in the previous section it is clear that the central-bank approach to estimating core inflation in practice involves a substantial judgmental element when it comes to deciding on what disturbances and/or price series to adjust for. Hence, in our implementation of the procedure, there are several possible candidates for variables to include in $Z_{t,1}$. In general, of course, the choice of variables in $Z_{t,1}$ (as well as $Z_{t,2}$) is a non-trivial issue that involves both theoretical and empirical considerations. In our empirical application, we let the procedures and estimates of the Swedish central bank (which are similar to those of other central banks) serve as guidelines when deciding on what variables to include in $Z_{t,1}$, and how they are allowed to enter equation (3.1). In this vector we therefore include data on changes in short-term nominal interest rates, changes in (the log of) nominal oil prices and nominal import prices, and dummies representing changes of indirect taxes. Furthermore, only the contemporaneous effects of these variables are considered. The $Z_{t,2}$ vector contains changes in (the log of) labour productivity and relative oil prices.[17] Equation (3.1) can then be re-written as:

$$\alpha(L)(\pi_t - \pi_t^{LR}) = \beta(L)y_t^{TRAN} + \delta_{0,1}Z_{t,1} + \delta_2(L)Z_{t,2} + \varepsilon_t, \qquad (3.2)$$

where $\delta_{0,1}$ captures the contemporaneous impact of the variables in $Z_{t,1}$ and $\delta_2(L) = \sum_{i=0}^{m} \delta_{i,2}L^i$.

Although the problem of selecting appropriate Z_t variables is present also in this parametric approach, some interesting differences compared to many of the previously discussed methods can be identified. To elaborate somewhat on this point, it is useful to rewrite equation (3.2) as:

[16] If (3.1) is viewed as an aggregate supply relationship, then ε_t is also usually interpreted as a supply shock.

[17] For purposes of identification, it is assumed that changes in real oil prices do not have an immediate impact on measured inflation. Although not problem-free, this assumption does not appear unreasonable in light of the fact that "behavioural" changes presumably show up with some lags. The data are quarterly and run from 1970:1 to 1998:1. For further details, see Appendix 1.

$$\pi_t = \pi_t^{LR} + \alpha(L)^{-1}\beta(L)y_t^{TRAN} + \alpha(L)^{-1}\delta_{0,1}Z_{t,1} + \alpha(L)^{-1}\delta_2(L)Z_{t,2} + \alpha(L)^{-1}\varepsilon_t .^{18} \quad (3.3)$$

Firstly, because we measure the variables' effects on inflation econometrically rather than using the weights of the items in the CPI, we may, at least to some extent, be able to capture the interdependence between different items. For example, an increase in the price of oil may give rise to contemporaneous price increases in a large number of items in the CPI basket. By estimating the average impact of changes in the price of oil (captured in $\delta_{0,1}$) rather than just using the weight of oil in the basket, it may be possible to obtain a more accurate measure of these effects on overall CPI inflation. Secondly, the fact that the specification contains dynamics of short-run inflation implies that it is possible to take into account potential dynamic feed-through effects of changes in the $Z_{t,1}$ variables (as well as, of course, of changes in $Z_{t,2}$ and y_t^{TRAN}). These effects are in this model reflected in the $\alpha(L)^{-1}$ term. For example, a change in an indirect tax may, due to inflation inertia, have effects in several consecutive periods. Just considering the first-round effect, possibly by simply using the change in the tax rate and the weight in the CPI of the items hit by the tax, may therefore give misleading results.[19]

In Phillips-type equations it is common to interpret the transitory component of output, y_t^{TRAN}, as an estimate of the "output gap". Since changes in aggregate demand are frequently regarded as the main source of business-cycle fluctuations, the output gap (or the unemployment gap) is often regarded as a measure of excess demand. The state of demand may hence be considered to be neutral when $y_t^{TRAN} = 0$. In most empirical studies, the transitory part of output (or unemployment) is calculated separately and inserted as an exogenous variable in the Phillips-curve specification. In the present STM/UC approach, however, it is possible to treat the transitory part of output as an endogenous variable and estimate it simultaneously with long-run inflation and the parameters of the model.

In the preceding section, three different views on core inflation were described. Equation (3.3) can be used to illustrate these views. In long-run equilibrium at a neutral state of demand and in the absence of shocks, equation (3.3) implies that $\pi = \pi^{LR}$.[20] This provides a justification for our interpretation of π_t^{LR} as the rate of inflation that occurs in the long run. A core inflation estimate closely related to the one proposed by Eckstein (1981) then obtains as:

$$\pi_t^{CORE} = \pi_t^{LR} .^{21} \quad (3.4)$$

[18] In going from (3.2) to (3.3) it is assumed that the polynomial $\alpha(L)$ is invertible so that short-run inflation, $\pi_t - \pi_t^{LR}$, does not contain any unit roots.

[19] Such dynamic feed-through effects could also have been allowed for by including lags of the variables in $Z_{t,1}$. However, at a conceptual level, we find it in our case more natural to model these as arising because of inflation inertia. More generally then, one may wish to consider different sets of AR parameters associated with short-run inflation changes depending on the source of the change of inflation. Because our empirical applications are foremost meant as illustrations we have chosen not to address this issue further, but we note that it is an interesting generalisation (although presumably not problem-free from a technical point of view) to be considered in future applications.

[20] The precise statement is: $y_t^{TRAN} = Z_{t,1} = Z_{t,2} = \varepsilon_t = 0$ for all $t \Rightarrow \pi = \pi^{LR}$ provided $\alpha(1) \neq 0$.

[21] It deserves here to be noted that the measurement of core inflation according to a strict interpretation of Eckstein's approach cannot be dealt with without knowing the precise nature of the sources of time variation that are prevalent in the process of long-run inflation. For example, if long-run inflation is driven by some stochastic shocks, then core inflation needs to be measured conditionally on the effects of these shocks (in order to fulfil the "in-absence-of-shocks" criterion). In our applications, we shall generally allow the estimates of core inflation interpreted as corresponding to the Eckstein view to depend on stochastic shocks, but it is emphasised that the estimates corresponding to the stricter interpretation obtain as simple special cases in which restrictions on certain parameters are imposed (that is, zero restrictions on the variances of long-run inflation). If all the sources of time variation are regarded as ultimately originating from shocks, then, intuitively, the Eckstein approach to core inflation has to predict that core inflation always is constant. In (3.3) then, core inflation is equal to the constant unconditional expectation of actual inflation. But, in this case, of course, there is no "estimation problem".

In the framework of Quah & Vahey (1995), core inflation is basically interpreted as the demand-driven component of inflation. In our model, this would correspond to the second term of the right-hand side of equation (3.3):

$$\pi_t^{CORE} = \alpha(L)^{-1}\beta(L)y_t^{TRAN} \text{ .}^{22} \qquad (3.5)$$

The central-bank view, in which the influence of different "undesirable" effects on measured inflation is reduced or eliminated, is in this framework most naturally approximated by subtracting the contemporaneous term $\delta_{0,1}Z_{t,1}$ from measured inflation. Hence, core inflation according to the central-bank view is taken to be:

$$\pi_t^{CORE} = \pi_t - \delta_{0,1}Z_{t,1} = \pi_t^{LR} + \alpha(L)^{-1}\beta(L)y_t^{TRAN} + \\ (\alpha(L)^{-1} - 1)\delta_{0,1}Z_{t,1} + \alpha(L)^{-1}\delta_2 Z_{t,2} + \alpha(L)^{-1}\varepsilon_t . \qquad (3.6a)$$

An advantage of our parametric approach, which is clear from the second equality in equation (3.6a), is that the resulting central-bank estimate of core inflation, in contrast to more mechanically derived estimates in this tradition, can be decomposed into economically interpretable components. As discussed previously, it is within this approach also possible to derive a "dynamically adjusted" central-bank estimate of core inflation:

$$\pi_t^{CORE} = \pi_t - \alpha(L)^{-1}\delta_{0,1}Z_{t,1} = \\ \pi_t^{LR} + \alpha(L)^{-1}\beta(L)y_t^{TRAN} + \alpha(L)^{-1}\delta_2 Z_{t,2} + \alpha(L)^{-1}\varepsilon_t . \qquad (3.6b)$$

Thus, the quantity $(\alpha(L)^{-1} - 1)\delta_{0,1}Z_{t,1}$ may be regarded as a measure of the importance of the dynamic feed-through effects associated with changes in $Z_{t,1}$.

To be able to estimate equation (3.2), it is necessary to specify a parametric process for long-run inflation, π_t^{LR}. In STM/UC applications, the most common assumption is that "permanent" unobservable long-run variables follow random walks. In our case this would mean that π_t^{LR} is I(1) and satisfies:

$$\pi_t^{LR} = \pi_{t-1}^{LR} + \varepsilon_t^{LR} , \qquad (\textit{specification A}) \qquad (3.7a)$$

where ε_t^{LR} is an IID error term with $E(\varepsilon_t^{LR}) = 0$ and a constant variance $\sigma^2_{\varepsilon^{LR}}$.

However, in the case of Sweden, one may question whether a non-stationary I(1) process like (3.7a) provides a reasonable approximation of the behaviour of long-run inflation during the entire sample period. From the early 1970s until the beginning of the 1990s, recurrent cost crises in Sweden were accommodated by several devaluations (and a depreciation when the fixed exchange rate was abandoned in November 1992). Both the mean and the variance of inflation were high and one may well argue that the Swedish economy during this period lacked a reliable nominal anchor. Shortly after the switch to a floating exchange-rate regime in 1992, an explicit inflation target of 2 percent was introduced. Since then inflation has been low and reasonably stable.

[22] It is of course difficult to translate the structural VAR framework of Quah & Vahey to the Phillips-curve framework used in this paper in a fully satisfactory way. One important difference is that the demand-generated part of inflation is assumed to be an I(1) process in Quah & Vahey whereas it in our specification – as equation (3.5) makes clear – is an I(0) variable. We emphasise that the I(1) assumption used by Quah & Vahey is not a necessary condition for applying the Blanchard-Quah identification scheme of demand shocks. If actual inflation instead is assumed to be I(0), then the bivariate VAR system would be driven by a permanent and a purely transitory shock. No further identifying assumptions would be needed to achieve exact identification. A stationary demand-driven component of inflation, consistent with the identification scheme of Blanchard & Quah, could then be computed by setting all permanent shocks equal to zero. This procedure, presumably, would generate a Quah-Vahey core inflation estimate which, at least from an empirical point of view, would be easier to compare with the estimate derived from equation (3.5).

Against this background, we consider the following two alternative specifications of the process of π_t^{LR}:

$$\pi_t^{LR} = \begin{cases} \pi_{t-1}^{LR} + u_{t,1} & t \leq 1992:4 \\ \mu + u_{t,2} & t > 1992:4 \end{cases}, \qquad (\textit{specification B}) \qquad (3.7b)$$

$$\pi_t^{LR} = \begin{cases} \mu_1 + \eta_{t,1} & t \leq 1992:4 \\ \mu_2 + \eta_{t,2} & t > 1992:4 \end{cases}, \qquad (\textit{specification C}) \qquad (3.7c)$$

where μ, μ_1, and μ_2 are constants and $u_{t,1}$, $u_{t,2}$, $\eta_{t,1}$, and $\eta_{t,2}$ innovations that are assumed to be IID with $E(u_{t,1}) = E(u_{t,2}) = E(\eta_{t,1}) = E(\eta_{t,2}) = 0$ and constant variances $\sigma_{u_1}^2$, $\sigma_{u_2}^2$, $\sigma_{\eta_1}^2$, and $\sigma_{\eta_2}^2$. Thus, the switch to a regime with an explicit inflation target is assumed to have affected the process for long-run inflation. In specification B, π_t^{LR} is assumed to follow a random walk in the period before the switch and to fluctuate randomly around a constant thereafter. In specification C, long-run inflation is assumed to fluctuate randomly around a constant in both periods, but the constants may be different for the two periods. Note that in (3.7c), long-run inflation will be equal to the constant unconditional expectation of actual inflation as $\mu_1 = \mu_2$ and $\sigma_{\eta_1}^2 = \sigma_{\eta_2}^2 = 0$ (see footnote 21).

It is by no means obvious that the regime shift occurred exactly at the point in time assumed above. Different types of data give a mixed guidance. For example, survey data on inflation expectations of households and agents on the money market show that households started to revise their expectations downwards already before the switch to the floating exchange-rate regime while agents on the money market did not start to revise their expectations downwards until after the switch. Thus, this evidence suggests the possibility of a smooth, rather than discrete, transition to the new regime. However, given the considerable technical difficulties associated with modelling a smooth transition to the new regime, we have in this illustrative application chosen to restrict ourselves to processes that imply a discrete shift. Given this, it seems quite reasonable to let the shift coincide with the switch to the floating exchange-rate system and the introduction of the explicit inflation target.

The relationships that are used to complete the system are

$$\gamma(L) y_t^{TRAN} = \varepsilon_t^{TRAN} \qquad (3.8)$$

and

$$y_t^P = \lambda + y_{t-1}^P + \varepsilon_t^P, \qquad (3.9)$$

where y_t^P is the permanent part of output (that is, $y_t^P \equiv y_t - y_t^{TRAN}$), λ a constant drift parameter, and ε_t^{TRAN} and ε_t^P innovations that are assumed to be IID with $E(\varepsilon_t^{TRAN}) = E(\varepsilon_t^P) = 0$ and constant variances $\sigma_{\varepsilon^{TRAN}}^2$ and $\sigma_{\varepsilon^P}^2$. All the roots associated with the lag polynomial $\gamma(L) = 1 - \gamma_1 L - \gamma_2 L^2 - ... - \gamma_n L^n$ are assumed to lie outside the unit circle so that y_t^{TRAN} is I(0). The permanent component of output y_t^P, on the other hand, is I(1) with a linear trend.

To summarise, the model consists of the four equations given by (3.2), (3.7a) (or (3.7b) or (3.7c)), (3.8), and (3.9). All shocks of the system are assumed to be mutually uncorrelated. For purposes of estimation, it is convenient to re-write the model in state-space form. Once the model has been put in state-space form, one can apply the Kalman filter and maximum likelihood to obtain estimates of the unknown parameters and the unobserved variables π_t^{LR}, y_t^{TRAN}, and y_t^P.[23]

4. Empirical Illustrations

When estimating the specifications A, B and C in their basic form, the prediction errors associated with real output turn out not to be serially uncorrelated. The correlogram of the prediction errors reveals that the autocorrelation problem is due to a significant correlation at lag one. To handle this problem, the error-process ε_t^P in equation (3.9) is replaced by

$$e_t = \rho e_{t-1} + \varepsilon_t^P, \qquad |\rho| < 1, \qquad (4.1)$$

where ε_t^P ~ IID (0, $\sigma_{\varepsilon^P}^2$). We note that while this generalisation of the process for the errors in (3.9) leads to sequences of prediction errors that appear to be free of serial correlation, the main results of our empirical analysis are not affected.[24]

The parameter estimates for specification A, in which long-run inflation is assumed to follow a random walk during the entire sample period, have in general the expected signs (the results are shown in the first column of Table A1 in Appendix 2). The variance of long-run inflation $\sigma_{\varepsilon^{LR}}^2$ is significantly different from zero at the 11 percent level.

As argued above, however, one may question whether the random-walk assumption accurately describes the behaviour of long-run inflation during the whole sample period. In specification B, long-run inflation follows a random walk during the period before the monetary-policy regime shift but fluctuates randomly around a constant thereafter. This reflects our belief that an explicit inflation target is a more reliable nominal anchor than a fixed, but frequently devalued, exchange rate. As is shown in Table 1, the maximised value of the log likelihood improves by approximately 10 units when using specification B instead of specification A.[25] Furthermore, this result obtains for both unrestricted and restricted versions of the two specifications. It should however be noted that because the models are not nested, a formal test cannot be undertaken in the usual way.

Table 1. Information criteria and maximised log-likelihood values for the three specifications

Spec.	AIC_{UR}	SC_{UR}	HQ_{UR}	l_{UR}	AIC_R	SC_R	HQ_R	l_R
A	5.283	6.212	5.659	221.223	5.230	5.814	5.466	231.668
B	5.133	6.115	5.530	211.943	5.062	5.699	5.319	221.490
C	**4.930**	**5.939**	**5.338**	201.101	**4.925**	**5.642**	**5.215**	211.878

Notes: The information criteria are defined as follows; Akaike's criterion: $AIC = T^{-1}2(P + l)$; Schwartz' criterion: $SC = T^{-1}(P\log(P) + 2l)$; Hannan & Quinn's criterion: $HQ = T^{-1}2(P\log(\log(P)) + l)$. Here, *T* is the number of usable observations, *P* is the number of parameters included in the system, and *l* is the maximised value of the log likelihood. In the table, the sub-index *UR* indicates that the system is unrestricted while the sub-index *R* indicates that some parameters of the system have been assumed to be equal to 0. More specifically, in these models, all parameters that are not significantly different from 0 at the 10 percent level of significance have in general been restricted to be equal to 0. Numbers in bold indicate a minimum.

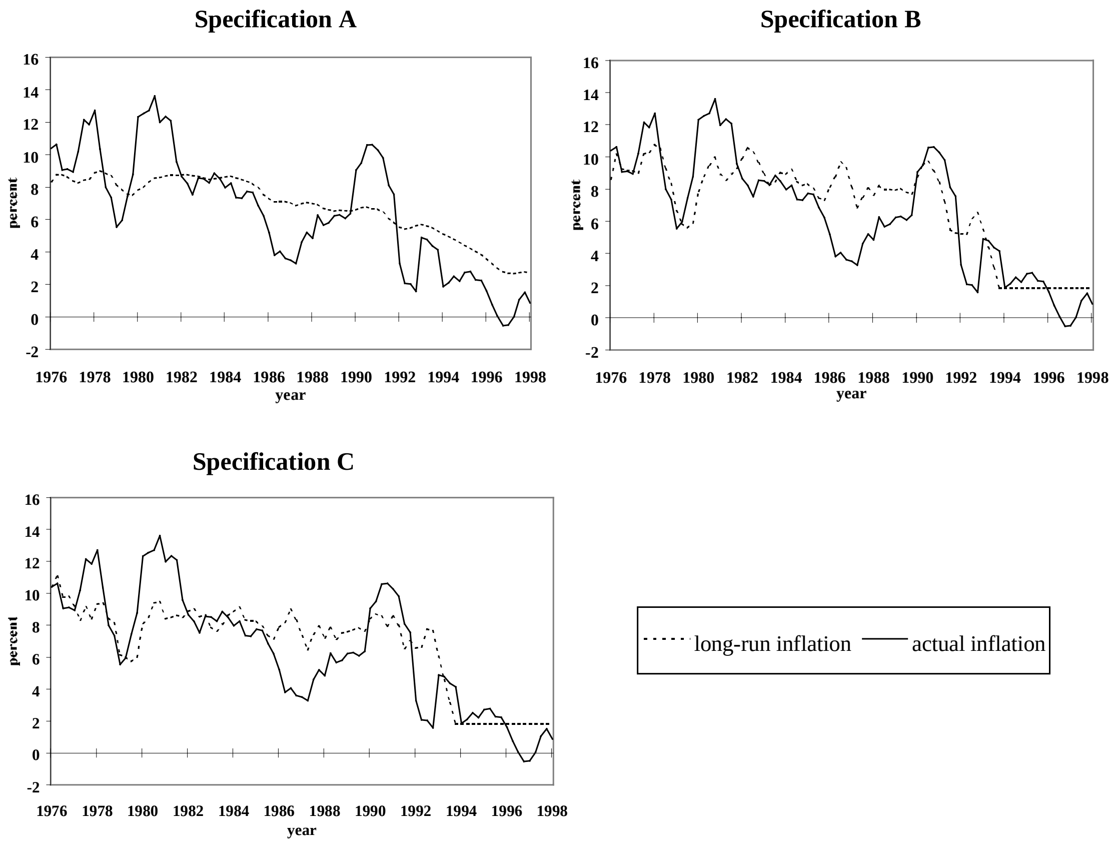
[23] For full technical details see, for example, Hamilton (1994) or Harvey (1989). The log likelihood is maximised in prediction-error decomposition form using a derivative-free SIMPLEX algorithm available in the program-package RATS. The program used for estimation is available from the authors upon request.
[24] The results for the basic specifications are available upon request.
[25] In the case of specification B, there are some (weak) signs of autocorrelation in the prediction errors of inflation (see the bottom rows of Table A1 in Appendix 2). Adjusting for this problem using an equation similar to (4.1) does not change the main results for this specification.

An informal way to discriminate between the different non-nested specifications is to rank them on the basis of different information criteria. The results in Table 1 show that the information criteria throughout favour specification B over specification A. Hence, the conclusion drawn upon directly comparing the specifications' log-likelihood values does not change.

It also appears from the evidence in Table 1 that the fit can be further improved upon by using specification C. In this specification, long-run inflation fluctuates randomly around a constant in both sub-periods, but the constant in the second period may differ from that in the first period. This suggests that the apparent lack of a reliable nominal anchor during the 1970s and 1980s empirically does not require the use of a non-stationary process for long-run inflation during these years. Rather, a stationarily fluctuating long-run inflation is preferred by all information criteria and thus seems sufficient. In the remainder of the paper we therefore concentrate our discussion on specification C.

Before proceeding, however, it may be informative to show the estimates of long-run inflation for the three specifications. This is done in Figure 1, where the inflation measures – as in the rest of the figures in the paper – are plotted as annual rates derived from the unrestricted versions of the specifications.

Figure 1. Actual inflation and estimated long-run inflation for different specifications



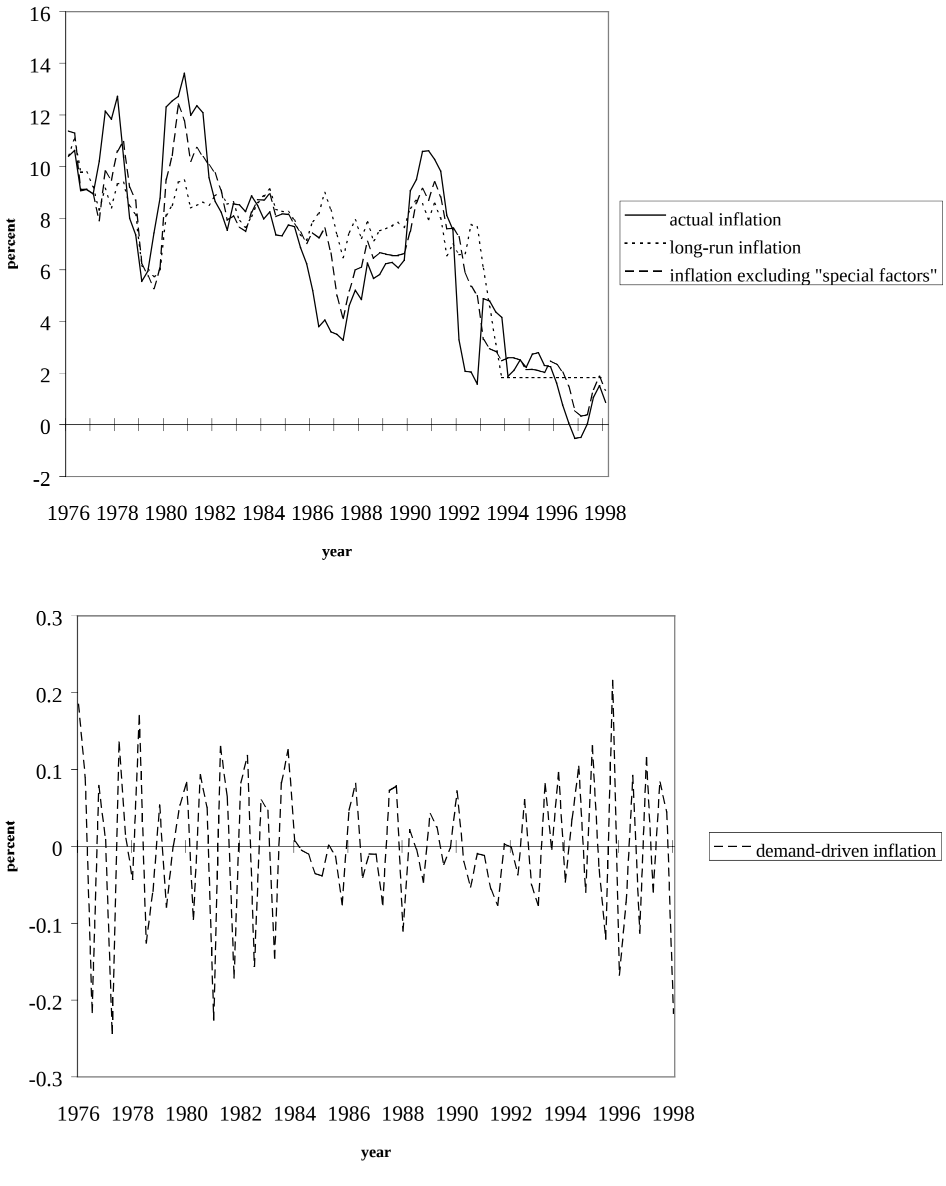
The difference between the development in recent years and that in the 1970s and 1980s regarding the level of long-run inflation is apparent for all specifications, even though specification A depicts the transition to a low-inflation regime as a rather drawn-out process. The fact that the fits are better for the specifications with a discrete deterministic shift suggests that the transition process was faster than indicated by specification A (the *p* values for testing the null hypothesis of no shift in long-run inflation are well below 1 percent for both specifications B and C). A second result worth noting is that when introducing a discrete deterministic shift but allowing for different variances of long-run inflation before and after the shift, only the variance of long-run inflation in the first sub-period becomes significantly different from 0. Both these results support the view that there has been a shift in the Swedish economy from a regime with high inflation and a less reliable nominal anchor to a regime with low inflation and a more reliable explicit inflation target.

4.1. Estimates of Core Inflation

In Section 3, it was shown that the approach may be used to derive counterparts to three different estimates of core inflation used in the literature – long-run inflation, demand-driven inflation, and inflation excluding certain undesired "special factors". Figure 2 displays these estimates as obtained from equations (3.4), (3.5), and (3.6a), respectively, using specification C.

As expected, the estimate that follows actual inflation most closely is the one based on the central-bank view. In this particular case, inflation has been adjusted with respect to all variables in the $Z_{t,1}$ vector; that is, with respect to contemporaneous changes in nominal interest rates, nominal oil prices, nominal import prices, and dummies representing changes of indirect taxes (below we discuss alternative central-bank estimates where adjustments are made with respect to only some of these variables). Deviations between actual inflation and the central-bank estimate of core inflation occur for example during the oil crises and in connection with the abandonment of the fix exchange rate in late 1992 when import prices increased considerably as a result of the depreciation of the krona.

Figure 2. Actual inflation and different estimates of core inflation

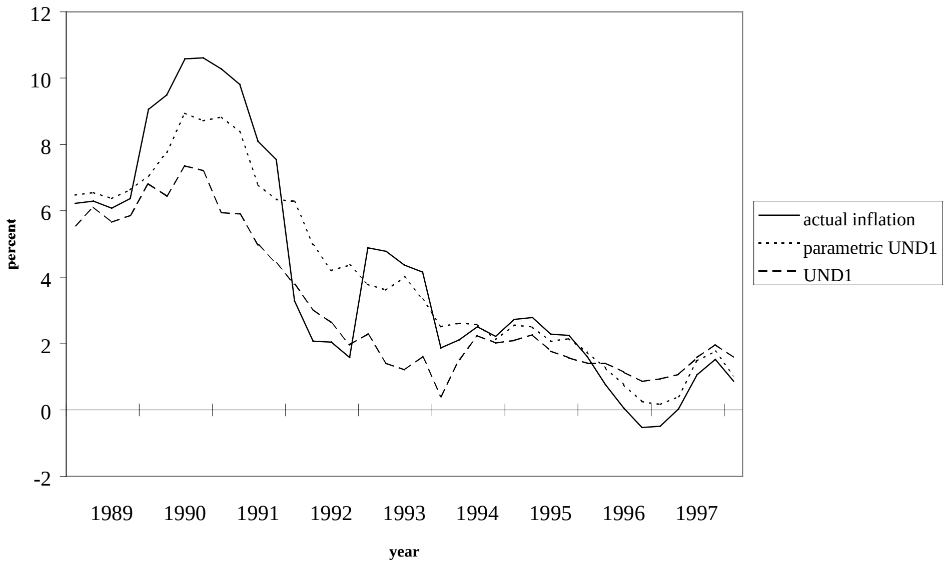


Demand-driven inflation is in this model estimated as a series that fluctuates stationarily around zero rather erratically. Since this estimate of core inflation is a linear function of y_t^{TRAN} (see equation (3.5)), this implies that the (endogenously derived) transitory component of output has a similar shape. Even though this result is not in line with the common view on the evolution of cyclical economic activity (or the output gap), it remains a fact that this is the way a seemingly reasonable model prefers to describe the relationship between real output and inflation when allowing for a simultaneous estimation of the transitory component of output and long-run inflation. It should be noted that this feature is robust across all specifications considered (see Table A1 in Appendix 2). Furthermore, the estimates of the β_i parameters in equation (3.2) do not appear numerically unreasonable, and are in most cases significant at the conventional test levels.[26]

Like many central banks, the Swedish central bank calculates different estimates of underlying inflation. The estimates that are published in the quarterly inflation report are obtained by using a combination of the previously described case-by-case and excluding-food-and-energy approaches. A measure called UND1 is obtained by excluding house mortgage interest costs and taxes and subsidies. UND2 is equal to UND1 excluding petroleum and petrol prices. UNDINH is calculated by also excluding prices of goods that are mainly imported.

It may be interesting to compare these estimates with the parametric central-bank estimates that can be derived using our model. Figures 3 to 5 show actual inflation along with the Swedish central bank's estimate and the closest corresponding parametric estimate that can be derived from the estimated equations (called parametric UND1, UND2, and UNDINH).

Figure 3. Actual inflation, the Swedish central bank's estimate of underlying inflation (UND1), and the closest corresponding parametric estimate



[26] Some further insight into this issue may be gained by studying how the explanatory power (as measured by the R^2 statistic from a regression analysis) of (a version of) the inflation equation (3.1) relates to the degree of persistence in the transitory component of output. Transitory components of output with different degrees of persistence may be generated by filtering actual output with the HP filter, using a wide range of values of the smoothing parameter in the filtering procedure. The results confirm that there seems to exist a stationary high-frequency component of output that produces a good fit for equation (3.2).

Figure 4. Actual inflation, the Swedish central bank's estimate of underlying inflation (UND2), and the closest corresponding parametric estimate

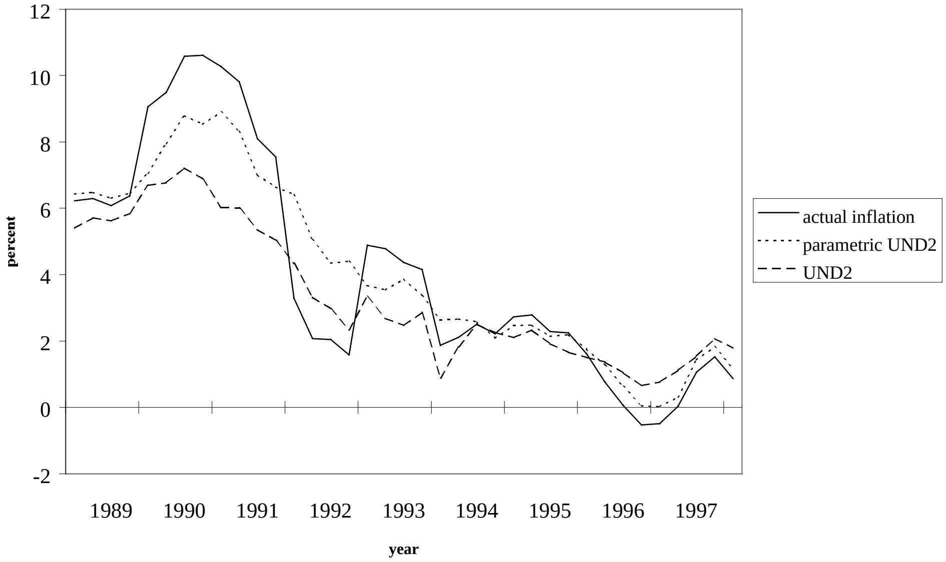
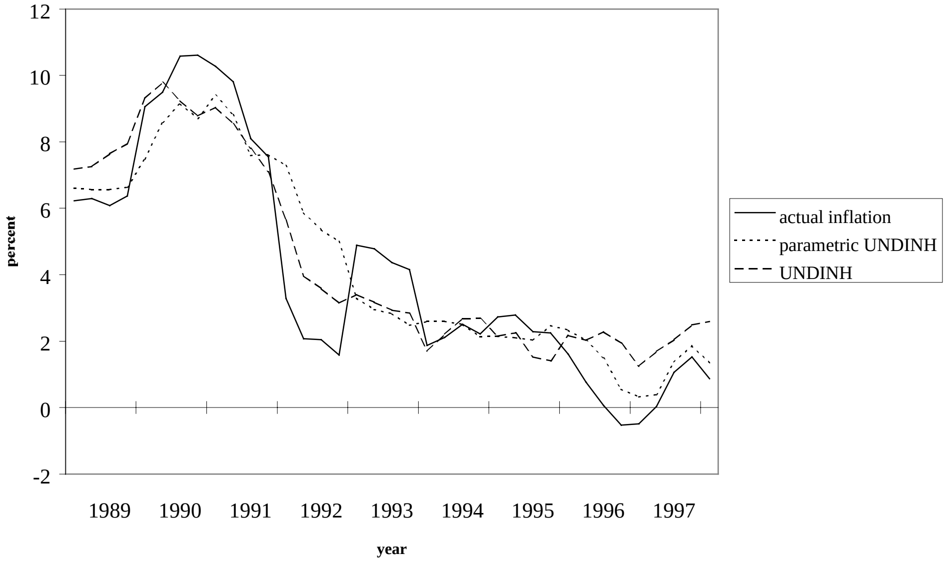


Figure 5. Actual inflation, the Swedish central bank's estimate of underlying inflation (UNDINH), and the closest corresponding parametric estimate



Both sets of estimates smooth the actual inflation series and are in most cases on the same side of actual inflation. However, occasionally they differ substantially. One obvious explanation is that the variables included in $Z_{t,1}$ -- dummies for changes in indirect taxes, changes in short-term nominal interest rates, oil prices, and import prices -- do not exactly match the items excluded from the CPI basket in the central bank's calculations of underlying inflation.[27] For example, the effects of the Swedish tax reform in the beginning of the 1990s are treated quite differently in the two sets of estimates. As concerns direct effects, the parametric estimates are only affected by this reform through its effects on indirect taxes, while additional adjustments have been undertaken for the central bank's estimates.

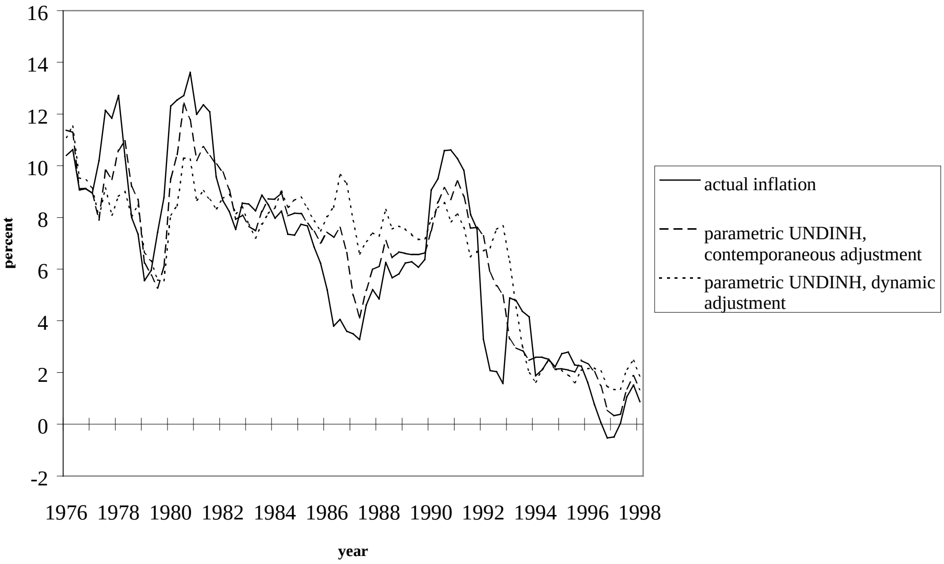
[27] Historical data on the price developments of the different components in the CPI basket are not readily available.

Another explanation may – as emphasised above -- be that simply excluding an item from the CPI does not guarantee that the item's full impact on the CPI is eliminated. If a price change of an item affects the prices of other items, then its total effect will be broader than reflected by its relative weight in the CPI. A parametric approach can, at least potentially, take this into consideration.

Another property of the parametric estimates that is worth emphasising is that they explicitly are ensured to fluctuate stationarily around long-run inflation. This implies that our parametric estimates have an explicitly defined, and economically interpretable, low-frequency behaviour, which the estimates of underlying inflation from the case-by-case and excluding-food-and-energy approaches do not have.

So far we have only reported the contemporaneously adjusted parametric central-bank estimates of core inflation (according to equation (3.6a)). Above we argued that it is possible to take into account potential feed-trough effects of the $Z_{t,1}$ variables (using equation (3.6b)). The two alternative estimates of UNDINH are shown in Figure 6.

Figure 6. Actual inflation and contemporaneously and dynamically adjusted estimates of core inflation



As can be seen, the difference between the contemporaneously and dynamically adjusted series is rather substantial. This suggests that the feed-through effects of the variables in $Z_{t,1}$ may be quite important. It needs however to be recalled that our procedure probably only provides a very crude approximation of the importance of such effects, and the results have thus to be interpreted with care (see the discussion in footnote 19).

5. Concluding Remarks

In this paper we have suggested an approach that generates parametric estimates of core inflation using an empirical macroeconomic model in which long-run inflation and the state of aggregate demand (as measured by a transitory component of real output) are determined endogenously. The key equation of the model is a Phillips-type inflation equation in which actual inflation depends on a tripartite set of basic factors: the two above-mentioned factors – that is, long-run inflation and demand – and a set of "special factors" including proxies for supply shocks. The probably most important advantage of the approach is that, because it is based on an empirical macroeconomic model, it can be used to analyse the inflation process and to generate estimates of core inflation that are economically interpretable and statistically well-defined. Although the approach does of course not solve all problems associated with the concept of core inflation, it appears as an interesting alternative or complement to other procedures.

Appendix 1

Data Description

The quarterly data set runs from 1970:1 to 1998:1. All series are seasonally adjusted except for the oil price, the index for the price of imports, and the short-term nominal interest rate. The method used for seasonal adjustment is the additive version of X11. Inflation is defined as $100\Delta\ln(P_t)$, where P_t is the consumer price index (quarterly averages, 1980=100). The changes in the price of oil and imports are defined correspondingly as $100\Delta\ln(OIL_t)$ and $100\Delta\ln(IMP_t)$, where OIL_t is the price of oil and IMP_t is the implicit import deflator. The oil price is converted from USD to SEK per barrel (brent). The change in the relative price of oil is defined as $100\Delta(\ln(OIL_t)-\ln(P_t))$. Output is expressed as $100\ln(GDP_t)$, where GDP_t is real GDP in fixed 1991 prices. Labour productivity is defined as $100(\ln(GDP_t)-\ln(H_t))$, where H_t is hours worked. The short-term nominal interest rate is a three-month interest rate. The dates of the changes in value-added taxes used to construct the dummy variables are 74:4, 77:2, 79:3, 80:4, 81:4, 83:1, 90:1, 90:3, 91:1, 92:1, 93:1, 93:3, 94:1, 95:1, 96:1, and 97:3. The source of all series except the oil price and the short-term nominal interest rate is Statistics Sweden. The oil price is taken from the EcoWin database and the short-term nominal interest rate from Sveriges Riksbank.

Appendix 2

Table A1. Estimation results for the three different specifications

Parameters	***Specification A***	***Specification B***	***Specification C***
The Phillips-curve relationship:			
α_1	0.25 [0.01]	0.28 [0.00]	0.33 [0.00]
α_2	0.30 [0.01]	0.28 [0.00]	0.18 [0.00]
β_0	2.87 [0.00]	0.55 [0.00]	0.60 [0.16]
β_1	1.71 [0.01]	-0.55 [0.00]	-0.59 [0.00]
D74	0.71 [1.00]	3.28 [0.00]	1.42 [0.03]
D77	1.42 [0.13]	1.22 [0.04]	2.10 [0.00]
D79	1.25 [0.01]	0.81 [0.17]	1.04 [0.07]
D80	0.91 [0.06]	1.61 [0.03]	1.81 [0.00]
D81	-0.85 [0.07]	-1.33 [0.03]	-0.47 [0.41]
D83	0.27 [0.59]	1.03 [0.12]	0.88 [0.12]
D90A	1.74 [0.00]	1.54 [0.01]	1.97 [0.00]
D90B	0.39 [0.48]	-0.29 [0.67]	-0.03 [0.96]
D91	1.86 [0.00]	3.38 [0.00]	2.21 [0.00]
D92	-2.19 [0.00]	-1.99 [0.00]	-2.43 [0.00]
D93A	1.70 [0.00]	2.14 [0.00]	1.92 [0.00]
D93B	-0.94 [0.04]	-0.08 [0.68]	-0.17 [0.33]
D97	-0.17 [0.74]	0.08 [0.69]	-0.21 [0.11]
NSIR(0)	0.17 [0.00]	0.19 [0.00]	0.17 [0.00]
NOIL(0)	0.00 [0.45]	0.01 [0.17]	0.01 [0.15]
NIMP(0)	0.02 [0.39]	0.07 [0.00]	0.08 [0.00]
PROD(0)	-0.08 [0.05]	-0.02 [0.46]	-0.02 [0.45]
PROD(-1)	-0.11 [0.03]	-0.03 [0.26]	-0.04 [0.11]
PROD(-2)	0.01 [0.81]	0.11 [0.01]	0.06 [0.01]
PROD(-3)	0.04 [0.40]	0.11 [0.00]	0.13 [0.00]
ROIL(-1)	0.00 [0.95]	-0.00 [0.18]	-0.00 [0.28]
ROIL(-2)	-0.00 [0.47]	-0.00 [0.42]	-0.01 [0.09]
ROIL(-3)	0.03 [0.03]	0.00 [0.60]	0.01 [0.05]
σ_{ε}	0.00 [1.00]	0.00 [1.00]	0.00 [1.00]
The equation for long-run inflation:			
$\sigma_{\varepsilon^{LR}}$	0.09 [0.11]	--	--
μ	--	0.46 [0.00]	--
σ_{u_1}	--	0.55 [0.00]	--
σ_{u_2}	--	0.00 [1.00]	--

Table A1. (continued)

Parameters	*Specification A*	*Specification B*	*Specification C*
μ_1	--	--	1.98 [0.00]
μ_2	--	--	0.46 [0.00]
σ_{η_1}	--	--	0.56 [0.00]
σ_{η_2}	--	--	0.00 [1.00]
The equation for permanent real output:			
λ	0.40 [0.00]	0.40 [0.00]	0.40 [0.00]
ρ	-0.29 [0.00]	-0.26 [0.03]	-0.31 [0.01]
σ_{ε^P}	1.20 [0.00]	1.17 [0.00]	1.19 [0.00]
The equation for transitory real output:			
γ_1	-0.81 [0.00]	-1.15 [0.00]	-0.79 [0.01]
γ_2	-0.54 [0.00]	-0.66 [0.00]	-0.78 [0.02]
$\sigma_{\varepsilon^{TRAN}}$	0.15 [0.00]	0.15 [0.00]	0.13 [0.00]
Goodness of fit and diagnostics:			
Log likelihood	-221.22	-211.94	-201.10
$Q_\pi(10)$	8.67	20.87	6.54
$Q_y(10)$	14.73	13.39	11.44

Notes: The numbers given within square brackets are *p* values for tests of the null hypothesis that the true parameter value is equal to 0. Specification A includes equations (3.2), (3.7a), (3.8), (3.9), and (4.1). Specification B includes equations (3.2), (3.7b), (3.8), (3.9), and (4.1). Specification C includes equations (3.2), (3.7c), (3.8), (3.9), and (4.1). D74-D97 are dummy variables capturing the effects of changes in value-added taxes. NSIR(*q*) denotes a parameter on the *q*th lag of the change of the short-term nominal interest rate. NOIL(*q*) denotes a parameter on the *q*th lag of the log difference of the nominal price of oil. NIMP(*q*) denotes a parameter on the *q*th lag of the log difference of the nominal price of imports. PROD(*q*) denotes a parameter on the *q*th lag of the log difference of labour productivity. ROIL(*q*) denotes a parameter on the *q*th lag of the log difference of the relative price of oil. All variables expressed in logs have been multiplied by 100. The interest rate is expressed in percentage form. Further details of the data are given in Appendix 1. $Q_j(10)$ ($j = \pi,\ y$) are Ljung-Box tests against general serial correlation based on 10 autocorrelations.

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Efficient Inflation Estimation

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EFFICIENT INFLATION ESTIMATION

Abstract

This paper investigates the use of trimmed means as high-frequency estimators of inflation. The known characteristics of price change distributions, specifically the observation that they generally exhibit high levels of kurtosis, imply that simple averages of price data are unlikely to produce efficient estimates of inflation. Trimmed means produce superior estimates of 'core inflation,' which we define as a long-run centered moving average of CPI and PPI inflation. We find that trimming 9% from each tail of the CPI price-change distribution, or 45% from the tails of the PPI price-change distribution, yields an efficient estimator of core inflation for these two series, although lesser trims also produce substantial efficiency gains. Historically, the optimal trimmed estimators are found to be nearly 23% more efficient (in terms of root-mean-square error) than the standard mean CPI, and 45% more efficient than the mean PPI. Moreover, the efficient estimators are robust to sample period and to the definition of the presumed underlying long-run trend in inflation.

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1 Introduction

How should we interpret month-to-month changes in the measured Consumer Price Index? Over the years, this question has led to the construction of several measures of what has come to be called 'core' inflation. Common measures of core inflation regularly remove certain components from the construction of the CPI. In the U.S., 'volatile' food and energy price movements, are often ignored, and core inflation is synonymous with the CPI that excludes food and energy.[1] But is it truly the case that food and energy price changes never contain information about trend inflation? Or, for that matter, is it only the volatile food and energy components that distort attempts to measure the underlying inflation trend? Surely not. This leads us to consider how we might develop a systematic, statistical methodology for reducing the transitory noise in measured inflation indices.

This paper follows our recent work, largely beginning with Bryan and Cecchetti (1994), where we investigate the estimation of aggregate consumer price inflation using trimmed means of the distribution of price changes. These are estimators that are robust to the distributional anomalies common to price statistics. They are order statistics that are computed by trimming a percentage from the tails of a histogram, and averaging what is left. For example, the sample mean trims zero percent, while the median trims fifty percent, from each tail of the distribution of price changes.

Every student in introductory statistics learns that, when data are drawn from a normal distribution, the sample mean is the minimum variance estimator of the first moment. But price changes are not normally distributed. In fact, as we discuss in Bryan and Cecchetti (1996), the cross-sectional distribution of inflation has very fat tails, with a sample kurtosis that is often substantially above ten. Underlying leptokurtotic distributions create inferential difficulties, as they routinely produce skewed samples. In our earlier papers, we discuss how these problems lead to transitory movements in the sample mean, causing it to have a high small-sample variance.

Given what we know about the distribution of price changes, what is the most efficient estimator of the first moment of the price change distribution? How can we produce a reduced-noise estimate of aggregate inflation at high frequencies? Our answer is to trim the price change distribution, not by removing food and energy prices every time, but by ignoring some percentage of the highest and lowest price changes each month.

We study monthly changes in both consumer and producer prices in the U.S. Data availability dictate that we examine 36 components of the CPI from 1967 to 1996 and 29 components of the PPI over the same period. Throughout, we take as our benchmark the thirty-six month centered moving average of actual inflation. We evaluate the ability of candidate estimators to track the movements in the benchmark. Our conclusions are that the most efficient estimate of inflation at the consumer level comes from trimming 9% from each tail, while efficient estimation of producer prices trims 45%. By trimming

[1]The 1997 *Economic Report of the President* is a prime example. Chart 2-6 on page 76, and accompanying text, use the now commonplace designation of core inflation as the 'Consumer Price Index excluding the volatile food and energy components.'

a cumulative 18% of the consumer price distribution we are able to reduce the root-mean-square-error (RMSE) of aggregate inflation by nearly one-quarter. For the PPI, the improvement is even more dramatic, as the RMSE declines by over 45 percent!

The remainder of the paper is composed of five sections. Section 2 reports descriptive statistics for the distribution of CPI and PPI price changes. Section 3 discusses the statistical problems we attempt to overcome. Section 4 follows with by a discussion of the Monte Carlo results that guide our choice of the optimal trimmed estimator. We provide various robustness checks in Section 5. These include examining changes in sample period, changes in the degree of disaggregation of CPI data, and changes in the benchmark. Section 6 concludes.

2 Characteristics of Price Change Distributions

By how much would the monthly measure of the consumer price index have to deviate from its recent trend for us to be relatively certain that the trend has changed? This is the question that is in most people's minds when the Bureau of Labor Statistics releases the price statistics each month.[2] Figure 1 plots the monthly changes in consumer and producer prices, at an annual rate, together with a three-year centered moving average, both for the period 1967:02 to 1997:04.[3]

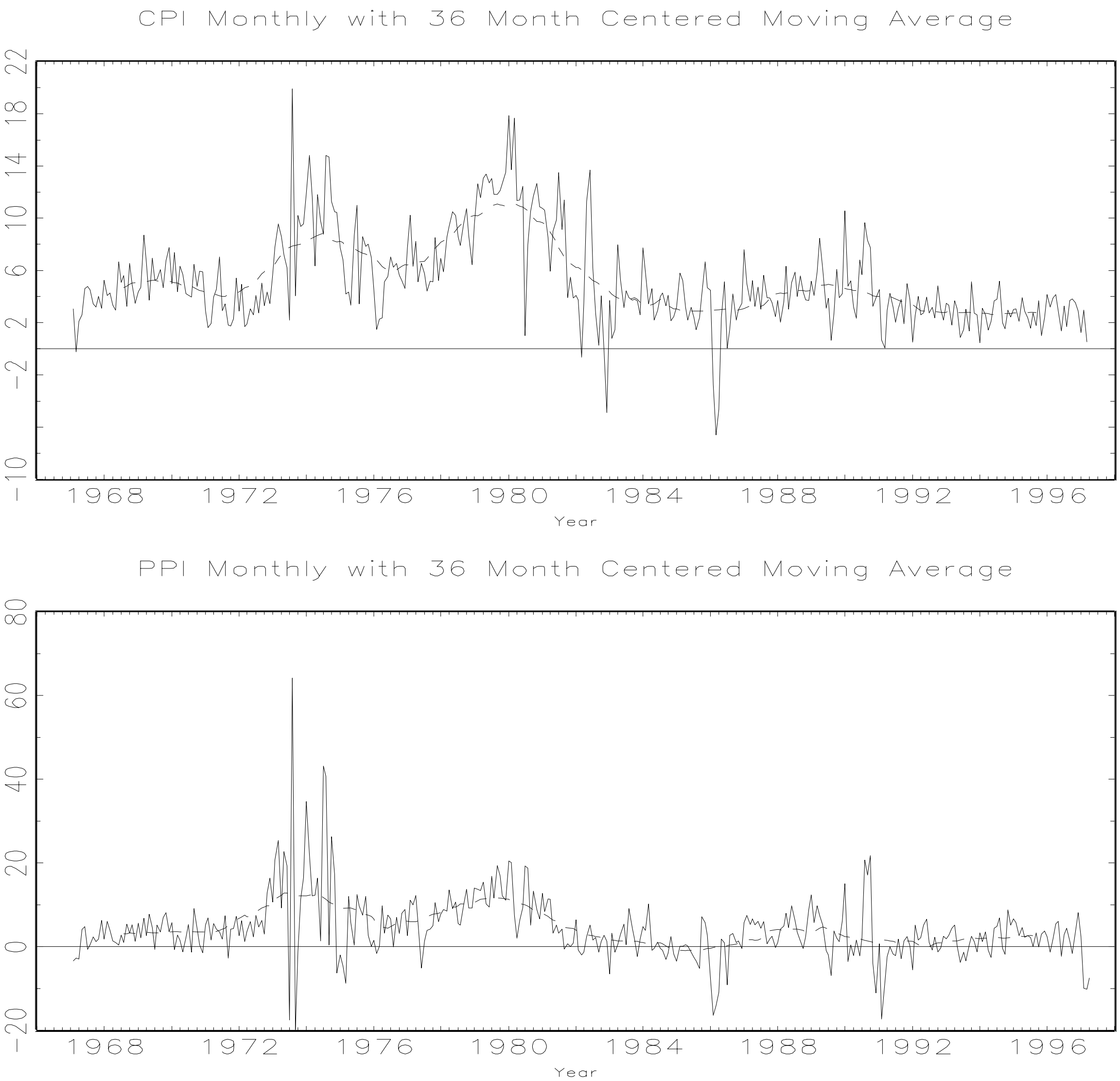
As is evident from the figure, the monthly changes in both of these price indices contain substantial high-frequency noise. By this we mean that deviations of the monthly changes from the trend are quite large and often reversed. In fact, the standard deviation of the difference between the monthly and the moving average aggregate price change is 6.92 percentage points for the PPI and 2.50 percentage points for the CPI (both at annual rates). A look at the actual distributions shows that a 90% confidence interval for the CPI is from -3.92 to +3.76 percentage points, while for the PPI it is from -10.35 to +8.97 percentage points. In other words, since 1967, monthly changes in producer prices have been either more than 10 percentage points below or 8 percentage points above the thirty-six month moving average one in every ten months!

The common method of excluding food and energy simply does not help much. In fact, the standard deviation of the difference between the CPI ex food and energy and the thirty-six month average CPI is 2.31 percentage points, and the 90% confidence interval shrinks slightly to [-3.73,+3.76] percentage points. By contrast, for the PPI, excluding food and energy improves things, as the standard deviation of difference between the PPI

[2]Cecchetti (forthcoming) suggests a preliminary answer to exactly this question.

[3]We use 36 components of the Consumer Price Index for Urban Consumers, seasonally adjusted by the BLS. These data are all available continuously, monthly, since 1967:01. The housing service component is based on the rental equivalence measure of owner occupied housing, and so prior to 1982, the series is essentially the experimental CPI-X1. The producer price is based on the PPI for commodities, and uses a set of between 29 and 31 components. All data are seasonally adjusted using the ARIMA X-11 procedures available with SAS. A detailed Appendix containing descriptiona of the sources and construction of the data sets used is available from the authors upon request.

FIGURE 1



CPI Monthly with 36 Month Centered Moving Average
22
18
14
10
6
2
-2
-10
1968
1972
1976
1980
1984
1988
1992
1996
Year
PPI Monthly with 36 Month Centered Moving Average
80
60
40
20
0
-20
1968
1972
1976
1980
1984
1988
1992
1996
Year

excluding food and energy and the 36 month centered moving average of the actual PPI drops by about 40% to 4.14, and the 90% confidence interval shrinks by about the same amount to [-5.94,+4.76].

In an effort to better understand the nature of the transitory fluctuations in high-frequency inflation measurement, we begin by examining the characteristics of the price change distributions. It is useful to pause at this stage to introduce some notation. We define the inflation in an individual component price over an horizon k as

$$\pi_{it}^k = \frac{1}{k}\ln(p_{it}/p_{it-k}) \ , \tag{1}$$

where p_{it} is the index level for component i at time t. From this, we define the mean inflation in each time period, over horizon k, as

$$\Pi_t^k = \sum_i r_{it}\pi_{it}^k \ , \tag{2}$$

where the r_{it}'s are relative importances that are allowed to change each month to reflect the fact that the actual index is an arithmetic average.[4]

The higher-order central moments are then

$$m_{rt}^k = \sum_i r_{it}(\pi_{it}^k - \Pi_t^k)^r \ , \tag{3}$$

Skewness and kurtosis are the scaled third and fourth moments, respectively:

$$\mathcal{S}_t^k = \frac{m_{3t}^k}{[m_{2t}^k]^{(3/2)}} \tag{4}$$

and

$$\mathcal{K}_t^k = \frac{m_{4t}^k}{[m_{2t}^k]^2} \ . \tag{5}$$

Table 1 reports numerous descriptive statistics for the cross-sectional distribution of monthly price changes at overlapping horizons of one to thirty-six months. Among the noteworthy characteristics is that the distributions are often skewed. The mean absolute value of the skewness, the mean of $\mathcal{S}_t^1$, in monthly CPI changes is 0.20 and in PPI changes it is 0.04, suggesting that the distributions are nearly symmetrical on average. But the standard deviation of $\mathcal{S}_t^1$ is 2.35 for the CPI and 2.36 for the PPI, implying that distributions of one-month changes are often highly skewed. This standard deviation falls off as the horizon increases, implying that the distribution of longer-run changes are

[4]It is straightforward to show that if the price level index utilizes fixed weights, call these w_i, then the percentage change in the aggregate index can be approximated by the weighted sum of the percentage changes in the components, where the weights change to reflect changes in relative prices. Defining the aggregate price level $P_t = \sum w_i p_{it}$, then $r_{it} = w_i(p_{it}/p_{t-1})$.

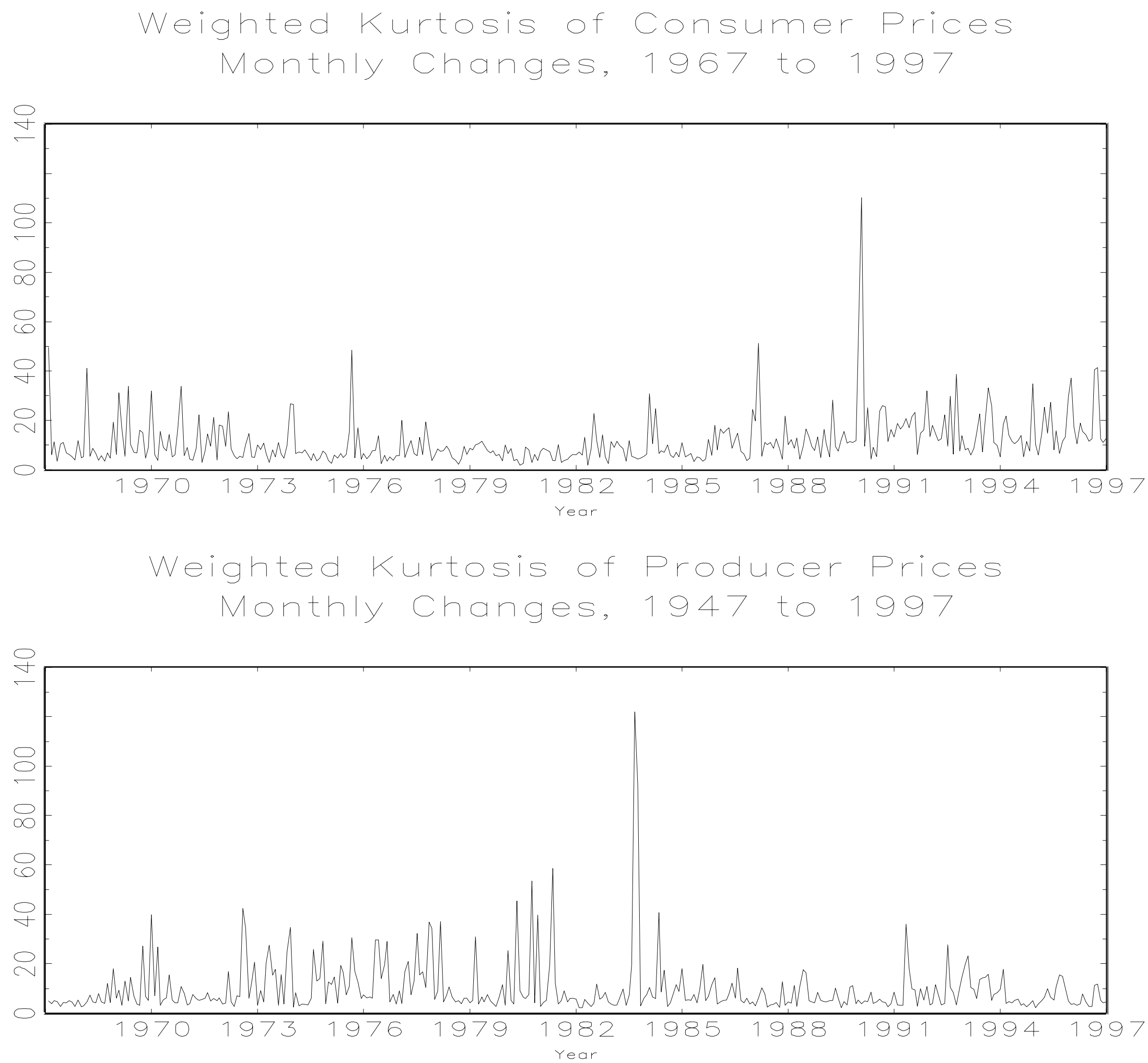
Table 1: Summary Statistics for Price Change Distributions

Deviations from 36 Month Moving Average

Consumer Prices, 1967.01 to 1997.04 36 Components					
	$k = 1$	$k = 3$	$k = 12$	$k = 24$	$k = 36$
Standard Deviation					
Average	9.18	6.64	4.06	3.36	3.14
Std. Dev.	190.45	79.80	25.49	11.81	8.83
Skewness					
Average	0.20	0.16	0.21	0.29	0.26
Std. Dev.	2.35	2.15	1.51	1.38	1.41
Kurtosis					
Average	11.24	9.56	5.72	4.52	4.23
Median	8.60	7.37	4.65	3.89	3.75
Std. Dev.	9.80	8.36	3.49	2.39	2.20
Producer Prices, 1967.02 to 1997.04 29-32 Components					
	$k = 1$	$k = 3$	$k = 12$	$k = 24$	$k = 36$
Standard Deviation					
Average	15.59	10.60	6.24	4.82	4.44
Std. Dev	955.66	266.64	86.85	35.08	22.82
Absolute Skewness					
Average	0.04	0.14	0.04	0.02	0.01
Std. Dev.	2.36	2.12	1.74	1.53	1.46
Kurtosis					
Average	10.35	8.80	7.26	5.47	4.03
Median	6.38	6.23	4.89	3.51	2.78
Std. Dev.	11.51	8.47	6.50	6.11	3.43

All data are at annual rates.

FIGURE 2



much less likely to exhibit skewness.[5]

The price change distributions also have very fat tails. The average kurtosis of monthly changes, the average value of $\mathcal{K}_t^1$, is 11.24 for the CPI and 10.35 for the PPI. In fact, the weighted kurtosis of monthly price changes is in excess of 20 about ten percent of the time. See Figure 2.

These facts allow us to identify a potentially important source of high frequency noise in the measurement of inflation. In a given month, there is a high probability of observing some subset of prices change by a substantial amount — generating the skewness and kurtosis that we see. But, over time, these extreme changes are balanced out, reducing

[5]For example the 5th and 95th percentiles of $\mathcal{S}_t^1$ for the CPI are $[-3.52, 4.26]$. But the same percentiles for $\mathcal{S}_t^{36}$ are $[-2.39, 1.93]$.

the observed skewness.

One economic interpretation of these distributional characteristics is that if price change is costly, we will not observe the distribution of desired price changes each month. If the size and timing of price changes are based on two-sided state-dependent rules, as in Caballero and Engel (1991), or Caplin and Leahy (1991), what we observe will depend on the rule used by the price-setter and the history of the shocks to desired prices. As a result, we will rarely see prices that exactly equal the price that would be set in the absence of any price-adjustment costs. The amount of noise decreases over longer periods, when each price has changed numerous times. But for high frequencies of one quarter or one month, the problem can be a serious one.[6]

However, one need not necessarily attach oneself to a particular model of price-setting behavior in order to accept our conclusions. It is well known that a mixture of random draws from normal distributions with differing variances will produce a leptokurtic sample. As a statistical matter, then, we can show that the mean price-change statistic is unlikely to provide the efficient estimate of inflation, regardless of the price setting model that is assumed.

We can think of two possible approaches to handling the problem. One would be to actually model price-setting explicitly using the theory as it has been worked out. But this has substantial drawbacks, as it requires that we actually estimate the time-varying price change rules themselves. Alternatively, we can treat the complication presented by state-dependent price change rules as a statistical sampling problem. We view the monthly, skewed distributions as small-sample draws from the longer-horizon (roughly) symmetrical population distribution. The fact that the population has such high kurtosis leads us to consider a family of estimators that are robust to the presence of fat tails, a topic to which we now turn.

3 Robust Estimation

We begin by assuming that we have available a sequence of samples from a symmetric distribution with an unknown, and possibly changing, mean. At issue is the efficient estimation of the mean. We consider a set of estimators called trimmed means, that average centered portions of the sample. The method of averaging is to order the sample, trim the tails of the sample distribution, and average what remains.

To calculate the (weighted) α-trimmed mean, we begin by ordering the sample, $\{x_1, ..., x_n\}$, and the associated weights, $\{w_1, ..., w_n\}$. Next, we define W_i as the cumulative weight from 1 to i; that is, $W_i \equiv \sum_{j=1}^{i} w_j$. From this we can determine the set of observations to be averaged for the calculation: the $i's$ such that $\frac{\alpha}{100} < W_i < (1 - \frac{\alpha}{100})$.

[6] An alternative interpretation is implied by Balke and Wynne (1996), who show that a multi-sector, dynamic general equilibrium model with money and flexible prices can produce similar characteristics in an environment of asymmetric supply shocks. A distinguishing feature of this model is that the 'noise' in the estimator need not significantly diminish at lower frequencies.

We call this I_α. This allows us to compute the weighted α-trimmed mean as

$$\bar{x}_\alpha = \frac{1}{1 - 2\frac{\alpha}{100}} \sum_{i \in I_\alpha} w_i x_i \ . \tag{6}$$

There are two obvious special cases. The first is the sample mean, $\bar{x}_0$, and the second is the sample median, $\bar{x}_{50}$.[7]

The efficient estimator of the mean, in the class of trimmed sample means, will depend on the characteristics of the data-generating process.[8] If, for example, the data are drawn from a normal distribution, then we know that the sample mean is the most efficient estimator. That is, the sample mean is the estimator that has the smallest small-sample variance.

But when the data are drawn from leptokurtic distributions — distributions with much fatter tails than the normal — the sample mean will no longer be the most efficient estimator of the population mean, even in the class of trimmed sample means. It is relatively easy to see why this is so. With a fat-tailed distribution, one is more likely to obtain a draw from one of the tails of the distribution that is not balanced by an equally extreme observation in the opposite tail. That is to say, as the kurtosis of the data-generating process increases, samples have a higher probability of being skewed.[9]

The impact of kurtosis on the efficiency of trimmed-mean estimators is straightforward to demonstrate. To do so we construct a simple experiment in which we draw a series of samples from distributions with varying kurtosis and compute the efficiency of the entire class of trimmed-mean estimators, including the mean and the median.

In all of our experiments, the data-generating process is characterized by a two parameter distribution that is a mixture of two normals, one with unit variance, and one with changing variance. We consider a random variable z, such that

$$z = s * y_1 + (1 - s) * y_2 \ , \tag{7}$$

where

$$\begin{aligned} Pr(s = 1) &= p \ , \\ y_1 &\sim N(0, 1) \ , \text{ and} \\ y_2 &\sim N(0, A) \ . \end{aligned}$$

With probability p draws come from a standard normal and with probability $(1 - p)$

[7] See Stuart and Ord (1987) pg. 50-51 and particularly Huber (1981) for general definitions of limited-influence estimators and their properties.

[8] For example, Yule and Kendall (1968) discuss the impact of changing kurtosis on the relative efficiency of the sample mean and the sample median. But we know of no general results concerning the relative efficiency of trimmed-mean estimators.

[9] Bryan and Cecchetti (1996) demonstrate this point in another context. We can show that the standard deviation of the sample skewness increases with the kurtosis of the data-generating process.

they come from a $N(0, A)$. The population mean, $E(z)$, is zero. The kurtosis of this distribution, $\frac{E(z^4)}{E(z^2)^2}$, varies with p and A:

$$\mathcal{K}(A, p) = \frac{3p + 3(1-p)A^2}{[p + (1-p)A]^2} \ . \tag{8}$$

We examine five cases, all with $p = 0.90$, and A set such that $\mathcal{K} = (3, 10, 15, 20, 30)$. In each of our experiments, we construct 10,000 replications of 250 draws each. We then compute the $\bar{x}_\alpha$ for $\alpha = \{0, 1, ..., 49, 50\}$. This yields 10,000 estimates of all of the trimmed-mean estimators, which we label $\bar{x}^j_\alpha$. From these we compute the root-mean-square error (RMSE) and the mean absolute deviation (MAD). These are

$$\text{RMSE}_\alpha = \sqrt{\frac{1}{N}\sum_j^N (\bar{x}^j_\alpha)^2} \tag{9}$$

$$\text{and} \tag{10}$$

$$\text{MAD}_\alpha = \frac{1}{N}\sum_j^N |(\bar{x}^j_\alpha)| \ .$$

Figure 3 plots the RMSE_α and the MAD_α for experiments based on distributions with varying kurtosis, $\mathcal{K}(A, p)$. To adjust for the fact that the variance of the distribution also changes with A and p, we have normalized RMSE_0 and MAD_0 to one for each case. The results clearly show that the efficient trim — the trim that minimizes either the RMSE or the MAD — increases with the kurtosis of the data generating process. As the kurtosis increases from 3 to 30, the efficient trim goes from 0 to 16%.

We caution that the results from these experiments are illustrative and apply only to the specific distributions we examine. We know of no general analytic result deriving the optimal trimmed mean estimator as a function of the moments of the underlying distribution and the size of the sample.

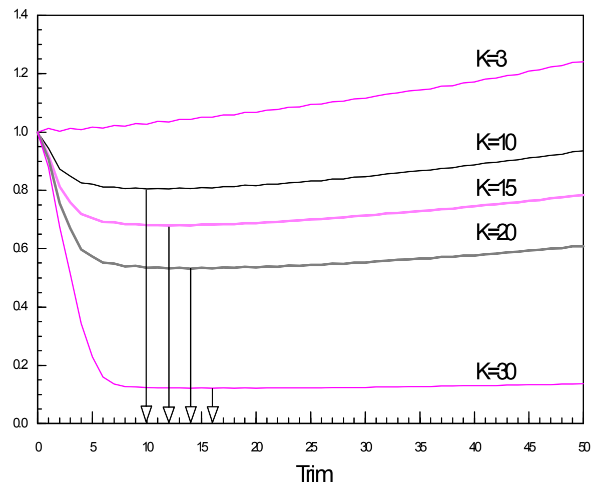
4 Efficient Estimation of Inflation: Preliminaries

We have now established one property of price data and a related statistical fact. First, the cross-sectional distribution of price changes, both in the CPI and the PPI, is fat-tailed. Second, trimmed-means are the efficient estimator of the mean of a leptokurtic distribution. We now combine these two insights and ask what is the most efficient estimator of inflation?

We begin with a preliminary examination of the data using a simple Monte Carlo experiment based on actual price data. In order to judge efficiency, we need to have a measure of the population mean we are trying to estimate. Following Cecchetti (forthcoming), we choose the thirty-six month centered moving average of actual inflation.

FIGURE 3

RMSE of Trimmed Estimators as Kurtosis Changes



MAD of Trimmed Estimators as Kurtosis Changes

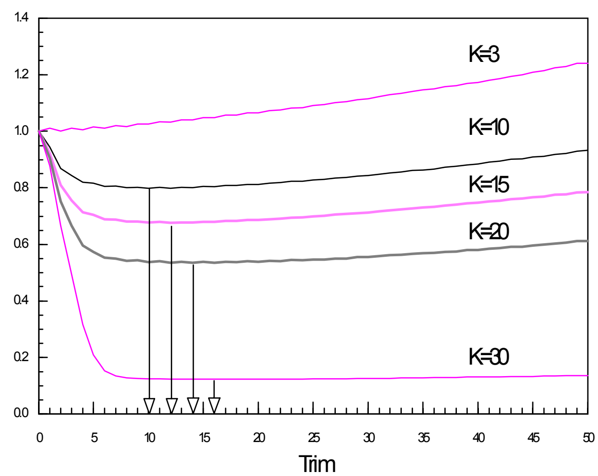
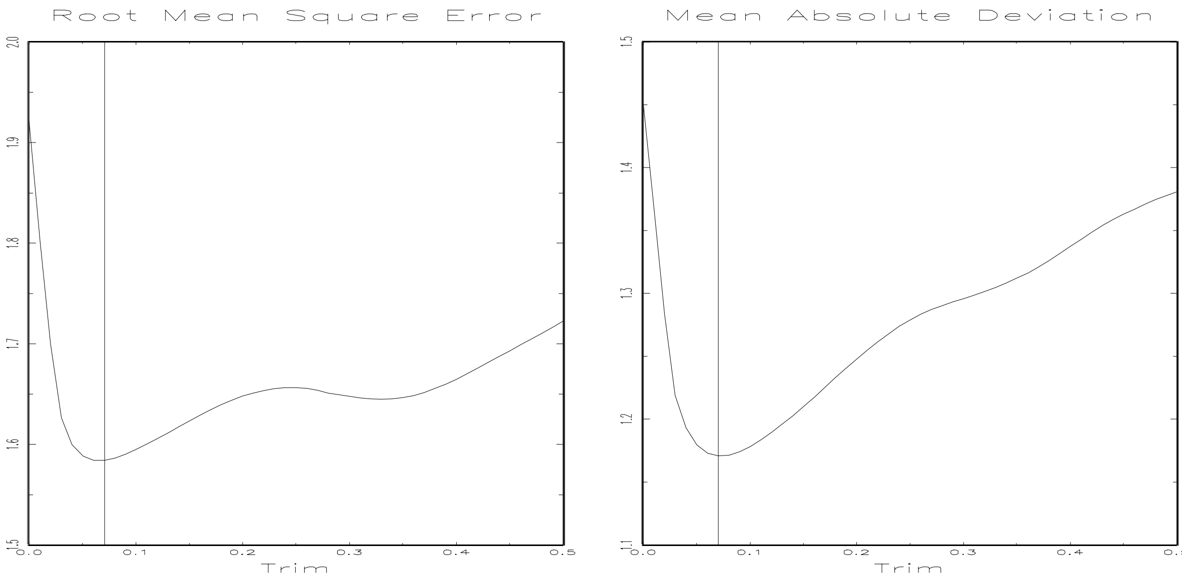


FIGURE 4: Consumer Prices

Efficiency of Trimmed Estimators, Monte Carlo Results



This is an approximation of the long-term trend in inflation that is likely to be what people have in mind when they attempt to construct measures they label *core* inflation.

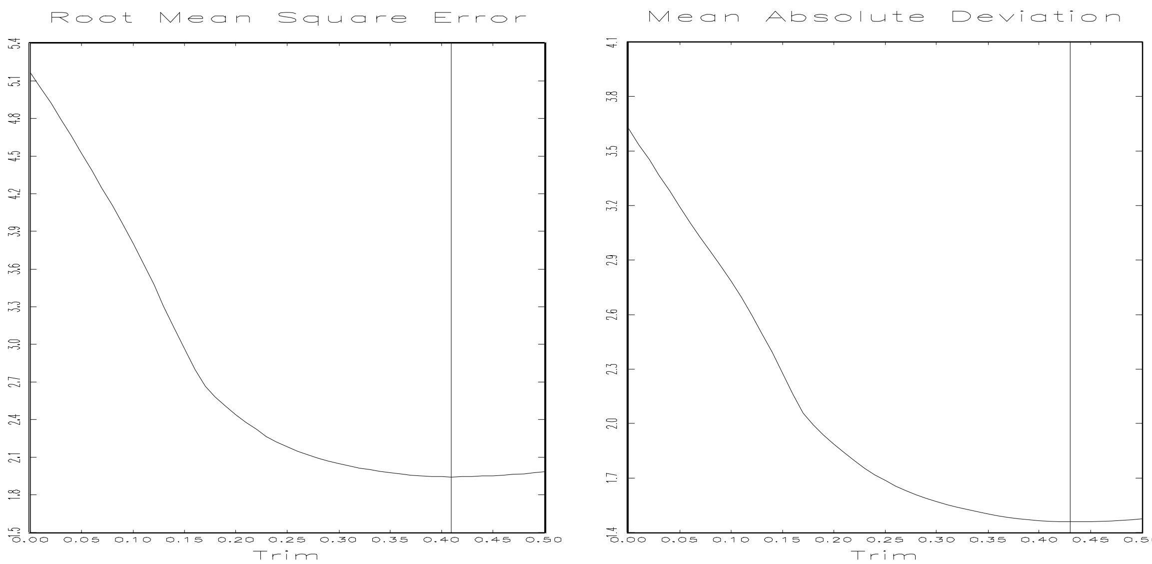
To proceed, we take the deviation of monthly component price changes from this thirty-six month centered moving average of inflation. For the CPI, we use 36 components of the CPI-U over the period 1967.02 to 1997.04, with its 1985 weights. To simplify the experiments, we set the relative importances (r_{it}) equal to the 1985 weights (w_i), and leave them fixed throughout. For the PPI, we use a reduced set of 27 components also available over the 1967.02 to 1997.04 sample and their fixed 1982 weights. After subtracting each price change from the thirty-six month moving average change in the appropriate index, we have two matrices of relative price changes.

In each experiment, we randomly draw a series of samples by taking one observation for each of the component time-series — one draw from each column in the relative-price-change matrix. This is a bootstrap procedure from which we generate 10,000 samples, each with 36 relative price changes for CPI data, or 29 relative price changes for PPI data. We then compute the two measures of efficiency — the root-mean-squared error (RMSE) and the mean absolute deviation (MAD).

The results are reported in Figures 4 and 5. The weighted means are found to be the least efficient of all of the estimators. The efficiency of the inflation estimates greatly improves with even very small trims from the sample. For example, in the case of the CPI, trimming as little as 3% from each tail of cross-sectional distribution improves the efficiency of the estimator by over 15%. The most efficient estimator for monthly CPI data was the 7% trimmed mean where the efficiency gain is approximately 20%, although

FIGURE 5: Producer Prices

Efficiency of Trimmed Estimators, Monte Carlo Results



trims in the neighborhood of this estimator perform nearly as well.[10]

For the PPI, however, much larger trims of the sample distribution are necessary to achieve the efficient estimator. The optimal trim, which occurs in the range of 40%, has an RMSE that is only one-third that of the sample mean!

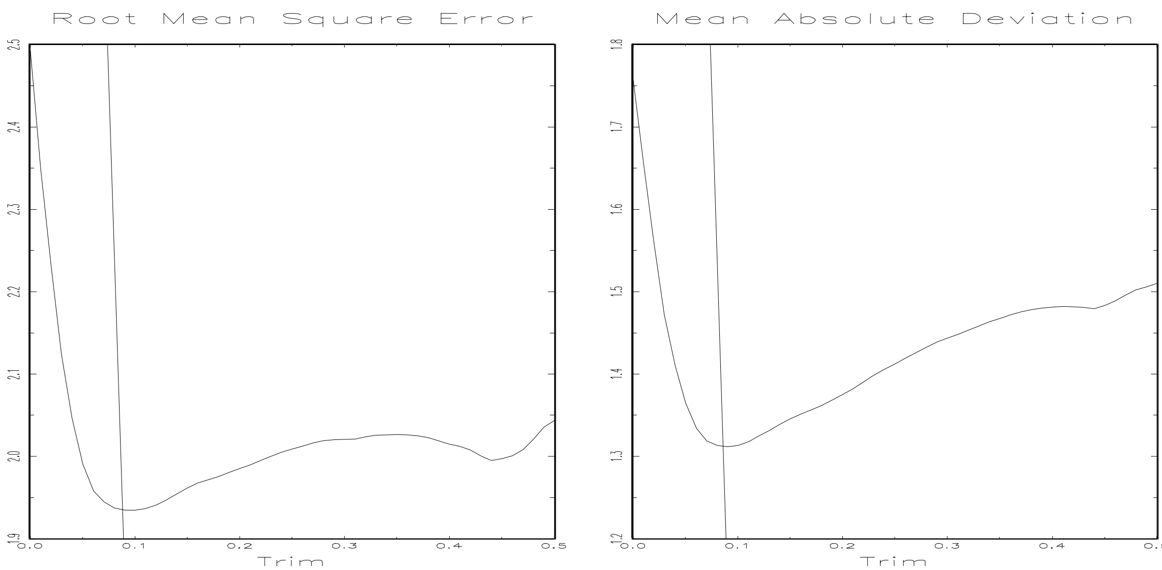
5 Efficient Inflation Estimation: Historical Data

We now move to a more complete examination of the actual data. Here we will compare the relative efficiency of trimmed estimators using the historical time series, taking account of the changes in the relative importances [the r_{it}'s in equation (2)] over time. That is to say, we will compute the weighted distributions of inflation each month, where the weights vary based on changes in relative prices as well as the periodic rebasing done by the Bureau of Labor Statistics roughly once per decade.

[10]The technique we suggest here is appropriate for cases in which the price-change distributions are symmetrical on average. We know of instances where this is not the case. For example, Roger's (1997) examination of New Zealand price data reveals a persistent, positive skewness in the price change distribution that produces a bias in the trimmed estimators of the mean. Roger constructs trimmed estimators centered on the mean percentile, or the percentile of the distribution corresponding to the mean of the distribution. That is, for New Zealand price data, Roger trims the tails of the distribution asymmetrically, centering on the 57th percentile. In this way, the trimmed estimator is an unbiased estimate of the CPI trend in New Zealand. Roger's insight implies a procedure in which the trim and centering parameter are chosen jointly to minimize either the RMSE or MAD criterion, subject to the estimator being unbiased in the sample.

FIGURE 6: Consumer Prices

Efficiency of Trimmed Estimators, Historical Data



In Section 5.1, we look for the optimal trimmed mean estimator using the entire 1967 to 1997 sample currently available. Are the results of the previous section robust to several obvious changes in methods? We examine three cases. In the first, reported in Section 5.2, we study more disaggregated CPI data over a shorter sample period. In Section 5.3, we look at the implications of changing the measurement benchmark from the thirty-six month centered moving average of actual inflation to moving averages of from twenty-four to sixty months. Finally, in Section 5.4, we study estimator stability by looking at optimal trims over varying sample periods. We conclude this section with a summary and comparison of the trimmed means with the inflation measures that arbitrarily exclude food and energy.

5.1 The Baseline Case

In this section we consider the time-series characteristics of the trimmed-mean estimators. We calculate the RMSE and the MAD for each trimmed estimator using monthly historical component price data. That is, we compute the trimmed-mean estimators of inflation month-by-month, and compare their deviations from the centered thirty-six month moving average. The results, reproduced in Figure 6 for the CPI, and Figure 7 for the PPI, are virtually identical to those in the Monte Carlo experiments shown in Figures 4 and 5.[11]

It is easy to see how much inflation measures are stabilized by trimming. Figure 8

[11]Throughout this section, the PPI data set uses a set of components that varies from 29 to 31 in number, depending on data availability

FIGURE 7: Producer Prices

Efficiency of Trimmed Estimators, Historical Data

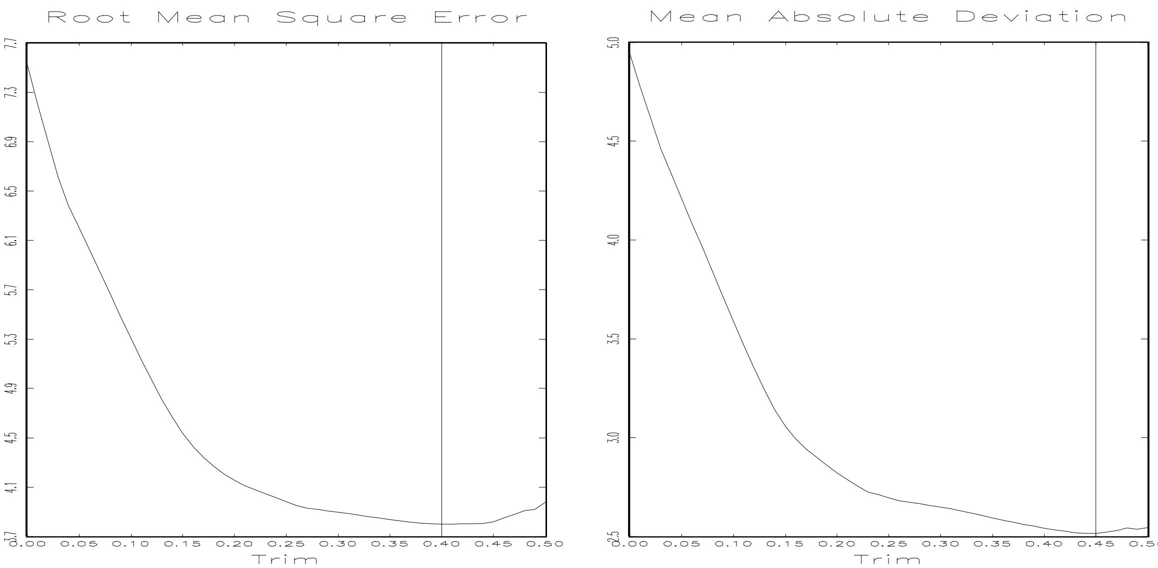


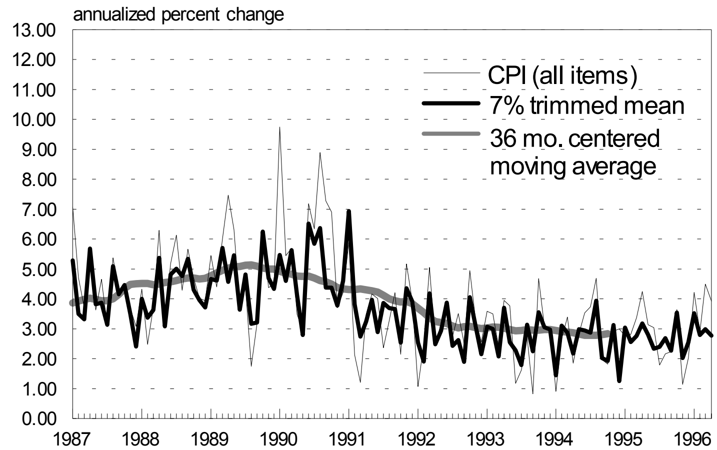
Table 2: Comparison of Inflation Estimators

	CPI 1967 to 1997		PPI 1967 to 1997	
	RMSE	MAD	RMSE	MAD
Mean ($\bar{x}_0$)	2.50	1.76	6.91	4.27
ex Food& Energy	2.31	1.62	4.14	2.55
Median ($\bar{x}_{50}$)	2.04	1.51	3.98	2.55
Optimal Trim	1.93	1.31	3.80	2.52
Trim at Opt.	9%	9%	40%	45%

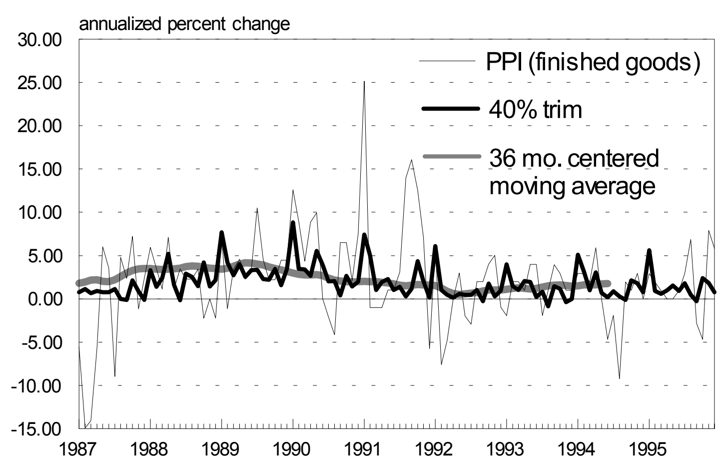
All values are computed from monthly changes as annual rates. Deviations are from the 36-month centered moving average. The optimal trim is the trim that minimizes either RMSE_α or MAD_α.

FIGURE 8

Monthly CPI Estimators



Monthly PPI Estimators



plots the mean, the thirty-six month centered moving average, and the efficient trimmed estimator for monthly CPI and PPI data for the January 1990 to December 1996 period.

Table 2 compares the properties of a number of commonly used estimators for consumer and producer price inflation. Focusing first on the CPI, we note that excluding food and energy produces little improvement in efficiency. The CPI excluding food and energy is only slightly more efficient than the CPI-U itself, reducing the RMSE from 2.50 to 2.31. But trimming clearly helps. Trimming 9% of the cross-sectional distribution of consumer prices reduces the RMSE by just under 23 percent.[12]

For producer prices, the improvements are even more dramatic. Using the long sample period, we find that trimming 40% of the distribution from each tail improves the RMSE by over 45 percent. Excluding food and energy from the PPI reduces the RMSE by less than 40 percent.[13]

5.2 More Disaggregated Data

The price statistics are collected at a much more disaggregated level than what we have used thus far. Does the optimal trim change with the level of aggregation? The experiments in Section 3 suggest that the answer to this question will depend on what happens to the kurtosis of the cross-section distribution of price changes as we vary the level of aggregation.

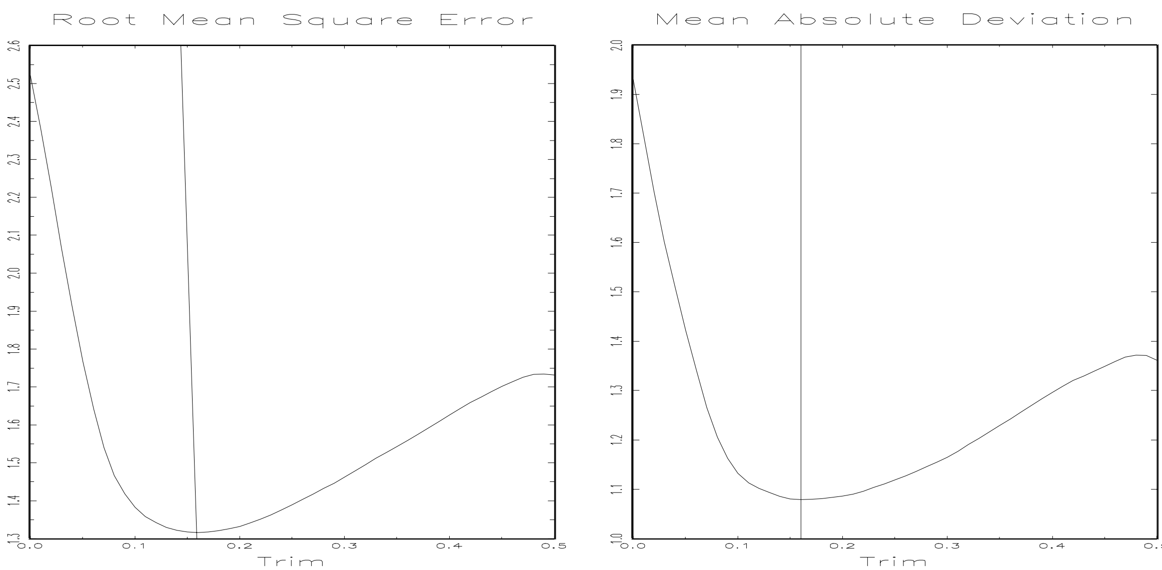
To examine this issue, we assembled a data set composed of between 142 and 175 components of the CPI-U from 1978 to 1996. The number of series (and the relative importance of each series) varies each month depending on availability. The weighted kurtosis of these data is much higher than that for the 36 component dataset examined in the previous section. For monthly changes, for example, Table 1 reports that inflation in the 36 components of the CPI-U has median kurtosis of 9.68. By contrast, the kurtosis

[12] Bryden and Carlson (1994) also note that this trim produces the minimum time-series variance of any trimmed-mean estimator over the 1967 to 1994 period.

[13] A common technique for reducing the noise in the high frequency inflation estimates uses time-series averages. We have conducted experiments that combine trimming with time-averaging. We note that averaging the component price change data prior to trimming, or *pre-trim averaging*, decreases the amount of trimming necessary to produce a minimum RMSE estimator of the inflation trend. For example, using three-month average price changes of component CPI data, the minimum RMSE of the inflation trend is found by trimming 6% from the tails of the price change distribution, compared to the 9% trims required of monthly data. Similar results were found for *post-trim averages*, where we average the monthly trimmed means. That is, if we calculate the trimmed estimators, and compute a 3-month average of that result, the minimum RMSE estimate of the inflation trend is found by trimming 6% from each tail of the price change distribution. Even at relatively low frequencies, some amount of trimming of the price change distribution seems warranted. For example, using a 6-month component price change and a 6-month average of the trimmed estimators, the minimum RMSE estimator of the CPI trend is obtained by trimming 5% from each tail of the price change distribution. These alternative smoothing techniques address a somewhat different question from the one posed in this paper: How much new information does a monthly price report contain? We leave the investigation of this important area for future research.

FIGURE 9: Consumer Prices, 142 to 175 Components

Efficiency of Trimmed Estimators, Historical Data



in the more disaggregated data set has a median of 43.1!

As in Section 5.1, we construct, using historical data, the RMSE and MAD for each of the trimmed estimators, from $\alpha = 0$ to 50. These provide a gauge of the efficiency gains from trimming the outlying tails of the price-change distribution. The results in Figure 9 confirm that, in the case of consumer prices, the efficient estimation of inflation requires more trimming when more disaggregated data are used. In this experiment, the optimal trim is 16%, at which point the RMSE is cut nearly in half. But again, virtually any trimming helps. For example, trimming 9% from each tail — the optimal amount for the 36 component data set — reduces the RMSE by about 40%.

The practical implications of this exercise are fairly important. We have found that since the kurtosis of the price-change distributions depends on the level of disaggregation, so does the optimal trim. As a result, implementation of these techniques for the production of a core inflation index will depend critically on the exact dataset used.

5.3 Changes in the Benchmark

As we noted at the outset of the previous section, in order to assess efficiency, we must specify a goal: What is it we would ideally like to measure? Our second robustness check involves deviating from the thirty-six month centered moving average as the benchmark.

Table 3 reports optimal trims as a function of the length of the moving average specified for the benchmark, similar to those in Sections 4 and 5.1 for the optimal trim. Included are the optimal trims using the Monte Carlo methods, as well as those for the historical data. The table also reports an informal confidence interval constructed as the set of trims with RMSE or MAD within five percent of the minimum. For example, using

Table 3: Optimal Trim for Changes in the Benchmark

Monte Carlo Results

	CPI		PPI	
MA	RMSE	MAD	RMSE	MAD
24	0.07	0.07	0.43	0.45
	(0.03,0.35)	(0.03,0.17)	(0.31,0.50)	(0.33,0.50)
36	0.07	0.07	0.41	0.43
	(0.03,0.44)	(0.03,0.17)	(0.31,0.50)	(0.33,0.50)
48	0.06	0.07	0.43	0.46
	(0.03,0.42)	(0.03,0.17)	(0.31,0.50)	(0.34,0.50)
60	0.06	0.07	0.42	0.45
	(0.03,0.41)	(0.03,0.17)	(0.30,0.50)	(0.33,0.50)

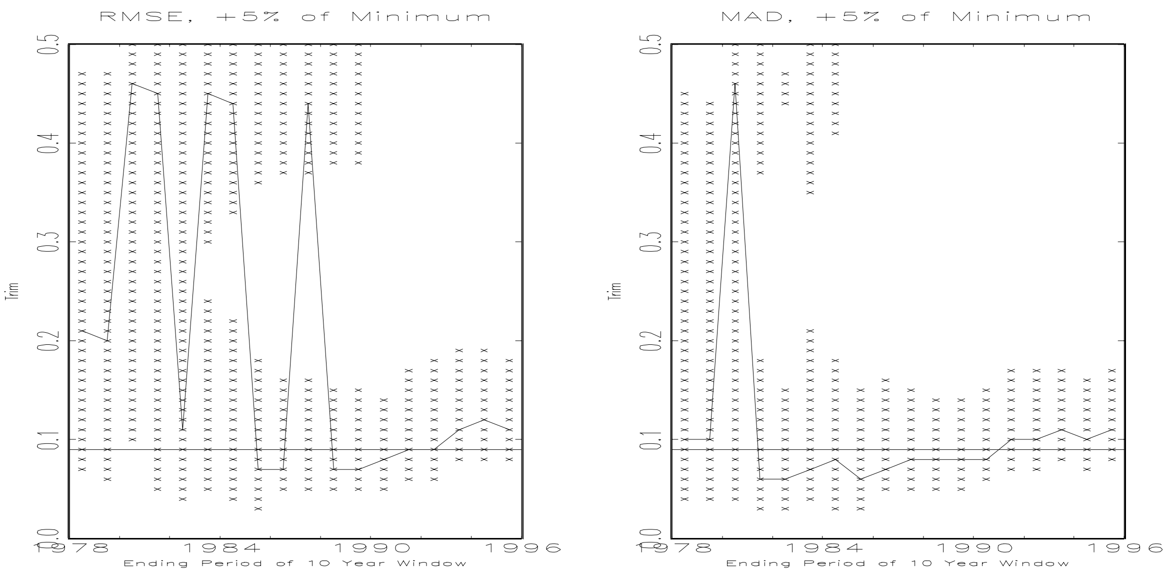
Historical Data

	CPI 36 Components 1967 to 1997		PPI 29 to 31 Components 1967 to 1997		CPI 142 to 175 Components 1978 to 1996	
MA	RMSE	MAD	RMSE	MAD	RMSE	MAD
24	0.09	0.09	0.40	0.45	0.14	0.16
	(0.05,0.25)	(0.05,0.17)	(0.25,0.49)	(0.30,0.50)	(0.08,0.23)	(0.09,0.24)
36	0.09	0.09	0.40	0.45	0.16	0.17
	(0.05,0.48)	(0.05,0.19)	(0.25,0.50)	(0.31,0.50)	(0.10,0.24)	(0.11,0.26)
48	0.09	0.09	0.43	0.45	0.17	0.17
	(0.05,0.50)	(0.05,0.21)	(0.25,0.50)	(0.29,0.50)	(0.11,0.25)	(0.12,0.25)
60	0.09	0.09	0.43	0.49	0.18	0.18
	(0.05,0.50)	(0.05,0.23)	(0.25,0.50)	(0.27,0.50)	(0.12,0.26)	(0.12,0.28)

Numbers in parentheses are trims with RMSE or MAD within 5% of the value at the minimum. Monte Carlo experiments use 10,000 replications.

FIGURE 10: Consumer Prices, 36 Components

Efficiency of Trimmed Estimators, Changing Sample



the historical data in the case of the 36 components CPI data and the thirty-six month centered moving average benchmark, the minimum RMSE of 1.93 occurs at a trim of 9% (see Table 2). The fourth line in the first bottom panel of Table 3 reports that all of the trims between 5% and 48% have an RMSE below 1.93*1.05=2.03.[14]

Several patterns emerge from these results. First, the 'point estimate' of the optimal trim does not vary as we change the benchmark. But the approximate confidence intervals have a tendency to grow as the degree of the moving average increases. Second, for the PPI, there is little difference between the 'optimal trim' and the median. In all cases but one, the RMSE and MAD of the median are well within the 5% standard. Finally, for CPI at both levels of aggregation there is a large benefit to trimming a small amount.

5.4 Variations in the Sample Period

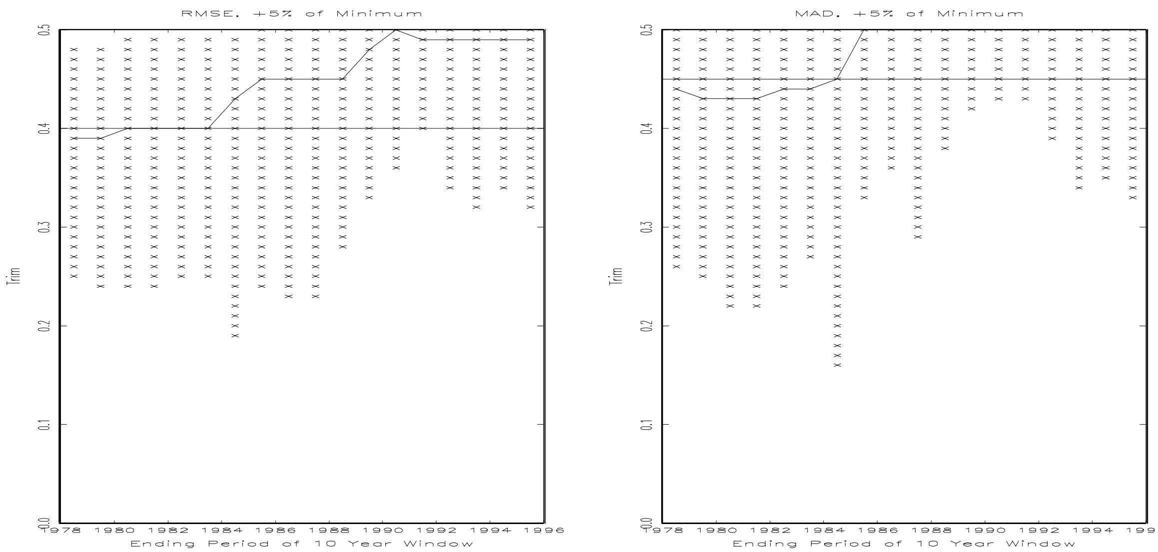
Next, we examine the sensitivity of the results to the sample period. This is analogous to asking whether the underlying distributional characteristics of the data are stable. To do this, we perform a series of Monte Carlo experiments comparable to those in Section 4, but instead of using the full sample from which to draw, we use rolling ten year samples. For example, in the case of the CPI we compute the optimal trim based on data from 1967 to 1976, then from 1968 to 1977, moving forward twelve months at a time.

Figures 10 and 11 report the results of these experiments. Each figure has a horizontal line at the optimal trim calculated using the full sample, together with a second line

[14]Note that there is no reason for the approximate confidence intervals to be either symmetrical or continuous. The ones reported in Table 3 all happen to be continuous.

FIGURE 11: Producer Prices

Efficiency of Trimmed Estimators, Changing Sample



plotting the optimal trim based on each of the ten year samples. The horizontal axis shows the final date of the sample. To give some sense of precision, the X's in the figures represent the approximate confidence intervals constructed as all of the trims such that the criterion, RMSE or MAD, is within 5 percent of the minimum.

The RMSE and MAD of the optimal full-sample trim are nearly always within 5 percent of the minimum value for the 10 year sub-samples. In fact, for the CPI, using the mean absolute deviation (MAD) criteria, the optimal trim is never outside of this rough confidence bound. For the PPI, there are thirty-six 10 year sub-periods. Using the RMSE criteria, the optimal full sample trim of 40 percent is within the confidence band in 33 of the 36 cases.

5.5 Summary and Comparisons

Given that the "CPI excluding food and energy" is the measure of core inflation in common use, it is useful to compare this measure of core inflation to ours. We do this is two ways. First, we ask which components we are trimming. And second, we look at a closer comparison of various candidate measures based on the RMSE criteria used above.

Table 4 examines which components we are trimming. For each month, we counted the frequency at which some portion of the weight of each component was trimmed using the optimal trim — 9% for the CPI and 40% for the PPI. We also note which components are systematically excluded by the 'ex food and energy' measures (highlighted in bold-faced type). The results show that we often trim some of the food and energy prices. Indeed, for the CPI, food and energy components are trimmed from the efficient estimator nearly 40% of the time — nearly one and one-half times as frequently as the average component.

Table 4: Frequency That a Component is Trimmed: CPI 9% trim

CPI Component	Average Relative Importance	Percent of Sample period that a portion of the good is trimmed
Fruits and vegetables	2.26	69.61
Motor fuel	3.82	67.13
Fuel oil and other household fuel commodities	0.80	59.94
Used cars, etc.	2.27	58.84
Infants and toddlers apparel	0.11	54.97
Meats, poultry, fish and eggs	4.61	54.70
Womens and girls apparel	2.71	43.09
Public transportation	1.41	40.33
Other apparel commodities	0.58	37.85
Other private transportation commodities	0.67	37.85
Gas and electricity (energy services)	3.35	34.81
Tobacco and smoking products	1.63	33.43
Dairy products	1.92	28.73
Other private transportation services	3.35	24.59
Mens and boys apparel	1.90	23.48
Other utilities and public services	2.30	23.20
Personal and educational services	1.96	22.65
Toilet goods and personal care appliances	0.93	20.99
Medical care services	5.20	20.72
Other food at home	3.01	19.06
Footwear	1.02	19.06
Cereals and bakery products	1.86	17.96
School books and supplies	0.48	17.96
New vehicles	3.64	17.13
Housekeeping supplies	1.37	16.57
Housefurnishings	4.00	16.30
Entertainment services	1.88	15.47
Medical care commodities	1.01	14.92
Shelter	25.24	12.98
Housekeeping services	1.80	9.67
Entertainment commodities	2.37	7.46
Personal care services	0.94	7.18
Alcoholic beverages	1.73	6.91
Apparel services	0.92	5.25
Auto maintenance and repair	1.37	3.87
Food away from home	5.58	3.31
Mean of All Items		26.89
Mean of Food & Energy		39.93

Table 5: Frequency That a Component is Trimmed: PPI 40% trim

PPI Component	Average Relative Importance	Percent of Sample period that a portion of the good is trimmed
Farm products	7.47	98.90
Fats and oils	0.42	97.52
Meats, poultry, and fish	3.56	96.97
Prepared animal feeds	1.22	96.14
Fuels and related products and power	12.16	96.14
Metals and metal products	11.86	92.84
Hides, skins, leather, and related products	0.81	90.08
Lumber and wood products	2.40	88.98
Sugar and confectionery	1.04	87.88
Electronic computers and computer equipme	0.65	86.78
Transportation equipment	8.88	86.78
Chemicals and allied products	6.86	86.23
Processed fruits and vegetables	0.75	85.67
Dairy products	1.72	85.40
Cereal and bakery products	1.58	83.20
Miscellaneous processed foods	1.15	82.64
Miscellaneous Instruments	0.55	82.09
Beverages and beverage materials	1.90	81.54
Motor vehicles and equipment	7.01	81.54
Miscellaneous products	3.47	80.72
Electrical machinery and equipment	4.54	78.79
Construction machinery and equipment	0.74	78.51
Agricultural machinery and equipment	0.58	77.41
Textile products and apparel	5.33	77.13
Rubber and plastic products	2.56	77.13
Pulp, paper, and allied products	6.82	76.03
Nonmetallic mineral products	2.75	74.10
Miscellaneous machinery	1.73	72.45
Special industry machinery and equipment	1.19	71.35
Furniture and household durables	2.98	70.80
General purpose machinery and equipment	2.06	69.42
Metalworking machinery and equipment	1.24	66.39
Mean of All Items		83.05
Mean of Food & Energy		90.08

Still, some food and energy goods, notably food away from home, appear to provide an efficient signal of core inflation as we define it here. In fact, of the 36 CPI components considered, food away from home was the least likely to be trimmed. Moreover, many non-food, non-energy goods appear to provide little information about the economy's inflation trend. Notable among these are used cars and infant and toddler apparel that are likely to be trimmed out of the efficient estimator nearly twice as frequently as the average good (the average component is trimmed out of the 9% trimmed mean in 27% of the months in the sample).

The components most likely to be included in the calculation of the efficient CPI estimator include a wide variety of services and the shelter component which, despite its hugh average relative importance of 25.24, is likely to be on one of the trimmed tails of the price change distribution only about 13% of the time.

Similarly for the PPI, food and energy goods tend to be trimmed from the efficient estimator a disproportionately large share of the time. But some food components, such as beverages and beverage materials and miscellaneous processed foods, are trimmed at the same frequency as the average component. The least frequently trimmed component, metalworking machinery and equipment, is still trimmed about two-thirds of the time. This is a relatively low proportion when one considers that, for any given month, 80% of the price change distribution is trimmed to produce an efficient estimator for PPI core inflation.

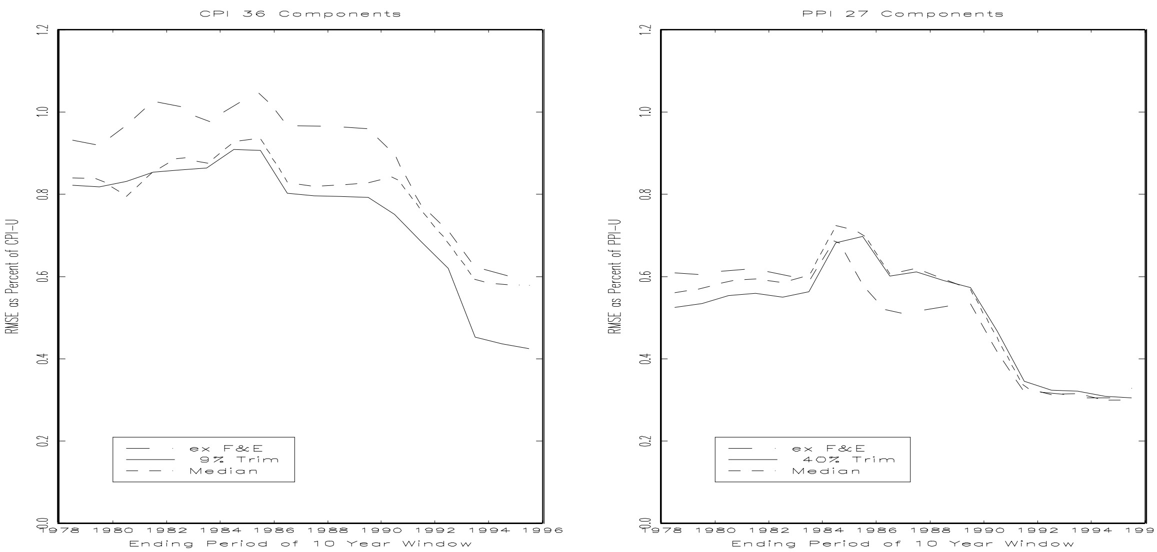
Finally, in Figure 12 we plot the ratio of the RMSE of various measures to the RMSE of the CPI-U and PPI themselves over different sample periods. For example, for the ten-year period ending July 1995, the RMSE for the CPI 'ex food and energy' was 57.8% than of the CPI-U itself — about the same as that of the median. But the RMSE of the 9% trim was 42.5% of the RMSE of the CPI-U. The main result is that, for the CPI, the 9% trim is always more efficient that the CPI excluding food and energy. But for the optimally trimmed PPI and the PPI 'ex food and energy' are very close.

6 Conclusion

In this paper we challenge the conventional wisdom that core inflation can be measured by simply excluding food and energy from monthly price data. We show that price change distributions are highly leptokurtic, or 'fat-tailed,' and so commonly used measures, such as the sample-mean, are inefficient estimators of the population mean of interest. We demonstrate that trimmed-mean estimators significantly improve the efficiency of inflation estimates. Furthermore, we are able to show that as the kurtosis of the distribution increases, efficiency dictates trimming an increasing percentage of the sample.

We proceed to apply these insights to inflation data. For consumer prices beginning in 1967, we find that trimming 9% from each tail of the cross-sectional price-change distribution produces the minimum root-mean-square error and minimum mean-absolute deviation estimate of monthly inflation. This estimator provides efficiency improvements

FIGURE 12: Comparison of Various Estimators
Efficiency with Changing Sample



on the order of 23 percent relative to the mean. By contrast, the CPI excluding food and energy provides virtually no efficiency improvement at all.

More disaggregated data amplify the difficulties, as the kurtosis of the distributions increases. Moving from a dataset composed of 36 components of the CPI to one with 185 components beginning in 1978, we show that the optimal trim nearly doubles to 16%. Here we find an efficiency gain of nearly 50 percent (although the sample period is substantially shorter). For producer prices beginning in 1947, where price-change distributions are more leptokurtic, trimming 40% to 50% from each tail produces the most efficient estimate of monthly aggregate price movements and improves efficiency by over 40 percent relative to the mean.

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BANK OF CANADA

Core Inflation: A measure of inflation for policy purposes

by Marianne Johnson*

1. Introduction

Monetary authorities generally seek to preserve the value of money and therefore to maintain a low rate of inflation. This is most evident in the communications of countries which have inflation targets, such as Australia, Canada, New Zealand, Sweden, and the United Kingdom. This focus on inflation raises several practical concerns including issues related to the accurate measurement of inflation.

In the context of particular economic models, inflation is a straightforward concept representing the rate of change in prices. Models are usually limited to a few markets at most and, correspondingly, to a few prices. In addition, shocks of any type are controlled events with effects readily distinguishable from the base-case dynamics of the model. In the context of implementing monetary policy, however, the conceptual definition of the inflation about which the monetary authority should be concerned is an open question, while the question of how to measure it, which can be thought of as putting the concept into practice, is just as difficult.

To implement policy, practitioners must take a stand on which inflation rate matters for policy. Many inflation-targeting countries, including Canada, have announced the inflation targets in terms of the growth in the consumer price index (CPI). CPI inflation approximates increases in the cost of living, and it is the final cost of consumer goods and services that matters for many contracts. This is important since the success of inflation targeting works largely through anchoring the inflation expectations which will be incorporated into decisions and contracts. The CPI directly affects both businesses and consumers. However, the CPI may not be the best measure of inflation on which to focus for policy purposes. Generally, policy makers focus on the more persistent movements in prices. Measures of the general underlying trend in inflation have been coined *core inflation*.

To better understand the motivation for research on core inflation, we introduce the notion of core inflation and its potential policy purposes. This provides some insight into the attributes of a useful measure of core inflation and what basis might be used to evaluate its success. To put the various measures of core inflation in some context, we discuss two broad approaches that have been used to measure core inflation: the statistical approach which focuses on exploiting the properties of the data, and the modelling approach, which draws on a conceptual notion of core inflation. We then introduce Canadian inflation measures in this context. To date, Canadian measures of core inflation are based on research using the first approach. This paper offers a preliminary evaluation of the measures of core inflation at the Bank of Canada. Most of the measures do seem to track the persistent movements in inflation. However, it is difficult to discriminate among them as they are quite similar in many respects. As a whole they provide useful information on the evolution of inflation.

• The views expressed in this paper are those of the author; no responsibility for them should be attributed to the Bank of Canada. Thanks to Jean-Pierre Aubry, Chantal Dupasquier, Dave Longworth, Thérèse Laflèche, Paul Gilbert, Richard Dion, Seamus Hogan, Tiff Macklem and Dinah Maclean for their helpful discussions and comments and to Frédéric Beauregard-Tellier for excellent research assistance. Thanks to Scott Roger for the methodology used to calculate measures of weighted skewness and weighted kurtosis.

The paper proceeds as follows. Section 2 introduces the notion of core inflation while Section 3 outlines its policy purposes. Section 4 reviews the two main approaches to the measurement of core inflation in the literature. This is followed in Section 5 by a discussion of research on core inflation at the Bank of Canada. Several measures of underlying inflation are currently in use at the Bank of Canada and Section 6 contains some evaluation of these core measures. Section 7 concludes.

2. The notion of core inflation

Monetary authorities are not concerned with every fluctuation in prices. Rather, they focus on the underlying trend. Core inflation corresponds notionally to that general trend in inflation.

One way of defining core inflation is in the context of the quantity theory of money where the general trend in inflation corresponds to the inflation that arises as a result of a monetary disturbance. As quoted in Bryan and Pike (1991), Friedman (1969) noted that there are usually two different explanations of price movements.

> "One, common to all disturbances, is that the price movements reflect changes in the quantity of money... The other explanation has been in terms of some special circumstances of the particular occasion: good or bad harvests; disruptions in international trade; and so on in great variety."

To the extent that these special circumstances are the source of shifts in relative prices, the corresponding price movements will represent transitory fluctuations in the inflation rate. Their temporary nature suggests that they would not be of primary interest to policy makers. Moreover, these price changes will not become permanently incorporated into the underlying inflation process unless there is a change in the stance of monetary policy that accommodates any change in inflation expectations resulting from the shock.[1] For policy purposes, therefore, monetary authorities focus on the persistent trends in inflation. Measures of core inflation are used to capture these trends. As such, core inflation may be considered a measure of the inflation which is the outcome of policy.

Focusing on a measure of inflation which excludes short- to medium-run fluctuations is based on the idea that they represent changes in prices that are not of direct concern to policy makers and to which policy should not react. There are two main types of these fluctuations.

First, there will be fluctuations in prices to which the monetary authority will not wish to react simply because they are likely, by their volatile nature, to be quickly reversed on their own. Seasonality, the infrequent survey of particular prices, the timing of particular price changes, and other events may introduce noise into published price indexes.[2] Core inflation measures attempt to abstract from this noise.

Second, there will be other short-term fluctuations which represent price shocks arising from sources beyond the control of the monetary authority. These price shocks will be idiosyncratic to the markets

1. This is the spirit of the Bank of Canada's original inflation target announcements. It was stressed that "only the first-round effects on the CPI of short-run movements in food and energy prices and substantial changes in indirect tax changes would be accommodated, not any second-round or ongoing effects on the rate of inflation." *Bank of Canada Review*, September 1991, page 1.
2. There may be bias or noise in published inflation rates. Research on bias, where the methodology used to generate the price index creates persistent measurement problems, is critical though distinct from the research on core inflation and is not dealt with in this paper. (See Crawford et al. (1998) for a detailed discussion of bias in the CPI.)

where they originated and can be thought of as shifts in relative prices. Examples include: changes in supply, such as a crop failure, which might generate large changes in the relative price of a particular good or service, changes in taste which might also lead to a change in demand for a particular product and hence a sharp change in its relative price, or specific events such as changes in indirect taxes. One-time shifts in the level of the real exchange rate due to non-monetary sources could also lead to shifts in relative prices.

Since policy instruments have only a generalized and indirect effect on inflation, affecting it through a complex transmission mechanism, policy instruments are not well suited to reversing specific price changes originating in particular markets. Hence, policy makers focus on measures of inflation which abstract from these shifts in prices.

Until the 1990s, core inflation remained essentially a term for CPI inflation excluding food and energy in many countries. Recent experience with inflation targeting has motivated further research on core inflation. Policy is now tightly linked to published inflation rates. Measures of core inflation attempt to extract from published inflation rates the inflation that is of direct interest to policy makers. As a practical matter, this is done by decomposing published inflation into its persistent and transitory components. This may be achieved by specifying a theoretical model of core inflation and attempting to directly measure this inflation. Alternatively, a core measure can be derived by eliminating, to the extent possible, the price shocks that can be identified as being either noise, or as arising from a source that is somehow exogenous to the process influenced by monetary policy. In effect, the ongoing interest in core inflation reflects its usefulness as a tool for policy. A measure of core inflation would be both a better guide for current and future policy than published inflation rates and also represents the inflation that is most controllable.

3. Policy purposes of a core measure

To further understand why core inflation might be a useful tool for policy makers, we begin with a discussion of its policy purposes. Ideally, core inflation would be:

- *a good indicator of current and future trends in inflation;*
- *a good measure of inflation for empirical work; or*
- *a viable target for monetary policy.*

It may be that a core measure would suit one or all of these needs.

- ***A good indicator of current and future trends in inflation***

Monetary authorities closely monitor all available data on the current state of the economy and the current inflation rate. This ensures that the most up-to-date information is incorporated into policy decisions. However, policy decisions are based on the more persistent movements in inflation. Core measures assist in the analysis of new developments by providing a means by which the monetary authority can separate the noise and short-run fluctuations in the data from its more persistent trend.

Considering that monetary policy affects inflation with long and variable lags, central banks are more concerned with the future evolution of inflation than with its current level. Recent data on inflation may represent one of the best sources of information about its future movements. When new data are available, core inflation measures extract the signal in the new data. The most useful measures of core inflation will minimize misleading signals about the future trend in inflation.

As an indicator, core inflation is a guide to policy makers as to whether current policy settings are likely to achieve the target. Policy makers may respond to the indicator at their discretion or they may take a less discretionary approach and incorporate the indicator into a policy rule. For example, Taylor rules use the current deviation of inflation from its target as a guide for policy.

By allowing policy makers to see through temporary or misleading fluctuations, core inflation can be a useful tool to assess the effectiveness of policy. It may even be a public measure. In this case, core measures would aid in the communication or transparency of policy since they may help to clarify why policy makers are or are not reacting to recent fluctuations in published inflation rates. Its use in communication of policy could also improve public understanding of the notion that policy is linked to the more persistent movements in inflation.

- ***A good measure of inflation for empirical work***

Policy makers are also concerned with developing their understanding of the evolving interactions between monetary policy, economic activity, and inflation. This suggests the need for empirical research as well as further investigations into policy rules. This research agenda requires the accurate measurement of inflation. It also raises the possibility that some of the changes in prices, although technically contributing to inflation, ought not to be included in the measure of inflation used in empirical work. Transitory shocks might obscure important relationships between monetary policy and prices as captured, for example, in an expectations-augmented Phillips curve. In this case, a core inflation measure might better illuminate the relationships of interest.

- ***A viable target for monetary policy***

If price fluctuations from non-monetary sources can be excluded, the resulting core inflation could be regarded as a measure of the inflation that is the *outcome* of policy. Therefore, some measures of core inflation could be considered to be more controllable by the monetary authorities than published inflation rates. This closer relationship suggests that core inflation might be a better target for monetary policy than published inflation rates.

Since the use of a target implies that the monetary authority will accept responsibility for inflation *ex post,* it makes sense to define the target in terms of the measure of inflation for which it has the most *ex ante* control. This would further establish accountability for policy.

Use of a core measure as a target would focus public attention on the persistent trend in inflation, bringing it into line with the focus of the monetary authority. This is important since the success of inflation targeting works largely through anchoring the inflation expectations which will be incorporated into decisions and contracts. To the extent that this focus reduces the passthrough of temporary shocks to public inflation expectations, the variability of inflation would be further reduced.

A target core measure would have to be viewed by the public as objective if it were also to be used for accountability for policy. This suggests that the methodology used to extract core inflation from public inflation rates ought not change frequently or be viewed by the public as either obscure or under the control of the monetary authority itself. In particular, the arrival of new information should not result in a change in the historical core inflation series.

CPI inflation is designed to approximate changes in the cost of living, an aspect of primary concern to the public. To the extent that core inflation differs from the concept of a cost of living measure, it might not be readily understood or accepted by the public. In particular, it might be difficult to explain an ongoing focus on core inflation by the monetary authority if core inflation deviated from published inflation rates for an extended period.

4. Alternative approaches to the measurement of core inflation

Research in the 1990s can be thought of as following two broad approaches that roughly correspond to focuses on the two main problems in the core inflation literature. These are:

- ***the modelling approach***

This research focuses on the conceptual problem: How do we define core inflation?

- ***the statistical approach***

This research focuses instead on the practical problem: How can we measure it?

Ideally, a measure of core inflation would *both* define core inflation and directly exploit the data in its measurement. To date, this ideal measure of inflation remains elusive.

4.1 The modelling approach

The **modelling approach** takes as its starting point a behavioural definition of core inflation. This approach has been dominated by the research of Quah and Vahey (1995). These authors acknowledge the importance of a theoretical definition for core inflation and use the notion to determine the long-run restrictions in their model. Other researchers that have come up with alternative Structural Vector Autoregressions (SVARs) based upon the original Quah and Vahey approach include Blix (1995), Bjornland (1997), Claus (1997), Dewachter and Lustig (1997), Fase and Folkertsma (1998) and Gartner and Wehinger (1998). Each of these papers tries to address some criticism of the SVAR literature or of its application to core inflation. Other models of inflation have also been proposed and may be notionally linked to the core inflation literature. For example, p-star, or the long-run equilibrium level of prices in standard p-star models could be interpreted as the price level that corresponds to core inflation. (Attah-Mensah (1996), Armour et al. (1996), and Hallman, Porter, and Small (1989) have developed versions of the p-star model.)

The modelling approach involves an attempt to define core inflation and to use a model to operationalize it. This approach provides the advantage that it draws a direct link between policy and core inflation as the inflation which is controllable through policy. This link makes it clear why the monetary authorities would care about this measure of inflation. The main obstacle to obtaining a model-based definition of core inflation is that any model will be subject to scrutiny of its assumptions. Assumptions about the flexibility of prices, the formation of inflation expectations, and about the nature and distribution of price shocks will drive the results in the model. Further, it is unlikely that the distribution of these shocks is time or policy invariant. One feature of the structural model approach is that the arrival of new data could change the historical core inflation series produced by the model. Another is that it is generated directly by the policy maker. These features ensure that all available information and the most up-to-date techniques are used to estimate the trend. The estimates will evolve over time. This is an important advantage on occasions where new data reveals problems with past estimates of the trend. On the other hand, these features complicate public discussion since revisions would continuously require explanation. Too many revisions would undermine the credibility of the core measure.

Finally, it is useful to note that the farther a core measure deviates from published inflation rates or the more obscure the link becomes, the less useful the measure becomes as a formal target or as a public gauge of current underlying inflation that can be used for accountability to the public.

Furthermore, if the model itself has everything needed to forecast inflation then there is no independent role for core. The empirical implementation of any model-based core measure including VARs will be subject to degrees of freedom problems once various relative price shocks have been taken into account. This suggests that if there are many types of shocks one wants to deal with - admittedly with priors - there may be advantages to the statistical approach.

These features limit the use of these measures of inflation to roles as indicators of inflation. Still, it should be noted that this is a very important use for a measure of underlying inflation.

4.2 The Statistical Approach

Researchers using the **statistical approach** focus directly on the problem of how to measure core inflation using existing data. They typically take published price indexes and inflation rates as a starting point and ask how the available data can be exploited to provide a core measure. In general, this research can be divided into two branches which effectively correspond to the aggregated and disaggregated approach. Within the disaggregated approach, there are two types of inflation measures: i) those that use the distribution of inflation at a point in time and ii) those that use the time series properties of the data.

The main weakness in this approach is its atheoretical nature. Some researchers using this approach have focused on techniques for decomposing inflation into its core and non-core components without formally providing a framework of why a particular choice of decomposition is appropriate or desirable. Ideally, a definition or at least some notion of core inflation would be used to justify the exclusion of particular sub-indices or events. This makes it clear exactly why policy makers would care about a particular subset of published inflation rates.

The main advantage to this approach is that it uses the available data to the fullest extent possible. Also, when the measure of core inflation is derived using a straightforward, non-subjective technique it can be used for public discussions of policy.

4.2.1 Aggregate approach

The first branch of the statistical approach is one that uses the full sample of aggregate data and statistical techniques to identify directly the core measure itself. This approach focuses exclusively on the information contained in the dynamics of the aggregate index.

In effect, $\pi_t = \pi_t + \varepsilon_t$ where π_t is the core inflation movement and ε_t is the error term which may be interpreted as noise or may be further decomposed into two terms which represent noise and short-run fluctuations which are not of concern due to their volatility or source.

Research along these lines includes simple averaging as is done with year-over-year calculations or averages over other horizons and seasonal adjustment, as well as more sophisticated filters such as those of Cogley (1998).

4.2.2 Disaggregated approach

The second branch of the statistical approach uses disaggregated price data to create a measure of the general increase in prices, or core inflation.

Research using the disaggregated approach includes the various papers on the weighted median and other limited information estimators by Bryan and Pike (1991); Bryan and Cecchetti (1993b, 1996); Bryan, Cecchetti and Wiggins II (1997); Cecchetti (1996); Roger (1995, 1997) and Shiratsuka (1997). Measures of core inflation used at the Bank of Canada are based on this approach. These measures are proposed in Crawford et al. (1998) and Laflèche (1997a, 1997b).

- ***Disaggregated approach using the distribution of inflation at a point in time***

An aggregate price index, such as the CPI, is the weighted average of many individual sub-indices at any particular time period, *t*. The disaggregated approach focuses exclusively on the cross-sectional distribution of the individual sub-indices. In these measures, large or volatile movements in particular sub-indices are compared to some threshold (such as the mean of the distribution). These fluctuations are interpreted as non-representative or idiosyncratic movements in individual prices which are excluded from the measure of the aggregate tendency in prices. Once a high variance subset of the distribution is excluded, the remainder of the distributed is reweighted so that the weights sum to one. The weighted mean of the remaining sub-indices is calculated and interpreted as core inflation. In some cases, the high variance subset is down weighted rather than excluded.

Let π_t^i be the growth in the ith subindex of an aggregate price index, and c and nc designate core and non-core parts of inflation, respectively, such that: $\pi_t = w_t \sum c\pi^i_t + x_t \sum nc\pi^i_t$ where $w_t + x_t = 1$. By implication, movement in the ith non-core component, $\sum nc\pi^i_t$, represents either noise or is interpreted as non-core price shocks. It is important to note that the sub-indices that are included in the core inflation part will differ from period to period.

Canadian measures based on this approach include: a measure which eliminates movements in the tails of the distribution (*meantsd*) and the weighted median (*wmedian*).

- ***Disaggregated approach using the time series properties of the data***

Other statistical measures use the full sample to derive a measure of underlying inflation from all existing data. Transitory movements are identified as either noise or one-time-only relative price shocks, where the latter are usually assumed to correspond to supply shocks. Unfortunately, transitory movements can only be perfectly identified with the benefit of hindsight. To get around this problem, this research uses the broad historical time-series properties of the sub-indices to determine the candidates for exclusion. These properties may not persist into the future so these measures ought to be re-evaluated occasionally.

The most widely known Canadian measure based on this approach is the consumer price index excluding food, energy and indirect taxes (*CPIxFET*). The consumer price index excluding its eight most volatile components as well as indirect taxes (*CPIX*) also uses the historical volatility of individual sub-indices to identify the candidates for exclusion. There is also a measure which reweights the components according to their historical variability (*CPIW*).

5. Measures of underlying inflation at the Bank of Canada

For any purpose, it would seem that core would necessarily be a smooth measure of inflation. This suggests that averages might be a simple approach that could resolve many of the problems associated with the use of published inflation series. However, for the purpose of inflation as an indicator, there is a trade-off between longer-run averages, which tend to be reliable measures of underlying trends, and the up-to-date information in recent data. Though quite noisy, the timeliness of monthly data makes it an invaluable source of information on new developments that may hint at future trends in inflation.

The early-warning indicator use of a core measure has led some researchers to focus on short-term fluctuations in inflation in defining a core measure which takes full advantage of the timeliness of the data. For example, various U.S. researchers derive core measures based on monthly fluctuations (Bryan and Pike (1991), Bryan and Cecchetti (1993b)), while Roger (1995, 1997) emphasizes measures based on quarterly changes in inflation for New Zealand. However, the volatility in monthly and quarterly data suggests that sole reliance on higher frequency data could lead to policy errors or unnecessary volatility in the instruments of monetary policy. Cecchetti (1996) reports that changing the growth calculation from a month-to-month to a quarter-over-quarter growth rate halves the noise in inflation. (This is evident in Figure 1 which compares monthly, quarterly, and year-over-year movements in the CPI.)

Some of the noise in monthly inflation rates is inherent to the process of surveying prices and constructing a price index. Some prices are infrequently sampled and other prices are only adjusted occasionally. For example, tuition fees change once a year in Canada. These infrequent price changes are part of the overall inflation process and ought to be included in the inflation rate. However, at a monthly frequency, the magnitude of such price changes might be misleading if they are not well understood. Year-over-year growth rates allow a reasonably longer-term perspective. Further, they avoid by construction the problem of regular seasonality, though certainly not stochastic seasonal problems.

In Canada, monthly growth rates are scrutinized and compared to anticipated monthly growth rates but are not used in an official core measure. Since policy making is an imprecise art at best, changes in the trend in inflation require some confirmation before policy makers act. Thus, it seems prudent to limit the importance of a single month's data in a measure of underlying inflation.

Annual growth has important advantages if the core measure is to be used as a target. The smoothness of annual inflation rates enhances communication with the public. The inflation rate is not changing rapidly each month since it is an annual average and this helps to pin down the longer range inflation expectations of individuals and businesses. Finally, it is likely that an annual horizon or longer corresponds to the planning horizon of consumers and businesses negotiating and establishing changes in wages, pensions, loans, or other contracts that may take inflation into account.

For all of these reasons, core inflation measures in Canada are based on annual price changes. These core measures are introduced below.

- ***CPIxFET as a measure of core inflation***

The term core CPI inflation at the Bank of Canada officially corresponds to the 12-month change in the CPI excluding food and energy and the effects of indirect taxes (CPIxFET), which is shown in Figure 2.

Although CPI inflation is the official target in Canada, the Bank of Canada has officially adopted the CPIxFET inflation as the *operational target* for policy. This choice reflects several considerations.

First, its construction is easily understood by the public. Second, it is perceived as an objective measure of inflation because the CPI excluding food and energy is published independently by *Statistics Canada* and the methodology for adjusting for the effects of indirect taxes is clearly documented in the *Bank of Canada Review* (1991). Third, CPIxFET is a measure of core inflation. As such, CPIxFET shares the same general trend as the CPI but is much less volatile. Food and energy prices are notoriously more volatile than other prices. They have frequently been the source of large, unanticipated changes in CPI inflation. However, these large price changes have also typically been temporary. Since monetary policy acts only indirectly and over a long horizon to influence inflation, it is not well-suited to offsetting these temporary shifts in the inflation rate. Moreover, even if it were possible to offset these temporary shocks it might not be desirable to do so since it would involve increasing the volatility of monetary instruments. In addition, the nature of food and energy markets suggests an economic rationale for excluding these particular items. These prices are determined in markets where supply shocks (unrelated to monetary policy) are very important so that excluding these prices should produce a measure of inflation which is more controllable. As there has been no tendency for food and energy prices to rise at a different rate than total CPI inflation, focusing on the CPIxFET is effectively the same as focusing on the trend in the CPI itself with the advantage that uncertainty around the trend is reduced. Fifth, this common trend relationship to the official target is generally understood by the public. This understanding is necessary for transparency of policy. It creates a common ground for the communication of policy, particularly when CPIxFET deviates from the CPI and policy decisions require some explanation. It also aids in accountability since being outside the CPI target bands is placed in the context that the Bank is concerned with the more persistent movements in inflation. In summary, the use of CPIxFET as the operational target enhances communications and improves accountability since policy is based on a measure of inflation which is understood to be more controllable than the CPI.

One disadvantage to this measure is that, in excluding a portion of the expenditure-weighted CPI basket, it deviates even further from a cost-of-living index. This could lead to criticism from the public since they will be concerned with changes in the cost of living. Secondly, it is unlikely that every price movement in food and energy represents a relative price shock. Work by Crawford et al. (1998) shows that food consumed away from home, for example, is not a volatile price series and therefore belongs in the calculation of the underlying dynamics in inflation.

The effects of indirect taxes are also excluded from CPIxFET. In practice, this involves an adjustment to the inflation rate as a whole rather than the exclusion of specific portions of the basket as is the case when excluding food and energy. Price changes resulting from changes in indirect taxes represent one-time-only shifts in the price level. Moreover, indirect taxes are not related to the price of the good or service which is purchased, instead, they are charges to finance other government activity. In Canada, large changes in indirect taxes included the introduction of the value-added tax in 1991 and a large decline in tobacco taxes in 1994. The size of these shocks suggests the prudence of an approach that directly takes these changes into account, no matter that it is ad hoc in that it assumes tax changes are passed through one-for-one to consumer prices.

Since policy makers focus on the more persistent changes in inflation, they do not attempt to reverse these one-time shifts in the price level. Once these one-time shifts from changes in indirect taxes are excluded, the resulting inflation measure should be even more representative of price changes driven by the state of excess demand pressures in the economy and monetary phenomena. This further enhances its suitability as an operational target.

For these reasons, the CPIxFET is a useful guide for policy and tool for public communication and accountability. Its use as an operational guide will continue to work well as long as the two inflation series do not deviate for extended periods. It is also worth noting that, to the extent that the core measure more directly captures the underlying trend in inflation that is the outcome of policy, uncertainty about longer-run trends in inflation could be reduced even further by directly naming the core measure as the target. This would further disseminate to the public the notion that policy decisions are based on the more persistent movements in inflation.

5.1 Alternative measures of underlying inflation in use at the Bank of Canada

Other Canadian measures have been derived based on the disaggregated approach. Crawford et al. (1998) and Laflèche (1997a, 1997b) use the monthly distribution of 12-month changes in prices for 54 different subindexes of the CPI to generate the measures of core inflation discussed in the following sections. The longest consistent series of disaggregated prices that is available for all 54 subindices begins in 1985, therefore, these 12-month inflation measures begin in 1986.

The disaggregated approach was adopted because it makes the most of the available data. Aggregate time series approaches to measuring core inflation have been hampered by changes in the Canadian inflation process. There is evidence of regime changes in the Canadian data. (Ricketts and Rose 1995). The most recent of these shifts occurred in the early 1990s. Year-over-year growth in the CPI fell from 4.7% for the 1986 to 1991 period to 1.4% for the 1992 to 1998 period. Evidence on the time-series properties of the data suggest that this regime switch may be more than a shift in the mean. Research also suggests that the inflation process was non-stationary in earlier periods, but is now stationary in the recent inflation-targeting environment (St-Amant and Tessier 1998). These results must be interpreted cautiously due to the low power of the test and the short period used for the analysis, but there does seem to be evidence of a regime change emerging in the literature. (In a sense this is not surprising for a successful regime with a constant target would imply stationarity.) Close review of the individual prices that make up the aggregate inflation index suggests that this regime change may have occurred in a wide variety of prices. Almost all of the disaggregated prices in the CPI have lower means and standard deviations in the period after 1992 than in the earlier period (see Table A1).

Use of the empirical modelling approach is made difficult by this recent historical experience. Once a researcher has adjusted for regime changes and other important temporary shocks (such as the introduction of the GST) in the Canadian data, there remains very few degrees of freedom to estimate model-based measures of core inflation. A model which ignores these changes in the inflation process could lead to misleading inference. On the other hand, the existence of these changes in the inflation process cannot be firmly established unless the recent regime persists for a long enough period to generate a long time series. It may be that there is no regime change. In this case, a model which allows for these changes in the inflation process could lead to misleading inference. Explicit use of the disaggregated price data allows the researcher to access a wider range of information for the analysis. While the model-based approach is theoretically appealing, it has these practical problems; in contrast, the statistical approach is likely to yield a stable measure of core inflation even through periods of rapid change.

- ***MEANTSD***

MEANTSD is the weighted average of the cross-sectional distribution of price changes that has been trimmed to exclude values farther than 1.5 standard deviations from the average (see Figure 4). As such, it excludes the most volatile components at each *point in time*. This provides a measure which is roughly equivalent to one which trims 5% of the largest and smallest changes in the distribution, however, it has the advantage that it allows the amount trimmed to be dependent on the tightness of the distribution itself. The determination that any price change larger than 1.5 standard deviations represents an outlier is somewhat arbitrary. Interestingly, the same subcomponents are often excluded on both extremes of the distribution. In other words, extreme fluctuations tend to be reversed. This supports the interpretation that they represent temporary supply shocks.

One feature of this measure is that it may be more volatile *over time* than most measures of underlying inflation (See Tables 1 and 2). If annual price movements for a particular component vary such that the price is always close to 1.5 standard deviations, then it may be included one month when it is just below 1.5 standard deviations and then excluded the next when it is just above. This makes it difficult to compare monthly reports of the 12-month changes in inflation since the coverage of the measures tend to vary from month to month.

MEANTSD is not published by the Bank of Canada but is used in internal current analysis of evolving inflationary pressures. Every month, it is used in conjunction with information on which subcomponents are actually excluded (see Table 3 for an example). Thus, it is used as much as a way of highlighting the specifics of extreme price movements as it is of providing an underlying inflation rate.

- ***CPIX***

This measure of inflation is defined as the CPI excluding the eight subindices which have been most volatile, as well as indirect taxes (see Figure 5). These eight are fruit, vegetables, gasoline, fuel oil, natural gas, mortgage interest costs, inter-city transportation (mainly air fare), and tobacco products. In practice, this involves placing a weight of zero on the eight excluded price subindices and recomputing the aggregate price index. Year-over-year growth of the price index is then defined as CPIX inflation. CPIX is similar in spirit to the notion behind the CPIxFET. The subcomponents which are eliminated, however, are chosen based on a more objective evaluation of their volatility. The exclusion of this particular set of prices is also appealling due to the source of their dynamics. Most of the prices are volatile due to their particular market, for example, fruit, vegetables, gasoline, fuel oil, natural gas and inter-city transportation. All of these are items which are affected by world prices and are sensitive to the exchange rate. Others such as tobacco products and mortgage costs are affected by government policy.

The idea for CPIX originated with the observation that some elements of the aggregate food and energy subcomponents were not at all volatile. For example, food purchased in restaurants, dairy products, and bakery products were rarely excluded from MEANTSD. Eliminating these elements from the basket, as is done in CPIXFET, might in fact be excluding useful information on the trend in inflation. This suggested that it might be possible to have a measure of core inflation which was less volatile but which included more of the basket.

CPIX makes the most of what we do know about the historical variability of disaggregated prices to determine which price changes ought to be not to be included in core inflation. The following calculation is used to identify the most volatile subindices. First, a limited information estimator - trimmed of the 10% highest and lowest values of the ordered distribution in each period - is computed. Second, MEANTSD is computed. Recall that MEANTSD is trimmed of price changes over 1.5 standard deviations from the weighted average in each period. Any subcomponents which are trimmed from the limited information estimator over 50% of the time and from MEANTSD over 25% of the time are identified as volatile. In other words, the components that are most often among *the most volatile subcomponents at a point in time* are identified as candidates for exclusion. This calculation is made over the longest sample possible: November 1979 to November 1996 for most components and January 1986 to November 1996 for the exception.

The resulting core measure actually contains more of the basket than the Bank's official core inflation measure. Based on the 1996 basket weights, the CPIxFET excludes 26% of the total CPI basket, whereas the CPIX excludes only 16%. CPIX is also less volatile that CPIxFET. It is published regularly in the *Bank of Canada Review.*

- ***CPIW***

The choice to zero-weight particular components and recompute the aggregate index (as is done for CPIxFET, CPIX and MEANTSD) is based on the view that these extreme movements are uninteresting for the purposes of monetary policy. Yet, it is unlikely that all large movements correspond to either noise or one-time-only relative price shocks. At least on occasion, these movements may reflect changes in the inflation process. This will be an important exception from the perspective of the monetary authority. It may be useful to compute a measure that includes some effect from these large changes in prices rather than ignore these movements entirely. This is the notion behind CPIW (see Figure 6), which attenuates the influence of highly variable components. This measure has the advantage that it includes all elements of the initial basket. CPIW is published regularly in the *Bank of Canada Review.*

CPIW calculates the inflation rate by taking the initial basket weights and multiplying them by a second weight which corresponds to the reciprocal of the *historical* standard deviation of the relative price change. This standard deviation of the relative price change is computed as the difference between the variation in the component and the variation in the total CPI. It is calculated over the period 1986m1 to 1997m4. The new weight is obtained by multiplying the initial weight by the second weight. The product is then normalized so that the weights sum to one.

- ***Wmedian***

The weighted median is an order statistic which is defined as the 50th percentile of the weighted cross-sectional distribution of price changes. It is shown in Figure 3. As an order statistic, the weighted median will be a more robust measure of the tendency of the individual price changes that make up the distribution than the weighted mean if the distribution of price changes is non-normal. This measure is not used regularly at the Bank of Canada but we include it in this analysis since there is some evidence that the distribution of price changes in Canada may be non-normal.[3] Conclusions are tentative because the skewness and kurtosis of the distributions vary with the horizon used to calculate the price changes. Furthermore, the moments of the distribution are changing over time.

The cross-sectional distribution of price changes seems to be leptokurtic. Calculations based on the distribution of year-over-year changes indicate weighted kurtosis of 9.72 for the 1986-1991 high inflation subperiod. Weighted kurtosis does decline to 6.11 for the 1992-1998 sample, but this is far more than the kurtosis of 3 for a normal distribution. This suggests that eliminating extreme movements may be worthwhile. Note, however, if the distribution is symmetric, trimming the tails and recalculating the weighted mean will not result in any change in the weighted mean. Hence, we look at the skewness in the distribution.

There is evidence of skewness in the distribution when price changes are calculated at some frequencies, though not for those calculated over an annual horizon which is the one used in Canada to calculate measures of underlying inflation. Weighted skewness in year-over-year price changes averages about 0.15 for the full sample. However, weighted skewness seems to have fallen along with the mean of inflation in recent years. Average weighted skewness fell from 0.32 in the 1986-1991 period to zero in the 1992-1998 period. Therefore, it does not appear that on average skewness is a particular problem in the Canadian data. However, the standard deviation surrounding the skewness for the full sample is 1.44, indicating that skewness presents a problem during particular periods. The possibility of skewness during particular episodes could support the use of the weighted median as a measure of core inflation.

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3. Appendix 2 includes a detailed discussion of the moments of the distributions of price changes in Canadian data.

6. An evaluation of various measures of underlying inflation

All of the measures in section 5 yield useful information about core inflation. Nonetheless, policy makers require a means of discriminating among them. Any evaluation is complicated by the fact that there are no formal criteria by which the accuracy of a core inflation measure can be assessed. Since core measures are to be tools for policy it is reasonable to assess them based on their suitability to various policy purposes. Hence, we begin with a discussion of the attributes that would make different measures suitable as an indicator of current and future trends in inflation; for empirical work; or as a target for monetary policy.

As an indicator of current and future trends in inflation, the ideal core inflation would be a smooth measure that closely approximates the general trend in inflation. Furthermore, it would have some forecasting ability for the trend. In other words, the excluded portion would reflect short-run movements in inflation. As such, it would be independent of the future trend in inflation. Timeliness is also an important attribute if core inflation were to be used as a guide for policy. However, all of the core inflation measures are available at the same time so we do not evaluate these particular measures based on this last criteria.

As a better measure for empirical work, the core measure would tighten the estimates of the relationship between policy and other variables, for example, in expectations-augmented Phillips curves. Unfortunately, the absence of long time series makes this difficult to evaluate.

Generally, the same attributes that would make a core measure useful as an indicator of the trend in inflation or as a better measure for empirical work would also make it suitable as a guide to policy and more precisely, as an operational or intermediate target for policy. As a direct target, however, the core measure would be a public measure; therefore, it would also require a few additional attributes.

Targets are an important element in a strategy for communication with the public. Therefore, to be a viable target, a core measure would have to be understood by the public and acceptable to it. This suggests that measures which exclude too much of the consumer basket might be challenged by the public since they deviate too much from a cost of living index. This might recommend the CPIX rather than the CPIxFET, since the proportion of the basket which is excluded is smaller and can be defended on variability criteria. In addition, the relationship of the core measure as target to other published inflation rates (such as the CPI) would have to be transparent and its construction easily understood, since deviations of the core measure from published inflation rates would have to be addressed.

As a target, a core measure would have to make sense based on economic theory. This implies that it would be a good measure of the persistent trend in inflation. Furthermore, it should be clear to the public that the core measure is closer to the trend in inflation than other published measures and that it is the persistent movements in inflation that matter to the monetary authority. Only in this event would use of a core measure improve the transparency of policy decisions. This requirement would exclude very obscure measures of underlying inflation as candidates for the target, even if they were fairly accurate. For example, this would seem to suggest that MEANTSD is not a candidate for a public measure of core inflation and this is one reason why the Bank of Canada has chosen not to publish this measure.

A principle reason for naming a target for policy is to provide a benchmark on which to evaluate the success of policy. As a tool for accountability, it would have to be fairly clear that the monetary authority had some capacity to realize the target given the monetary policy instrument. This provides a strong argument for the use of a core measure as a target if that measure is shown to be a tighter measure of the inflation that is controllable. If such a core measure is named as the target, it might be possible to be more precise about the target since the core measure would be closer to the trend in inflation than CPI inflation; this could imply a smaller range for the target.

Note finally that, for a core measure to be useful, it would have to be clear why the particular decomposition chosen isolates core inflation and not something else.

- ***Does the core measure capture the persistent movements or is it still volatile?***

Table 1 lists the mean and standard deviation of each of the various core measures as well as the CPI. In terms of variability, defined as the standard deviation divided by the mean, each of the core measures improves on the variability in the CPI. However, there is very little to differentiate among the various core measures. The mean over the full sample ranges from 2.76 for the weighted median to 2.90 for both CPIW and MEANTSD . Measures of variability range from a low of 0.42 for CPIX, the least variable measure, to 0.51 for the weighted median.

Table 2 also reports the same statistics but over the period 1992m1 to 1998m8 to evaluate whether the core measures continue to perform well in the recent low and stable inflation period. The mean has declined for each of these measures and the CPI. The mean of the core inflation measures now ranges from 1.52 for the weighted median to a high of 1.87 for CPIX inflation. The higher mean for the CPIX reflects the exclusion of mortgage costs which have been declining due to low interest rates. The standard deviation has also fallen sharply, ranging from 0.43 for the MEANTSD to a low of 0.30 for CPIW. For most of the core measures, variability is about half of the 0.50 calculated for the CPI, with the lowest variability of 0.18 reported for both CPIW and CPIX.

As suggested by Cecchetti (1996), a longer-run two-sided moving average of inflation will provide us with a fairly good benchmark of the trend in inflation. We use this benchmark to assess the various core measures. Figure 7 graphs the weighted mean of the CPI changes and the two-sided 36-month moving average of the monthly weighted mean. The weighted mean is equivalent to CPI inflation except that the basket weights have changed approximately every four years and also, we have adjusted the components used to calculate the weighted mean for the effects of the GST in 1991 and the tobacco tax shock of 1994 to remove misleading shifts before calculating the more persistent trend. Table 4 reports the root mean square error and mean absolute deviations to compare how close each core measure captures the benchmark trend. It appears that the CPIW more closely approximates the persistent movements in the weighted mean better than the alternative measures.

- ***Does the core measure help predict future trends in inflation?***

In order to assess whether the core measure has any indicator properties for the future trend in inflation, we review the simple correlations between each core measure and the CPIxT (CPI excluding indirect taxes) at various future intervals: 6 months, 12 months, 18 months, and 24 months (see Tables 5 and 6)[4]. We report correlations between the core measures and the CPIxT rather than the CPI itself in order to abstract from the large indirect tax shocks in the data. The importance of indirect tax shocks is evident when comparing the CPI and the CPIxT at all samples. At 6 months ahead the correlation between the CPI and the CPIxT is only 0.65 despite a 6 month overlap in the data.

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4. Note that contemporaneous correlations and those 6 months ahead will include some overlap between the core measure and CPIxT since these are 12-month averages.

Table 5 shows the correlations over the full 1986 to 1998 sample period. These correlations are quite high. They suggest that core measures do contain information about future movements in inflation. At 24 months ahead, the correlation between CPIX and CPIxT is 0.75.

It may be that correlations are high simply because all of these measures capture the large downward shift in inflation in 1991. In addition, it is interesting to see how they perform in the recent inflation environment. Therefore, the same correlations are reported for the recent sample as well (see Table 6). At 6 and 12 months ahead, CPIxT is negatively correlated with most of the core inflation measures. The exception is the CPIxFET, which is slightly positively correlated 6 months ahead (during the period of overlap) and generally uncorrelated 12 months ahead. At 18 months ahead, correlations change sign and are now all positive. At this point, CPIxFET is the most highly correlated at 0.44 and CPIX the next highest at 0.40. This pattern of correlations through time suggests that many of the shocks which are excluded from the core measures but are included in the CPIxT have been eliminated between 12 and 18 months ahead. The core measures are still notably correlated with the CPIxT at 18 and 24 months ahead, suggesting that they do have useful information on the future trend in inflation. The highest correlation at 24 months is between CPIxT and CPIW; it is reported at 0.42.

These statistics represent correlations at particular periods in time. Other research at the Bank suggests that these conclusions hold up in a more dynamic analysis. Regressions on the CPI or core measures which use long lags (18 to 29 months) of either the CPI or core as explanatory variables indicate that the use of core measures significantly reduces the standard errors in simple forecasting equations. In effect, more closely identifying the trend improves forecasts of inflation. Not surprisingly, the core measures perform even better if the sample is limited to the recent period of low and stable inflation.

- ***Is it reasonable to exclude these particular subsets of the CPI?***

One can check to see whether the portion of the CPI excluded from a core measure has similar attributes to noise or reversible prices shocks. For example, we look for persistence in the excluded-from-core series. For the CPIX we evaluated each of the eight subcomponents which have been eliminated from this measure to see if they contain information on the trend in inflation. Augmented Dickey-Fuller (ADF) tests suggest that over the 1986m1-1998m8 sample, year-over-year changes in the price of each of the following subcomponents are stationary series: fruit, vegetables, inter-city transport, fuel oil, natural gas, and gasoline. This is encouraging since it suggests that these price changes are temporary. Tobacco and mortgage interest costs are I(1). These are the subindices most directly influenced by government policy so their exclusion is motivated differently. ADF tests run over the longest possible sample suggest all of the series are stationary. This longest available sample for most of these particular series is 1950m1 to 1998m8 for each of the subcomponents except fruits and vegetables, for which a consistent series is only available from 1979m1 to 1998m8.

Figure 8 graphs the difference between the CPI and each of the different measures of underlying inflation. These gaps are the excluded portions of each of the core measures and therefore, should represent temporary movements in inflation around its trend. These gaps could be interpreted as measures of relative price shocks. We test whether core inflation and the excluded portion are independent. To do so, we do a variation of Cogley (1998)[5] and test whether the excluded portion over or underpredicts the transient component of the CPI.

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5. These regressions are quite similar to those included in Crawford et. al (1998) $\pi_{t+h} = f(\pi_t , \pi_t^{core})$ and their finding that the sum of the coefficients was close to one.

We do the following OLS regression where π_t is CPI inflation at time *t*, π_{t+h} is CPI inflation at time *t+h*. In each regression, *h* equals 6, 12, and 18, respectively. π_t^{core} is the core measure and u_t is the random error term.

$$(\pi_{t+h} - \pi_t) = \alpha_t + \beta_t(\pi_t^{core} - \pi_t) + u_t$$ [6]

We test the joint restriction that $\alpha_t = 0$ and $\beta_t = 1$.[7] The restriction on β_t indicates whether the excluded portion of the core measure over- or under-predicts the transitory movements in inflation. If β_t is less than one then it overstates the transitory movements, if greater than one then it understates. This experiment captures the extent to which transient movements are subsequently reversed.

The regressions over the full 1986m1 to 1998m8 sample provide some interesting results (see Tables 7-9).[8] Six months ahead, CPIW provides the most encouraging result since the estimated coefficients are $\alpha_t = 0$ and $\beta_t = 1$ even without a restriction (see Table 7). We cannot reject the restriction that $\alpha_t = 0$ and $\beta_t = 1$ for any of the core measures (except CPIX) suggesting that what has been excluded from these measures reflects transitory movements. At this horizon, CPIX seems to underpredict the transient movements in the CPI.

However, at 12 and 18 months ahead, the test results are reversed (see Tables 8 and 9). The CPIX clearly performs much better at capturing transitory movements that are reversed over these longer horizons, since the freely estimated coefficient β_t is very close to one. The joint restriction that $\alpha_t = 0$ and $\beta_t = 1$ cannot be rejected for CPIX and MEANTSD at either the 12 or 18 month horizon, nor can it be rejected for CPIxFET at the eighteen month horizon. Overall, these results support a few measures of inflation, in particular, CPIW and CPIX seem to be useful measures of core inflation though over different horizons.

Next, we re-estimate the regressions to investigate whether these conclusions hold up for the low and stable inflation period of 1992m1 to 1998m8 (see Tables 10-12). Six months ahead, all measures do well. CPIW still fares best at this horizon since it is still the case $\beta_t = 1$ even without a restriction. We cannot reject the joint restriction that $\alpha_t = 0$ and $\beta_t = 1$ for any of the core measures except CPIX. These results suggests that what has been excluded by these measure accurately captures the transitory movements in the CPI at this horizon. As in the regressions over the full sample, CPIX seems to underpredict the transient movements in the CPI.

At the longer horizons of twelve and eighteen months, all of the measures overestimate the variable portion of the CPI (see Tables 11 and 12). The joint restriction is easily rejected by the data in each of the regressions and the estimated coefficients are well above one. This may reflect the fact that there is much less variability in the CPI over this period (except for the temporary decline in inflation due to the tobacco tax cut in 1994).

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6. Standard errors have been corrected using the Hansen and Hodrick (1980) adjustment where appropriate.
7. The simpler restriction that $\beta_t = 1$ leads to identical conclusions in each of the regressions.
8. Samples identified in Tables 7-12 are shorter than the full sample since the sample is adjusted as required to allow for *t+h* period ahead observations.

- ***Does a closer look at the components suggest that the logic behind their construction holds up?***

Both CPIX and CPIW use data on the historical volatility of the components to derive measures of underlying inflation. This approach is based on the assumption that the past will be representative of the future. To evaluate how this holds up, we investigate the recent period.

In deriving the CPIX, the standard deviation of the individual components of the CPI could have been used to determine which components are volatile instead of the components that were most frequently eliminated by MEANTSD or a 10% limited information estimator. Table A1 lists the mean and standard deviations of 54 individual components of the CPI. Over the full sample period, these eight are among those with the highest standard deviations. It is not surprising that they are frequently be in the tails of any monthly distribution of price changes.

Interestingly, though the means and standard deviations of all of the subcomponents have fallen dramatically, the same subset of eight still represent some of the most volatile components. Table A1 also reports the mean and standard deviations of two major subperiods, 1986 to 1991 and the low inflation period of 1992 to 1998. The Spearman rank correlation coefficient between the two periods is 0.63, suggesting that the relative volatility of the various components in the first period is indicative of that in the recent low and stable inflation period. This supports the choice of CPIX in the sense that it will likely perform out of sample. It also indicates that using constant weights based on an earlier period to reweight the components, as in CPIW, is a not a bad approximation.

Notice that if the premise upon which the CPIX measure is based is true, the eight subcomponents excluded historically ought to correspond to those most frequently excluded by MEANTSD in the current period. An investigation of the subcomponents eliminated indicates this is the case. Five of the components excluded from MEANTSD in August 1998 were among the eight excluded from the CPIX measure due to their historical volatility, namely fuel oil, gasoline, natural gas, inter-city transportation, and tobacco products (recall Table 3). This is not an unusual month.

Tables A2-A5 report the frequency that these components were eliminated from MEANTSD over the full sample and over two different subperiods: 1986m1 to 1998m8; 1992m1 to 1998m8; and 1996m12 to 1998m8. The columns in this table report the type of price included in the subindex, the number of times it was excluded from MEANTSD and the percentage of time it was excluded. In Table A2, for example, the first row indicates that education prices were eliminated by the MEANTSD procedure 44 times or 55% of the time. In each of these periods, the eight removed from CPIX were among the nine subindices thrown out due to their location over 1.5 standard deviations from the weighted mean. The ninth most frequently discarded subindex is education, which is also the one with the largest mean of any component (7.5%). This is not surprising given the large hikes in tuition fees in recent years due to cut-backs in government funding of universities. Note, however, that the education price subindex does not have a particularly high standard deviation. This would suggest although education prices is discarded by the criteria for MEANTSD , it may not belong among those components excluded from CPIX on the basis of their volatility, since it is not really volatile, merely persistently high.

6.1 Summary and related work

This assessment has focused on the properties that are required if these measures are to be a good indicator of current and future trends in inflation. This leaves further work to evaluate their usefulness as a measure for empirical work or as a viable target for monetary policy.

Other work at the Bank of Canada does lend some insight into the suitability of these measures to these last two uses. Hogan (1998) compares the performance of various core inflation measures in Taylor rules. He finds that the CPIxFE outperforms the CPI and the other measures of core in historical estimates of Taylor rules. However, his conclusions, like our own, are tentative due to the short sample available for the recent low inflation period. Kichian (1998) shows that the tighter the measure of core inflation used in the analysis, the more suitable is the model to estimate the output gap. She finds that the CPIxFE performs better than the CPI in a state-space model to measure potential output. Note that her model allows for dynamic effects of indirect taxes changes on inflation.

Finally, evaluation of the usefulness of core measures as a target is based on their performance in the other two roles as an indicator of current and future trends in inflation and as a measure of inflation for empirical work, as well as their suitability for public scrutiny and discussion. This suggests that the traditional core measure, CPIxFET could be considered as a possible direct target since the attributes which make it a useful operational target also make it suitable as a direct target. Moreover, it is the most straightforward and easily understood measure of core inflation. CPIX inflation might also make a suitable target since it is less variable than CPIxFET and at the same time, includes more of the original CPI basket than CPIxFET.

7. Conclusion

As a measure of the general trend in inflation, core inflation is a useful tool for policy makers in three possible ways: as an indicator of current and future trends in inflation, as a better measure of inflation for empirical work, or as a target for monetary policy.

The Bank of Canada currently monitors several measures of core or underlying inflation on a regular basis. All of these measures are based on the disaggregated approach to measuring core inflation. Furthermore, they are all based on 12-month price changes. Several items support the choice of year-over-year growth in monthly data for the inflation as either a guide to policy or as a target for policy. First, it provides an important smoothing aspect to the data. Month-over-month changes are simply too volatile for policy makers to respond to every movement. Second, for movements in year-over-year growth in the CPI, excess skewness and kurtosis do not seem to present any particular difficulties. Third, there are some price changes which are infrequently sampled and other prices which really only change occasionally or annually (such as tuition fees). These infrequent price changes can be gradually included in the inflation rate. Fourth, by construction, year-over-year growth rates avoid the problem of regular seasonality, though not stochastic seasonality. Finally, it is reasonable to think that contracts, pensions, and other economic planning that takes inflation into account would largely be done based on a somewhat longer horizon, such as an annual horizon. This final point supports the use of an annual inflation rate for public inflation targets.

The range of measures considered in this paper includes one which excludes the most volatile components historically (CPIX); one which includes all elements of the basket but down weights their influence on the aggregate inflation rate based on their volatility (CPIW); one which reflects the 50th percentile (wmedian); one which excludes the most volatile components at a point in time (MEANTSD) and identifies those shocks; and one which excludes prices traditionally considered to be affected by temporary supply shocks (CPIxFET). Each of these measures fares quite well in a comparison to aggregate CPI. However, the environment of low and stable inflation in Canada makes it difficult to differentiate among them, since the variability of all the measures is now quite low. Some tests seem to suggest the CPIW does best at capturing the trend in inflation, while others suggest the CPIX as a useful measure. Other research at the Bank of Canada, reviewed briefly above, shows that the Bank’s official core measure, CPIxFET, performs best on some other criteria. Overall, no one measure of core seems to stand out as ideal in the analysis.

Interestingly, the sharp drop in the means and standard deviations of the various core measures and the aggregate CPI are mirrored in the disaggregated data. The low inflation environment is evident in almost all disaggregated prices, at least to some extent. A review of their relative means and standard deviations suggests that if we recalculated the eight most volatile components to determine which to exclude based solely on recent data, we would choose the same eight which were excluded historically, namely, fruit, vegetables, gasoline, fuel oil, natural gas, inter-city transportation, mortgage interest costs, and tobacco products. Furthermore, it is reasonable to exclude these particular items for economic reasons. The first six of these subindices contain prices which are sensitive to the situation in world markets and to the exchange rate while the last two are heavily influenced by central bank or government policy.

Along with the decline in the mean and standard deviations of inflation, we report a decline in the skewness and kurtosis of the cross-sectional distribution of inflation. Although it appears that weighted skewness is not a problem on average, the level of kurtosis and the standard deviation of skewness suggests that the distribution of price changes is non-normal during specific episodes. This suggests that the weighted median is worth considering as a robust measure of underlying inflation.

Comparisons of the various measures of underlying inflation suggests that different measures do well along different dimensions. Each measure of core provides some particular insight into how inflation is evolving. Therefore, rather than selecting one measure as the best to perform the role of core inflation as an indicator of the trend in inflation, it might be more useful to have a limited number of measures of underlying inflation and to use the varied information in each of them to put together a more accurate picture of the dynamics in inflation. This is the approach currently in place at the Bank of Canada. In particular, the use of MEANTSD , the measure which specifically identifies the subcomponents which have extreme fluctuations, and others that exclude or down weight traditionally variable elements - CPIxFET, CPIX and CPIW - assist in identifying the source of the shock if there are differences in inflation as indicated by the different core measures. For example, CPIX has a higher mean over recent years because it excludes mortgage interest costs which have been declining due to low interest rates. It seems reasonable to adopt an approach which uses what is known about the data to its fullest extent. This ensures that the policy maker understands what is captured (or not) by the core inflation measures. For example, the list of what is eliminated from MEANTSD each month highlights the components which are most volatile at the moment. This approach will be most useful in periods of change when the core inflation measures diverge, since it would raise a warning signal to investigate further.

It may be interesting to pursue alternative avenues of research in the future. To date, work on the model-based approach has been hampered by the recent regime change. However, once low and stable inflation period persists for some time, the model-based approach could yield some interesting insights. The evidence on the usefulness of various core measures described in this paper would be strengthened by comparison with the very different alternative measures that are produced by the model-based approach.

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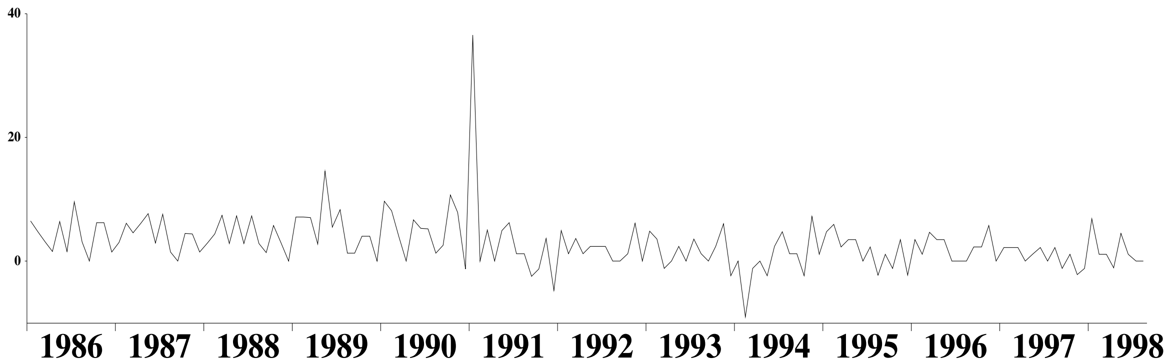
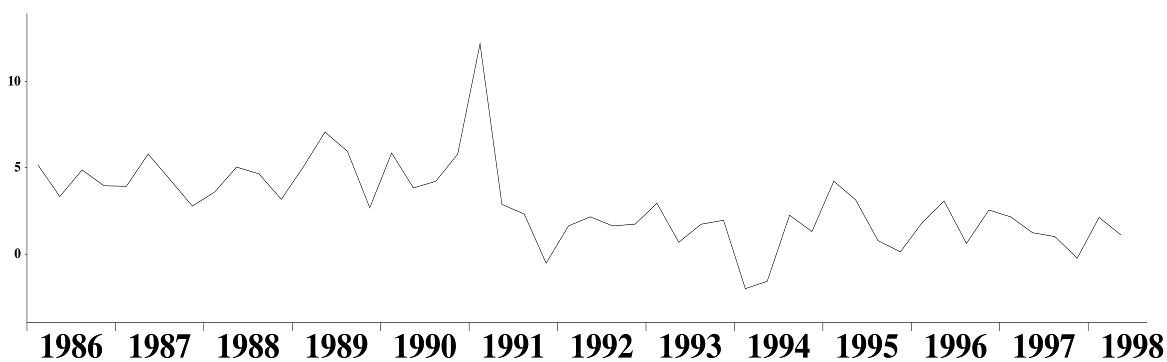
Figure 1: A comparison of different frequencies for price changes

Month over month growth of CPI, annualized
sample 86m1 to 98m8



Quarter over quarter growth of CPI, annualized
sample 86q1 to 98q2



Year over year growth of CPI
sample 86m1 to 98m8

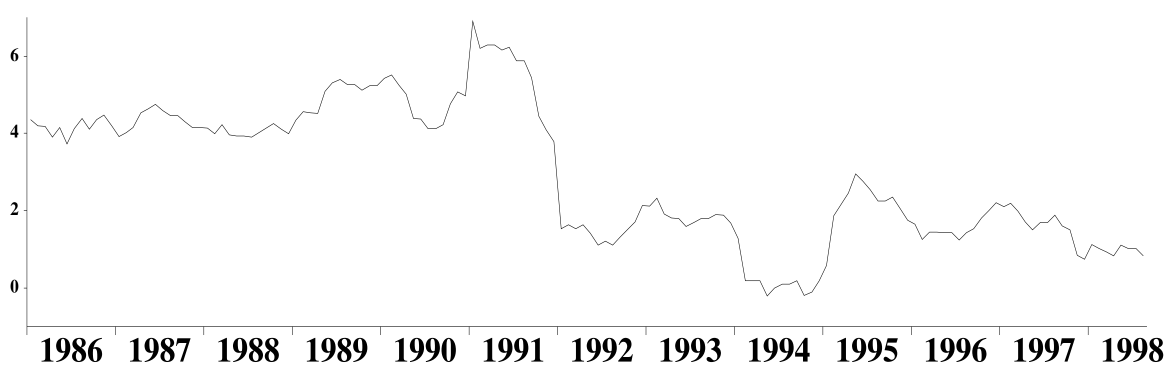


Figure 2: Year-over-year growth of CPIXFET and CPI (Sample 86m1 to 98m8)

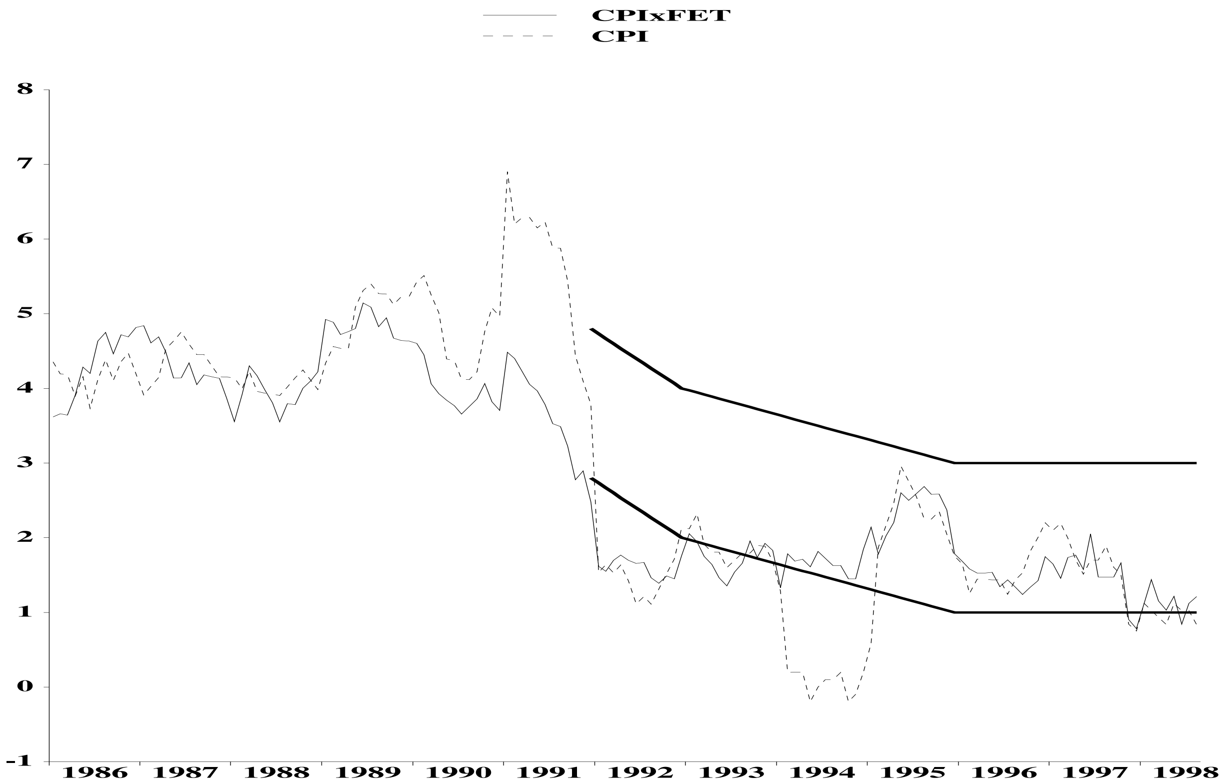


Figure 3: Year-over-year growth of WMEDIAN and CPI (Sample 86m1 to 98m8)

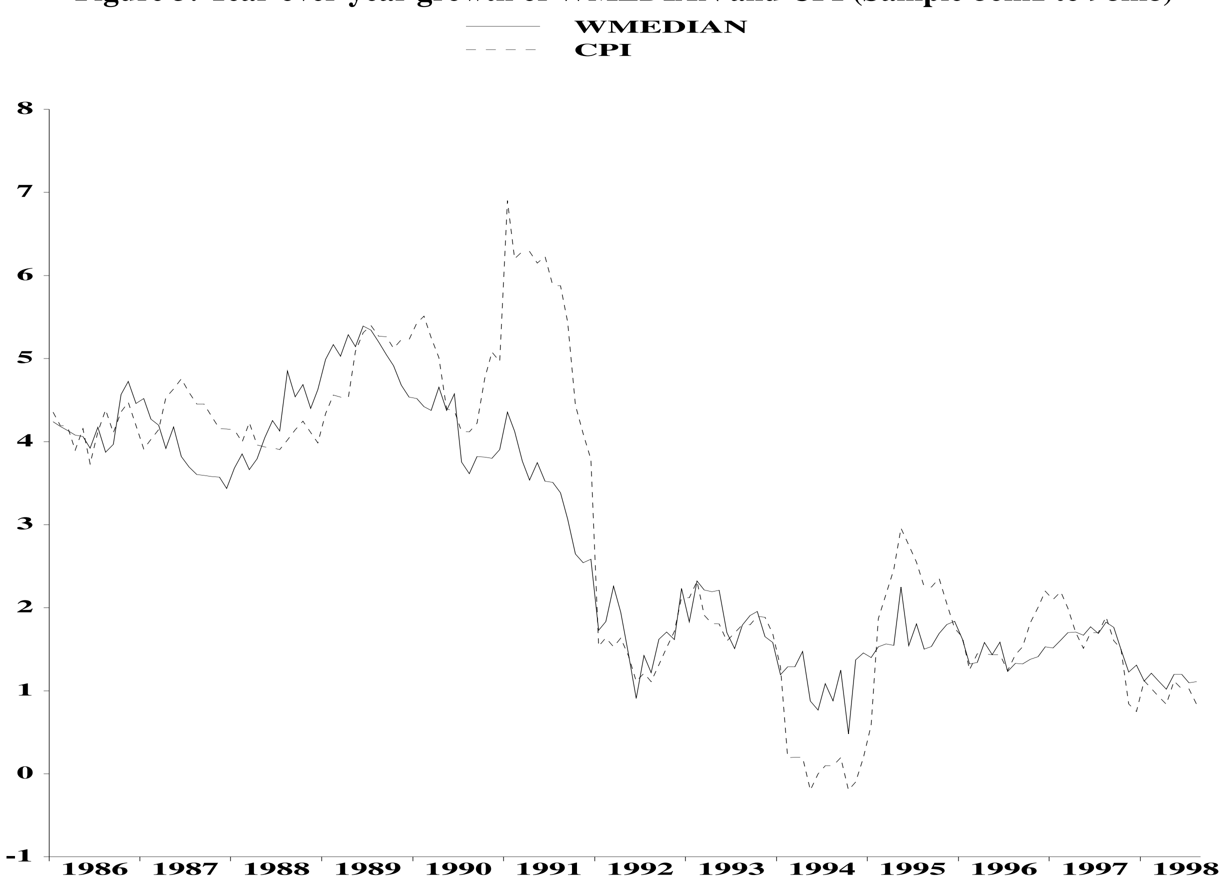


Figure 4: Year-over-year growth of MEANTSD and CPI (Sample 86m1 to 98m8)

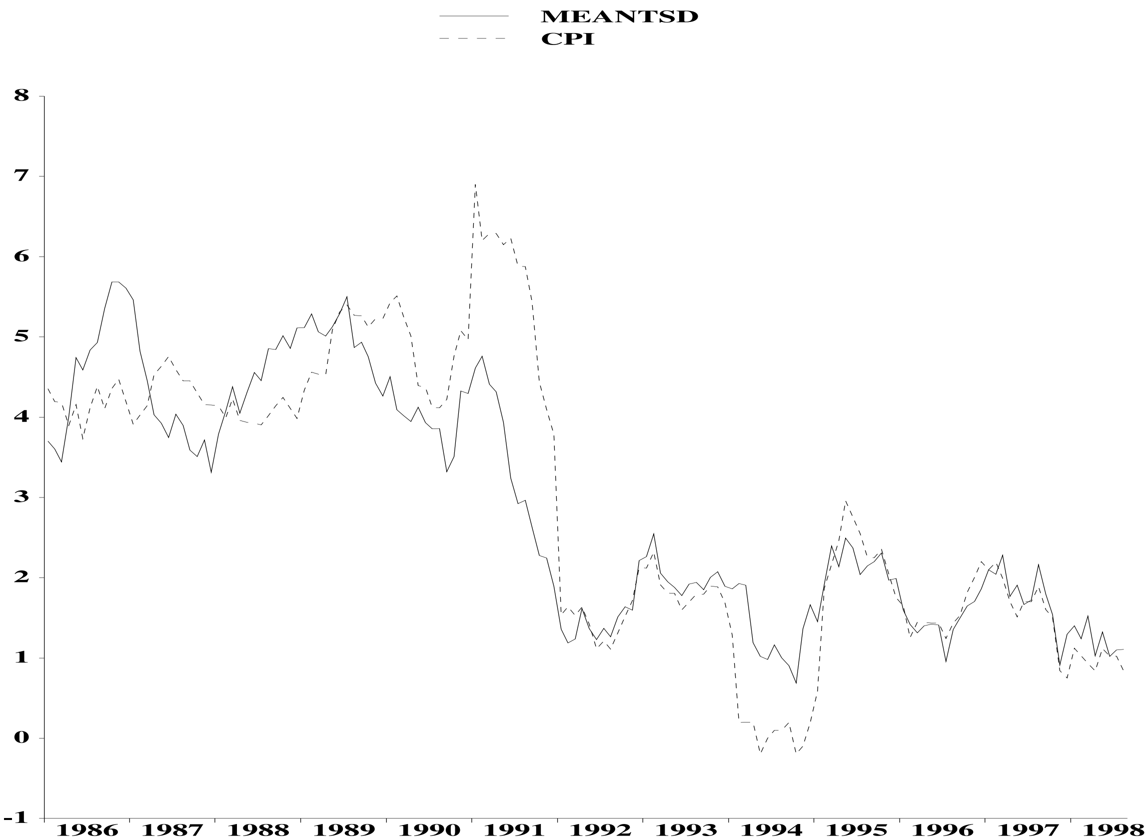


Figure 5: Year-over-year growth of CPIX and CPI (Sample 86m1 to 98m8)

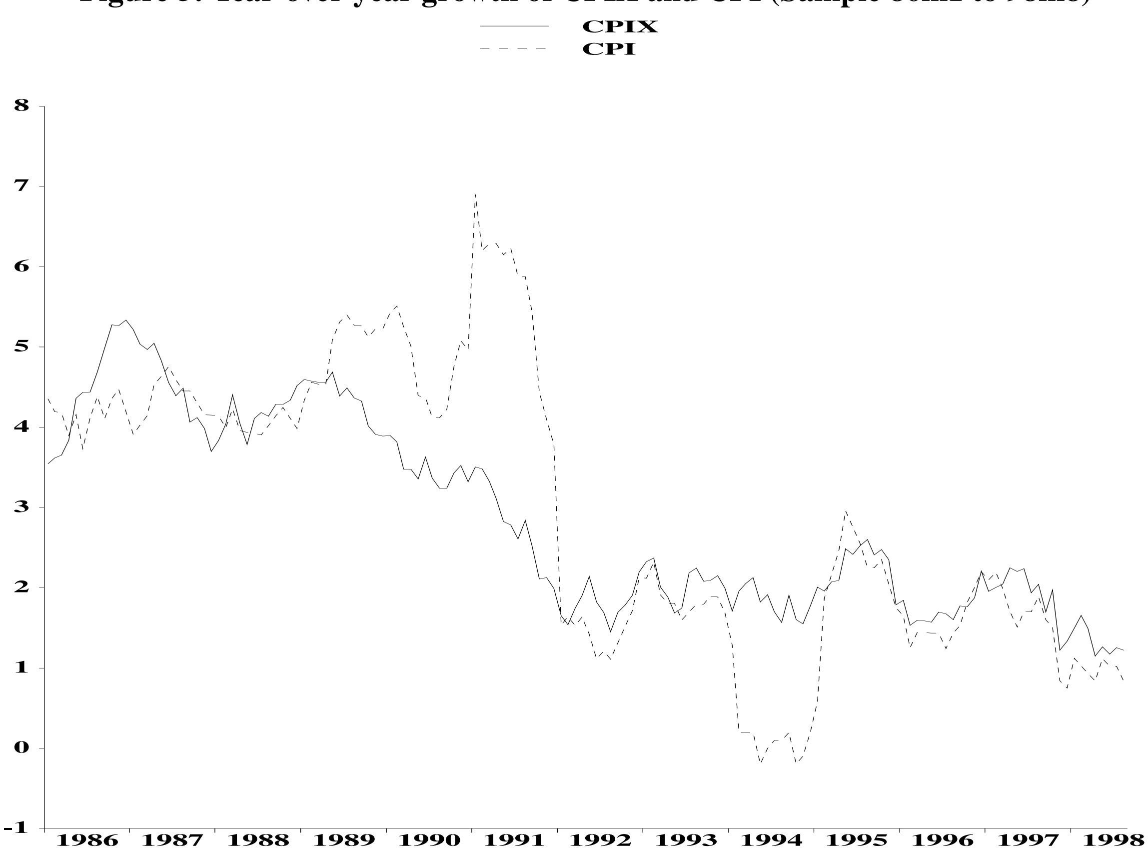


Figure 6: Year-over-year growth of CPIW and CPI (Sample 86m1 to 98m8)

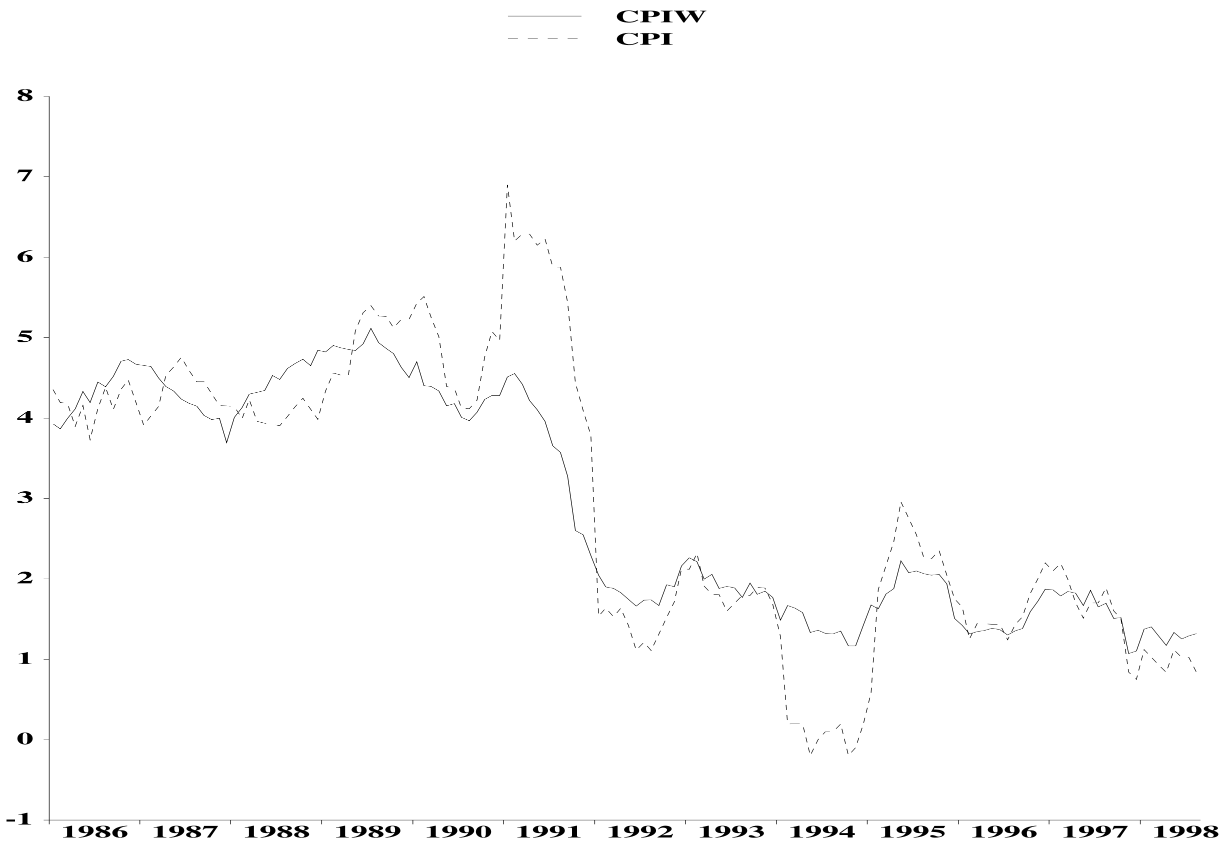


Figure 7: Moving average of weighted mean (Sample 86m1 to 98m8))

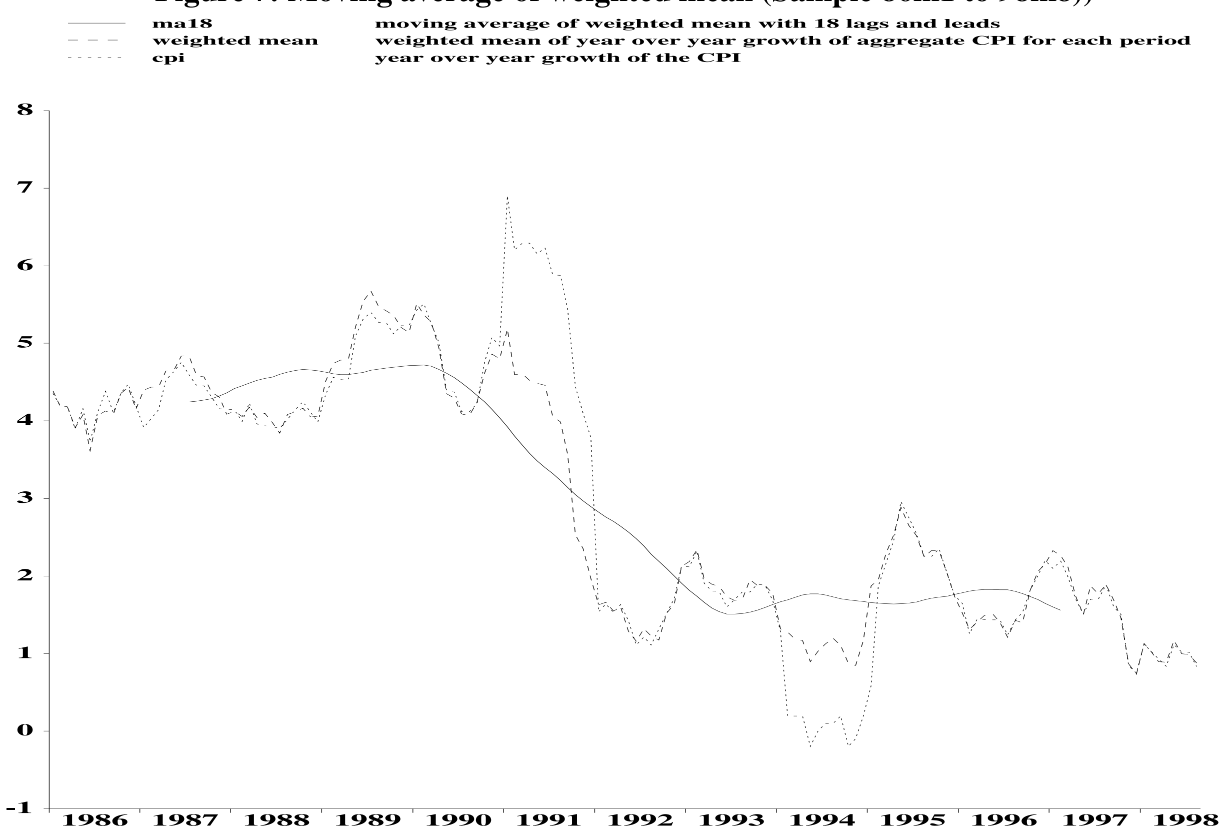
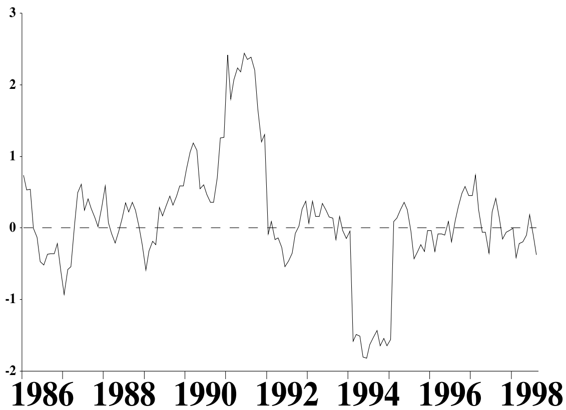
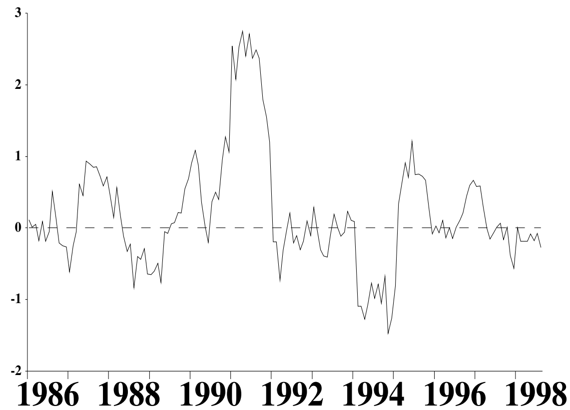


Figure 8: CPI minus core measure (Sample 86m1 to 98m8)

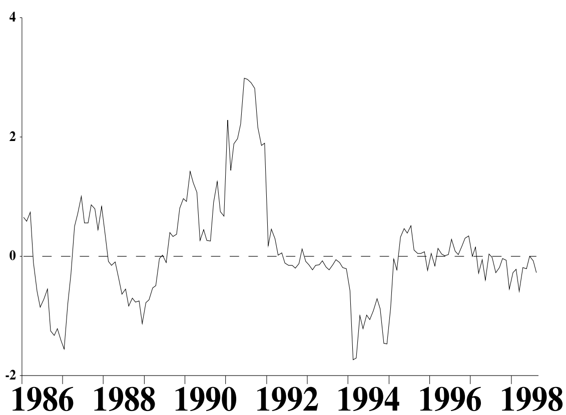
(CPI-CPIXFET)



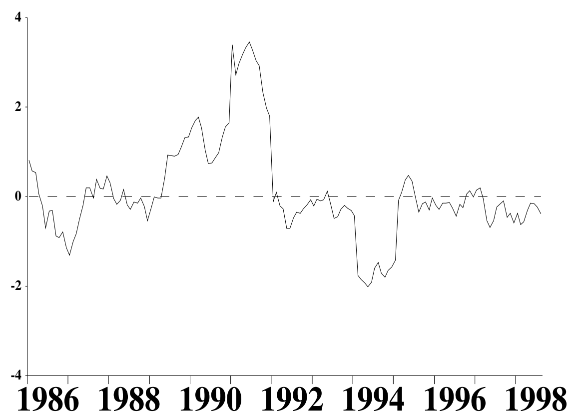
(CPI-WMEDIAN)



(CPI-MEANTSD)



(CPI-CPIX)



(CPI-CPIW)

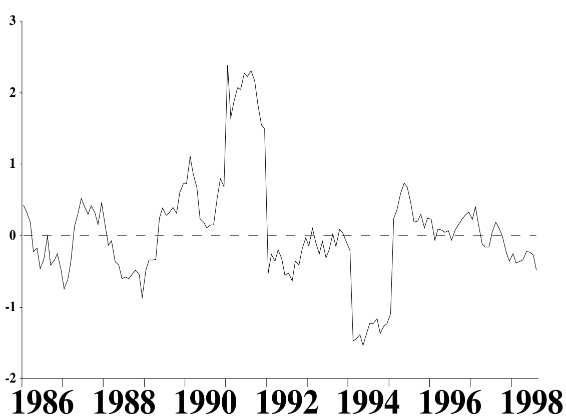


Table 1: Core inflation measures: growth over 12 months
Sample 86m1 to 98m8

	mean	standard deviation	variability (stddev/mean)
CPI	2.96	1.77	0.60
CPIxFET	2.84	1.34	0.47
wmedian	2.76	1.41	0.51
CPIX	2.86	1.20	0.42
CPIW	2.90	1.40	0.48
meantsd	2.90	1.44	0.50

Table 2: Core inflation measures : growth over 12 months
Sample 92m1 to 98m8

	mean	standard deviation	variability (stddev/mean)
CPI	1.43	0.72	0.50
CPIxFET	1.66	0.39	0.24
wmedian	1.52	0.36	0.24
CPIX	1.87	0.34	0.18
CPIW	1.66	0.30	0.18
meantsd	1.64	0.43	0.26

Table 3: Components excluded from the *MEANTSD* measure in August 1998

Component	Growth over 12 months
Natural gas	10.9%
Fuel oil and other fuels	-10.0%
Gasoline	-11.9%
inter-city transportation	6.7%
Travel services	7.0%
Tobacco products	6.6%

Table 4: Root Mean Squared Error and Mean Absolute Deviation Sample 87m7 to 97m2

Core	RMSE[a]	MAD[b]
WMEAN	0.64	0.56
CPIxFET	0.50	0.40
WMEDIAN	0.51	0.42
CPIX	0.57	0.47
CPIW	0.40	0.34
MEANTSD	0.61	0.52

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

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

Table 5: Correlation of core measures with future CPIxT inflation
Sample 86m1 to 98m8

	CPIxT[t]	CPIxT[t+6]	CPIxT[t+12]	CPIxT[t+18]	CPIxT[t+24]
CPI	0.92	0.65	0.46	0.49	0.40
CPIxFET	0.93	0.84	0.74	0.71	0.61
WMEDIAN	0.90	0.85	0.75	0.70	0.60
CPIX	0.86	0.85	0.79	0.77	0.75
CPIW	0.93	0.85	0.74	0.70	0.62
MEANTSD	0.89	0.85	0.73	0.70	0.64

Table 6: Correlation of core measures with future CPIxT inflation
Sample 92m1 to 98m8

	CPIxT[t]	CPIxT[t+6]	CPIxT[t+12]	CPIxT[t+18]	CPIxT[t+24]
CPI	0.61	-0.21	-0.62	0.02	0.12
CPIxFET	0.72	0.11	-0.05	0.44	0.17
WMEDIAN	0.43	-0.22	-0.46	0.10	0.29
CPIX	0.79	-0.09	-0.34	0.40	0.31
CPIW	0.57	-0.14	-0.44	0.22	0.42
MEANTSD	0.75	-0.10	-0.56	0.24	0.39

Table 7: Regressions : six months ahead (Sample 86m1 to 98m2)

CPI[t+6]	CPIxFET	WMEDIAN	CPIX	CPIW	MEANTSD
$\bar{R}^2$	0.35	0.40	0.29	0.45	0.39
α	-0.02 (0.10)	0.06 (0.35)	-0.06 (0.31)	-0.06 (0.31)	-0.06 (0.30)
β	0.82 (3.35)	0.90 (4.36)	0.56 (2.68)	1.01 (4.93)	0.80 (3.52)
p-value $H_0 : (\beta=1, \alpha=0)$	0.75	0.86	0.07	0.95	0.62

Table 8: Regressions: twelve months ahead (Sample 86m1 to 97m8)

CPI[t+12]	CPIxFET	WMEDIAN	CPIX	CPIW	MEANTSD
$\bar{R}^2$	0.58	0.63	0.50	0.67	0.49
α	-0.06 (0.42)	0.10 (0.69)	-0.12 (0.79)	-0.13 (1.00)	-0.14 (0.85)
β	1.48 (8.31)	1.59 (10.87)	1.03 (6.41)	1.71 (10.81)	1.25 (6.29)
p-value $H_0 : (\beta=1, \alpha=0)$	0.02	0.00	0.73	0.00	0.37

Table 9: Regressions: eighteen months ahead (Sample 86m1 to 97m2)

CPI[t+18]	CPIxFET	WMEDIAN	CPIX	CPIW	MEANTSD
$\bar{R}^2$	0.55	0.55	0.52	0.54	0.45
α	-0.19 (2.22)	-0.06 (0.61)	-0.23 (2.55)	-0.27 (2.98)	-0.26 (2.63)
β	1.39 (13.07)	1.42 (13.71)	1.01 (11.75)	1.49 (13.64)	1.16 (10.10)
p-value $H_0 : (\beta=1, \alpha=0)$	0.00	0.00	0.03	0.00	0.02

Table 10: Regressions : six months ahead (Sample 92m1 to 98m2)

CPI[t+6]	CPIxFET	WMEDIAN	CPIX	CPIW	MEANTSD
$\bar{R}^2$	0.29	0.29	0.26	0.32	0.20
α	-0.23 (1.25)	-0.12 (0.55)	-0.41 (3.22)	-0.26 (1.37)	-0.23 (1.19)
β	0.81 (3.91)	0.96 (6.57)	0.82 (4.08)	1.00 (5.80)	0.90 (1.94)
p-value H_0 : (β=1, α=0)	0.44	0.79	0.36	0.98	0.48

Table 11: Regressions : twelve months ahead (Sample 92m1 to 97m8)

CPI[t+12]	CPIxFET	WMEDIAN	CPIX	CPIW	MEANTSD
$\bar{R}^2$	0.70	0.50	0.64	0.64	0.41
α	-0.48 (2.98)	-0.20 (1.13)	-0.83 (4.28)	-0.49 (2.76)	-0.43 (2.08)
β	1.63 (11.60)	1.67 (7.13)	1.67 (11.99)	1.85 (10.25)	1.70 (5.21)
p-value H_0 : (β=1, α=0)	0.00	0.00	0.00	0.00	0.03

Table 12: Regressions : eighteen months ahead (Sample 92m1 to 97m2)

CPI[t+18]	CPIxFET	WMEDIAN	CPIX	CPIW	MEANTSD
$\bar{R}^2$	0.66	0.34	0.60	0.46	0.44
α	-0.47 (4.83)	-0.20 (1.67)	-0.73 (6.11)	-0.43 (3.66)	-0.42 (3.55)
β	1.36 (14.55)	1.17 (7.33)	1.37 (16.91)	1.34 (12.06)	1.49 (11.15)
p-value H_0 : (β=1, α=0)	0.00	0.14	0.00	0.00	0.00

Appendix 1: An investigation of the sub-components of the CPI

Table A1: Year-over-year growth of the 54 subcomponents of the CPI

		Full sample 86m1 to 98m8		Sub-Sample 86m1 to 91m12		Sub-Sample 92m1 to 98m8	
Component	Wt.	Mean	Std. Dev	Mean	Std. Dev	Mean	Std. Dev
Meat	0.0290	2.64	3.85	4.20	4.47	1.21	2.48
Fish	0.0041	3.24	3.61	4.74	3.94	1.88	2.64
Dairy products and eggs	0.0208	2.10	1.61	2.84	1.29	1.44	1.59
Bakery and other cereal products	0.0204	2.71	1.69	3.32	1.46	2.16	1.70
Fruit, fruit preparations and nuts	0.0140	1.26	5.23	3.96	5.23	-1.17	3.89
Vegetables and veg. preparations	0.0125	2.56	9.64	4.68	10.08	0.65	8.85
Other food products	0.0282	1.72	3.00	2.24	2.61	1.25	3.26
Food purchased from restau-rants	0.0498	3.06	1.57	4.60	0.74	1.67	0.37
Rented accommodation	0.0717	2.78	1.31	4.02	0.59	1.67	0.57
Mortgage interest cost	0.0491	0.94	6.02	5.42	5.04	-3.10	3.41
Replacement cost	0.0268	3.12	5.58	6.26	6.75	0.29	1.22
Property taxes	0.0355	4.78	2.59	6.61	1.05	3.14	2.46
Homeowners' insurance prems.	0.0105	4.09	4.96	6.52	6.06	1.91	1.93
Homeowners' maint. & repairs	0.0169	1.65	2.56	2.83	1.55	0.59	2.83
Electricity	0.0265	3.42	2.47	4.87	1.63	2.10	2.37
Water	0.0039	5.14	2.73	6.12	3.04	4.25	2.06
Natural gas	0.0102	0.78	5.46	-1.68	3.45	3.00	5.97
Fuel oil and other fuel	0.0058	0.55	11.49	0.68	15.24	0.43	6.61
Communications	0.0279	0.88	2.62	-0.68	2.29	2.28	2.06

		Full sample 86m1 to 98m8		Sub-Sample 86m1 to 91m12		Sub-Sample 92m1 to 98m8	
Component	**Wt.**	**Mean**	**Std. Dev**	**Mean**	**Std. Dev**	**Mean**	**Std. Dev**
Child care and domestic services	0.0110	4.37	2.02	5.87	1.23	3.02	1.60
Household chemical products	0.0073	1.51	2.76	3.58	1.44	-0.36	2.31
Paper, plastics and foil supplies	0.0079	2.88	4.73	3.56	2.46	2.26	6.05
Other household goods&serv.	0.0148	2.78	2.36	4.99	1.03	0.78	1.09
Furniture	0.0137	1.82	1.99	3.17	1.62	0.60	1.44
Household textiles	0.0052	1.55	2.65	3.22	2.13	0.05	2.12
Household equipment	0.0164	1.08	1.69	2.17	1.64	0.10	0.98
Services rel. to hh furnishings	0.0033	3.26	1.73	4.51	1.10	2.13	1.39
Clothing	0.0417	2.01	1.83	3.45	1.38	0.72	1.07
Footwear	0.0093	1.85	1.93	3.30	1.32	0.53	1.37
Clothing accs. & jewellery	0.0055	1.40	2.50	3.37	1.44	-0.38	1.83
Clothing mat., notions and ser.	0.0059	2.92	1.57	4.42	0.60	1.58	0.72
Purchase of automotive vehicles	0.0630	3.96	2.75	3.77	3.33	4.12	2.10
Gasoline	0.0393	0.89	9.07	1.88	11.81	-0.01	5.51
Auto. parts, maint. & repairs	0.0230	2.05	2.17	3.68	1.94	0.58	1.01
Other auto operating expenses	0.0398	6.32	2.67	7.42	2.21	5.32	2.68
Local & communter transport.	0.0063	5.45	2.88	6.60	1.58	4.41	3.36
Inter-city transportation	0.0100	6.58	8.90	6.99	11.73	6.21	5.23
Health care goods	0.0085	3.98	3.69	7.29	2.46	0.99	1.25
Heath care services	0.0126	3.43	1.47	4.63	0.42	2.35	1.20
Personal care supplies&equip.	0.0155	1.53	2.04	2.71	1.32	0.46	2.00
Personal care services	0.0095	3.79	1.97	5.53	1.16	2.23	0.99
Recreational equip.&services	0.0206	0.45	2.94	2.81	2.02	-1.66	1.81
Purchase of recreational vehicles	0.0067	4.11	2.22	4.67	2.80	3.60	1.34

Component	Wt.	Full sample 86m1 to 98m8		Sub-Sample 86m1 to 91m12		Sub-Sample 92m1 to 98m8	
		Mean	Std. Dev	Mean	Std. Dev	Mean	Std. Dev
Operation of recreationl vehicles	0.0041	3.41	3.37	5.54	3.56	1.49	1.55
Home entertain. equip.& services	0.0156	-0.55	1.98	0.35	1.90	-1.35	1.68
Travel services	0.0169	3.48	3.67	3.93	2.93	3.08	4.20
Other recreational services	0.0220	5.09	1.97	6.68	1.42	3.65	1.09
Education	0.0192	7.48	2.83	7.45	3.61	7.51	1.91
Reading mat.&oth. print. matter	0.0075	4.50	2.31	6.04	1.35	3.11	2.11
Served alcoholic beverages	0.0058	3.96	3.05	6.82	1.78	1.39	0.86
Alcoholic beverages from store	0.0130	3.97	2.55	6.02	1.73	2.12	1.55
Tobacco products & supplies	0.0130	8.91	11.17	16.35	9.82	2.21	7.49
Leaserent	0.0082	2.48	5.09	3.47	4.95	1.59	5.09
Other owned accomodation	0.0107	3.42	3.12	6.14	2.15	0.96	1.23

Table A2: Frequency of elimination of the CPI components in the calculation of *MEANTSD* (Sample 1986m1 to 1998m8))

Component	MEANTSD	
	#	%
Vegetables and vegetable preparations	76	50
Inter-city transportation	74	49
Natural gas	72	47
Fuel oil and other fuel	70	46
Gasoline	69	45
Education	54	36
Tobacco products and smokers’ supplies	53	35

Component	MEANTSD	
	#	%
Mortgage interest cost	51	34
Fruit, fruit preparation and nuts	38	25
Rental and leasing of automotive vehicles	27	18
Communications	26	17
Replacement cost	26	17
Homeowners’ insurance premiums	24	16
Recreational equipment and services	17	11
Other automotive vehicle operating expenses	17	11
Fish and other seafood	17	11
Local and commuter transportation	16	11
Travel services	16	11
Paper, plastics and foil supplies	15	10
Water	14	9
Home entertainment equipment and services	13	9
Health care goods	12	8
Property taxes	12	8
Other food products	9	6
Homeowners’ maintenance and repairs	7	5
Reading material and other printed matter	7	5
Household textiles	6	4
Clothing accessories and jewellery	5	3
Personal care supplies and equipment	5	3
Meat	4	3
Other recreational services	3	2
Electricity	2	1
Household chemical products	2	1
Child care and domestic services	2	1

Component	MEANTSD	
	#	%
Operation of recreational vehicles	2	1
Other owned accommodation expenses	1	0
Furniture	1	0
Footwear	1	0
Purchase of recreational vehicles	1	0
Served alcoholic beverages	1	0

Table A3: Frequency of elimination of the CPI components in the calculation of *MEANTSD* Sample 92m1 to 98m8

Component	MEANTSD	
	#	%
Education	44	55
Mortgage interest cost	36	45
Vegetables and vegetable preparation	35	44
Natural gas	34	43
Inter-city transportation	30	38
Gasoline	24	30
Fuel oil and other fuel	24	30
Tobacco products and smokers' supplies	22	28
Fruit, fruit preparations and nuts	21	26
Rental and leasing of automotive vehicles	18	23
Recreational equipment and services	17	21
Travel services	16	20
Other automotive vehicles operating expenses	16	20
Local and commuter transportation	16	20
Paper, plastics and foil supplies	15	19
Water	12	15

Component	MEANTSD	
	#	%
Property taxes	12	15
Home entertainment equipment and services	10	13
Other food products	8	10
Homeowners' maintenance and repairs	7	9
Fish and other seafood	7	9
Reading material and other printed matter	7	9
Household textiles	5	6
Clothing accessories and jewellery	5	6
Personal care supplies and equipment	5	6
Electricity	2	3
Communications	2	3
Child care and domestic services	2	3
Household chemical products	2	3
Homeowner's insurance premium	1	1
Furniture	1	1
Footwear	1	1
Purchase of recreational vehicles	1	1
Other recreational services	1	1

Table A4: Frequency of elimination of the CPI components in the calculation of *MEANTSD* (Sample 96m12 to 98m8)

Components	MEANTSD	
	#	%
Fuel oil and other fuel	19	91
Inter-city transportation	19	91
Mortgage interest cost	18	86
Education	17	81
Natural gas	14	67
Gasoline	13	62
Vegetables and vegetable preparations	10	48
Home entertainment equipment and services	8	38
Other automotive vehicle operating expenses	7	33
Travel services	6	29
Tobacco	5	24
Fruit, fruit preparations and nuts	2	10
Communications	1	5
Clothing accessories and jewellery	1	5
Rental and leasing of automotive vehicles	1	5

Appendix 2: An investigation of the skewness and kurtosis

It may be that the moments of the distribution of price changes have implications for the methodology to be chosen to measure core inflation. Bryan and Cecchetti (1993b, 1996) and Bryan, Cecchetti, and Wiggins II (1997) offer evidence that the population of price changes is characterized by skewness and kurtosis in the United States. Roger (1997) offers similar evidence for New Zealand. This skewness and kurtosis suggests the choice of an order statistic as a robust and efficient estimator of the central tendency in prices. In this Appendix, we report the skewness and kurtosis of the distribution of price changes for the Canadian CPI. Not surprisingly, we find that the price change distributions for Canada are characterized by skewness and kurtosis. However, the extent of the skewness and kurtosis depends on the horizon used to calculate the price change.

Tables A5-A8 provide summary statistics on the skewness and kurtosis in the Canadian data. To show how these calculations are made, we take the year-over-year case as an example. For each month from 1986m1 to 1998m8, we create a cross-sectional distribution of the 12th-month-over-12th-month price changes of each of 54 subindexes of the CPI.[9] Then, we calculate the skewness and kurtosis of each of the monthly distributions. As suggested by Roger (1998), these statistics take into account the different expenditure weights that were actually used each month in the calculation of the CPI. The resulting measures of weighted skewness and weighted kurtosis are presented in Table A5. Figures A1 to A5 illustrate the time series of the skewness and kurtosis coefficients graphically. Although the discussion in this section focuses exclusively on the weighted measures, we also report the more traditional, equally weighted, measures of the third and fourth moments for comparative purposes (see Table A6). Both methods of calculating skewness and kurtosis produce statistics that suggest similar conclusions.

A2.1 Kurtosis

For the Canadian data, it appears that kurtosis depends on the frequency over which the growth rates are calculated. Below the year-over-year horizon, kurtosis is very large (22.02 for monthly growth rates, 17.57 for quarterly changes). At longer horizons, kurtosis is much lower (7.82 for yearly growth rates, 6.31 for 36 month changes) but remains at problematic levels when compared to the kurtosis of 3 that corresponds to a normal distribution.

Koenecker and Bassett (1978) state that 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 is sensitive to kurtosis. High kurtosis and in particular, a leptokurtic distribution, indicate that the mean is a less efficient and less robust estimator of the population or underlying mean price change than an order statistic such as the median. Canadian measures of core inflation are based on the distribution of year-over-year price changes. At a year-over-year frequency, kurtosis averages 7.82, therefore, it is important to consider the weighted median as a robust estimator of the underlying population mean and by extension, as a prospective measure of core inflation.

A2.2 Skewness

Skewness also varies with the frequency over which it is calculated. As the horizon increases, from a monthly to quarterly to yearly basis, skewness falls. On average, skewness does not seem to present a major problem for distribution of year-over-year changes, where the average weighted skewness is 0.15. For longer horizons, however, skewness increases again.

9. We choose 54 subindexes because disaggregation at this level provided us with the longest sample possible. Changes to the prices surveyed and to the basket made it difficult to extend the data back further.

At the top of each of Figures A1-A5, we graph the weighted mean and the weighted median of the Canadian data to emphasize the problem that might be created by skewness. Note that 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 and 12th-month-over-12th-month changes in the CPI. However, for the 24th-month-over-24th-month, the weighted median is increasingly below the weighted mean. In the 36th-month-over-36th-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. Roger (1997) concludes that although the median is the most robust estimator, it is a biased estimator when the population is skewed. Roger finds that “slightly higher percentile of the price change distribution reliably corrects for the asymmetry of the distribution, while maintaining its efficiency and robustness.” He therefore calculates an alternative order statistic (the 57th percentile) as the most efficient and robust estimator for New Zealand. However, since skewness is not a major problem on average at the year-over-year frequency, there seems to be no need to calculate an alternative order statistic to the 50th percentile for Canada as Roger proposes for New Zealand.

A2.3 Seasonal adjustment

We also seasonally adjust the individual price change series using the ARIMA-X11 procedure. As shown in Table A7, this reduces both the weighted skewness and weighted kurtosis in the monthly and quarterly changes. Seasonal adjustment of the individual price changes reduces the weighted skewness for the 1986-1998 period from 0.36 to 0.19 for the monthly changes and from 0.33 to 0.17 for the quarterly changes. This supports the view that some of the observed skewness and kurtosis reflects seasonality in price changes. Thus, weighted skewness may not characterize the Canadian data even at these higher frequencies. Kurtosis is also reduced although it remains at problematic levels. Kurtosis is 19.41 for monthly changes, as compared to 22.02 in the unadjusted data; and 13.34 for quarterly changes, as compared to 17.57 in the unadjusted data.

A2.4 Changes in the skewness in the Canadian data in the low inflation period

Ball and Mankiw (1995) suggest that if the distribution of price shocks is skewed (and it would likely be positively skewed), then the mean and skewness in inflation will be correlated. This supports the interpretation that the values in the tails of the distribution represent supply shocks and therefore, also supports measures of core inflation which trim the tails of the distribution. If supply shocks represent short- to medium-term fluctuations in inflation then they ought to be excluded from the measure of inflation.

Bryan and Cecchetti (1996) challenge the existence of this positive correlation between the sample mean and sample skewness in the distribution of price changes. Their monte-carlo experiments suggest that this positive correlation is actually due to a large positive small-sample bias. The intuition is as follows. If we have a random draw from a symmetric distribution with mean zero, then draws that deviate from the population mean of the distribution will affect both the first and third moments of the distribution, leading to a correlation between the moments. They suggest that the thickness of the tails of the probability distribution from which the draws are taken will determine the likelihood of an extreme draw.[10] Therefore, the kurtosis determines the size of the small sample bias. Their monte-carlo experiments suggest that kurtosis above 4 results in a significant small sample bias.

10.Note that if you increase the variance of a normal distribution gives the same result.

We do observe a positive correlation between the mean and the weighted skewness in Canadian data. In recent years, the weighted mean of the year-over-year price changes has fallen from 4.4% for the January 1986 to December 1991 period to 1.6% for the January 1992 to August 1998 period. At the same time, the average weighted skewness fell from 0.32 in the first period to 0.00 in the second period (see Table A8). The correlation between the weighted mean and weighted skewness in inflation is quite evident in Figure A3, for example. Interestingly, weighted kurtosis has also fallen from 9.72 in the first period to 6.11 in the second period, though it remains problematic. Moreover, there is much less variation in the measures of skewness and kurtosis (both weighted and unweighted) in the recent period of low inflation, suggesting that skewness and kurtosis may reach problematic levels less often in the current low inflation environment.

Note that the dramatic decline in both weighted skewness and weighted kurtosis in the recent low inflation period would suggest that there is no one underlying population of price changes. The distribution of price changes is evolving over time with the policy environment and the resulting inflation process.

Table A5: Summary statistics for price change distributions of various horizons (Sample 86m1 to 98m8)

	M/M	3M/3M	12M/12M	24M/24M	36M/36M
	Weighted Skewness				
Average	0.36	0.33	0.15	0.59	0.96
Std. dev	3.27	2.71	1.44	0.93	1.03
	Weighted Kurtosis				
Average	22.02	17.57	7.82	6.17	6.31
Std. dev	15.67	12.08	4.19	2.94	4.28

Table A6: Summary statistics for price change distributions Equally weighted price changes (Sample 86m1 to 98m8)

	M/M	3M/3M	12M/12M	24M/24M	36M/36M
	Skewness				
Average	0.29	0.25	0.19	0.46	0.74
Std. dev	2.73	2.27	1.31	0.79	0.89
	Kurtosis				
Average	15.99	13.48	7.31	5.58	5.69
Std. dev	9.45	7.18	3.76	2.23	3.76

Table A7: Summary statistics for price change distributions
Seasonally adjusted data & Weights varied
(Sample 86m1 to 98m8)

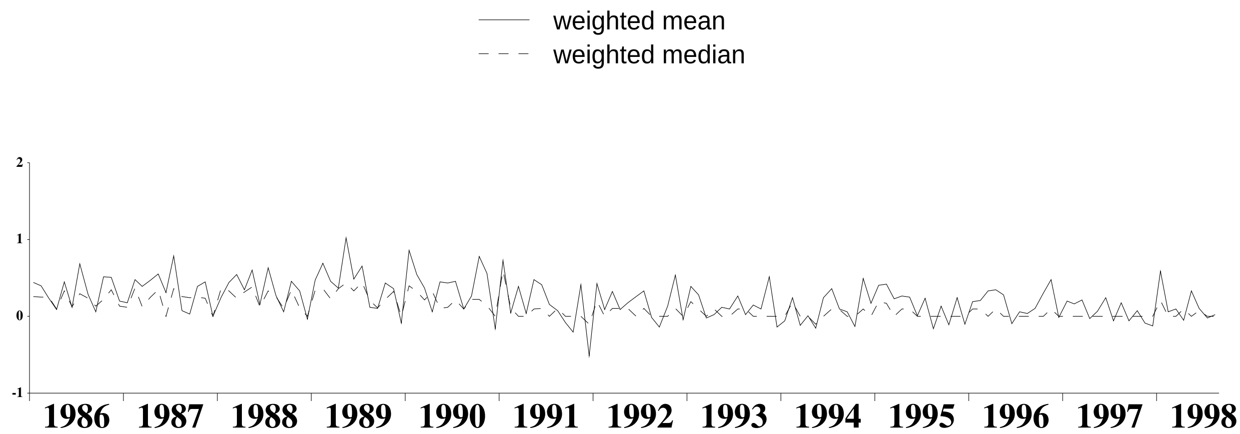
	M/M	3M/3M
	Weighted Mean	
Average	0.22	0.69
Std. dev	0.19	0.45
	Weighted Skewness	
Average	0.19	0.17
Std. dev	3.13	2.35
	Weighted Kurtosis	
Average	19.41	13.34
Std. dev	15.87	10.71

Table A8: Summary statistics for 12M/12M price change distributions

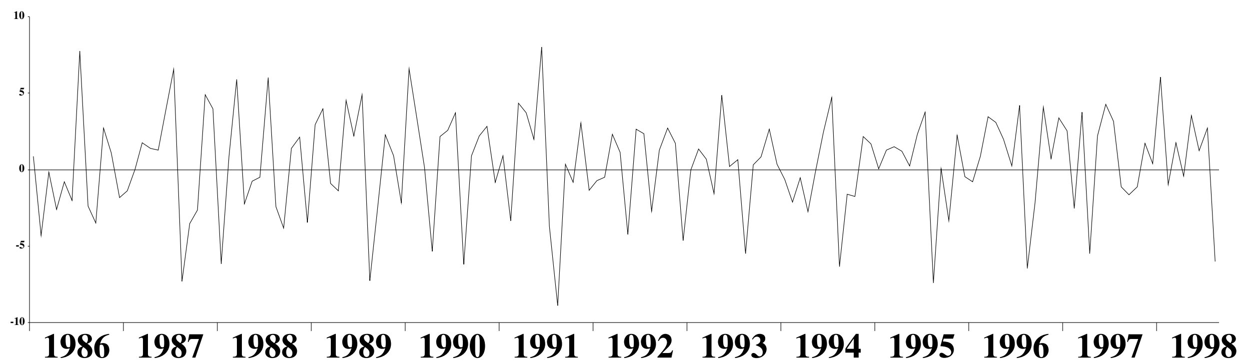
	86m1 to 91m12		92m1 to 98m8	
	Weighted mean			
Average	4.40		1.60	
Std. dev	0.66		0.49	
	unweighted	**weighted**	**unweighted**	**weighted**
	Skewness			
Average	0.07	0.32	0.30	0.00
Std. dev	1.76	1.93	0.68	0.75
	Kurtosis			
Average	9.04	9.72	5.75	6.11
Std. dev	4.23	4.42	2.40	3.12

Figure A1: month-over-month changes

Weighted Mean vs Weighted Median
Month over month growth of CPI, monthly data
Jan. 1986 to Aug. 1998



Skewness over sample
Month over month growth of CPI, monthly data
Jan. 1986 to Aug. 1998



Kurtosis over sample
Month over month growth of CPI, monthly data
Jan. 1986 to Aug. 1998

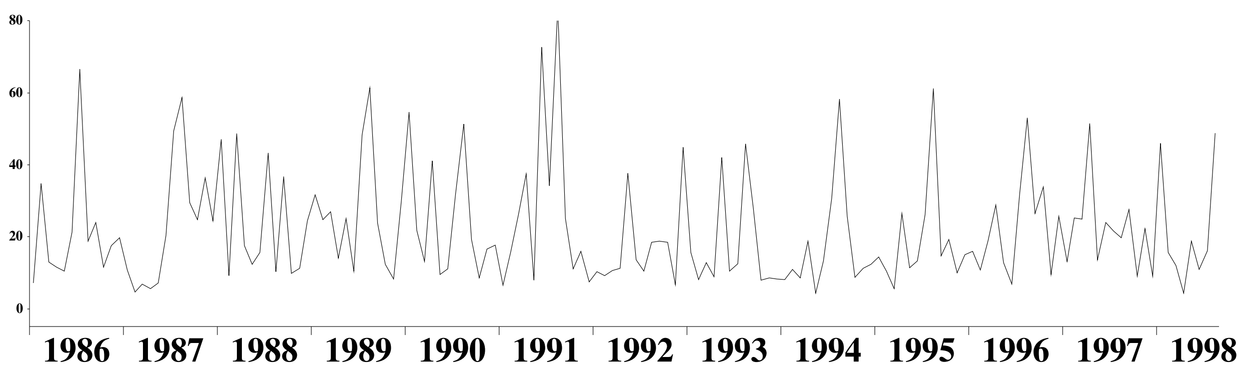
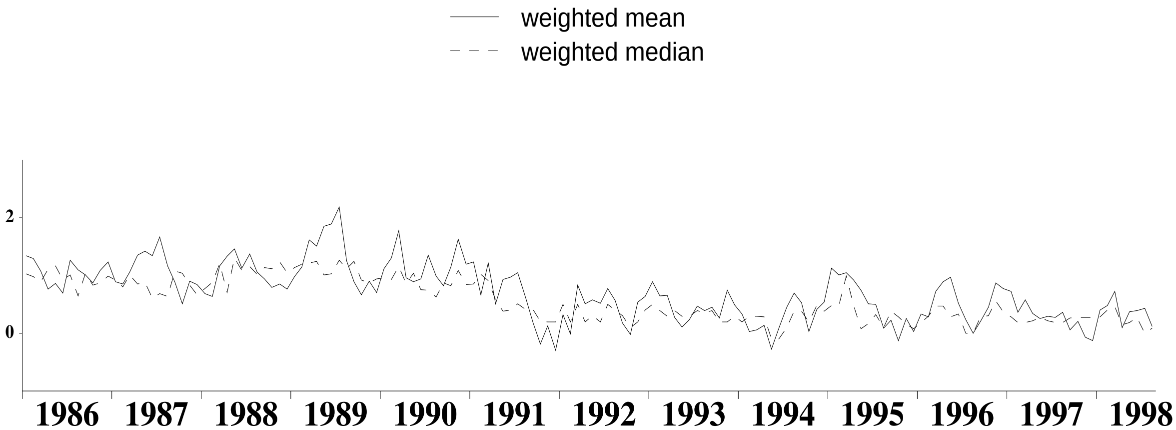
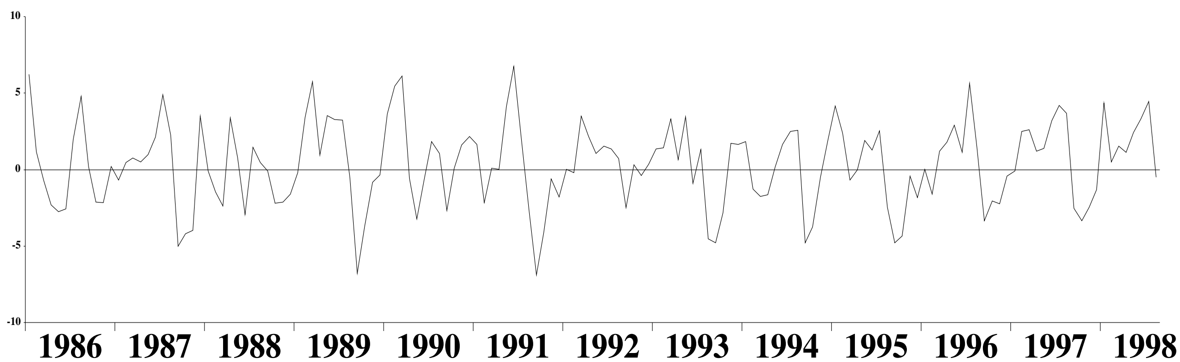


Figure A2: quarter-over-quarter changes

Weighted Mean vs Weighted Median
Quarter over quarter growth of CPI, monthly data
Jan. 1986 to Aug. 1998



Skewness over sample
Quarter over quarter growth of CPI, monthly data
Jan. 1986 to Aug. 1998



Kurtosis over sample
Quarter over quarter growth of CPI, monthly data
Jan. 1986 to Aug. 1998

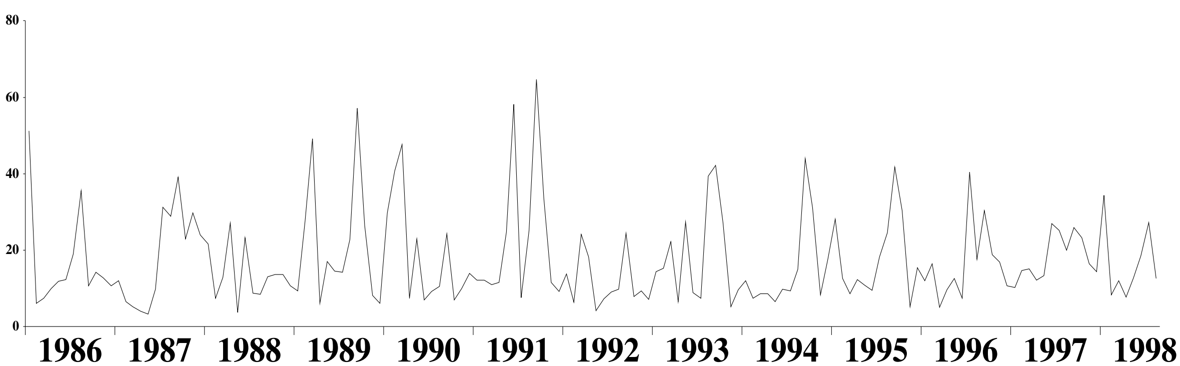
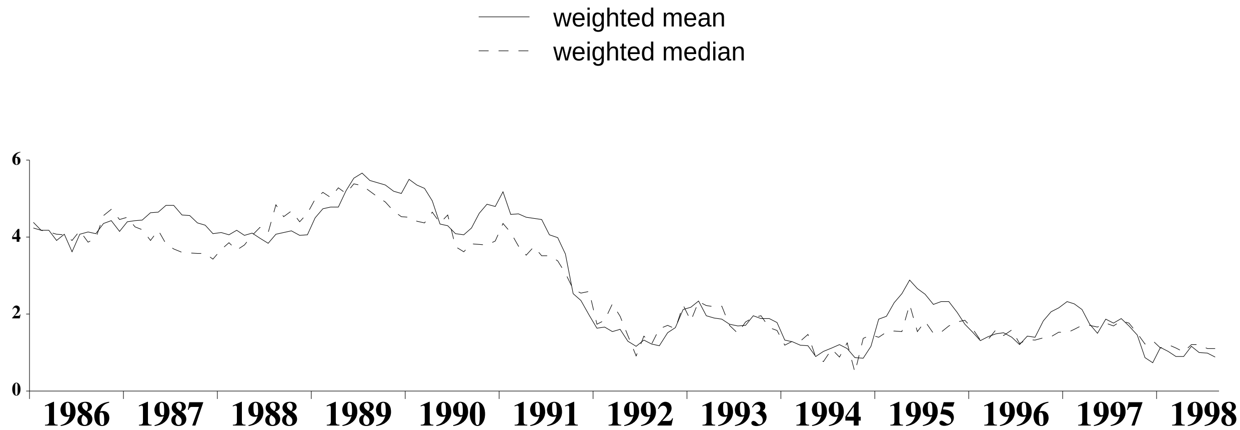
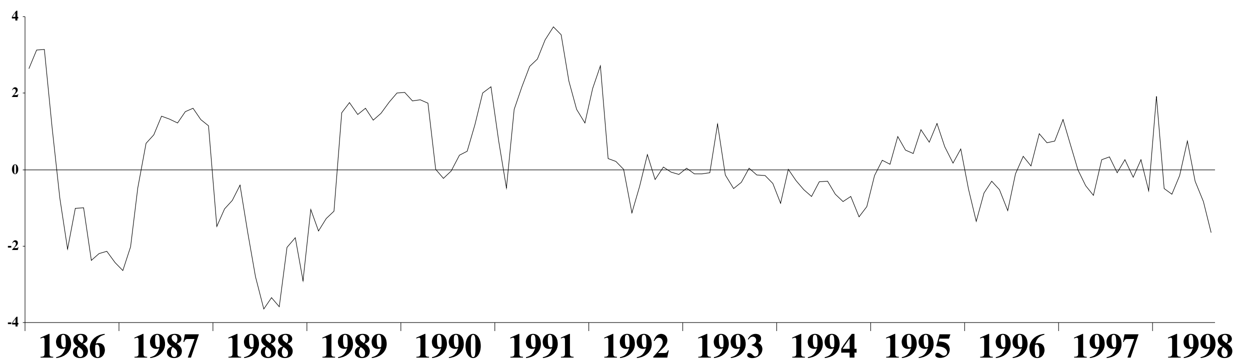


Figure A3: year-over-year changes

Weighted Mean vs Weighted Median
Year over year growth of CPI, monthly data
Jan. 1986 to Aug. 1998



Skewness over sample
Year over year growth of CPI, monthly data
Jan 1986 to Apr 1998



Kurtosis over sample
Year over year growth of CPI, monthly data
Jan 1986 to Apr 1998

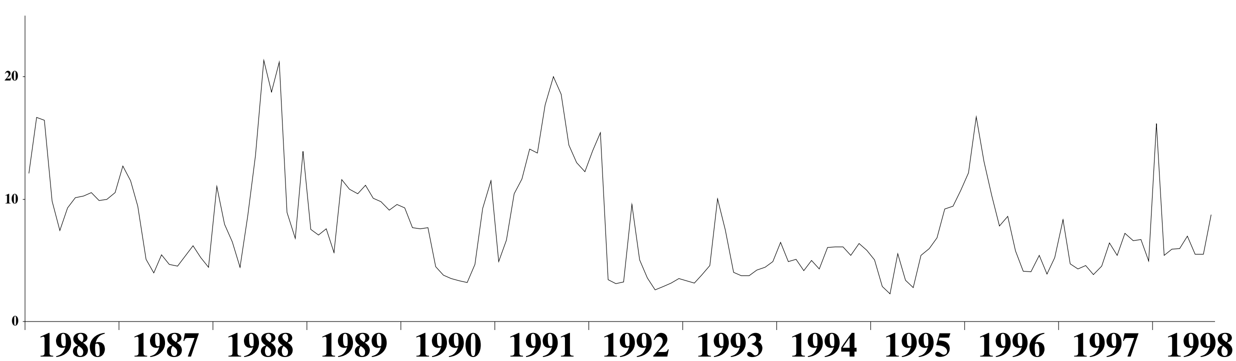
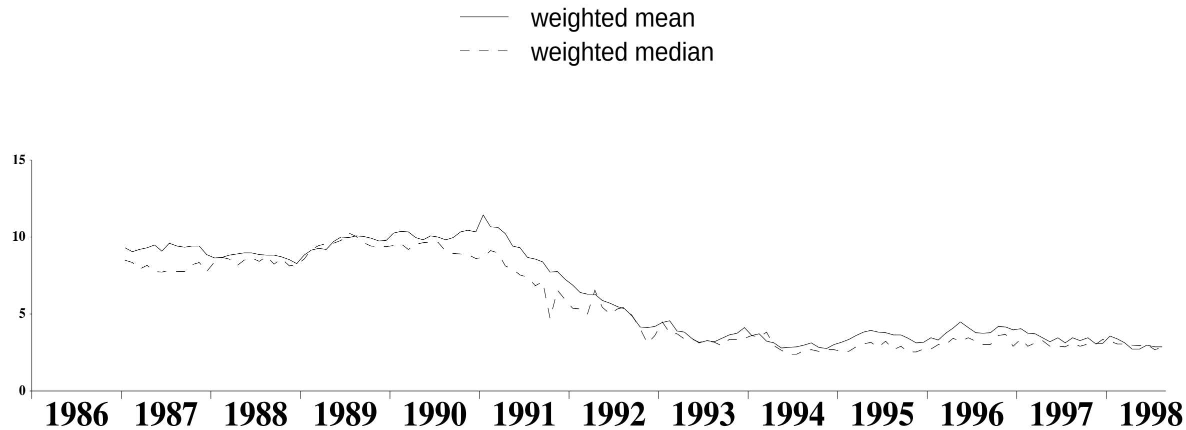
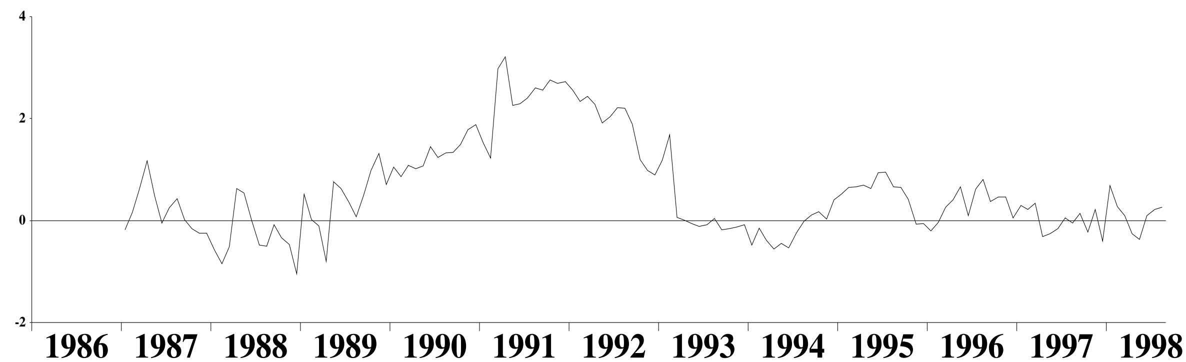


Figure A4: 24-month-over-24-month changes

Weighted Mean vs Weighted Median
24 months over 24 months growth of CPI, monthly data
Jan. 1986 to Aug. 1998



Skewness over sample
24 months over 24 months growth of CPI, monthly data
Jan. 1986 to Aug. 1998



Kurtosis over sample
24 months over 24 months growth of CPI, monthly data
Jan. 1986 to Aug. 1998

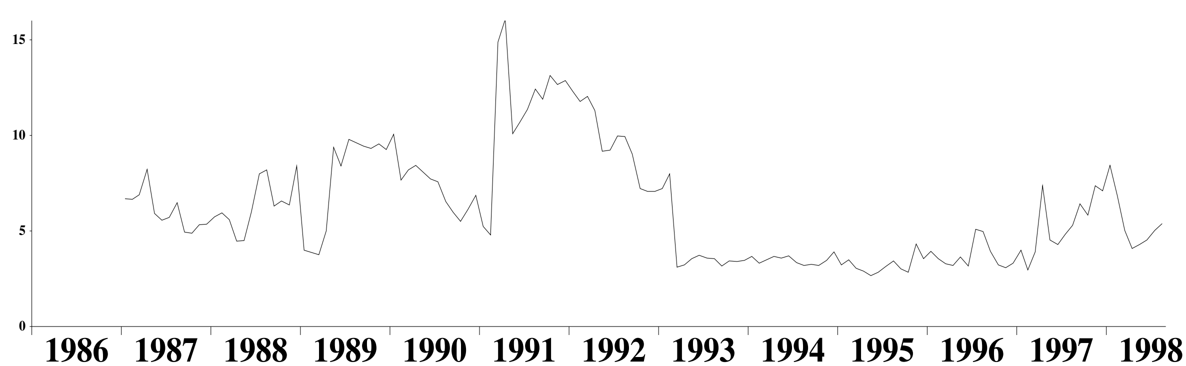
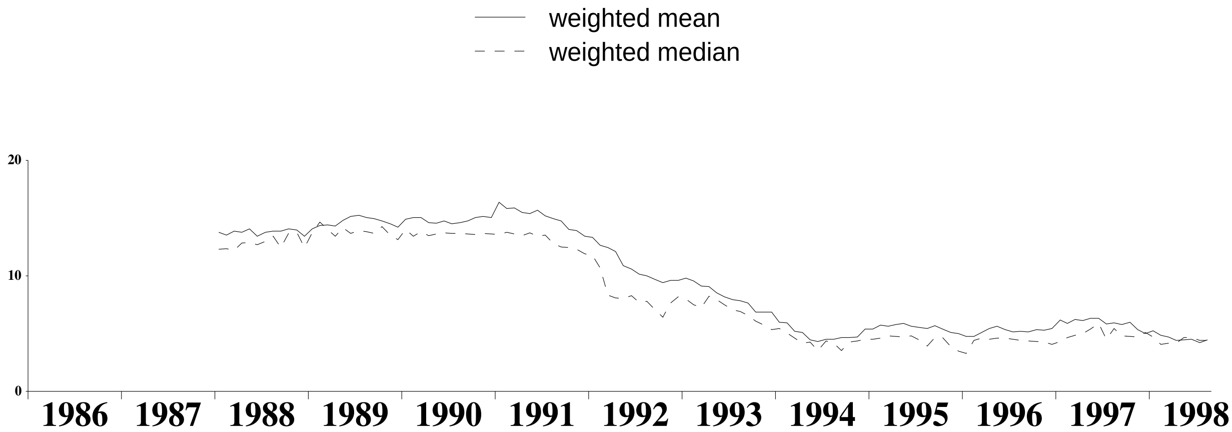
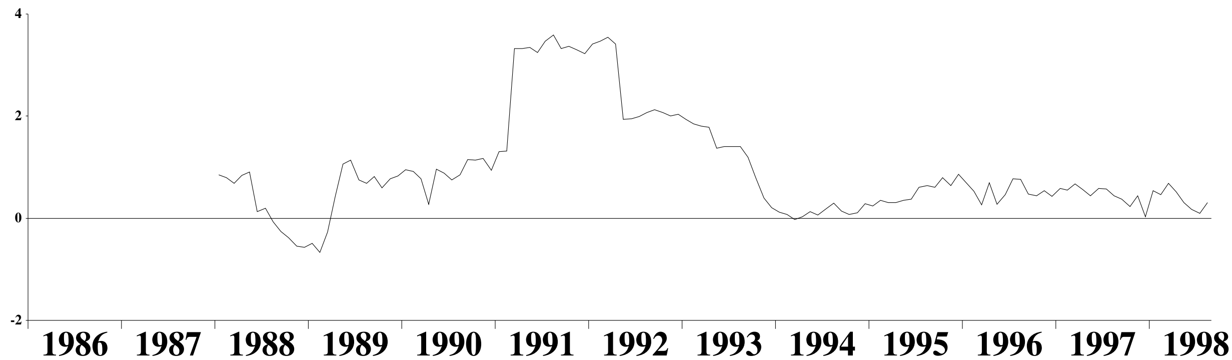


Figure A5: 36-month-over-36-month changes

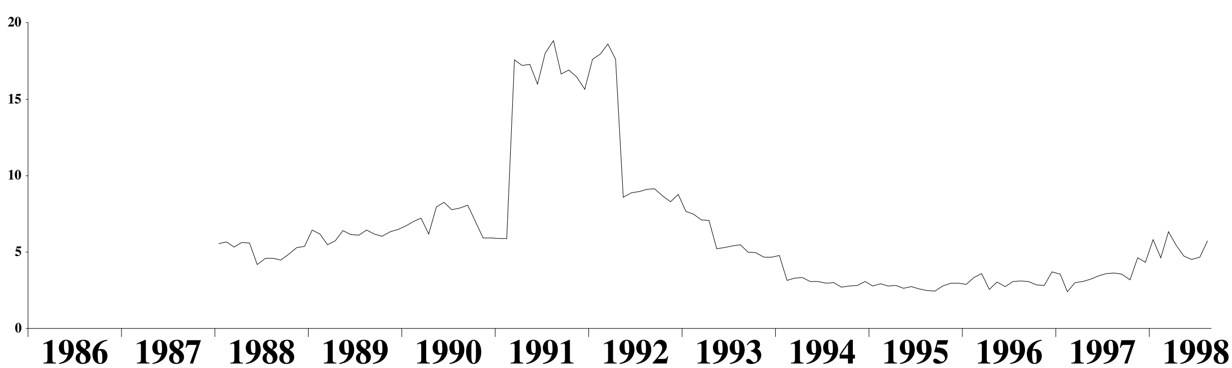
Weighted Mean vs Weighted Median
36 months over 36 months growth of CPI, monthly data
Jan. 1986 to Aug. 1998



Skewness over sample
36 months over 36 months growth of CPI, monthly data
Jan. 1986 to Aug. 1998



Kurtosis over sample
36 months over 36 months growth of CPI, monthly data
Jan 1986 to Apr 1998



RESERVE BANK OF AUSTRALIA

MEASURES OF INFLATION AND INFLATION TARGETING IN AUSTRALIA

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Reserve Bank of Australia

Paper prepared for Meeting of Central Bank Model Builders, Bank for International Settlements, Conference 18-19 February 1999

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Abstract

Australia's inflation target has recently been adjusted to be specified in terms of the headline Consumer Price Index, rather than an 'underlying' measure. This followed the recent decision by the Australian Statistician to exclude interest rates from the CPI, thus removing the main obstacle to its use as the focus of the inflation target. The adjustment to the policy target reflected a judgement that the advantages of using the CPI, in terms of public recognition, outweighed the disadvantages in terms of its greater volatility.

The fact that the inflation target in Australia is expressed in terms of a medium-term average means that the distinction between 'core' and CPI inflation does not have a direct operational significance for monetary policy. The main difference is one of presentation. Indicators of core inflation remain useful in assessing and forecasting the trend in inflation, and a number of such indicators are used in policy analysis by the Reserve Bank. This paper summarises the policy context for the use of core inflation measures in Australia and analyses the properties of the main alternative measures.

Table of Contents

1. The Policy Context

Since 1993, monetary policy in Australia has been conducted under an inflation-targeting framework, under which the objective is to achieve a medium-term average rate of inflation of 2 to 3 per cent.[1] This was formalised with the *Statement on the Conduct of Monetary Policy* jointly released in 1996 by the incoming Governor of the Reserve Bank and the Federal Treasurer. The specification of the target as a medium-term average recognises the inherent variability of inflation, and allows some scope for countercyclical policy in the short run to the extent consistent with the target.

The Statement specified the target for inflation in terms of underlying or core inflation.[2] The main reason for this was that the inclusion of interest charges in the headline CPI from 1986 represented a serious impediment to the use of the headline index for the assessment of monetary policy. A secondary consideration was that core measures of inflation were subject to less short-run volatility than the headline measure. Recent changes to the CPI by the Australian Statistician have meant the removal of interest charges from the index from the September quarter 1998 onwards, thus removing the main obstacle to its use as the policy target. The Reserve Bank and the Federal Treasurer have agreed in the light of this change that specifying the target in terms of the *headline* CPI is consistent with the intent of the original Statement on monetary policy.[3]

The primary argument for shifting to the headline rate is that it represents a more widely accepted and understood measure of inflation. Its use is therefore likely to promote accountability, as well as public understanding and acceptance of the targeting framework. One concern in making this change is that the headline rate of inflation still includes changes in prices which are unrepresentative of general inflation and correspondingly tends to be a noisier measure of general price inflation. For this reason, core measures will remain a source of information about the general direction of price inflation. Another secondary source of information will be other indicators of the future direction of inflation such as inflation expectations and growth in unit labour costs.

Specification of the target in terms of the headline rate of inflation does not represent any significant shift in the operation of monetary policy. The medium-term nature of the inflation objective means that policy is not required to respond to unrepresentative short-term price movements or statistical noise in the headline inflation rate. Over longer periods of time, headline and core measures of inflation should be similar on average. It is clear that the Reserve Bank has achieved the inflation objective in the 1990s whether this is assessed in terms of headline or any measure of underlying or core inflation (refer Table 1). Over the 1990s, the difference between the CPI and core measures of inflation is largely explained by interest rates which, on average, fell over the period.

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[1] For a discussion of the specification of the Australian inflation target see Debelle and Stevens (1995).

[2] Although no explicit reference was made in this Statement, the assessment of the inflation target became closely associated with the Treasury measure of 'underlying' or 'core' inflation.

[3] Refer Reserve Bank of Australia (1998).

Table 1
Measures of Inflation
Average annual rate; per cent

	1990-98[(a)]	1993-98[(b)]
Consumer Price Index	2.2	1.9
Core measures:		
Treasury underlying CPI	2.5	2.0
Trimmed mean	2.5	2.0
Median price change	2.4	2.0

(a) Sample period from March 1990 to September 1998.
(b) Sample period from March 1993 to September 1998.

2. Defining Core Inflation

The concept of core inflation appears to have emerged from dissatisfaction with the Consumer Price Index (CPI) as a measure of general inflation. In Australia, the CPI was not designed as a measure of general inflation but rather as a cost-of-living index. Consequently, it includes items whose prices are not determined primarily by market forces in the economy. For example, movements in the price of tobacco are heavily influenced by changes to taxation whilst other prices, such as health and education, are largely set by the government, independent of market forces. Yet, even movements in the other prices included in the CPI will not always be representative of general inflation. Of particular concern is the potential for transitory relative price changes — that is, a market or firm-specific shock to prices — to obscure information about the general direction of inflation.

Measures of core inflation are designed to abstract from these influences on the aggregate or headline measure of inflation. However, there remains no clear consensus on what core inflation should be measuring. The silent debate would appear to be how broadly core inflation should be defined. One standard definition of core inflation relates to the concept of the implied steady-state rate of inflation: where inflation would be if output was consistent with the natural rate and the economy was free of all supply shocks.[4] Alternative definitions also include one or more of the following: the persistence or momentum in inflation, the transitory impact from fluctuations in aggregate demand and/or movements in the real exchange rate.

In the discussion of core inflation, one of two non-mutually exclusive frameworks is generally applied. As noted by Bryan and Cecchetti (1993), these frameworks should not be considered complete theories of inflation as they ignore the policy response to ‘price’ shocks and therefore are subject to the Lucas critique.

The most common approach taken to discuss the core rate of inflation is to describe it as the persistent or permanent component of inflation. This generally involves inflation, π, being divided in a statistical sense between its trend, π^p, and transitory components, π^t, whereby:

[4] This is the definition of core inflation in Eckstein (1981) and also in Romer’s (1996) macroeconomic textbook.

$$\pi = \pi^p + \pi^t \qquad (2.1)$$

This characterisation is seemingly intentionally vague about the determinants of inflation. Correspondingly, this description of inflation affords many interpretations. (For example, compare the interpretations offered by Bryan and Cecchetti (1993), Freeman (1998), Eckstein (1981) and Kearns (1998)). The trend component is usually identified as being at least partially determined by the stance of monetary policy. The transitory component may include fluctuations in aggregate demand as well as supply shocks to inflation.

A second approach is the Phillips curve framework, which may be thought of as a special case of the general framework just described:

$$\pi = \pi^e + \alpha(y_t - \bar{y}) + \beta\Delta e_t + \varepsilon^s \qquad (2.2)$$

Equation (2.2) describes an open-economy version of the Phillips curve[5] where inflation settles down to the level of inflation expectations, π^e, in the steady state when output y is at the natural rate $\bar{y}$, the real exchange rate, e, is stable and the economy is absent of supply shocks, ε^s. A textbook definition in this framework would identify core inflation with the steady-state inflation rate, which is given by inflation expectations.

Core Measures and Monetary Policy

Some of these distinctions in defining core inflation perhaps may be clarified if more was said on the envisaged purpose for the measure of core inflation. For the purposes of monetary policy, the core rate of inflation should reflect the current supply and demand pressures in the economy. The emphasis is on the exclusion of temporary influences on inflation, due to a once-off shift in the price level resulting for example from a change in the tax rate, or due to reversals in large price movements such as may result from extreme changes in weather conditions on food prices. This measure of inflation corresponds to a broad definition of core inflation based on the distinction between transitory and persistent components of the inflation rate. It is this rate of inflation which is referred to as the ‘core’ measure in this paper. In terms of the Phillips curve framework, this measure would not only include the steady-state component identified with inflation expectations but would also incorporate medium-term inflationary pressures from fluctuations in demand and movements in the real exchange rate as well as any general persistence in the inflation rate. In addition to providing a current measure of inflation, core inflation may be thought of as summarising information about the predictable component of inflation and therefore provide an important input for producing forecasts of aggregate inflation.

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[5] Gruen and Sheutrim (1994) derive an open-economy Phillips curve using this intuitive explanation. Aggregate inflation is determined as a weighted average of domestic and import price inflation: $\pi = \delta\pi_d + (1-\delta)\pi_m$. Domestic inflation is described by a standard Phillips curve: $\pi_d = \pi^e + \alpha(y_t - \bar{y})$. Assume the law of one price for imports, that is, the world price of imports rises with the world inflation rate, π^*. Then the change in the real exchange rate is given by $\Delta e_t = \Delta n_t + \pi_t - \pi^*$ where Δn_t is the change in the nominal exchange rate. The open-economy Phillips curve thus derived as $\pi_d = \pi^e + \alpha(y_t - \bar{y}) - \frac{(1-\delta)}{\delta}\Delta e_t$.

The analysis presented in Section 3 below assesses some alternative methods of operationalising these concepts.

3. Comparing Measures of Core Inflation

Measures of core inflation first appeared in the 1970s as policy makers and academics came to grips with the implications of food and energy price shocks for understanding the general direction of inflation. In the U.S., as in many other countries around the world, 'core' inflation became synonymous with a measure of the CPI excluding food and energy prices. In Australia, the Federal Treasury constructed a measure of 'core' inflation which excluded components of inflation based on a wider set of criteria; the excluded components representing more than 40 per cent of the consumption basket.

In the 1980s, smoothing techniques were adopted as an alternative approach to abstract from temporary influences on inflation. More recently, attention has centred on the implication of skew and kurtosis in the inflation distribution for understanding the efficiency and robustness of the conventional CPI measure of inflation.

Quarterly inflation data is used in the following discussions as this is the highest frequency with which the CPI is published in Australia.

3.1 Measures of Core Inflation

Measures of core inflation are designed to abstract from unrepresentative price movements which may distort the headline measure of inflation. In the literature, considerable emphasis is placed on the potential for relative price changes to give misleading indications of general inflation. Relative price changes relate to market or firm-specific shocks, such as a productivity shock in a particular industry, a bout of bad weather impacting on food prices, or an exchange rate shock impacting on the traded sector of the economy. These shocks may appear as short-lived fluctuations in measured inflation obscuring the general direction of price movements.

In addition, prices which are administered by the government are often set independently of supply and demand considerations. Some prices are also sensitive to changes in fiscal policy. For example, tobacco and alcohol are subject to frequent revision of their excise taxes. Also, price changes in a particular quarter may be unrepresentative if the prices are seasonal or are only subject to infrequent adjustment.

Exclusion-based measures of core inflation are designed to directly identify and explicitly exclude distortionary changes in components of inflation. Statistical measures, on the other hand, use standard statistical techniques to filter large and influential price movements from the core measure of inflation.

The most prominent measure of core inflation in Australia, developed in the 1970s by the Federal Treasury, is a measure based on the *exclusion* of a *pre-defined* subset of the CPI. Components are excluded if they are deemed to be volatile, seasonal or subject to government policy. An exclusion-based measure of core inflation may alternatively exclude different CPI components each period based on *subjective* judgement each period as to which components have moved in a manner unrepresentative of general inflation.

Statistical approaches to measuring core inflation are generally based on the observation that the moments of inflation are non-normal and that these moments are correlated.

In Australia, it has been observed that the distribution of quarterly inflation rates tends to be both highly skewed and leptokurtic (that is, the distribution has fatter tails than a normal distribution) (Table 2). The skewness in the inflation distribution is still apparent even after the exclusion of policy components and seasonal adjustment of the data.

Table 2: Moments of Inflation[(a)]

	Mean	Standard Deviation	Skewness	Kurtosis
		September 1980 to March 1998		
Original:				
All components	1.35	2.87	0.69	24.97
Excluding policy components[(b)]	1.23	2.45	0.49	31.36
Seasonally adjusted:				
All components	1.35	2.47	0.32	22.27
Excluding policy components[(b)]	1.23	2.06	0.41	29.32
		September 1990 to March 1998		
Original:				
All components	0.70	2.34	0.35	26.65
Excluding policy components[(b)]	0.52	2.06	0.20	37.66

(a) Source: Kearns (1998). The moments are calculated for quarterly data for the components of the CPI basket excluding interest charges.
(b) The excluded components are Government Owned Dwelling Rents; Local Government Rates and Charges; Household Fuel and Light; Postal and Telephone Services; Automotive Fuel; Urban Transport Fares; Tobacco and Alcohol; Health Services; Pharamaceuticals; and Education and Childcare.

Correlations between the moments of inflation are described in Table 3. The mean of inflation is shown to be positively correlated with both the dispersion and skew in the sample distribution of inflation. The skew and kurtosis are also shown to be positively correlated. These observations are not unique to Australia with similar distributional characteristics found for the U.S. (Bryan and Cecchetti, 1993) and New Zealand (Roger, 1997).

Table 3: Correlations of Moments[(a)]

	Mean	Standard Deviation	Skew	Kurtosis
Mean		0.30	0.25	-0.09
Standard Deviation	0.24		-0.12	-0.04
Skew	0.27	-0.07		0.38
Kurtosis	-0.12	-0.05	0.41	

(a) The correlations are for the moments of the CPI basket excluding interest charges. The lower triangle gives the correlations for September 1980 to March 1998 whereas the upper triangle is for September 1990 to March 1998. Source: Kearns (1998)

It is a well-established characteristic of inflation that when inflation is high it is also less predictable.[6] More recently, Ball and Mankiw (1992) have developed a model which supports a positive correlation between the level of inflation and the degree of positive skew in inflation.[7] The Ball and Mankiw model introduces menu costs into the price-setting behaviour of firms. Therefore, in the face of a relative price shock, only firms facing large shocks will find it profitable to change prices in the short term. If these shocks are asymmetrically distributed then ‘large’ shocks will be concentrated on one side of the distribution. The average rate of observed price changes is now a biased measure of the average of the distribution of shocks. The causal relationship is from the skew in the shocks facing price-setters into a biased measure of the general price inflation when calculated in the standard fashion as the mean of all price changes.

In an extension of the Ball and Mankiw menu cost model to allow for trend inflation, it is the mean inflation which leads to the observed skew in price changes. In this case, the inflation distribution may be skewed even if the distribution of relative price shocks firms face is not. The asymmetry is in the incentive firms have to change prices when faced with positive and negative ‘price’ shocks. De Abreu Lorenco and Gruen (1995) argue that firms which face large negative ‘price’ shocks will face a reduced incentive to change prices immediately as they can rely on trend inflation to do much of the work in making the desired relative price change. Whereas firms facing relatively large positive ‘price’ shocks will have an increased incentive to change prices as the benefits in paying the menu cost will be returned to the firm more quickly. Over a longer horizon, the skew in inflation should diminish as all firms take the opportunity to set their prices optimally.

The standard Ball and Mankiw menu cost model raises the possibility that the mean may not be the most appropriate estimator of the central tendency of a skewed distribution. The extended model introduces a distinction between the ‘effectively’ discontinuous distribution of shocks facing the firm in the short run versus a symmetric and continuous distribution of shocks over the long run. Therefore, whilst the mean will be both a biased and inefficient measure of the population distribution in the short term, the long-run mean is an unbiased and efficient estimator of long-run inflation. We will return to this distinction in our comparison of the estimators in the next section of the paper.

An argument raised by Zeldes (1994) and others is that an observed skew in the price distribution does not necessarily imply that the mean is a biased measure of inflation. If we believe that inflation is set by the supply and the demand for money and money is neutral, then a large rise in one price implies slower growth in the other components of inflation such that aggregate inflation is unaffected. This argument presented by Zeldes effectively relates to a long-run concept of inflation. Over the short term, inflation would still be subject to demand and supply shocks and therefore these issues concerning the measurement of inflation would remain.

The second observation, that the kurtosis and skew of the sample of the distribution is positively correlated, is unsurprising if the population distribution from which the samples are drawn is leptokurtic. A small sample drawn from a leptokurtic distribution will draw too often from the tails, generating skewness and kurtosis in the sample distribution. Bryan, Cecchetti and Wiggins II (1997)

[6] Refer Golob (1993) for a review of these models.

[7] Balke and Wynne (1996) provide an alternative explanation for a positive correlation between the mean and skew of inflation by introducing asymmetry into the input-output relationship between sectors in a dynamic equilibrium model.

note that a mixture of random draws from normal distributions with differing variances is sufficient to produce a leptokurtic distribution.

A standard statistical solution to the difficulties associated with skewed and leptokurtic distributions is to use limited-influence estimators. These estimators reduce the weight attributed to extreme price movements compared with the mean and therefore more efficiently estimate the central tendency of the population inflation distribution if that distribution is either leptokurtic or skewed.

The weighted mean is the standard technique for calculating the CPI and can be derived as the estimator which minimises the sum of weighted *squared* deviations. Whereas, the *weighted median*, which is a limited-influence estimator, places reduced weights on extreme observations by minimising the sum of weighted *absolute* deviations. The weighted median is more intuitively calculated as the rate of inflation corresponding to the 50th percentile of the inflation distribution, appropriately weighted by the CPI components.

The *trimmed mean*, as the name would suggest, involves taking a weighted average of a subset of the CPI which trims the most extreme movements in inflation. Following the notation of Bryan, Cecchetti and Wiggins II (1997), the calculation of the trimmed mean involves first ranking changes in the prices of the sub-groups of the CPI, x_i, with their associated weights, w_i, according to size.[8] Let W_i denote the cumulative weight, $W_i \equiv \sum_{j=1}^{i} w_j$. Then the subset of the index to be averaged is given by the set, $\{I_\alpha : \frac{\alpha}{100} < W_i < 1 - \frac{\alpha}{100}\}$. The *trimmed mean* which excludes α % of the distribution from each tail is then defined as:

$$\bar{x}_\alpha = \frac{1}{1 - 2\frac{\alpha}{100}} \sum_{i \in I_\alpha} w_i x_i \qquad (3.1)$$

The weighted average is a special case where none of the tails are trimmed, $\bar{x}_0$, and the weighted median is another special case where 50 per cent of the tails are trimmed from both sides, $\bar{x}_{50}$.

Whilst there are no general analytical results, Bryan, Cecchetti and Wiggins II (1997) demonstrate with a monte carlo experiment that for samples drawn from a mixture of normals with differing variances, the statistically efficient trim increases with the kurtosis. Also in a bootstrapping exercise, it is shown that the efficiency of the mean increases even with small trims from the distribution's tails.

The trimmed mean and weighted median are both unbiased estimators of the population mean if the population from which the samples are drawn is approximately symmetrically distributed. For New Zealand, Roger (1997) has noted a divergence between the long-run average of headline inflation and the weighted median measure of inflation. To produce an unbiased estimator of the 'population' mean as measured by the moving average, Roger promotes asymmetric trimming of the median. Instead of choosing the 50th percentile of the price distribution, to compensate for the positive skew in inflation, some percentile above 50 is chosen to produce an unbiased estimator.[9]

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[8] Refer Kearns (1998) for details of calculations of time-varying weights for the Australian CPI.

[9] Refer Kearns (1998) for details of an asymmetrically trimmed mean measure of inflation for Australia.

3.2 Criteria for Comparison

Whilst the statistical measures described above may represent technical advances in the calculation of core measures of inflation, it is not apparent that these measures will provide the best measure of 'core' inflation in all circumstances. Most inflation-targeting countries specify their target in terms of a headline rate of inflation but still publicly discuss 'core' measures in defence of their policy stance. The public credibility of the core measure in this circumstance earns a higher weight than statistical superiority. Whereas, for internal purposes, policy makers can weigh the information from a variety of core and headline inflation measures — with respect of their relative advantages — in their assessment of domestic inflationary pressures.

Credibility

The desired properties of a credible measure of core inflation would include that the method of calculation be transparent, verifiable, easy to communicate, widely recognised, produced on a timely basis, not subject to revisions and calculated independently of the central bank.

A simple measure which excludes a defined subset of the CPI basket perhaps best meets these criteria. Australia's inflation target was initially specified in terms of core inflation and it was on this rationale that the target came to be closely associated with the Treasury measure of core inflation.

An exclusion-based measure which subjectively excludes components from the CPI is unlikely to hold up as a credible measure of core inflation. The statisticians must first be able to identify significant supply shocks and other unrepresentative movements in inflation. This may involve some arbitrary decisions as to what constitutes a significant shock and therefore which components should be excluded. Unless the statisticians institute specific rules for excluding components, the index will not even be verifiable. Even if such rules are in place, the calculation of the core measure of inflation is not likely to be very easy to communicate as it requires detailed explanations about movements in individual components of inflation in the period.

The statistical measures of core inflation are both transparent and verifiable by independent observers. However, the justification for calculating trimmed means and weighted medians is based on the non-normality of the inflation distribution — at least for high frequency data — and the inefficiency, in a statistical sense, of the mean in these circumstances: concepts not easy to explain to the general public. Consequently, these measures of inflation have held little prominence in public discussions of inflation in Australia. Although the choice of trim for the calculation of the trimmed mean and the choice of percentile for an asymmetrically trimmed median are subjectively made, these measures of core inflation are likely to be fairly robust to these decisions. If statistical measures are able to prove their superiority through consistently providing the most appropriate indications of current inflation then they may potentially become established as credible measures of inflation.

As for timeliness, three out of four of these measures of core inflation can be calculated with no time delay following the publication of the price components of the CPI. The exception is the measure which excludes components based on subjective judgement. Time will be required to assess which components of inflation have been subject to unusually large shocks during the period and whether large movements in the prices of some components of inflation represents information or noise. In addition, the index may be subject to revision as more information becomes available as to the causes of a particular episode of inflation.

Robustness, efficiency and bias

It is also desirable that the estimator of core inflation is robust to distortionary price changes in *any* of the components of the CPI. The prime criticism of the measure of core inflation which excludes a defined subset of the headline price index is that it is not robust to large shocks to components of inflation which are included in the measure. In addition, this index excludes components from the CPI even when they contain useful information about the direction of inflation. The exclusion-based measure which involves subjective judgement is potentially more robust to these criticisms, but this advantage of this measure will rely on the quality of the judgements made.

The statistical measures however, by design, place a reduced weight on large price movements from any source and are therefore more robust to the distortionary impact of large price movements. The advantage is that these approaches do not require any pre-specification of the source of the price disturbance.

However, the danger is that the systematic exclusion of large movements also excludes any information contained in these price changes (Roger, 1994). A particular example is a shock to the exchange rate. The exchange rate change will have a relatively direct impact on the price of imported and import-competing goods. However, this change in the exchange rate will also have a less direct impact on inflation over time as the change in the price of imported intermediate and capital goods feed their way into the price of final domestic products. In a small open economy such as a Australia, the exchange rate is an important source of persistence in aggregate inflation. The statistical criteria provided in Section 3.3 give some indication of the information content in the excluded components of inflation.

It is a more complicated issue as to in what sense the measure of core inflation should be ‘unbiased’. The question raised by Roger (1997) is whether the long-run average of core inflation should be an ‘unbiased’ estimator – in a non-rigorous sense – of long-run headline inflation. The appropriate answer to this question is not immediately apparent. We offer one theoretical reason and one practical reason why the long-run averages of core and headline inflation should be the same.[10]

If we consider the extension to the Ball and Mankiw menu cost model to incorporate trend inflation, then the skew in the observed distribution of price changes is a result of an increased incentive for firms facing positive shocks, over firms facing negative shocks, to change their prices rather than any skew in the underlying distribution of shocks. Given time, firms fully adjust to their optimal nominal price. In this case, despite a persistent skew in quarterly inflation rates, the long-run distribution is symmetric and therefore the long-run average of price movements is the appropriate measure of long-run inflation.

The practical argument is perhaps more compelling. If the central bank has adopted an inflation target with reference to a headline measure of inflation, then it is desirable that core measures of inflation used to inform policy have the same long-run mean as the headline inflation rate. Clearly, any persistent deviations may misinform policy makers about the current and future position of inflation relative to the target rate or band. In addition, persistent deviations between headline and core

[10] Clearly, an array of theoretical models can be envisaged for which the long-run averages of core and headline inflation would differ.

measures of inflation will tend to undermine the credibility of the core measures of inflation as a defence of policy actions.

Conceptually correct

It would seem appropriate to ask at this point, whether these measures of core inflation are actually measuring the desired concept of core inflation as defined in section 2 of the paper. That is, the measure of core inflation should abstract from the direct impact of exogenous shocks and other movements in prices which are unrepresentative of more generalised inflation in the quarter. However, we would like the core inflation measure to still include the persistent influence fluctuations in aggregate demand and fundamental movements in the exchange rate exerts on inflation. The exclusion-based measures are clearly designed to measure this notion of price inflation.

The statistical measures of inflation are designed to identify the centre of the distribution of price changes in the components of the CPI in the period. As such, it is more difficult to match the concept with the calculation. However, since only a cross-section of information is contained in these measures, they will tend to include current inflationary pressures from demand fluctuations and real exchange rate fluctuations, as desired. The simple statistical tests presented below also provide some insight into the relevance of these measures.

3.3 Statistical Criteria

The emphasis in this paper has been on producing measures of core inflation which represent that rate of inflation most useful for the setting of monetary policy. The desired criteria for assessing this measure of inflation therefore does not include minimisation of its variance over time or minimisation of its deviations away from some long-run moving average. Some simple tests can be applied to Australian data to consider how closely the different measures accord with the economic intuition of core inflation.

The excluded component from the CPI would generally be expected not to contain any forward-looking information about core inflation. This is because a preferred measure of core inflation should exclude the temporary impact of ‘price’ shocks but should include any persistence in inflation arising from these shocks. A simple test of this hypothesis is to conduct a Granger-causality test of the impact of the excluded component on the respective core measure of inflation. Following Roger (1997) the excluded components are referred to as “relative price” shocks, RP_t, and are measured as the difference between the headline CPI and the respective core rate of inflation. The results, presented in Table 4, show that for the statistical measures, the “relative price” shocks do not contain leading information about core inflation. However, for the exclusion-based Treasury measure, the excluded component does contain leading information about this measure of core inflation suggesting that some information is being disregarded when this measure is calculated.

Table 4: Granger-causality Tests

$H_0 : \beta_i = 0 \text{ , } i = 1,\ldots,4$ [(a)]

	Measures of Core Inflation[(b)]		
	Treasury	Trimmed Mean	Weighted Median
$\Delta core_t = \sum_{i=1}^{4} \alpha_i \Delta core_{t-i} + \sum_{i=1}^{4} \beta_i RP_{t-i} + \varepsilon_t$	4.81**	0.18	1.04
$RP_t = \sum_{i=1}^{4} \alpha_i RP_{t-i} + \sum_{i=1}^{4} \beta_i \Delta core_{t-i} + \varepsilon_t$	1.84	0.32	0.20
$\Delta CPI_t = \sum_{i=1}^{4} \alpha_i \Delta CPI_{t-i} + \sum_{i=1}^{4} \beta_i \Delta core_{t-i} + \varepsilon_t$	3.43*	1.99#	2.50*

(a) An F-test is performed to test the null hypothesis. **, * and # denote 1%, 5% and 10% level of significance respectively. The sample period for estimation is 1977:4 to 1998:3. The CPI measure excludes interest charges.

(b) The core measure also refers to the measure in the calculation of the "relative price shock" term.

As defined, core measures of inflation can be thought of as summarising information about the future path of aggregate inflation. This is because the component excluded in the calculation of the core measure should represent the temporary movements in inflation and contain little information about future rates after accounting for the core measure of inflation. This intuition is confirmed for both the exclusion-based and statistical measures of inflation considered. That is, the core measure of inflation Granger-causes the headline inflation rate.

Following Roger (1997), we also consider whether, as defined, these "relative price" shocks can be explained in a Phillips curve framework. A desirable property of any definition of core inflation is that it does not exclude price movements that are explainable by the factors incorporated in an aggregate model of the forces driving inflation. To test this hypothesis we estimate an open-economy version of the Australian Phillips curve and test the inclusion of a relative price term (Table 5). A constant is included in these regressions to allow for the persistent bias in the Melbourne Institute measure of inflation expectations which is one of the explanators in the equation. Under the null hypothesis that the core measure excludes only the unexplained component of inflation, the relative price term should have a unit coefficient. This corresponds to the intuition that the relative price shock feeds fully into the headline CPI and that this effect is not captured by the other explanators of inflation. For both statistical measures of inflation, this condition is satisfied, but is rejected in the case of the Treasury measure. These results give some support to the Granger-causality tests in suggesting that the two statistical measures have superior properties. They also lend some support to the notion that the Phillips curve is best specified in terms of core rather than headline inflation. Although it is possible to discriminate between these measures of core inflation on statistical grounds, it is noted below that the differences between the alternative series are quite small in economic terms.

Table 5: Phillips Curve[a]

$$\Delta CPI_t = \alpha + \beta\pi_t^e + \sum_{i=2}^{4}\phi_i ygap_{t-i} + \sum_{i=0}^{1}\gamma_i \Delta pm_{t-i} + \delta RP_t + \varepsilon_t$$

		Measures of "Relative Price" Shocks[b]		
		Teasury[c]	Trimmed Mean	Weighted Median
Constant, α	0.00 (0.00)	0.00** (0.00)	0.00** (0.00)	0.00** (0.00)
Inflation expectations, π_t^e	0.81** (0.10)	0.87** (0.06)	0.85** (0.05)	0.86** (0.05)
Output gap, $ygap_{t-2}$	0.02 (0.06)	0.03 (0.03)	0.08* (0.03)	0.08* (0.03)
$ygap_{t-3}$	0.01 (0.08)	0.03 (0.03)	-0.04 (0.03)	-0.04 (0.04)
$ygap_{t-4}$	0.12* (0.06)	0.05# (0.03)	0.04 (0.02)	0.05 (0.03)
Import prices, Δpm_t	0.04# (0.02)	0.01 (0.01)	0.01 (0.01)	0.01 (0.01)
Δpm_{t-1}	0.05* (0.02)	0.04** (0.01)	0.04** (0.01)	0.03* (0.01)
Relative price shock, RP_t		0.77** (0.07)	1.26** (0.13)	1.09** (0.08)
R^2	0.63	0.87	0.87	0.90
D.W.	2.21	1.36	1.66	1.69
Homogeneity: $H_0: \beta + \sum_{i=0}^{1}\gamma_{t-i} = 1$	1.00	2.52	3.45*	4.48*

(a) The dependent variable is the Consumer Price Index excluding interest charges. The sample estimation is 1977:4 to 1998:2. **, * and # denote significance at the 1%, 5% and 10% level of significance. The standard errors are in parentheses. Inflation expectations is the Melbourne Institute measure of inflation expectations over the coming year divided by four. The output gap is the difference between actual output and smoothed output using a Hodrick Prescott filter. Import prices is the implicit price deflator for endogenous imports.
(b) The relative price shock is calculated as the difference between the CPI inflation rate and the core measure of inflation.
(c) In this regression the standard errors are corrected for serial correlation.

3.4 Which Measure of Core Inflation?

In Australia, the Australian Bureau of Statistics publishes an array of exclusion-based measures of core inflation, of which, the 'Treasury' measure is the most widely recognised. Trimmed mean and weighted median measures are published by the Reserve Bank.

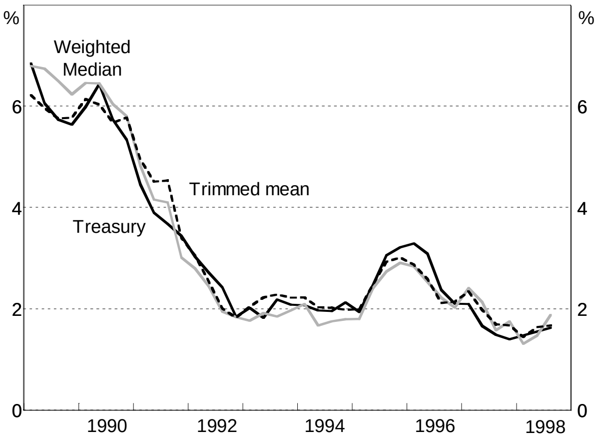
The consistently close relationship between the various core measures of inflation is striking (Figure 1).[11] It is seemingly unnecessary to distinguish between these series on theoretical grounds in particular quarters if they are essentially providing the same information. Consequently, both internal and external discussions have focussed on arguably the more credible Treasury measure of underlying or core inflation, whereas, the statistical measures have held very little prominence.

Since each series has relative advantages and the costs of computation are small, there is good reason to monitor a range of core measures of inflation and to discriminate between these series when differences arise. For example, in September 1995, the Treasury measure of core inflation rose above the trimmed mean and weighted median measures. In this quarter, and also in the preceding, the government had increased wholesale tax rates. These tax increases should result in temporary increases in prices and therefore their impact should ideally be excluded from a core measure of inflation. Seemingly, the Treasury measure was less effective at dealing with this generalised price disturbance than the statistical methods. However, none of the measures are designed to adequately deal with a generalised price shock. There were few exceptional movements in the components

Figure 1

Measures of Core Inflation

Year-ended rate



excluded from the CPI in this quarter,[12] suggesting that the Treasury measure did exclude some components containing information about the general direction of inflation. This is confirmed when we discover that compared to the weighted median, of the components excluded, 60 per cent of their weight was in the left hand tail of the distribution; and only a small portion of the movements in these components were sufficiently extreme to be excluded in the calculation of the trimmed mean — only 8 per cent of their weight was trimmed compared with 15 per cent for the entire distribution.

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[11] The trimmed mean shown symmetrically trims 15% from each tail of the CPI distribution.

[12] Large positive movements in components excluded from the CPI included lamb and mutton (5.7%), fresh potatoes (9%) and cigarettes and tobacco (6.3%) covering 4% of the CPI basket and contributing 0.24 percentage points to aggregate inflation. Components in the left-hand tail excluded in the Treasury measure included poultry (-1.8%), fresh vegetables (-2.8%), fabrics and knitting wool (-1.2%), women’s footwear (-1.2%), children’s footwear (-2.6%) and pharmaceuticals (-2.7%) detracting 0.08 percentage points from the CPI inflation rate.

4. Conclusion

The fact that the inflation target in Australia is expressed as a medium-term average means that the distinction between underlying and CPI inflation (as now defined) does not have a direct operational significance for monetary policy. Over time, core and headline measures of prices can be expected to increase at similar rates. The main advantage of expressing the policy target in terms of the headline rate is that this is likely to be better understood and accepted by the public, although this comes at a cost of greater volatility than core measures.

Core inflation measures remain a useful analytical device for summarising information about the persistent component of the inflation rate, and for isolating temporary factors that are less relevant for monetary policy. Of the two main approaches to constructing core inflation measures – the exclusion-based and the statistical approaches – it is the exclusion-based approach that has in the past had greater prominence in Australia. This partly reflected the existence of an established and independently-calculated exclusion-based measure (the Treasury underlying measure) when the inflation-targeting framework was adopted. The comparative analysis presented in this paper suggests that the statistically-based measures of core inflation, based on trimmed mean and weighted median price changes, have superior properties, but that the economic differences among the alternative measures are not large.

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BANK OF SPAIN

Underlying inflation measures in Spain (*)

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(*) We would like to thank Eilev S. Jansen (Norges Bank) as well as the rest of participants at the BIS Meeting of Central Bank Model Builders and Econometricians held in February 1999. This paper draws on Álvarez and Matea (1997).

Underlying inflation measures in Spain

Abstract

Applying the concept of underlying inflation can be thought of as an attempt to capture the general trend in inflation more accurately than with readily available data on headline inflation. In this paper a number of approaches to the analysis of underlying inflation are examined from a unifying standpoint, stressing their complementary nature, and empirical results are presented for the Spanish economy. Different measures differ from each other in the information set which is considered to be relevant for estimating the underlying rate of inflation. We first examine the simplest of the procedures that amounts to ignoring price developments in the most volatile sub-components of the CPI and then consider limited-influence estimators that take advantage of the information contained in the cross-sectional distribution of individual prices. Statistical methods of extracting the trend component of inflation are also discussed. Finally, measures that allow for the interplay of are other economic variables considered.

1. Introduction

It is widely acknowledged that the adequate assessment of inflationary trends is a complex undertaking and no single variable covers it fully. The Banco de España therefore uses a relatively complex analytical approach based on the examination of various economic, monetary and financial indicators, with the consumer price index (CPI) serving as a key element.

It is also well established that various shocks may, at least temporarily, produce noise in inflation statistics. Furthermore, there is general consensus that in view of the lags in the transmission mechanism, monetary policy should have a medium term orientation and thus transitory inflationary developments should not unduly affect policy decisions. The existence of short-term volatility in prices which cannot be controlled by monetary policy points to the need of developing measures of underlying inflation aimed at minimising this type of problem. This need has recently become even more important as central banks focus their attention on inflation as the primary goal of monetary policy.

While the terms "underlying inflation" and "core inflation" enjoy widespread use, they appear to have no widely accepted definition. Therefore, we think that it would be useful to present the main approaches that have been proposed in the literature. In our view, however, no single approach is able to summarise all relevant information; therefore, the different available measures should be jointly examined, taking into account their complementary nature. Moreover, since the various methods present different advantages and limitations we feel that users of these underlying inflation measures should be fully aware of them.

Solutions to the problem of high-frequency noise in price data include excluding certain prices in the calculation of the index based on the assumption that these are the ones with a high-variance noise component. This is the "ex. unprocessed food and energy" strategy which is discussed in section 2. Alternatively, it has been suggested to employ limited-influence estimators motivated by the observation that sizeable individual price changes tend to reflect transitory supply shocks and that these shocks may originate in any sector of the economy. Underlying inflation measures based on this type of estimators are discussed in section 3. Another approach, which is presented in section 4, involves calculating a low-frequency trend over which the noise is reduced. The fifth section describes two approaches based on a multivariate model and which are consistent with the existence of a vertical long-run Phillips curve and a monetary view of inflation. Finally, the sixth section presents the main conclusions drawn on the paper. A number of Tables summarising the use of underlying inflation measures by other authors and institutions are also included.

2. Underlying inflation by exclusion

From a monetary policy standpoint, a drawback to the direct use of the CPI is that this index is obscured by transitory price movements which hamper the description of lasting and more permanent price trends. To avoid, or at least to reduce, this problem it was initially proposed in the literature to exclude highly volatile prices from the CPI.

A possibility would be to adjust headline inflation for the estimated impact on prices of specific disturbances when they occur. However, it might be argued that transparency would be enhanced if reported inflation were adjusted for specific price disturbances according to a pre-specified rule. Depending on the structure of the economy, institutional arrangements and the methodology employed in the calculation of the CPI, European Union central banks (see Table 1) exclude different sub-components of the CPI to obtain measures of underlying inflation. Here, we will focus our attention in the case of Spain. In particular, following the Banco de España traditional breakdown[1] of the CPI into five major sub-components (unprocessed food, processed food, energy, non-energy industrial goods and services) it seems reasonable to exclude the most

[1] This is also the breakdown that the European Central Bank has adopted to employ.

volatile sub-components[2]: unprocessed food and energy. In this section we put forward the arguments that are typically employed when trying to justify the exclusion of these sub-components.

TABLE 1. - Underlying Inflation (UI) Measures of EU Central Banks
Underlying Inflation by Exclusion

Central Bank	**Underlying inflation** **(i.e. headline inflation adjusted for:)**
Bank of England	- RPIX (mortgage interest payments (mips)) - RPIY (mips, indirect and local taxes) - RPIXFE (mips, food, fuel, light) - TPI (direct taxes) - THARP (indirect and local taxes)
Sveriges Riksbank	- UND1 (interest costs for owner-occupied housing, indirect taxes, subsides, depreciation after float) - UND2 (ditto, plus heating oil and propellants)
Suomen Pankki	- IUI (capital costs in owner-occupied housing, indirect taxes, subsidies)
Banco de España	- IPSEBENE (energy, unprocessed food) - Case-by-case (indirect taxes, exogenous prices)
Deutsche Bundesbank	- CPI net (most indirect taxes) - Case-by-case (food and/or energy)
Oesterreichische Nationalbank	- Case-by-case (indirect taxes, seasonal food)
De Nederlandsche Bank	- ULI (vegetables, fruit and energy) - CPI market (public services, natural gas, rents, indirect and consumption-linked taxes)
Banque Nationale de Belgique	- CPI net (main indirect taxes) - ULI1 (food and energy) - ULI2 (energy) - ULI3 (energy, main indirect taxes)
Institut Monétaire Luxembourgeois	- ULI (oil) - Case-by-case (indirect taxes)
Banque de France	- ULI (food, energy, tobacco and taxation effects)
Danmarks Nationalbank	- CPI net (indirect taxes, subsidies) - ULI 1 (indirect taxes, subsidies, food, energy, rents, public services, effect of imports) - ULI2 (indirect taxes, subsidies, food, energy, rents, public services)
Central Bank of Ireland	- ULI1 (mortgage interest payments) - ULI2 (mips, food and energy)
Banco de Portugal	- ULI (unprocessed food and energy)
Banca d'Italia	- CPI net (indirect taxes)
Bank of Greece	- ULI (food and energy) - Case-by-case (oil, public utilities, regulated prices, indirect taxes, subsidies, etc.)

Source: Ravnkilde Erichsen and van Riet (1995)

[2] See, for example, Espasa et al. (1987) and Matea (1993).

As can be seen in Figure 1, which depicts the year-on-year rates for the CPI excluding unprocessed food and energy, the CPI and its major sub-components, the two sub-components whose year-on-year rates fluctuate most are those corresponding to energy and unprocessed food prices. This graphical evidence is also supported by the quantitative results in Table 2. Furthermore, among non-energy components, for which ARIMA models are available [see Table 3], the unprocessed food index is also the one with the largest residual standard deviation.

CPI AND ITS MAJOR SUB-COMPONENTS Fig. 1

Year-on-year rates

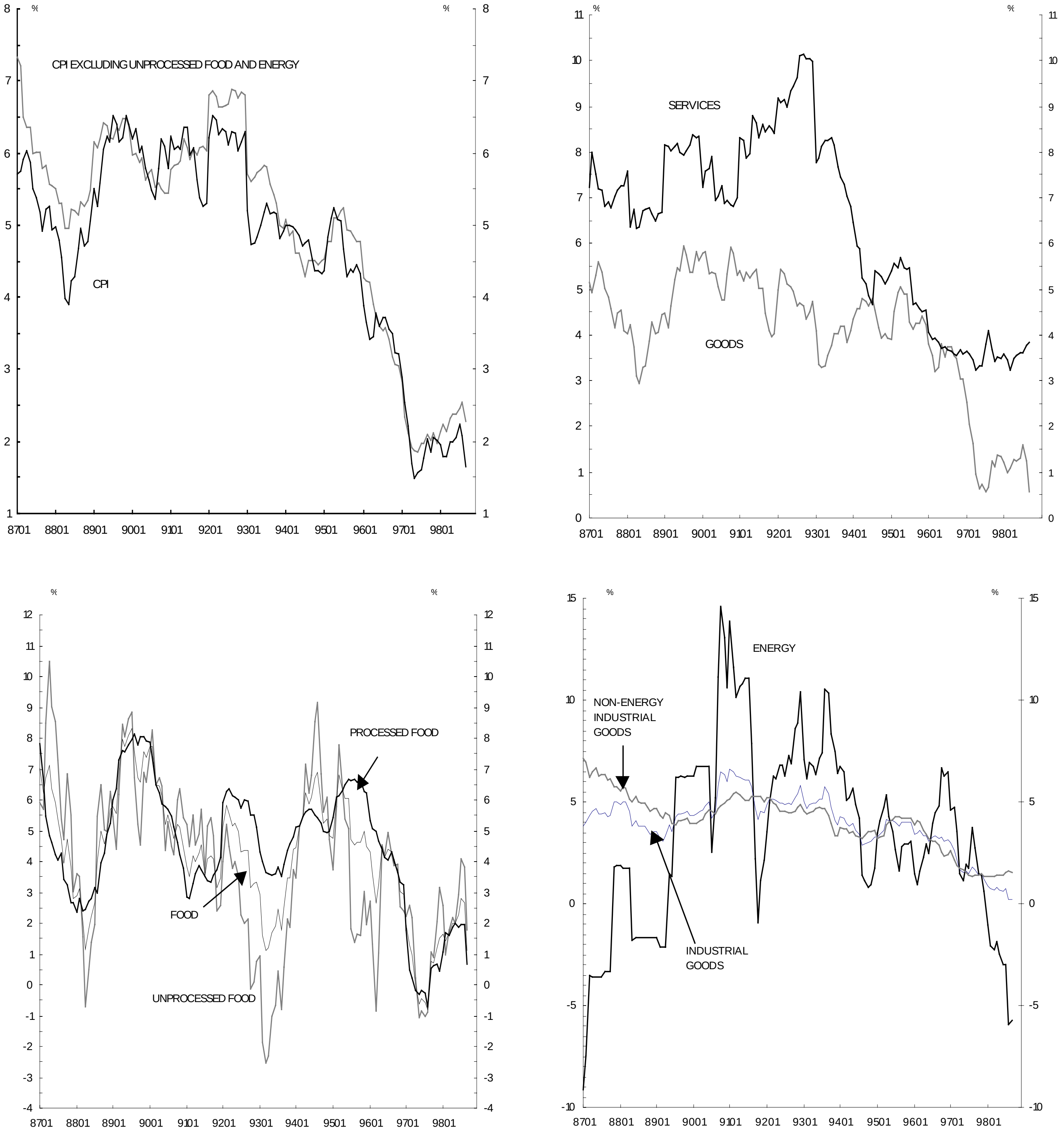


TABLE 2. VOLATILITY IN MAJOR CPI SUB-INDICES (*)

Total	1.42
Goods	1.38
Food	2.03
Unprocessed food	2.73
Processed food	2.07
Industrial goods	1.41
Non-energy industrial goods	1.37
Energy	4.55
Services	1.98
Memo item:	
CPI excluding unprocessed food and energy	1.46

(*) Standard deviation of year-on-year rates
Sample period 1987:1 - 1998:9

TABLE 3. Unexpected volatility in major non-energy CPI subindices

COMPONENT	MEASURE OF VOLATILITY (*)
Unprocessed food	0.96
Processed food	0.18
Non-energy industrial goods	0.13
Services	0.14

(*) Residual standard deviation (multiplied by 100) of ARIMA models with intervention analysis, built on the logarithmic transformation.

The volatility of the unprocessed food index is generally seen as the result of two factors. On the one hand, changes in weather conditions determine changes in the supply of unprocessed food. On the other hand, a relatively low demand elasticity make supply shifts cause relatively large changes in prices. These two reasons justify the exclusion of unprocessed food from the all items CPI to obtain a clearer picture of the inflationary process[3].

A number of authors have recently made a case for the exclusion of all food prices. As regards the Spanish CPI, the intense impact of the 1995 drought on various processed foods (e.g. olive oil and wine) has indeed caused some to wonder whether the entire food component should not be excluded. However, it would probably be going too far to exclude all processed food prices since demand conditions and other input prices, besides those of agricultural products, generally play a non-negligible role in their determination.

The volatility of energy prices is determined by several factors. First, energy prices on international markets fluctuate considerably. Second, imports of energy products are, to a large extent, priced in dollars and the exchange rate of the peseta vis-à-vis the dollar is far from constant. Third, indirect taxes are a major component of energy prices and changes in excise duties generally result in sizeable price changes; and fourth, the energy index has mainly included regulated prices, which are only changed from time to time, but by quite a large extent. This last factor has recently lost some relevance since, following the entry into force of the Hydrocarbons Act, only electricity prices are fully regulated.

As a result of these factors it is not surprising that the energy index remains highly volatile. It may therefore be well to use the CPI ex. unprocessed food and energy as a measure of underlying inflation.

To end the brief discussion of this underlying inflation measure it may be well to present its main advantages and shortcomings. Adjustment by exclusion has the advantage that it increases the transparency and verifiability of the underlying inflation measure by completely pre-specifying its construction. On the contrary, the main criticisms levelled at this type of measure are that temporary disturbances are not necessarily limited to some sub-components, that prior exclusion of specific prices requires the use of non-controversial elements of judgement and, also, that there is a potential risk that significant information will not be taken into account. In any case, it should be stressed that a careful analysis of the inflation process may not be obtained exclusively from this underlying inflation measure.

3. Underlying inflation measures with limited-influence estimators

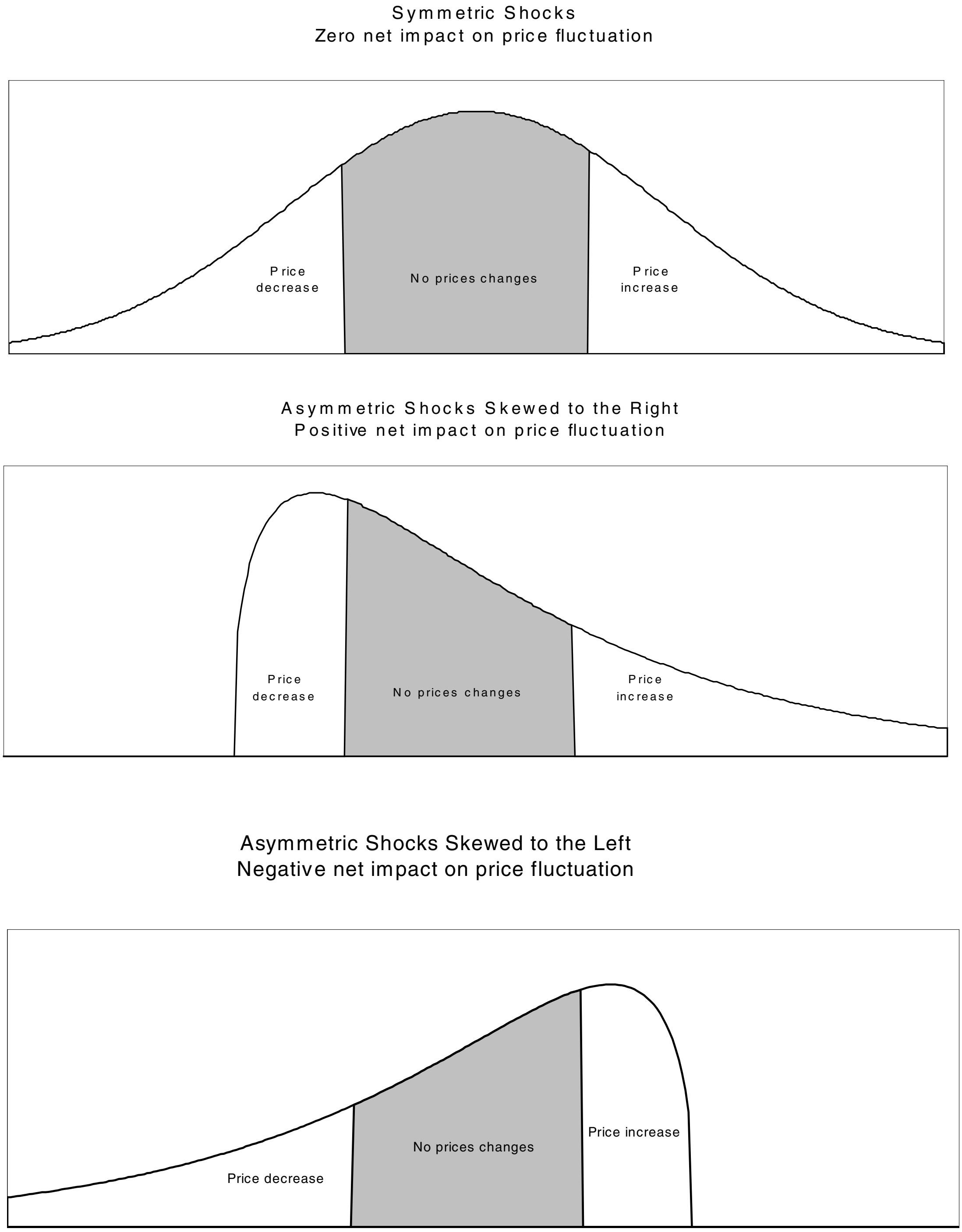
It has been argued that measured CPI is affected by monetary factors but also by changes in relative prices when there is some nominal rigidity. When these changes in relative prices are sizeable and result mainly from transitory supply shocks that are unrelated to the general trend in inflation, it may be advisable to follow Bryan and Cecchetti (1994) and use limited-influence estimators of a measure of the central tendency of the cross-sectional distribution of individual product price changes. Specifically, these authors argue that the weighted median and the trimmed mean should be used, rather than the weighted mean, for computing a measure of underlying inflation. By reducing the weight of extreme values and the distorting influence of shocks, these two statistics may provide a clearer signal of price level changes. The use of these measures reflects the intuition that the types of shocks that may cause problems with price measurement are infrequent but are not concentrated in some sectors of the economy. Compared to the underlying inflation measures obtained by exclusion of sub-components, these limited-influence estimators present the strength of not requiring prior determination of the origin of shocks that have a distorting influence in the measurement of trend inflation.

[3] It should also be borne in mind that some components of the unprocessed food index present methodological differences with the rest of the sub-indices of the CPI. Specifically, in its fresh fruit and vegetables sub-components weighted averages of twelve terms are used.

3.1. Theoretical model

In general terms, Ball and Mankiw's single period model (1995) focuses on the problem of price setting for firms that incur costly price adjustment. Typically, firms do not instantly adjust prices to every change in circumstances; instead, they adjust only if their desired price change is large enough to justify the costs of adjustment ("menu costs"). Therefore, firms have a range of inaction in response to shocks. In this model, shocks that affect relative prices may have an impact on the aggregate price level; this will depend on the distribution of the shocks (see Figure 2). Specifically, if the distribution is symmetric the average effect will be zero, as price increases of some firms will be offset by price cuts made by others. By contrast, if the distribution of shocks is skewed, the aggregate price level will temporarily increase or decrease depending on the importance of firms raising prices relative to those lowering them. In this case, costly price adjustment may result in transitory movements of headline inflation from its long-run trend.

Fig. 2 .



To be more specific we present the version of Bryan and Cecchetti (1994) of Ball and Mankiw's model of price setting. This model takes place in a single period and there is a large number of firms which face the same "menu costs" when adjusting their prices. Besides, money growth $(\dot{m})$ is constant and exogenously determined, velocity of circulation is constant, and trend output growth is normalised to zero. Under these assumptions, at the outset of the period, each firm will decide to increase its price by $\dot{m}$. As a result, aggregate inflation in this model will equal monetary inflation. Therefore, in this case, core or underlying inflation (π^c) may be defined as:

$$\pi^c = \dot{m}$$

Following this initial price-setting exercise, each firm (i) experiences a shock to (ε_i) either its product demand or its production costs. In general, however, the distribution of shocks across firms may have any shape. After the shock is realised only firms for which ε_i in absolute value exceeds the "menu cost" will adjust their price. For these firms, the growth rate of prices π_i will be:

$$\pi_i = \dot{m} + \varepsilon_i$$

If it is also assumed that the level $(\bar{\varepsilon})$ at which firms decide to adjust their prices is the same, then the observed inflation rate will be:

$$\pi^o = \dot{m} + \sum_{i=1}^{n} \left[\frac{\varepsilon_i}{|\varepsilon_i| - \bar{\varepsilon}} \; max(|\varepsilon_i| - \bar{\varepsilon}, 0) \right]$$

where n is the number of firms in the economy. If the distribution of shocks is symmetrical, the second term of the right hand side of the above equation cancels, but if it is skewed, actual inflation does not match monetary inflation. As the difference between π^o and $\dot{m}$ arises from the tails of the distribution of (ε_i), one way to reduce the impact of shocks on measured inflation is to use limited-influence estimators.

With regard to the theoretical model that is used to motivate the limited-influence estimators Zeldes (1994) points out that changes in relative prices do not have to be necessarily transmitted to aggregate inflation[4]. If this were not the case, then there would be no compelling reason to exclude extreme values. This author also notes that there may be permanent shocks to inflation associated with the existence of skewness in the distribution of relative price changes. However, if skewness were caused by permanent shocks it would clearly be misleading to exclude extreme values to obtain a measure of underlying inflation.

From an statistical point of view, it is well known that a small change in the tails of a distribution may entail a sizeable change in the arithmetic mean, while trimmed means and weighted medians are celebrated estimates of location in situations where the occurrence of outliers is suspected. Robustness arguments favour medians over trimmed means. However, under certain assumptions[5], heavily trimmed means have smaller asymptotic variance and hence are superior to medians. Therefore, from a statistical point of view, neither estimator is clearly preferable. This consideration suggests that both measures should be examined.

3.2. Estimates

[4] In classical economic theory, the price level is determined by the money supply and changes in supply and demand for various products affect not the price level, but relative prices.

[5] See Oosterhoff (1994)

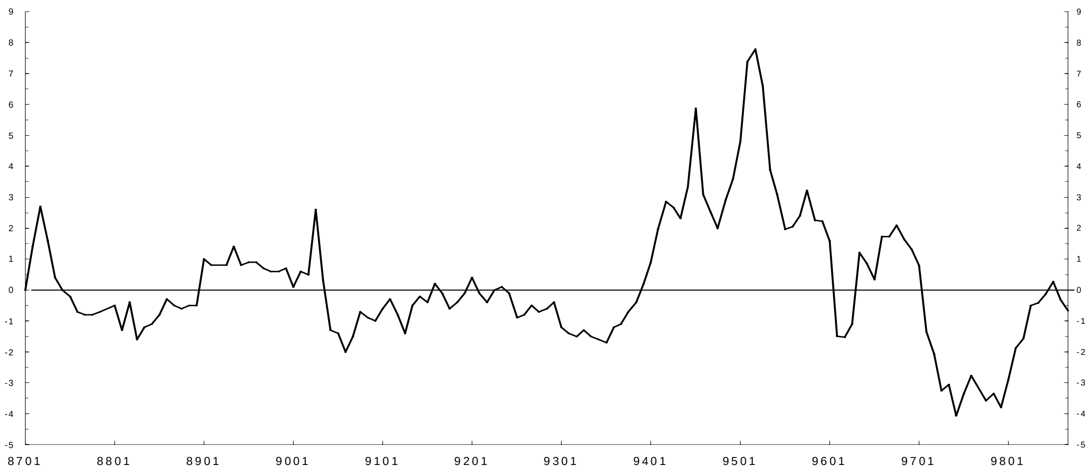
Disaggregated consumer price data for Spain were used to construct these types of underlying inflation measures. Specifically, the sub-indices[6] of the CPI were considered for calculating the weighted median and the trimmed mean. To minimise the effect of seasonality on the cross-sectional distribution, we follow Matea (1994a) and use year-on-year rates[7]. As each of the sub-indices includes the prices of various goods and services, we assume that the weight[8] of each sub-index in the CPI basket represents the percentage of the distribution of all prices that experiences that price change. To calculate the weighted median at a given time, the year-on-year rates of the individual sub-indices are multiplied by their weights and the resulting figures are then ordered from small to large; then the central point in the cross-sectional histogram is chosen. The trimmed mean is obtained by excluding a chosen proportion of unusually large and small price changes before the average is computed.

To determine whether or not the cross-sectional distribution of the CPI sub-indices' year-on-year rates is symmetrical, the skewness coefficient was computed[9]. As can be seen in Figure 3, skewness has changed considerably over time, and in some periods it is quite important. This suggests the usefulness of considering limited-influence estimators.

To select the size of the trimmed mean, 5%, 10% and 15% trimmed means were considered. Finally, a 5% trimmed mean was chosen (see Figure 4) as the resulting time-series showed the smallest variance. This result differs from that of Bryan and Cecchetti (1994) for the CPI of the United States , as they obtain a series with minimum variance with a 15% trimmed mean (see also Table 4 for further evidence). In any case, with the three alternatives considered for the Spanish CPI, very similar time-series were obtained. Also, as one would expect, the volatility of this underlying inflation measure is lower than that of headline CPI.

SKEWNESS COEFFICIENT OF THE CROSS-SECTIONAL YEAR-ON-YEAR CPI RATES DISTRIBUTION

Fig. 3



[6] Bryan and Cecchetti (1994) used 36 components of the U.S. CPI. Here these 156 indices resulted from crossing the two types of breakdown by sub-indices used by the INE [National Statistics Institute]. Thus, in each case, the classification that produces most disaggregation was used.

[7] Bryan and Ceccheti (1994) employ seasonally adjusted series. However, this has the disadvantage that including fresh data involves recomputing limited influence estimators for the whole sample period.

[8] Note, however, that if fixed weights are used, then, in general, the 0% trimmed mean of the cross-sectional year-on-year rates is not equal to the year-on-year rate of headline inflation. This is so because the (fixed-weight) weighted average of year-on-year rates does not equal the year-on-year rate of the (fixed-weight) weighted average. Since it seems advisable that the 0% trimmed mean and the year-on-year rate be equal, we have used variable weights. These weights correspond to the share of each sub-index in the CPI level twelve months ago. These shares will only equal the fixed weights if all prices grow by exactly the same amount every month.

[9] A distribution is symmetrical when this coefficient is zero, whereas if it is positive (negative), the area on the right-hand (left-hand) side of the distribution is greater than that on the left-hand (right-hand) side.

Fig. 4

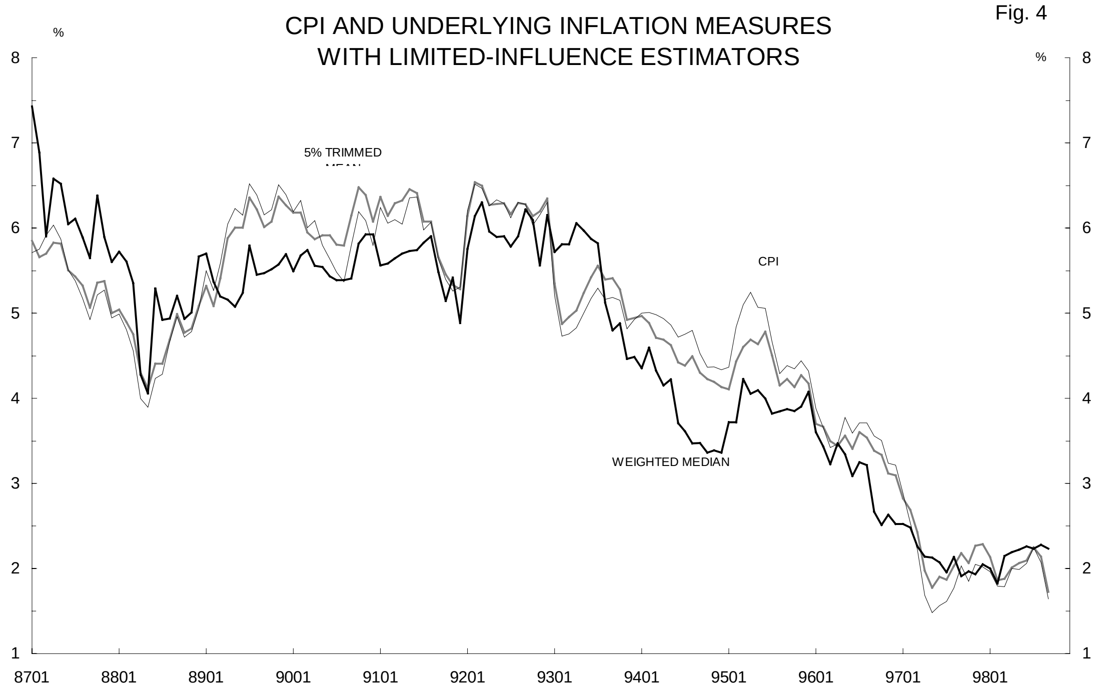


TABLE 4. – Underlying inflation with Limited-Influence Estimators	
Central Bank or Paper	**Underlying inflation measure**
Bank of England	- RPY 15% trimmed mean - RPIY weighted median
Sveriges Riksbank	- CPI 15% trimmed mean - CPI weighted median
Banco de España	- CPI 5% trimmed mean - CPI weighted median
Banca d'Italia	- CPI 20% trimmed mean
Bryan and Cecchetti (1994)	- CPI 15% trimmed mean - CPI weighted median
Cecchetti (1996)	- CPI 10% trimmed mean - CPI 25% trimmed mean - CPI weighted median
Mayes and Chapple (1995)	- CPI weighted median
Roger (1995)	- PXIG 10% trimmed mean - PXIG weighted median
Shiratsuka (1997)	- CPI 15% trimmed mean

Sources: For Central Banks: Spain (Banco de España), other EU countries (Ravnkilde Erichsen and van Riet [1995])

In analysing the 5% trimmed mean, no sub-index fails to be covered in the whole sample period under consideration. On the basis of this, it could be argued that there should be no prior exclusion of any sub-index, to say nothing of any of the 5 major components of the CPI. Even so, an examination of sub-indices grouped under the major sub-components shows that all those comprising the unprocessed food index were at some time in the tails of the distribution (see Table 5). By contrast, in the period under consideration, 28% of the sub-indices of the energy index, 31% of the processed food index, 36% of the services index, and 58% of the non-energy industrial goods index have always been considered in the trimmed mean. This result tallies with the exclusion of the unprocessed food index and, to a lesser extent, the energy index, i.e. the use of the CPI excluding unprocessed food and energy as a measure of underlying inflation.

TABLE 5. - Proportion of major subcomponents components always used in computing the 5% trimmed mean

COMPONENT	WEIGHT WITHIN MAJOR SUBCOMPONENTS OF THE SUB-INDICES ALWAYS INCLUDED IN THE 5% TRIMMED MEAN
Unprocessed food	0
Processed food	30.6
Non-energy industrial goods	58.0
Energy	28.2
Services	36.3

Note: Sample period: January 1987 to September 1998.

The five major sub-components of the CPI are captured in the weighted median. If, a comparison is made with the CPI, then we generally find that the weighted median shows markedly lower rates than the CPI. This clearly shows how substantial sector-specific price increases have affected the CPI. On the other hand, the weighted median shows substantial volatility; a feature that without additional treatment, could complicate an accurate analysis of the inflationary process.

To conclude, limited-influence estimators present a drawback as a result of the presence of goods and services whose prices do not change often and not always in the same month of the year. This causes the rate of change of these prices to be zero in some months and to be quite high in others. It is therefore not surprising that they are found in the tails of the cross-sectional distribution and, in practice, are commonly not taken into account in these measures of underlying inflation. For example, at the beginning of the sample period a sizeable portion of energy items, which had a regulated price, are usually excluded by a trimmed mean.

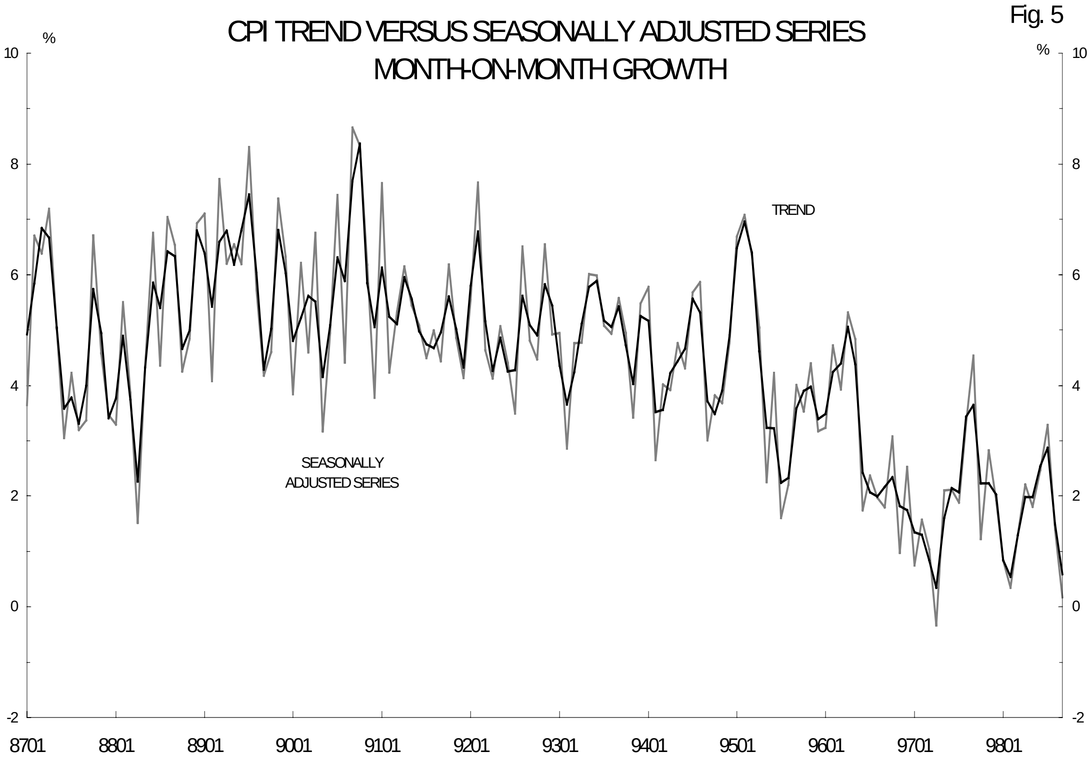
4. Underlying inflation by smoothing

Statistical signal extraction techniques have been used by economists to break down a time-series into its trend[10], seasonal and irregular components. Nonetheless, for monetary policy, it is particularly important to know whether price changes are transitory or, more importantly, whether they have a permanent nature. Consequently, since seasonal effects are cancelled out within a year and irregular movements disappear even sooner, it is the trend component which is crucial in the analysis of inflation[11]. Furthermore, as can be seen in Figure 5, the trend component fluctuates considerably less than the seasonally adjusted series.

[10] As a trend is a unobservable component, it has no single definition. Indeed, the concept used in this section is univariate whereas the ones employed in section 5 are multivariate.

[11] Since a seasonally adjusted series may be seen as a trend contaminated by noise, it is conceptually hard to find a convincing argument to base a descriptive analysis of inflation on a seasonally adjusted series.

Fig. 5



Note: Month-on-month inflation for January 1992 is adjusted for the impact of VAT changes

In the literature, several signal extraction techniques have been proposed, probably the most popular ones being X11-ARIMA, ARIMA model based procedures[12]and those based on structural time series models. Matea and Regil (1994) applied these different techniques to the Spanish CPI and found that they resulted in highly similar trend components. However, since seasonal factors seemed to be slightly better estimated with an ARIMA model based procedure, we will use here the program SEATS [see Gómez and Maravall (1998a)].

Our preferred underlying inflation measure by smoothing, in the case in which inflation is appropriately characterised by a purely stochastic process, will be defined as the centred year-on-year growth rate[13] of the trend of a price index. Centring a rate is necessary if it is deemed desirable to synchronise it with month-on-month growth[14]. It is often the case, however, that deterministic and stochastic elements are thought to be present in the series under study. Although several techniques exist to decompose a series into its deterministic and stochastic components, we will focus our discussion on ARIMA models with intervention analysis and their associated model-based signal extraction technique. Those models may be identified and estimated for all the major subindices of the CPI[15] and enable a breakdown into stochastic components (associated with the ARIMA models) and deterministic components (associated with intervention analysis). Correspondingly, unobservable components (e.g. trends), which may be estimated by using an ARIMA model-based signal extraction procedure,

[12] Note that this technique does not require to specify beforehand a particular functional form for the trend. Readers interested in this method may see Appendix A and Gómez and Maravall (1998b).

[13] A rate of change calculates growth between two periods. Centering consists in assigning said growth to the intermediate point in the period of time under consideration. As a consequence, when computing a centered rate for the most recent data either some information is lost or forecasts are required. The interest of policymakers in the most recent information makes the use of forecasts desirable.

[14] In other words, so that the maxima and minima of the year-on-year rate match those of month-on-month growth.

[15] The energy index may be an exception. This is due to the fact that these prices have been regulated during most of the sample period.

may have stochastic and deterministic elements. Specifically, the trend must not only capture the stochastic trend, but also those deterministic elements (interventions) with a permanent nature. As has been mentioned above, a growth rate on a stochastic trend should be centred. However, use of a centred growth rate on a series that has a deterministic component associated with the trend (e.g. the effect of VAT changes on the price level) would imply dating the exceptional event before it actually occurs. Therefore, the growth rate on permanent deterministic components should not be centred. Specifically, the following equation[16] may be used to obtain a measure of underlying inflation:

$$UIS_t = T^1_{12}(ST_t)^C + \left[\frac{1}{100}T^1_{12}(ST_t)^C + 1\right]T^1_{12}(PI_t)^{NC}$$

$$T^1_{12}(X_t)^C = \left[\frac{X_{t+6} - X_{t-6}}{X_{t-6}}\right]100 \qquad T^1_{12}(X_t)^{NC} = \left[\frac{X_t - X_{t-12}}{X_{t-12}}\right]100$$

Where UIS_t is the underlying inflation measure by smoothing, ST_t is the stochastic trend, PI_t is the effect of permanent interventions, T^1_{12} denotes year-on-year growth and superscripts C and NC indicate, respectively, whether the rate is centred or not.

A possible approximation to the year-on-year rate of the stochastic trend may be obtained by using a rate of growth on the series adjusted for intervention analysis. In this case a considerable simplification in the calculation of the measure is obtained. The rationale behind this approximation is based on the fact that the optimal estimator of the trend component involves the use of a centred weighted moving average (a two-sided filter). In practice, a growth rate on the original series adjusted for intervention analysis averaging a large enough number of observations may be a satisfactory approximation.

In particular, as can be seen in Álvarez and Matea (1997) for all the major CPI sub-indices, with the exception of unprocessed food[17], the centred T^3_{12} provides a very good approximation to the year-on-year rate of the stochastic trend[18]. However, rather than adopt a different rate for each CPI sub-component it is simpler to use a single growth rate. Therefore, we use the centred T^3_{12} for all major sub-components[19].

As a result, a measure of underlying inflation by smoothing may be approximated on the basis of the following equation:

$$UIS_t \cong T^3_{12}(SAI_t)^c + \left[\frac{1}{100}T^3_{12}(SAI_t)^C + 1\right]T^1_{12}(PI_t)^{NC}$$

$$T^{l3}_{12}(X_t)^C = \left[\frac{X_{t+7} + X_{t+6} + X_{t+5}) - (X_{t-5} + X_{t-6} + X_{t-7})}{(X_{t-5} + X_{1-6} + X_{1-7})}\right]100$$

[16] See Espasa and Cancelo (1993).

[17] For this component, due to its larger variability, a longer moving average is required. Note, however, that the validity of this approximation may be too country-specific. For other countries, there may not be a satisfactory approximation or the one valid may differ from the one used in Spain.

[18] The uncentered T^3_{12} represents the growth of the average of three consecutive months vis-à-vis the average of the same three months in the previous year. The centered T^3_{12} rate assigns said growth to the intermediate point in the period of time employed to compute the rate.

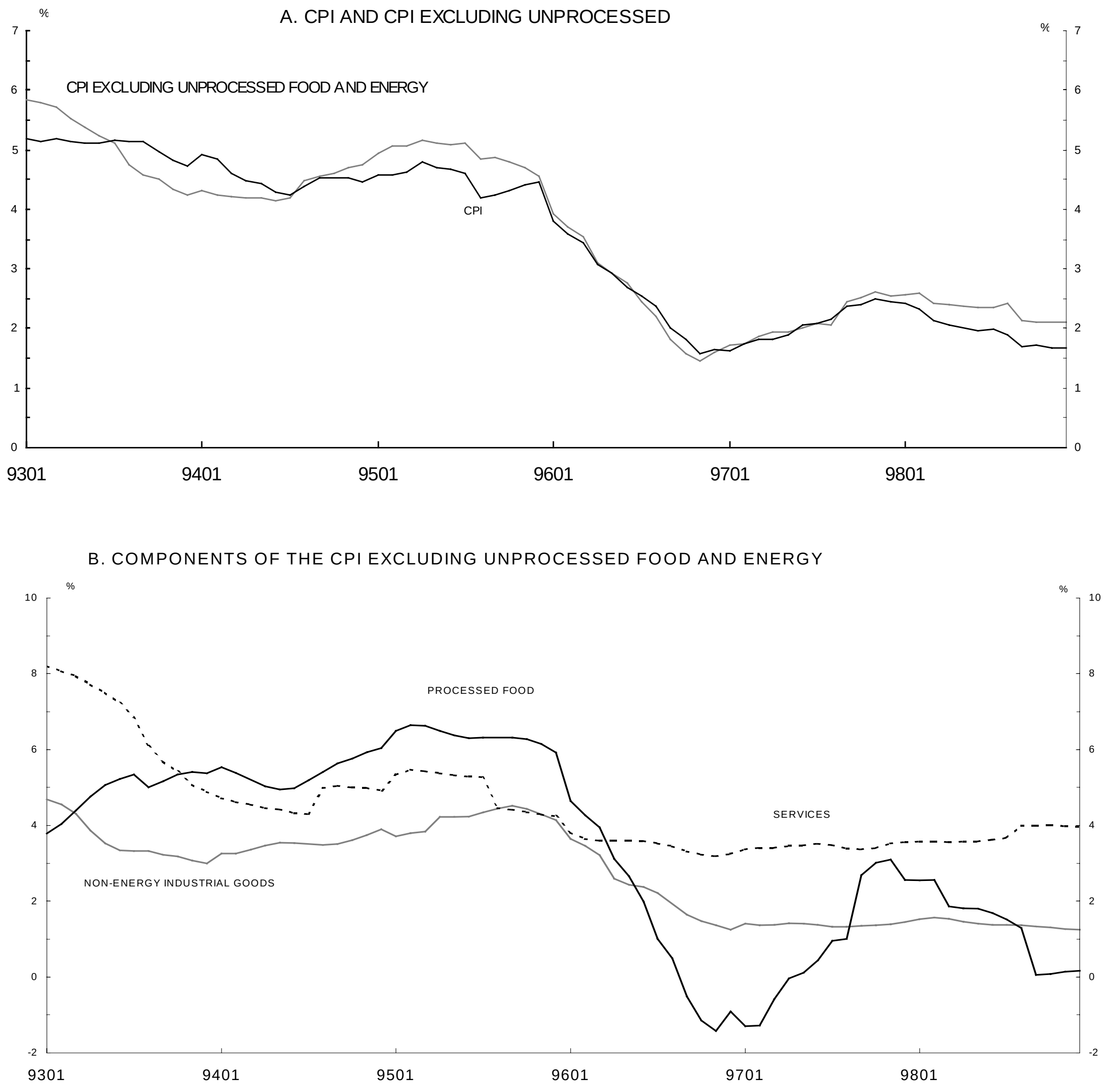
[19] This rate has the advantage of requiring at most 7 forecasts. Other rates involving longer moving averages require more forecasts, so that revisions in the measure will be more important at the end of the sample.

where SAI_t is the original series adjusted for all interventions.

Figure 6 depicts the measure of underlying inflation for the headline CPI, the CPI excluding food and energy and the major CPI components obtained using the approximation described above.

UNDERLYING INFLATION BY SMOOTHING

Fig. 6



Although the procedure outlined above is suitable for series with an important stochastic component, indices with regulated prices present a complication stemming from the fact that such prices rather than evolving smoothly change suddenly at specific times. In view of this peculiarity, which was especially notable in the energy index, a case has been made for estimating its underlying rate using the year-on-year rate of the original series.

With this underlying inflation measure, forecasts are required for the last observations. Therefore, as fresh data are released the measure is accordingly revised.

To conclude, it should be noted that the underlying inflation by smoothing measure involves greater complexity than the simple exclusion of some components. Moreover, being a model-based approach, different authors may obtain different underlying inflation estimates of this type by not considering the same deterministic elements in the CPI, by using different statistical techniques to estimate the trend or by considering a different sample period. However, it should be borne in mind that complexity and possible differences among researchers simply reflect the flexibility of the approach and the possible lack of agreement among econometricians. On the other hand, this approach eliminates transitory elements and yields a satisfactory way of analysing inflation trends.

5. Underlying inflation measures with multivariate models

As outlined above, we have been examining various measures of underlying inflation, either by excluding specific index components, as in the case of measures of underlying inflation by exclusion (see section 2) and limited-influence estimators (see section 3) or by smoothing (see section 4). The common denominator of all these approaches is their univariate nature; that is, they are constructed using only the information contained in price series.

Recently, however, some authors (see Table 6) have proposed using supplementary measures obtained from structural vector autoregressive (SVAR) models. These procedures are characterised by the use of restrictions based on propositions set forth by economic theory with regard to the long-run behaviour of several variables and, also, by their multivariate nature. This means that in determining the measures of underlying inflation they take into account information that supplements price series data (e.g. that contained in real activity or in a given monetary aggregate).

Specifically, two procedures are examined in this section which, even though they are not without drawbacks, supplement the methods discussed above. These approaches are consistent with a monetary view of inflation in the long run and meet the generally accepted
condition that the long-run Phillips curve is vertical, i.e. that there is no long-run trade-off between output and inflation, so that changes in nominal magnitudes do not have real effects in the long run. However, these approaches also permit an economy to be hit by shocks in the short run which, depending on their origin and duration, may affect both the cyclical component and the trend of inflation and output. Thus, two alternative measures of underlying inflation are obtained based on a structural dynamic model of inflation and output: permanent inflation and core inflation.

Permanent inflation captures the impact of disturbances which in the long run determine inflation. Assuming rationality, these shocks are incorporated in the expectations of economic agents and are therefore the driving force that determines the growth rate of nominal variables.

Core inflation[20] captures the impact on inflation of shocks which do not have a long-run effect on output. Although, no long-run inflation rate[21] can be obtained directly using this technique, a highly relevant by-product that is obtained is an estimate of the economy's trend output and, as a residual, an estimate of the output gap[22].

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[20] Quah and Vahey (1995) first proposed this measure.

[21] From a theoretical standpoint, core inflation cannot strictly be interpreted as long-run inflation, as not all transitory shocks on real output are necessarily transmitted to inflation. Strictly speaking, this measure considers not only permanent demand shocks, but also shocks associated with the business cycle. However, as is shown further on, permanent and core inflation closely resemble each other in the Spanish economy. As a result, it would seem proper in practice to interpret core inflation as long-run inflation.

[22] This measure is discussed in Álvarez and Sebastián (1998).

TABLE 6.- Literature on multivariate measures of underlying inflation

PAPER	COUNTRY COVERED	VARIABLES USED	MEASURE OF UNDERLYING INFLATION
Álvarez and Sebastián (1995)	Spain	Consumer prices Gross Domestic Product	1. Inflation with all disturbances having a temporary effect eliminated (permanent inflation) 2. Inflation with all disturbances having a permanent effect on output eliminated (core inflation) [Quah and Vahey (1995) core inflation]
Claus (1997)	United States	Consumer prices Capacity utilisation Producer prices Import prices	Permanent Inflation
Dias and Pinheiro (1995)	Portugal	Consumer prices Indicator of economic activity	Quah and Vahey (1995) core inflation
Gartner and Wehinger (1998)	Austria, Belgium, Germany, Finland, France, Italy, the Netherlands, Sweden, United Kingdom	Consumer prices Gross Domestic Product Short term interest rate	Quah and Vahey (1995) Core inflation
Fase and Folkertsma (1997)	The Netherlands, "European Union"	Consumer prices Output of production industries, excluding construction	Quah and Vahey (1995) core inflation
Fisher, Fackler and Orden (1995)	New Zealand	Consumer prices Gross Domestic Product Money	"Monetary" inflation
Jacquinot (1998)	France, Germany, United Kingdom	Consumer prices Industrial production	Quah and Vahey (1995) core inflation
Quah and Vahey (1995)	United Kingdon	Consumer prices Industrial output	Inflation with all disturbances having a permanent effect on output eliminated (core inflation)
Roberts (1993)	United States	GDP deflator Unemployment rate Velocity of circulation	"Monetary" inflation

It should be pointed out that the structural interpretation of the shocks that permit identification of these underlying inflation measures is not straightforward. Specifically, it is not possible to distinguish directly between supply shocks and demand shocks. The permanent inflation procedure distinguishes between disturbances according to their long-run effect on inflation. However, disturbances that affect inflation in the long run may arise from both aggregate demand (e.g. changes in the growth rate of the money supply) and the supply side (e.g. changes in the trend growth of the economy). By contrast, the core inflation procedure distinguishes among shocks on the basis of their long-run impact on output. However, shocks which do not have a long run impact on output may arise from both the demand side (e.g. monetary disturbances) and the supply side (e.g. transitory technological shocks). A comparison of the two measures of permanent core and inflation with observed inflation nevertheless facilitates an interpretation of the type of shocks predominant in the economy.

In any case, these measures, like any others seeking to approximate a phenomenon as complex as the inflation process, must be assessed and interpreted with due prudence and caution. The approaches discussed in this section are also limited by their initial assumption that there are only two types of disturbances that affect inflation and output. Actually, it seems likely that there are many sources of shocks and that some of them have differential effects on the economy. Therefore interpretations must be made in terms of the effect of groups of shocks. However, on the basis of the estimated transmission mechanisms hypotheses may be advanced as to the nature of the shocks. Moreover, these measures are constructed on the basis of changes in inflation, so that an additional hypothesis is needed to recover their level.

5.1. Permanent inflation

The unrestricted VAR model, common to both permanent and core inflation estimates, uses a sample period that is long enough. Since our identification schemes are based on long-run restrictions, we require enough data to plausibly claim that we can estimate long-run phenomena. Specifically, we begin in the first quarter of 1970 and end in the third quarter of 1998[23]. Four lags for each of the variables are used[24]. As deterministic variables, in addition to a constant term, it must be borne in mind that the GDP growth rate series shows different means across subsamples. Thus, breaks are included in the mean during the first quarter of 1976 and the last quarters of 1984 and 1991.

To obtain the structural shocks and transmission mechanisms (impulse response functions) that provide the basis for these measures of underlying inflation, the identification procedure first proposed by Blanchard and Quah (1989) is used. These authors decompose output movements into permanent and transitory components. One of our structural models also breaks down output movements into permanent and transitory components, although our main interest is the effect of these shocks on inflation. The other model performs a similar decomposition for inflation. The method[25] involves the use of long-run identification restrictions in a VAR model which captures the main interactions between inflation and output.

[23] In Álvarez and Sebastián (1995) the sample period ends in the fourth quarter of 1993. Results are almost identical to the ones discussed here.

[24] Four lags adequately cover the dynamics of the process. Using five lags does not practically change the results.

[25] This method is outlined in Appendix B.

It should be pointed out that the long-run identification used in studies of this kind involves no specific assumption with regard to the short-run transmission mechanism. Therefore, in order to give an economic interpretation of structural shocks, and as an informal test, not only must transmission mechanisms associated with each shock be examined; it must also be checked whether the signs and time patterns of the responses are in line with the interpretation being made.

Two types of shocks are identified for permanent inflation (see Table 7) and defined on the basis of their long-run effect on inflation. These disturbances and their transmission mechanisms may be obtained using the procedure outlined in Appendix B. Once these are known, the inflation rate (π_t) may be broken down into the sum of two terms: permanent inflation (π_t^p) and transitory inflation (π_t^t).

$$\pi_t = \pi_t^p + \pi_t^t$$

An analysis of the transmission mechanism of shocks associated with permanent changes in inflation (which determine π_t^p) shows that they have a positive but relatively mild impact on real activity. Such effect is significant in the short run, but not in the long run, so that long-run superneutrality would hold. This would be consistent with nominal disturbances having a short-run expansionary effect on activity but unable to modify potential output. On the other hand, the effect on real output of disturbances having no long-run effect on inflation (which determine π_t^t) is also positive but much larger. These disturbances may be associated with technological shocks by their positive and permanent effect on output.

TABLE 7. - Identification schemes used to obtain the measures of permanent inflation and latent inflation

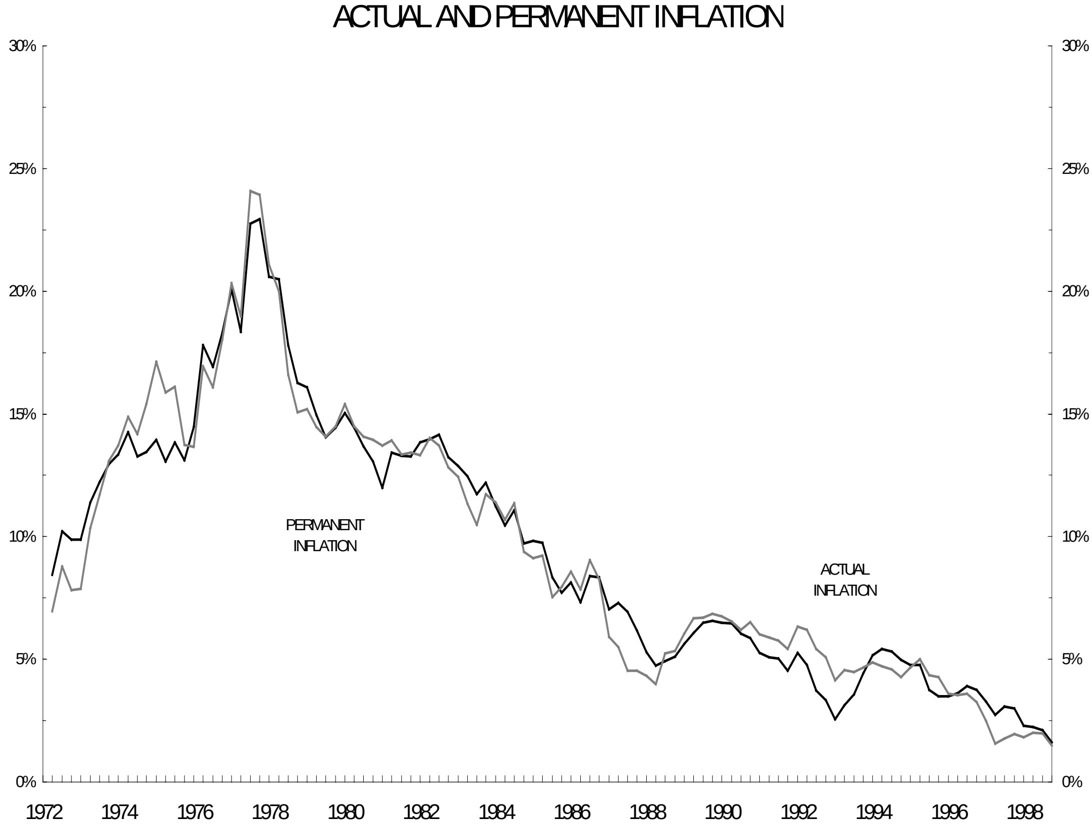
SCHEME 1	INFLATION	OUTPUT
Disturbances NOT having a long run effect on inflation (Identification restriction)	–	–
Disturbances HAVING a long run effect on inflation	Permanent inflation	
SCHEME 2		
Disturbances NOT having a long run effect on output (Identification restriction)	Core inflation	Business cycle
Disturbances HAVING a long run effect on output	–	Trend or potential output

By contrast, when inflation is examined, shocks that permanently affect it are, logically, more important than those having a transitory effect. Moreover, what we identified as technological shocks have a transitory downward impact on inflation. Thus, they do not affect the potential growth rate[26].

Using the methodology outlined in Appendix B, it is also possible to obtain an estimate of permanent inflation. Two separate considerations must be borne in mind when analysing this series. First, the difference between actual inflation and permanent inflation, and second, the time path of permanent inflation. The first

[26] In fact, considering output as an I(1) variable rules out the possibility of shocks with a long-run effect on the growth rate of output.

Fig. 7



factor may be controversial as the level of permanent inflation is not identified and requires an additional hypothesis[27]. However, the second factor is independent of such an assumption. Therefore, in the economic assessment of this measure, prime consideration should be given to whether permanent inflation is actually speeding up or slowing down, and not whether it is above or below actual inflation[28].

As may be seen in Figure 7, except for very specific periods, the time path of permanent inflation is generally similar to that of actual inflation. This result squares with the fact that, in relative terms, transitory shocks have a less important effect on inflation, so that inflation is dominated by its trend component.

In turn, the time path of the estimated permanent inflation series shows the effect of permanent disturbances in both demand (e.g. monetary disturbances) and supply, which are reflected in changes in the long-run inflation rate. It also bears noting that transitory inflation, even when not very great, is procyclical and lagged, which may be interpreted as reflecting the presence of demand shocks having transitory effects on inflation and output.

5.2. Core inflation

For core inflation, the two types of structural shocks are defined according to their long-run effect on real activity. The first type does not have a long-run effect on output, although it affects actual inflation. The

[27] The number of possible hypotheses is, theoretically, unlimited. In this paper, we use the hypothesis that the sum of deviations between both rates of inflation is zero. The rationale of using this assumption is that, by definition, deviations of the actual inflation rate from permanent inflation can only be temporary.

[28] This line of reasoning is also valid for core inflation.

second type affects the long-run trend of output, but not core inflation. Using again the method outlined in Appendix B, measured inflation may be, alternatively, broken down into the sum of core inflation (π_t^c) and non-core inflation (π_t^n). Core inflation is defined as the contribution to inflation of shocks which have no long-run effect on the level of output and is the time path of inflation that would have obtained in the absence of permanent shocks on real activity.

$$\pi = \pi_t^c + \pi_t^n$$

An analysis of the transmission mechanisms shows that disturbances which do not affect real activity in the long-run (which determine (π_t^c) do have a significant short-run impact on output, although it is quantitatively small. The transitory nature of the effect of these shocks on output and its explanatory power on real activity make it possible to associate these shocks with the business cycle. However, the impact of disturbances having a long run effect on output (which determine $\pi_t^n)$ is considerably larger. The permanent effect of these shocks is due to the fact that output is a non-stationary series and, by the identification restriction, the other shocks have a temporary effect on output. The considerable explanatory power of these disturbances on output is such that they may be associated with technological changes that permanently affect factor productivity or with increases in the use of productive factors.

Temporary shocks on output (which determine $\pi_t^c)$ have a powerful effect on inflation. Ninety-two percent of the variance of the one-year-and-a-half forecast error is due to these shocks, which suggests that they are ultimately responsible for changes in measured inflation. This result is consistent with its characterisation as a measure of underlying inflation and also with the results discussed in section 5.1. On the other hand, shocks with permanent effects on real activity also have permanent effects on inflation. Nevertheless, their explanatory power is considerably lower.

A further application of the methodology set out in Appendix B yields[29] the core inflation series depicted in Figure 8. Just as before in the case of permanent inflation, core inflation represents the major portion of the reported inflation rate during this period. The similarity of changes in core inflation to those of actual inflation indicates that inflation dynamics in Spain has shown an inertial behaviour minimally determined by disturbances having a permanent effect on the level of output.

ACTUAL AND CORE INFLATION

Fig. 8

[29] The assumption used in determining the level is more controversial inasmuch as, a priori, the fact that core inflation deviations from the actual inflation rate must just be transitory is not explained.

As discussed above, core inflation reflects the impact of shocks without a long-run effect on the level of output. In other words, this is the component of inflation which is determined by permanent demand shocks and the business cycle[30].

Non-core inflation is determined by shocks which have a permanent effect on the level of output. These may be technological or be determined by public or private investment decisions which affect the level of output through the accumulation of capital.

5.3. Comparison of results: the determinants of inflation

Starting from the above results, the determinants of inflation may be interpreted on the basis of two elements: first, a comparison of permanent and core inflation and second, a comparison of the time path of these measures of underlying inflation with that of actual inflation.

As mentioned above, permanent inflation is caused by permanent changes in the growth rate of monetary aggregates or technological factors which change the growth potential. Furthermore, core inflation develops on the basis of shocks to the growth rate of monetary aggregates, and business cycle shocks, which do not have a long-term effect on the level of output.

Therefore, if changes in the rate of core inflation resemble those of actual inflation, inflation is mainly determined by shocks that have no long-run effect on real activity. In turn, if changes in permanent inflation resemble those of actual inflation, transitory factors play a relatively minor role.

Moreover, if both underlying inflation measures are similar, it seems reasonable to believe that, on average, inflation in the chosen sample period was dominated by shocks that have a permanent effect on inflation and do not affect long-run output (e.g. permanent changes in the growth rate of monetary aggregates). On the other hand, the difference between the two measures provides information on the shocks specific to each of the concepts: i.e. as regards core inflation, temporary technological shocks, and, as regards permanent inflation, shocks with a permanent effect on the potential growth rate.

As can be seen in Figures 7 and 8 the time paths of permanent inflation and core inflation are quite similar; nor do they differ excessively from actual inflation, except at specific times. The similarity of the two measures of underlying inflation therefore indicates that permanent nominal shocks have played a key role in determining the path of inflation in the Spanish economy.

6. Conclusions

Direct use of the actual inflation rate in the analysis of the inflation process may be problematic, owing to the fact that inflation is contaminated by transitory factors, which obscure its true state. With a view to avoiding, or at least reducing, this shortcoming, the literature has developed various measures for capturing the most permanent signals of the inflation process. In this paper, we have examined various procedures in their application to the Spanish economy.

First of all, we discus the standard measure of underlying inflation by exclusion which is obtained by excluding from the CPI its two most variable components: the unprocessed food and energy indices. Alternative measures have recently been proposed that attempt to overcome some of the inadequacies of the standard underlying inflation measure. Thus, with limited-influence estimators (i.e. trimmed means and weighted medians), rather than always excluding the prices of the same articles, sub-indices are excluded if they exhibit outlying price changes. Another possibility would be to obtain an underlying inflation measure by smoothing.

[30] It is therefore not correct to interpret this measure as a cyclically adjusted measure of inflation.

Specifically, a rate of change is applied to the trend component of a price index. However, it may be better to calculate it on the basis of a sub-component of the CPI, rather than on the CPI itself. Specifically, its calculation on the basis of the CPI excluding its most volatile components may be informative. However, if large price changes in some periods originate in sectors whose prices are generally relatively stable, it may be better to use limited-influence estimators. Finally, we have also presented, using a multivariate perspective, a permanent inflation measure, which shows the explanatory power of shocks having a long-run effect on inflation, and a core inflation measure, which is determined by the effect on inflation of shocks that do not have a long-run effect on output. Besides providing underlying inflation measures, the joint examination of these multivariate approaches permits a reading of the economic determinants of inflation.

In any case, as all these measures have advantages and disadvantages (see Table 8) and none of them takes priority over the rest, it is well to examine them all in order to obtain a more reliable description of the state of inflation. While time-specific circumstances may make it advisable to focus on one of them in particular, it is nevertheless true that diagnosis of the inflation process gains in solidity insofar as they all convey the same message.

TABLE 8. - Main advantages and limitations of the various underlying inflation measures

MEASURE OF UNDERLYING INFLATION	ADVANTAGES	LIMITATIONS
Underlying inflation by exclusion	. Readily understandable . Easy to compute . No need for long time series	. A prior decision must be made as to articles whose prices should be excluded
Trimmed mean	. No need for a prior decision as to articles whose prices should be excluded . Easy to compute . No need for long time series	. Choice of where to trim the tails of the cross-sectional distribution
Weighted median	. No need for a prior decision as to articles whose prices should be excluded . Easy to compute . No need for long time series	. Fluctuates excessively in practice
Underlying inflation by smoothing	. Gives a clear signal of the trend of inflation	. Potential differences in the assessment of outliers and in the estimation of the trend
Permanent inflation	. Consistent with a widely accepted economic theory (vertical long run Phillips curve) . Multivariate nature	. An additional hypothesis required to determine its level
Core inflation	. Consistent with a widely accepted economic theory (vertical long run Phillips curve) . Multivariate nature	. An additional hypothesis required to determine its level

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APPENDIX A

Signal extraction with reduced-form models

In signal extraction by reduced-form models, the unobserved components of a series are constructed from the roots of the ARIMA model which best fits that series, assuming that these components, in turn, follow ARIMA processes. However, not all ARIMA models can be decomposed in this way. For example, an airline process where θ_{12} is not positive or very close to zero[31] is not permissible. Moreover, to be able to go from the ARIMA model to models of its components, certain restrictions must be imposed, which are set out below.

Suppose that series X_t follows a process of the type:

$$\phi(L)\, X_t = \theta(L)\, a_t \qquad \textbf{(A.1)}$$

where $\phi(L)$ may have unit roots and a_t is a white noise process, and it is wished to decompose it into its trend, seasonal and irregular components, i.e.:

$$X_t = T_t + S_t + I_t \qquad \textbf{(A.2)}$$

The roots of the polynomials $\phi(L)$ and $\theta(L)$ shall be assigned to each of these three components, taking into account the cycle of each root and the component to which it theoretically corresponds[32]. For this purpose, it is initially hypothesised that the three components, in turn, follow ARIMA processes of the form:

$$\begin{aligned} \phi_T(L)\, T_t &= \theta_T(L)\, a1_t \\ \phi_S(L)\, S_t &= \theta_S(L)\, a2_t \\ \phi_I(L)\, I_t &= \theta_I(L)\, a3_t \end{aligned} \qquad \textbf{(A.3)}$$

where $a1_t$, $a2_t$ and $a3_t$ are white noise processes independent of each other, and the polynomials of the trend and seasonal components may have unit roots.

In addition, it must hold that:

$$\phi(L) = \phi_T(L)\, \phi_S(L)\, \phi_I(L) \qquad \textbf{(A.4)}$$

without the autoregressive polynomials appearing to the right of the equals sign sharing roots in common.

When each of the roots of the polynomial ϕ (L) has been assigned to the three unobserved components, the restrictions are imposed that the maximum orders of θ_T (L) and θ_s (L) shall not exceed the maximum orders

[31] This result, as demonstrated by Hillmer and Tiao (1982), is common to all ARIMA (0, 1, 1) x $(0, 1, 1)_s$ models, and is, in turn, extendable to ARIMA (0, 0, 1) x $(0, 1, 1)_s$ models. These authors also establish from which values of θ_s, for different s, the ARIMA $(0,1,1)_s$ models are consistent with a decomposition by reduced form models, the sufficient condition being that θ_s >-0.1010.

[32] However, in some situations it may not be clear to which component a particular root corresponds.

of ϕ_T (L) and ϕ_S (L), respectively. Finally, as the system is not identified by these order restrictions only, it is usually required that the variance of the innovation of the irregular component σ^2_{a3} be maximised. This latter condition is called the canonical property, and implies that most of the variability is concentrated in the irregular component, while the other two components are as stable as possible.

When the ARIMA models, including their parameters, have been obtained for the components, a time series needs to be generated for each of them. To do this, the theoretical estimators of the components with minimum average quadratic error are obtained by applying symmetric filters to the original series. The filter for the trend component is:

$$\frac{\sigma^2_{a1}}{\sigma^2_a} \frac{\theta_T(L)\theta_T(F)\phi_S(L)\phi_S(F)\phi_I(L)\phi_I(F)}{\theta(L)\theta(F)} \qquad \textbf{(A.5)}$$

where F is the forward operator, i.e. $F=L^{-1}$.

In practice, it is necessary to apply the above filters (which are characterised by being symmetric and infinite, although convergent) to a finite sample, to obtain the empirical estimators of the components. For this purpose, they are approximated by finite filters, and forecasts are inserted at the ends of the series where values are not known.

APPENDIX B

Econometric methodology of the economic measures of underlying inflation with multivariate models

To obtain the various types of shocks on which the economic measures of underlying inflation will be based a bivariate time-series model is estimated, including logarithmic changes of output in real terms and absolute changes in the rate of inflation, using for this the logarithmic year-on-year rate[33]. We use the notation $X_t = (\Delta\pi_t \; \Delta y_t)'$ where Δ is the first difference operator, π_t the inflation rate and y_t output; we assume that X_t has a structural interpretation[34]:

$$\begin{aligned} X_t &= A(0)\, e_t + A(1)\, e_{t-1} + \ldots = \\ &= \sum_{j=0}^{\infty} A(j)\, e_{t-j} \\ & Var(e) = I \end{aligned} \qquad \textbf{(B.1)}$$

where e_t is the vector of structural disturbances in the system $(e_t^t, e_t^p)'$.This vector shows no serial correlation and is normalised to the identity matrix[35]. Equation (B.1) shows the transmission mechanism through which structural disturbances affect the economy.

Nevertheless, these structural disturbances e_t are not observed directly, but must be recovered on the basis of the moving average representation of the estimated VAR model:

$$\begin{aligned} X_t &= v_t + C(1)\, v_{t-1} + \ldots = \\ &= \sum_{j=o}^{\infty} C(j)\, v_{t-j} \end{aligned} \qquad \textbf{(B.2)}$$

with the first matrix of the polynomial C(j) being the identity matrix and Ω the covariance matrix of v_t, the vector of reduced-form innovations.

Comparison of (B.1) and (B.2) shows that reduced-form shocks are linear combinations of the structural shocks

$$v_t = A(0)\, e_t \qquad \textbf{(B.3)}$$

and, moreover, the transmission mechanisms are related through $A(j) = C(j) \cdot A(0)$ for any j. As v_t is computed on the basis of residuals of the VAR model, knowing A(0) allows us to recover structural shocks. The matrices A(j) that define the transmission mechanism may also be recovered. Once the structural shocks and their transmission mechanisms have been recovered, actual inflation may be broken down into two terms. Depending

[33] These transformations are used, in line with Augmented Dickey-Fuller and Phillips-Perron unit root tests to ensure that we are dealing with a stationary process. It should be pointed out that year-on-year inflation in Spain seems to be nonstationary, so that there have been permanent shocks to the inflation rate. Moreover, use of the year-on-year rate reflects a nonstationary stochastic seasonality of the CPI, as suggested by the Franses seasonal unit root tests run by Matea (1994). On the other hand, it is assumed, on the basis of the hypothesis of a vertical long-run Philipps curve and the results of the Johansen and Dickey Fuller cointegration tests, that there is no long-run relationship between inflation and output.

[34] To simplify notation, the determinist elements of the model are not included.

[35] Note that we are assuming that structural components are uncorrelated.

on which identification hypothesis is used, the measures of permanent and core inflation may be obtained. To do so, it is therefore necessary to identify the 4 elements of the matrix A (0).

From (B.3), we have

$$\Omega = A(0) \, . \, A(0)' \qquad \textbf{(B.4)}$$

which yields three restrictions. The fourth restriction required is obtained from the long-run identification restriction.

Thus, with regard to permanent inflation, the two types of disturbances are defined according to their long-run effect on the inflation rate: the first group has a transitory effect, while the impact of the second is permanent. To identify the first group of disturbances we restrict the long-run multiplier for e^t on π to be identically equal to zero, because this shock is not allowed to have a permanent effect on inflation. Restricting the sum of parameters in $a_{11}(L)$ to be zero achieves this condition.

$$\sum_{j=0}^{\infty} a_{11}(j) = 0 \qquad \textbf{(B.5)}$$

where $a_{11}(j)$ is the (1,1) element of A(j). To understand this restriction, it should be noted that $a_{11}(j)$ shows how π_t is affected after j periods following a unit innovation of e_t^t. Therefore, $\sum_{j=o}^{k} a_{11}(j)$ is the effect on inflation after k periods, so that in order for e_t^t not to have a long-run impact on inflation, it must be that $\sum_{j=o}^{\infty} a_{11}(j) = 0$.

Once the structural disturbances and their transmission mechanisms have been obtained, we may compute the desired breakdown of the change in the inflation rate into two components:

$$\Delta \pi_t = \sum_{J=0}^{\infty} a_{11}(j) e_{t-j}^t + \sum_{j=0}^{\infty} a_{12}(j) e_{t-j}^p$$

$$\Delta \pi_t = \Delta\pi_t^t + \Delta\pi_t^p \qquad \textbf{(B.6)}$$

The first term of the right hand side shows the effect on the change in the temporary component of inflation. The second term of the right hand side shows the effect on the change in the permanent component of inflation[36].

With regard to core inflation, the two types of structural shocks are defined on the basis of their long-run effect on real output. The first type does not have a long-run effect on output, although it affects actual inflation. The second type has a long-run effect on output, but does not affect core inflation. Core inflation is defined as the contribution of the first type of shocks on actual inflation.

[36] As the model is estimated in first differences, it is not permanent inflation which is identified, but the change in permanent inflation. To obtain its level it is necessary to make a further assumption. The same applies to core inflation.

In formal terms, to obtain core inflation, the long-run restriction[37] $\sum a_{22}(j) = 0$ must be replaced by $\sum \hat{a}_{22}(j) = 0$, so that the disturbance we now denote as $\hat{e}_t^c$, does not have a long-run effect on output.

Similar to equation (B.6), the inflation rate breaks down[38] as:

$$\Delta\pi_t = \sum_{j=0}^{\infty} \hat{a}_{11}(j)\, \hat{e}_{t\text{-}j}^c + \sum_{j=0}^{\infty} \hat{a}_{12}(j) \hat{e}_{t\text{-}j}^n \qquad \textbf{(B.7)}$$
$$\Delta\pi_t = \Delta\pi_t^c + \Delta\pi_t^n$$

The first term of the right hand side shows the effect on the change in core inflation and the second term, the difference between the changes in actual and core inflation.

[37] It should be noted that the coefficients and structural shocks change as the identification scheme changes. In this second scheme, we denote structural coefficients with a circumflex.

[38] In an analogous way, the output equation may be broken down into one term associated with the business cycle and another associated with trend or potential output. See Álvarez and Sebastián (1998).

NATIONAL BANK OF BELGIUM

A STRUCTURAL VAR APPROACH TO CORE INFLATION AND ITS RELEVANCE FOR MONETARY POLICY

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Introduction

When measures of core or underlying inflation are discussed, several measurement techniques are often referred to. Simplifying somehow, three major approaches can be distinguished. A first approach tries to remove from headline inflation, measured on the basis of the CPI, the component that is judged to be of a temporary nature and therefore veils the "true" or underlying (core) trend of inflation. This component is considered as noise. Traditionally the noise is removed on an *ad hoc* basis either by a smoothing technique or by the so called "zero weighting" technique, which gives a zero weight to those components of the CPI which are thought to be the source of the noise. Examples of measures of core inflation such as these are the well-known CPI excluding energy and seasonal food, or the CPI excluding changes in indirect taxes. In practice, these measures are very often used, probably because they are easy to calculate and are, from the point of view of the user, relatively transparent. However from a theoretical angle, they have the disadvantage that the selection of the removed components is made on a purely arbitrary basis.

A second approach emphasises the fact that inflation, which is a monetary phenomenon, should measure the increase of the *general* price level. However, in practice this is done using the CPI, which is a weighted average of prices of *individual* goods and services. Consequently, the CPI measures the increase in the general price level, as well as the changes in *relative* prices resulting from sectoral developments. According to Bryan and Pike (1991) "*the relative price "noise" has to be disentangled from the inflation signal*". They suggest that this can be done by using the *median* consumer price change instead of the increase of the CPI, which corresponds to the weighted *mean* of the price changes of individual goods and services. The median differs from the mean if the cross-sectional distribution of the price changes is skewed. Along the same lines, Bryan and Cecchetti (1994) propose the use of the weighted median or a 15 p.c. trimmed mean. They find that these measures of core inflation have a higher correlation than the CPI with past money growth, and provide better forecasts of future inflation. Ball and Mankiw (1995) relate the skewness of the cross-sectional distribution of individual price changes to the existence of menu costs in a model where price

1 The authors are members of the Research Department of the National Bank of Belgium (NBB). The views expressed in this paper are their own and do not necessarily reflect official positions of the NBB.

adjustment is costly, and they use measures of this skewness as indicators for aggregate supply shocks. Bryan, Cecchetti and Wiggins (1997) view this skewness as a statistical sampling problems. Roger (1995) provides an extensive discussion of the weighted median as a measure of core inflation in New Zealand, while Shiratsuka (1997) applies this concept to Japan. Roger (1997), confronted with a high degree of chronic right skewness in the data for New Zealand, introduces the idea of asymmetrical trimming. Of European central banks, it is the Bank of England which publishes the median and the trimmed mean on a regular basis in its Inflation Report.

Finally, the third approach to underlying inflation, which was proposed by Quah and Vahey (1995), defines core inflation as "*that component of measured inflation that has no medium to long-run impact on real output*". Incorporating the vertical long-run Phillips curve explicitly in this definition of core inflation, it is, in contrast to the previous approaches, based on economic theory. A bivariate structural VAR in output growth and the acceleration of inflation is used to extract core inflation from measured CPI inflation. This system is assumed to be driven by two independent types of disturbance. The first disturbance - the core shock - has no impact on real output in the long-run. The second disturbance - the non-core shock - is not restricted at all. This allows them to test whether the non-core shock has permanent effects on inflation or not. The non-existence of important long-run effects of the non-core shock on inflation is seen as a crucial element in a successful identification. A similar bivariate approach is presented in Fase and Folkertsma (1997). Blix (1995), Dewachter and Lustig (1997) and Gartner and Wehinger (1998) expand this approach to a trivariate SVAR, in order to incorporate a monetary shock as well. They find, in general, that there is little difference between the core inflation measure resulting from the bivariate VAR and the one resulting from the trivariate VAR.

In this paper we will concentrate on the issue of the conceptual definition of core inflation which is, from a theoretical point of view, of relevance for central bankers. A theoretical model is therefore discussed in Section 1. The model is an application of the real business cycle methodology for an open economy with sticky prices and wages, and money in the utility function. Using this model, an attempt is made to give some indication of the optimal monetary policy reaction to the different shocks that hit the economy. One of the findings is that, in contrast to conventional wisdom, the optimal responses to a positive demand shock and to a negative supply shock are very similar, as is the case in Goodfriend and King (1997) and in Svensson (1998). It has also been found that no reaction to the direct impact on inflation resulting from an energy shock or similar shocks to flexible prices is the best option. However, if these shocks have, over and above their immediate impact on CPI, important second round effects, a monetary policy reaction is still desirable.

Section 2 presents SVARs for three economies: the USA, Germany and Belgium. Five structural shocks - an aggregate supply shock, an aggregate demand shock, a monetary shock, an exchange rate shock and an energy shock - are identified. This allows us to analyse whether the effect of these shocks on prices, as well as the historically observed reaction of the monetary authorities, is consistent with what was predicted by the theoretical model. Before doing so, the impulse responses of the Quah and Vahey approach - a bivariate VAR in output growth and the *change in inflation* - are compared with those of a bivariate VAR in output growth and *inflation*. This distinction seems to be crucial as in the first case, the shock that has permanent effects on output is interpreted as *the non-core shock*, having no long-run consequences for inflation, while in the second case, the shock with permanent output effects is identified as *the supply shock*, having permanent effects on output *and*, in the opposite sense, on prices. Subsequently, our VARs in output growth and inflation are extended by introducing the short-term interest rate, the exchange rate and the oil price as additional variables. These VARs confirm to a large extent the findings of the theoretical model, and more particularly the importance of the supply shock for prices and for the observed monetary policy reactions. Consequently, we suggest that it is not optimal to exclude the effects of supply shocks from the measure of core inflation.

The final section presents our conclusions.

1. Theoretical foundation for the conceptual definition of core inflation

In this section we try to provide a theoretical foundation for the definition of core inflation. The starting point of our argument is that core inflation should be judged according to its relevance for monetary authorities. As a consequence, core inflation is defined as the inflation information concept that is optimal for monetary policy purposes.

The observed inflation results from a diversity of exogenous shocks affecting the economy: supply, demand, cost-push, exchange rates, monetary shocks etc. The question then is whether monetary policy should react in the same way on inflation whatever the underlying cause of the inflation movement. If monetary policy is unable to offset inflation resulting from some type of a shock, or can only do so by incurring great cost in terms of some other criteria in the loss function of the central bank, one would expect that it would be better to subtract this inflation component from observed inflation in calculating an optimal "core inflation" concept.

1.1 Theoretical considerations

In the literature on inflation targeting, many suggestions are given concerning this issue. Several papers have indicated that for open economies, it could be preferable to use domestic inflation as an indicator or target for monetary policy above CPI inflation. Svensson (1998) illustrates that under a monetary policy regime with a "strict inflation objective", the use of CPI targeting reduces the variance of CPI inflation but increases the variance of other relevant variables (output, domestic price inflation, real exchange rate etc.) compared to a similar policy using domestic inflation as its objective. The reason for this is that monetary policy, under strict CPI-inflation targeting, relies heavily upon the direct exchange rate channel, and neglects the other exchange rate channels disturbing aggregate demand allocations and domestic output decisions. The use of domestic inflation instead of CPI inflation performs better, as it makes monetary policy less dependent on the short-term exchange rate fluctuations. The inclusion of output variability as a second argument in the objective function also results in a better performance for the variability of other macroeconomic concepts than strict CPI-inflation targeting, as it shifts the emphasis of monetary policy more towards the long-run domestic inflation tendency that is caused by output or capacity utilisation. The use of CPI- versus domestic-inflation targeting is also analysed by Conway et al. (1998) using simulations of the FPS model for New Zealand. They obtain similar conclusions by introducing different inflation concepts in the forward-looking reaction rule of the central bank.

Mayes and Chapple (1995) and Yates (1995) describe how certain shocks that are expected to result in simply temporary price level movements should be extracted out of the inflation measure that is used in the inflation targeting approach. This idea is also present in the theoretical analysis of Goodfriend and King (1997) and of King and Wolman (1998) where the optimal inflation (or price level) concept for monetary policy is defined as the sticky price component of inflation. The motivation here is that only sticky prices result in a misallocation of demand and supply decisions as marginal costs deviate unnecessarily from marginal benefit in these circumstances, and therefore have a negative effect on welfare. By eliminating any variability in the marginal cost and suppressing any need for changes in the sticky price level, monetary policy can maximise economic welfare of private economic agents.

These examples illustrate the importance of the inflation concept that is central to monetary policy decision making.

Svensson (1998) and Goodfriend and King (1997) also discuss the optimal policy reaction on different kinds of shocks. In these sticky price models, demand and supply shocks have similar consequences for monetary policy. In the case of a demand shock, monetary policy should react restrictively, reducing aggregate demand and eliminating inflation pressure coming from increasing marginal costs or higher capacity utilisation. That supply shocks should ask for similar reactions is surprising, and, in emphasising the conflict between the inflation objective and the output objective, conflicts with conventional wisdom. However, when output gap stabilisation enters the loss function instead of output stabilisation, this conflict disappears. Indeed, a negative supply shock, reducing productivity and increasing marginal costs, increases inflation pressure. A restrictive reaction of monetary policy will decrease this inflation pressure but also aggravate the output reduction. However, the output reduction should not necessarily be considered as negative in this case: output should follow production capacity, and the result of a restrictive monetary policy reaction implies a minimisation of the output gap variance. The minimisation of output gap variance or marginal cost stabilisation increases the efficiency of production decisions. In this way demand shocks and negative supply shocks have similar implications for monetary policy.

This conclusion contradicts the Quah and Vahey approach of core inflation: that approach is concentrated on subtracting the inflation component related to permanent output shocks. If this shock is interpreted as a supply shock[2], it does not seem optimal to exclude its effect from the core inflation measure. In a broader theoretical sticky-price model, both supply and demand shocks can have persistent, but not permanent, effects on inflation, as both work through the capacity gap or the marginal cost channel on prices.

1.2 Evaluation criterion

In practice, there are different approaches possible to illustrate the relevance of different inflation concepts for monetary policy. Such an evaluation can be based on a purely statistical argument: which inflation component is the optimal forecaster of future inflation? However such a statistical approach does not contain any information on the relative costs of the monetary policy actions trying to offset different inflation sources. In contrast, our theoretical approach will combine the information on the specific dynamic pattern of the different inflation shocks with the impact profile of a monetary policy reaction and show the outcome of the joint action on other relevant macroeconomic variables. Together this gives the necessary information to evaluate how optimal an effect a monetary policy reaction has on specific shocks.

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[2] Quah and Vahey (1995) interpret this shock as the "non-core" shock. Dewachter and Lustig (1997), as well as Gartner and Wehinger (1998) interpret the shock with permanent output effects explicitly as a supply shock. Blix (1995) uses the expression "technology shock", while Fase and Folkertsma (1997) describe this shock as "output shock".

The same argument applies to the historical measure of the empirical importance of different shocks in explaining the inflation process. Such information can be obtained by the statistical decomposition of the forecast error variance of VAR estimations. Such exercises show the importance of specific shocks in predicting inflation, and they also illustrate the contribution of these shocks to the observed interest rate movements. For certain shocks that were historically important to explain the inflation process, one should indeed expect that there has been some interest rate reaction on it. However all this information on past policy experiences does not mean that the observed behaviour was also the optimal reaction. The historical importance of certain shocks for inflation and interest rates therefore does not yield definite answers on the optimal definition of core inflation.

For this reason we start our analysis with a structural theoretical model that is able to illustrate the implications of different reaction functions of the central bank on its loss function. By executing stochastic simulations of the model for different types of shocks, we will compare the results for the objective function (or its possible arguments) of a strong and a weak reaction of monetary policy on the specific shocks. If a strong reaction of monetary policy on inflation caused by one type of shock results in a smaller variance of inflation, output and other economic variables, we conclude that this type of shock should certainly be retained in the core inflation definition. If on the other hand, the variance of the relevant variables increases when monetary policy reacts more strongly on the shocks, one should subtract this inflation component from observed series in the calculation of core inflation.

The outcome of this exercise depends of course on the specification of the structural model. We will therefore start with a brief description of the model that is used (see Kollmann (1998) and Smets and Wouters (1998) for a detailed discussion of a similar model).

1.3 A real business cycle model for an open economy

The model is an application of the real business cycle methodology for an open economy with sticky prices and wages. Households maximise a utility function over a finite life horizon with the following arguments: consumption of domestic and foreign goods, money and leisure. Consumption appears in the utility function relative to the time-varying external habit variable (see Campbell (1998)). Labour is differentiated over households so that there is some monopoly power over wages which results in an explicit wage equation and allows for the introduction of sticky nominal wages à la Calvo. Households allocate wealth over money, equity, domestic and foreign assets, which are considered as perfect substitutes, so that UIRP applies in the linear approximation. Firms produce differentiated goods and decide on labour, capital (with capital adjustment costs), capacity utilisation (following the approach of King and Rebelo (1998)) and prices, again according to the Calvo model. Prices are therefore set in function of current and expected marginal costs. These marginal costs depend on the marginal unit labour cost (average over the economy) and on the price of imported intermediate inputs, described further in the text as energy inputs, which are used in fixed proportions in the production process. The composite domestic good is an imperfect substitute for the foreign good, so that the real exchange rate is not constant over time.

The model is calibrated on the German economy as far as the economic structure is concerned, while other behavioural parameters are set at realistic values found elsewhere in the literature (see appendix for more details on the parameter choice). The linear approximation is solved using the forward simulator available in the Troll-software.

Following the papers of Svensson (1998), Rotemberg and Woodford (1997) and Goodfriend and King (1997), models that are based on dynamic microeconomic foundations for macroeconomic relations are now also becoming the standard tool for analysing monetary policy questions. The specific application, discussed in this paper, allows us to discuss some specific topics: the open economy problem (total versus domestic inflation), energy or broader commodity price shocks (either as intermediate input in the production process or as final demand component in consumption), and wage versus price stickiness (against the one price models lacking an explicit treatment of the wage formation process in the labour market).

1.4 Discussion of the theoretical impulse response functions of different types of shocks under two monetary policy reaction functions

Using the theoretical model we will discuss different kinds of shock: monetary policy shocks, productivity shocks, demand shocks, energy price shocks (either as intermediate input or as final consumption good), exchange rate shocks and cost-push shocks.

The impulse-response functions of these shocks on major macroeconomic variables (total inflation, domestic inflation, output, interest rates, real marginal costs, exchange rate etc.) are presented in Figures 1 to 7. These graphs are based on two reaction functions of monetary policy represented by a simple instrument rule for the interest rate as a function of CPI inflation:

$$r(t) = a * \pi(t) + b * r(t-1)$$

The value $a/(1-b)$ determines the strength with which monetary policy reacts on inflation shocks. Only rules with $a/(1-b) > 1$ fulfil the stability condition of the model and are considered in this exercise. Under the "weak" reaction rule the parameter a is set at the value of 0.165 while b is 0.85, so that the long-run reaction of the interest rate on inflation equals 1.1. This can be considered as a very neutral monetary policy that is only oriented towards a stable long-term real interest rate. Under the "strong" reaction rule, coefficient a equals 0.45 and b equals 0.85.

a. monetary policy shock: increase in the interest rate (autocorrelation 0.3)

The impulse-response function of a monetary policy shock is not a crucial issue in this paper. However the discussion of these effects gives some indication of the implications of the endogenous reaction of monetary policy through the instrument rule on other exogenous shocks.

The monetary shock in our model has persistent effects on output and inflation. These results contrast with the results of other sticky price general equilibrium models (i.e. Andersen (1998), Jeanne (1998)). The difference is explained by some typical characteristics of our model:

- the introduction of both sticky prices and sticky wages slows down the adjustment speed of the price system. We therefore do not need to assume unrealistically slow adjustment coefficients in the price equation as is typical for models that consider only sticky prices. The assumed reaction lag for both prices and wages (average one year reaction lag in our calibration) remains empirically acceptable;

- a second reason for the persistence of the effects results from the assumption of aggregate demand behaviour. The introduction of habit formation in the consumption process implies that aggregate demand reacts more smoothly to shocks. A slower reaction of output also moderates the reaction of marginal costs and therefore of prices;

- the introduction of a variable capacity utilisation reduces the short-run impact of output fluctuations on marginal costs. Higher output in the short-run is produced with a more intensive use of production capacity so that marginal productivity of labour declines less strongly and employment moves only slightly more than proportional with production. The fact that marginal costs behave in a less volatile manner also implies that the effect on domestic inflation is somewhat smoothed over time;

- the persistence is influenced negatively by the assumption of a finite labour supply elasticity. With indivisible labour and the resulting infinite labour supply elasticity, wage costs would react less on a restrictive monetary shock and the downward pressure on prices should weaken. However the same argument applies for other types of demand shocks and inflationary pressure will decrease in that case. The finite labour supply elasticity together with the sticky wage assumption are retained in the calibration for reproducing the traditional Phillips-curve effect in the model.

Figure 1 describes the impulse-response of a 0.25 point increase in the interest rate. The interest rate is expressed on a quarterly basis so that the interest rate shock corresponds with a one point increase in the normal rate expressed on a yearly base. The immediate impulse is dominated by the direct exchange rate reaction. The exchange rate illustrates the traditional overshooting behaviour. The result is a strong decline in import prices and in CPI inflation. The real appreciation and the high real interest rate decrease aggregate demand. Lower demand and production and cheaper energy inputs lower the marginal production costs of the firms and lead to a downward pressure on domestic prices. The economy gradually returns towards the steady state path, but the accumulation of wealth and net foreign assets during the first phase of the adjustment allows for a positive consumption effect afterwards. The lower net exports and real exchange rate appreciation form the counterpart of the higher foreign capital income in the current account.

Under the strong reaction rule, the interest rate shock will be less strong and persistent as will be the effects on inflation and output.

b. demand shock: increase in the demand of the rest of world (autocorrelation = 0.9)

The impulse-response functions in Figure 2 show the results of an increase in the demand by the rest of the world that affects positively the exports of the economy considered (for a constant foreign price and interest rate level). Higher foreign demand increases domestic production and, as marginal costs increase with the higher capacity utilisation, domestic producer prices start to increase. Both the increased output (and income) and the improvement in the terms of trade stimulate domestic aggregate demand (both consumption and investment). Output and domestic inflation pressure is therefore further increased. Using the "weak" instrument rule for monetary policy (a=0.165) in terms of CPI inflation, monetary policy reacts by increasing the interest rate following the increase in total inflation. The increase in current and expected short-term interest rates, given the constant foreign rate, leads to an appreciation of the exchange rate. Both the interest and the exchange rate reaction reduce the increase of CPI inflation through the direct exchange rate effect and through the negative influence on aggregate demand and net exports and furthermore on marginal costs and the domestic inflation pressure on the sticky prices.

Using the "strong" instrument rule for monetary policy (a=0.45) in terms of CPI inflation, monetary policy reacts by decreasing the interest rate somewhat following the decline in total inflation. The exchange rate appreciation is stronger and more persistent than under a weak reaction rule. The stronger appreciation lowers import prices, and this effect more than compensates the initial weak positive effect of sticky domestic prices in the CPI. However after the initial jump in import prices, the domestic inflation process will become dominant and CPI inflation will turn positive, but by much less than under the weak policy scenario.

The difference between the results of the two interest rate rules illustrates that a stronger reaction rule of interest rates in terms of inflation does not necessarily lead to higher interest rate movements. On the contrary, private agents that recognise the central bank's reaction function will adjust their behaviour so that a higher stability of inflation is obtained not by larger swings in interest rates but by the adjustments in forward-looking behaviour. Of course, such a result is dependent on the assumed credibility of the monetary policy rule in the minds of private decision makers. By explaining that the main inflation concept which drives monetary policy explicitly takes into account the specific nature of different shocks, the recognition of the correct monetary policy by private agents can perhaps be strengthened, so that the results of policy actions will move towards the optimal result. The core inflation concept therefore probably has importance not only for the internal monetary policy evaluation, but also for the communication of the policy to the rest of the economy.

c. supply shock: increase in productivity (autocorrelation = 0.95)

An increase in productivity increases the mark-up of firms as prices and wages react slowly to the productivity shock. This means that the real marginal cost decreases and, as a consequence, there is some gradual downward movement in domestic prices. The increased profitability increases investment and the positive wealth effect stimulates consumer expenditures. Net exports increase also, following the decline in the relative price of the domestic good. Under a weak interest rate reaction rule, the exchange rate depreciation will be limited and CPI inflation will decrease following domestic inflation.

With a strong interest rate reaction, the exchange rate depreciation is stronger and more persistent. Net exports increase further, stimulating production and domestic income. A smaller decline in inflation results in lower real interest rates and stimulates domestic demand. Output will therefore increase more quickly and persistently in this case, remaining closer to the expanded output capacity. As a consequence, real marginal costs decline somewhat less, so that domestic prices will also decrease less. CPI is further influenced by the stronger depreciation leading to higher import costs and nominal wages.

The remarkable differences between the short-run reactions of the interest rate in the two policy scenarios are explained by the strength of the direct exchange rate channel on CPI inflation. Once again this illustrates that the differences between the two scenarios is more than just a different reaction of the interest rate on an observed inflation movement. A stronger reaction rule, meaning a stronger emphasis and willingness of monetary policy to react to a specific type of shock, changes private sector behaviour. Forward-looking financial asset prices, such as the exchange rate, are most sensitive to such differences.

d. ***energy price shock****:* increase in the energy price driven by a second order ARMA-process

Energy and other imported primary inputs influence the economy through two channels: directly, as final consumption goods, and indirectly, as inputs in the production process. To illustrate the different consequences of both channels, two model versions are considered. In the standard version, energy is considered as a pure intermediate input that only influences the domestic and CPI prices via the marginal production costs of firms. In an alternative version of the model, energy is treated exclusively as a final demand component that influences CPI directly. In both versions, energy prices are considered as flexible prices that reflect immediately the international market and exchange rate fluctuations.

In the version with energy as intermediate input, an energy price shock influences the economy basically as a supply shock (Figure 4). The marginal production costs of firms react positively to the energy price increase, at least during the first quarters illustrating the flexibility of energy prices compared to domestic costs. Lower profitability will have a negative effect on investment, and the terms of trade deterioration will have a negative wealth effect on private consumer expenditures. Lower economic activity and employment together with lower consumption, and the corresponding increase in the marginal value of wage income, both cause a decrease in the equilibrium real wage so that nominal and even real wages start moving downward. As illustrated in Figure 4, the decrease in the marginal unit labour costs will dominate the higher energy price after a few quarters. The forward-looking nature of the price-setting process implies that domestic prices start declining from the beginning, as the expected decline in wage costs more than compensates for the higher energy costs. Together with the absence of a direct effect of energy on CPI, these arguments explain the surprising negative effect on inflation and prices in Figure 4 under the weak reaction rule. Under a stronger interest rate reaction rule, there is a stronger depreciation in the short-term which will stimulate net exports and economic activity. The smaller loss in output implies a stronger increase in marginal costs and a more realistic inflation and price reaction (see Figure 4 under the strong reaction rule).

The results of an energy shock differ from these of a productivity shock although both can be considered as supply shocks. Two arguments explain the different results. A productivity shock has a relatively small impact on employment and the real wage reaction will therefore be weaker. With an energy price shock, real wages react more strongly as both consumption (and marginal value of wealth) and employment have a downward pressure on real wages. The real marginal cost should therefore be less sensitive to an energy shock than to a productivity shock, at least if the labour market functions correctly so that the real wage can adjust quickly towards its new equilibrium level. A second difference between energy price shocks and productivity shocks is situated in their impact on the current account and the exchange rate. A negative productivity shock causes a real appreciation of the exchange rate: lower exports coincide with an amelioration of the terms of trade. An increase in oil prices, however, means a deterioration of the terms of trade. In this way the terms of trade effect or the corresponding wealth effect reinforces the price increase of a negative productivity shock, while it works in the opposite direction for an oil price shock . Energy price increases, as far as they are considered as supply shocks, should not have strong effects on aggregate inflation, assuming that the labour markets adjust sufficiently towards the real equilibrium wage in the economy. Rotemberg and Woodford (1996) do indeed find a negative real wage effect for the US following an oil price shock.

Results are different for an energy price shock that directly (and exclusively) influences the final demand price (see Figure 5). Here CPI inflation increases directly, given the flexible price assumption for the consumption price of energy. Higher inflation implies an interest rate hike. Domestic prices, in contrast with the total price index, will start to decrease given the negative domestic aggregate demand effect resulting from the interest and wealth effects. A stronger interest reaction in this case causes not only a further fall in domestic demand, but also limits net exports through the temporary appreciation of the exchange rate. A more restrictive reaction on this temporal inflation shock causes an unnecessarily large downturn in economic activity and somewhat stronger fluctuations in domestic marginal costs.

It is a question which requires more empirical research as to whether oil shocks in the seventies caused unnecessarily strong declines in economic activity because of a monetary policy reaction which was too restrictive. The theoretical model explains a strong decline in economic activity following an oil shock for both weak and restrictive monetary policy reactions.

This result therefore indicates that shocks in flexible prices that affect the CPI index immediately, are no reason for monetary policy to react. These type of shocks should therefore be excluded from the core inflation concept. The result of the stochastic simulations will further illustrate this argument.

e. exchange rate shock: increase in the risk premium of the exchange rate (autocorrelation = 0.9)

The exchange rate effects the economy through different channels. It has a direct effect on the economy because it is responsible for adjusting import prices. In our model we assumed that the import prices were adjusted immediately with exchange rates. These import price increases have a further effect through the indexation of domestic costs and especially through the effect on wages. Exchange rates also effect the cost of imported energy inputs and through that channel influence the marginal production costs. The exchange rate influences relative prices and therefore the net exports. Finally the exchange rate exerts wealth effects on domestic demand, through the impact on the terms of trade.

In Figure 6, we present the impulse response function of a persistent exchange rate shock, that can be described as a shock in the risk premium on the domestic currency. The results of a purely temporal shock were very similar as far as the conclusions are concerned, and are therefore not presented here. A depreciation of the exchange rate increases CPI inflation directly through import prices. In doing so, CPI inflation typically shows a strong impact jump. The effect on domestic prices depends on the reaction of output and marginal costs. Domestic final demand decreases with higher real interest rates. Net exports on the contrary increase. Total demand is therefore only relatively weakly affected and the net effect depends on the reaction function of the central bank.

The comparison of the two reaction functions in Figure 6 indicates that a strong reaction on exchange rate shocks is preferable as far as prices are concerned. A strong reaction is able to diminish directly the exchange rate shock and its impact on CPI. Domestic prices and real marginal costs are also less strongly affected, but this has a cost in terms of lower economic activity. It is clear that the final outcome of this shock depends on the relative power of the different channels of the exchange rate on the rest of the economy: for instance the result will depend on the relative weight of the exchange rate in marginal costs against the weight in the CPI and on the size of the aggregate demand effects through the relative price elasticities. The outcome of the stochastic simulations will also depend on the particular calibration of the model.

f. cost-push shock: increase in the nominal wage equation (autocorrelation = 0)

Through the sticky reaction of nominal wages a one-period shock in the wage equation disappears only gradually over the next few quarters. Marginal costs of firms increase and domestic prices start to increase. Both domestic demand and net exports decline following the deterioration of profitability and competitiveness. Output will therefore decline also and this will reduce the marginal costs increase. A stronger reaction of monetary policy will increase the decline in aggregate demand and net exports (through the appreciation of the exchange rate). The decline in output will therefore be aggravated but this will stabilise marginal costs and domestic prices, and, together with the appreciation, also CPI inflation. These results point to the conflicting nature of pure cost-push shocks for monetary policy if output and inflation variance are central in the loss function. However, if output capacity is defined as the output level that corresponds with a steady state inflation rate (or price level), there is no longer a conflict with such an output gap concept in the loss function, instead of the output.

1.5 Results of the stochastic simulations

Table 1 summarises the results of the stochastic simulations. For each type of shock we run two stochastic simulations, one for each policy reaction function: a simulation with a weak reaction of the interest rate on the inflation process (a=0.165, b=0.85) and an alternative scenario in which the central bank reacts strongly to the inflation disturbances (a=0.45, b= 0.85). The table presents, for a list of variables, the relative standard deviation expressed as the standard deviation resulting from a strong reaction rule divided by the standard deviation resulting from a weak reaction rule. A value smaller than one therefore illustrates that the standard deviation of a variable is smaller under the stronger reaction function. We prefer to show a list of variables instead of the results for a specific loss function that combines the separate components.

The results illustrate that for a typical demand shock, the standard deviations of all variables considered decrease, with a stronger reaction of the central bank on the inflation resulting from this type of shock. This result indicates that it is optimal for the central bank to react strongly on the inflation component resulting from demand shocks. The demand shock component of inflation should therefore be an important element of the core-inflation measure.

The results for the simulation with supply shocks are somewhat more complicated. Inflation variance, both total and domestic inflation, decreases when monetary policy reacts more strongly. Output variability however increases, but this measure is of less importance in this context as the production capacity changes so that the output fluctuations can be optimal. The fact that these fluctuations are optimal is evidenced by the reduction in the real marginal cost fluctuations. This measure illustrates how efficient inputs are used in the production process: an optimal use of production capacity means that the marginal cost of inputs equals the marginal return of output. As positive productivity shocks increase marginal productivity of labour, the real marginal cost will decrease, unless real producer wages adjust sufficiently flexibly to follow the productivity shock. Sticky nominal wages and prices however prevent an immediate adjustment of real wages, which can be considered as an inefficiency in the production process. Therefore it would be more efficient to have a stronger expansion of output so that marginal productivity should decrease while real wages increase more quickly. As a result, the real marginal cost can remain constant. Hence it is optimal for the central bank to decrease the interest rate, stimulating economic activity and accelerating the necessary adjustment process in the economy.

The results for energy price shocks, in the version where energy is an input in the production process, are some way between these of supply shocks and demand shocks. The strong wealth effects of energy price shocks explain why it is less costly to offset the price effects of energy price shocks compared to pure supply shocks. The result implies that monetary policy should react on commodity price shocks which mainly affect the intermediate input costs of firms.

If the energy price shock only affects the final consumption price, it is less clear whether the central bank should intervene. The results in Table 1 show that a strong reaction can indeed minimise the effect on the CPI, but is rather neutral for domestic inflation, and the result implies a somewhat stronger variability in output and real marginal costs and especially in interest rates. It is therefore questionable whether the small gain in CPI inflation variance is worth the extra variance in the other relevant variables.

The impact of exchange rate shocks on prices can also be offset by a stronger monetary policy reaction. The remarkable decline in the variance of domestic inflation and real marginal costs illustrates that the inflation shocks resulting from exchange rate effects on imported intermediate inputs and second-round effects on wages, and subsequently on marginal costs, can be offset by a strong monetary policy reaction. The inconvenience of this strong reaction is the extra variability in demand components and aggregate production. This raises a similar evaluation problem as with supply shocks: higher costs of imported products are compensated by declining real wages in total marginal production costs. In this way the stabilisation of the real marginal cost, or of the mark-up, implies that the equilibrium output level, or the inflation-neutral capacity, shifts over time. The final evaluation depends again on the formulation of the objective function for monetary policy.

The positive conclusion for strong reactions on exchange rate shocks is not really in contradiction with the argument of Svensson (1998) that domestic-inflation targeting is preferable above strict CPI-inflation targeting. It is important in this discussion to stress the role of the exchange rate as a determinant of imported intermediate inputs prices and, via indexation of wages, of the marginal unit labour costs. Import prices and wage costs both induce domestic sticky prices to react. Both CPI- and domestic-inflation targeting will therefore react on exchange rate movements. However, models working exclusively with the output gap as the measure for cost pressures, following the Phillips curve approach, lack this important channel in the discussion. This illustrates the advantage of the microeconomically derived sticky-price setting relation above the traditional macroeconomic specifications.

The output effect of exchange rate shocks follows from the different impact of interest rate shocks and exchange rate shocks on respectively output and prices. In order to obtain the same price effect, interest rates have to have a stronger output effect compared to exchange rates. By responding more strongly to exchange rate shocks the effects on prices can be minimised, but this implies an overreaction in terms of output. The result indicates that monetary policy should look for an optimal reaction on exchange rate shocks, a problem related to the discussion on optimal MCI-weights.

The simulation results of pure wage shocks (cost-push shocks) illustrate again the possible conflict between different objectives of the central bank. Inflation can be stabilised in this case only at the cost of higher output variability. However, the relative standard deviation of the real marginal costs decreases somewhat. The result is therefore comparable to the productivity shock. A further argument in favour of a strong reaction lies here in the influence on future wage negotiations: rational behaviour will try to prevent the pure loss-situation that results from systematic central bank actions on unrealistic wage-deals.

Summarising the results, we can say that the distinction between demand and supply shocks as sources of inflation fluctuations is not of crucial importance for monetary policy, unless the variability of output as such is considered an important element in the objective function. For shocks originating from the rest of the world, the reaction should depend on how they affect the economy. Shocks that are limited to flexible prices which are part of the final consumption basket do not ask for a strong reaction, at least if the central bank has a broader objective function than strict CPI-inflation targeting. The use of the direct exchange rate mechanism to offset these shocks causes too many real effects in the rest of the economy. The same argument probably applies for shocks in domestic flexible prices and also for indirect tax shocks. If foreign price shocks disturb mainly the intermediate input costs of firms, the reaction of monetary policy will depend on whether other domestic costs components react sufficiently flexibly to offset the effects on marginal costs.

The final decision regarding the optimality of the reaction depends on the choice of the evaluation criteria. A correct specification of the loss function of the central bank in terms of inflation and output gap will result in similar conclusions as the microeconomic efficiency argument, which favours constant marginal costs so that sticky prices do not have to change. However different arguments are also possible. Following the approach of Rotemberg and Woodford (1997), the final choice will depend on the relative variability of the arguments that appear in the utility functions of households. Using one particular utility specification, their approach can be reduced to the inflation and output gap variance. But using a traditional utility function, the variance of consumption and employment should get more attention (especially if the utility function contains a habit persistence term). Furthermore, the optimal monetary policy will also depend on the relative cost of average inflation against the benefit of increased room for stabilisation policies, given the constraint that interest rates must remain positive. As long as there is no definite answer on the concept of optimal monetary policy, the choice of the optimal target and instrument rules is also open.

Drawing definite conclusions on optimal policy behaviour in open economies is also difficult because of the complexity of the transmission channels. The results obtained in this paper are certainly dependent on the model choice and the specific calibration. This applies not only to the role of the foreign prices and exchange rate shocks, but also to the relative importance of price versus wage rigidity, and to the implications of more complicated instrument rules. The theoretical model is able to analyse the implications of all these assumptions, but empirical estimation of the model is a necessary step, before one can draw definite conclusions from this exercise and lay down practical guidelines.

2. SVARs for the USA, Germany and Belgium

In order to illustrate the findings of the theoretical model, SVARs in output growth, inflation, the short interest rate, the change in the exchange rate and the change in the international oil price were estimated. Before presenting the results of these VARs, we want to highlight the fact that our specification differs from the specification proposed by Quah and Vahey. This is done in paragraph 2.1, while paragraph 2.2 presents the results of the VARs with five variables.

2.1 What enters the VAR: inflation or the change in inflation ?

Quah and Vahey (1995) estimate a bivariate VAR in output growth and the change in measured inflation. As measured inflation, defined as the 12 month change of the CPI, is integrated of order one, the change in inflation enters the VAR instead of inflation itself. It is assumed that this bivariate VAR is driven by two independent disturbances: the core shock, having no long-run impact on output, and the non-core shock. Core inflation is that component of measured inflation that results from the core shock. In other words, core disturbances affect prices and are output-neutral in the long-run, in line with the long-run vertical Phillips curve hypothesis. To identify both shocks, it is sufficient to impose one restriction, more precisely the fact that the core shock has no long-run impact on output. The long-run impact of the non-core shock on inflation is not restricted, nor do Quah and Vahey prescribe how quickly the core shock becomes output-neutral. Both aspects can be determined freely by the data, allowing them to test the validity of the imposed identification scheme.

Bivariate VARs of this type have been estimated for the USA, Germany and Belgium. Since it was preferable to perform this exercise on monthly data, the log of industrial production was used as the real output variable, while inflation corresponds to the 12 month change in the log of the CPI. Both variables finally entered the VAR as changes compared with the values of the previous month. The estimation covers the period from January 1972 to August 1998. Twelve lags were included, as well as a set of seasonal dummies.

The impulse responses of output (Y) and measured inflation (Pi) are, for each of the three economies considered, shown in the upper row of graphics in the Figures 8 to 10. The broken lines plotted around these responses represent bootstrapped 10 p.c. confidence intervals. The impulse responses are in several ways similar to those obtained by Quah and Vahey (1995) for UK-data. Indeed, the non-core shock is much less important for inflation than the core shock, and its long-run impact on inflation is not significantly different from zero, although a significant short-run impact of this shock exists for US inflation. The core shock very quickly becomes output-neutral in Germany, while this takes longer in Belgium (about 1 year) and in the USA (about 20 months). These findings are also illustrated by the forecast error variance decomposition shown in the upper row of graphics in the Figures 11 to 13.

However, if inflation is defined as the one month change in the log of the CPI and this (stationary) variable enters the VAR, the results of a similar identification scheme are quite different, as is shown in the lower part of Figures 8 to 10. It should be noted that in this case impulse responses for prices (P) are obtained. The shock with permanent output effects is important for prices too, even in the long-run. Having an influence on prices in the opposite sense as on output, this shock shows the same characteristics as the supply shock in the model of Section 1 and is therefore interpreted as such. The second shock is interpreted as a demand shock, including the response to a monetary shock. By extending the VAR in the next paragraph, a separate identification of the demand shock and the monetary shock will be possible. The forecast error variance decomposition for these VARs is reported in the lower row of graphics in the Figures 11 to 13. These figures indicate that in our VAR-specification the supply shock is definitely more important for prices than the corresponding core shock identified by Quah and Vahey. In Germany nearly 25 p.c. of the forecast error variance at all horizons is due to the supply shock. In Belgium this is nearly 40 p.c. at all horizons. In the USA, the influence of the supply shock is even more important. For the shorter horizons nearly 75 p.c. of the forecast error variance is due to the supply shock and this remains nearly 40 p.c. at the longer horizons. For Germany and Belgium the contributions of the supply shock are similar to those reported in Gartner and Wehinger (1998) for bivariate VARs in output growth and inflation, with quarterly GDP data.

The difference between the two approaches is also illustrated in Figure 14, where the impulse responses for prices resulting from our VARs have been recalculated as 12 month differences. As a result, they can then be compared on a direct basis with the impulse responses from the Quah and Vahey approach. Again, a more important effect on inflation is obtained in our approach. This difference is not only observed in the short-run, but appears to be rather persistent. Given these differences we prefer to continue with our specification of the VAR in the remaining part of this paper. The characteristics of the supply shock presented in the previous section, where a negative supply shock and a positive demand shock have similar effects on prices supports our view. This approach is not in contradiction with the long-run vertical Phillips curve, as supply shocks shift this curve to the left or to the right. Moreover, in several other papers - for instance that of Smets (1997) - VARs similar to ours which combine output growth and inflation rather than output growth and the change in inflation, have been published, and gave a fair description of the economies studied.

Summarising this paragraph, the Quah and Vahey approach was abandoned because it was feared that, by excluding what they call the core shock, important supply shock effects on inflation would be disregarded. Perhaps this is the reason why Dewachter and Lustig (1997), applying the specification proposed by Quah and Vahey, find that the differences between measured inflation and their core measure are very persistent.

2.2 Extending the VARs with a monetary shock, an exchange rate shock and an energy shock.

The bivariate VARs presented in the previous paragraph were progressively extended to include a monetary shock, an exchange rate shock and an energy shock. Extensions with a monetary shock were also presented in Blix (1995), Dewachter and Lustig (1997) and Gartner and Wehinger (1998). Given the openness of two of the examined economies (Germany and Belgium), the exchange rate was incorporated in the VARs. Finally, by analogy with the model of the previous section and taking into account the importance of changes in the oil price during the estimation period, an energy shock was considered. The results of the VARs with three variables (including a monetary shock) and with four variables (including a monetary and an exchange rate shock) are not reported here. However, they confirm the importance of the supply shock for prices. Finally, VARs in output growth, inflation, the short-term interest rate, the change in the exchange rate and in the international oil price were estimated for the period from January 1972 to August 1998. All exchange rates are expressed as units of domestic currency per unit of foreign currency. Hence, an increase of the exchange rate indicates a depreciation of the domestic currency.

The five disturbances driving this VAR were identified as follows. The demand shock, the monetary shock and the exchange rate shock do not have long-run effects on output. As a result, only the supply shock and, if the data reveal this, the energy shock can have permanent output effects. The monetary and the exchange rate shock were disentangled from the demand shock by restricting their contemporaneous impact on output to zero. This restriction, proposed by Gali (1992), is based on the so-called outside lag, indicating that monetary innovations do not have an immediate effect on aggregate demand. Following Smets (1997), the exchange rate shock is distinguished from the monetary shock, using the relative weight of the exchange rate in the short-run reaction function of the central bank. However, estimating these weights was beyond the scope of this paper. Instead, ad hoc assumptions were made. Finally, four additional restrictions are necessary to identify the five shocks successfully. These were provided by the assumption that the four domestic innovations do not have a contemporaneous effect on the oil price.

a. United States

In the VAR for the United States the exchange rate vis-à-vis the German mark was taken into account, whereas it was assumed that there is no weight on exchange rate stabilisation in the short-run reaction function of the monetary authorities. This assumption was also used by Eichenbaum and Evans (1995).

The impulse responses reported in Figure 15 show that an increase in the oil price (E) has a permanent effect on consumer prices (P) and on output (Y). The monetary authorities do not react strongly to an oil shock, as short-term interest rates (R) are nearly not increased. As was the case in the bivariate VAR discussed earlier, a positive supply shock coincides with an important downward effect on prices. The extended specification of the VAR did not change this conclusion but allows us to see how the monetary authorities react to a supply shock. They seem to have taken the downward effect on prices into account, as a positive supply shock was accompanied by a decrease of the short interest rate, although it was not possible to estimate this effect very precisely. On the contrary, they increase the short-term interest rate in the case of a demand shock, that increases output in the short-run and prices permanently. A positive demand shock has consequently similar effects on prices and on the monetary policy reaction as a negative supply shock. This evidence suggests that the monetary authorities try to diversify their answer to output fluctuations according to the type of shock that is at the origin and, consequently, aim at output gap stabilisation rather than output stabilisation.

A monetary shock leads, after some months, to a significant reduction of output and to a gradual fall in consumer prices. The dollar exchange rate (S) appreciates vis-à-vis the German mark when interest rates are increased. Finally the exchange rate shock does not have important effects on the American variables, highlighting the closed character of the US economy. The forecast error variance decompositions will be discussed later, in comparison with the results for Germany and for Belgium.

b. Germany

In the case of Germany, the exchange rate vis-à-vis the dollar is considered and it is assumed that there is some weight on exchange rate stabilisation in the short-run reaction function of the monetary authorities. Evidence of this was found in Clarida and Gertler (1997). Smets and Wouters (1998) estimate a 0.25 weight. However, Smets (1997) estimated a SVAR, using the zero weight hypothesis. In the VAR presented here a weight of 0.125 was assumed, since with this weight, uncovered interest rate arbitrage holds approximately for the impact effect. The impulse responses are reported in Figure 16, while Figure 17 shows the impulse responses if a zero weight on exchange rate stabilisation is assumed.

An oil price hike increases German consumer prices but has, in contrast to the US, no significant impact on German output. The reaction of the monetary authorities to an oil price shock was nearly zero. A positive supply shock has an important downward effect on consumer prices, evidence that was also revealed by our bivariate VAR. Moreover, the German monetary authorities react strongly on a positive supply shock by lowering the short-term interest rates. This reaction is stronger than in the case of the US and is also estimated more precisely. The strength of this reaction may result from the importance that the Bundesbank traditionally attaches to the outcome of wage negotiations in Germany. Wage increases are, in the absence of a typical cost push shock in the estimated VAR, presumably captured by the shock that was identified as a supply shock. A positive demand shock increases the price level and leads to an interest rate hike. In the German VAR it was also observed that a positive demand shock has similar consequences for prices and for the monetary policy reaction as a negative supply shock.

A monetary shock in Germany decreases output after some months and has a gradual downward effect on prices. The German mark tends to appreciate against the dollar when German interest rates are increased, although it has not been possible to estimate this effect precisely. The effects of an exchange rate shock - a depreciation of the German mark - on output and on consumer prices are very limited, as they are counterbalanced by the increase of short interest rates resulting from the assumption that the Bundesbank reacts to exchange rate movements. In an alternative scenario, where the German monetary authorities do not react contemporaneously to exchange rate innovations there are some more pronounced effects on output and consumer prices. In that case the effects of a monetary shock on prices and on output are also more pronounced. However, this identification scheme shows a depreciation of the exchange rate when interest rates are increased.

c. Belgium

The Belgian VAR is slightly different from those previously discussed. As the Belgian monetary policy is an exchange rate policy aiming to stabilise the exchange rate against the German mark, this exchange rate, as well as the short-term interest rate differential vis-à-vis Germany (instead of the Belgian interest rate) entered the VAR. Given that policy, it is clear that exchange rate stabilisation must be important in the short-term reaction function of the Belgian monetary authorities. In recent years, exchange rate stabilisation was the only objective of the central bank. In the seventies and the eighties the exchange rate policy was less ambitious and a depreciation against the German mark could not be prevented. On average, a weight of 0.75 p.c. was assumed. This corresponds to the weight that Smets (1997) estimated for France, a country that has an exchange record that is similar to that of Belgium. Impulse responses for Belgium are presented in Figure 18.

An increase in the oil price permanently shifts consumer prices to a higher level. Its negative impact on output is more pronounced than in Germany, but less than in the US. The impact on consumer prices is however the biggest of the three countries considered. This is illustrated in Figure 19, where the impulse responses of consumer prices to an energy shock have been recalculated as the 12 month change in prices (inflation). The difference between Belgium and Germany is striking, and results presumably from the indexation of Belgian wages on the CPI. As a consequence, the direct effect of an energy shock was followed by important second-round effects.

In Belgium supply shocks also have an important effect on prices which is the opposite of that of a positive demand shock. These findings are similar as in the case of the US and Germany. However, given the exchange rate policy, these shocks did not lead to important reactions on the part of the monetary authorities. In contrast, they tend to react strongly to a foreign exchange rate shock, which can be interpreted as a change in the market perception of the risk premium leading to a depreciation. The fact that the effect of the foreign exchange shock on the exchange rate is significant on impact, but not in the long-run, indicates that the central bank was sometimes successful in defending the exchange rate. We interpret these exchange rate shocks as periods of increased tension in the ERM. Given their temporary nature, the uncertainty about their final effect on the exchange rate and taking the accompanying increase of domestic interest rates into account, output is nearly not affected by an exchange rate shock and the result for prices is unclear. A positive monetary policy shock - an increase in the interest rate differential with Germany - leads to an appreciation of the Belgian franc. Obviously, all the monetary policy shocks of this type that were observed in the past worked in the opposite direction, more particularly each time a decrease in the interest rate differential coincided with a devaluation of the ERM parity vis-à-vis the German mark. These observed monetary shocks - a decrease in the interest rate differential, accompanying a change in the ERM parity - tend to expand output moderately in the short-run and increase prices permanently.

d. Forecast error variance decomposition for consumer prices and for short interest rates

Figure 20 shows the relative importance of each of the structural shocks for consumer prices. This figure confirms to a large extent the conclusions about the importance of the supply shock made earlier on the basis of the bivariate exercise. For the US and Germany the supply shocks account for about 40 p.c. of the forecast error variance at longer horizons and this measure tends to be significantly different from zero for both countries. Compared to the bivariate VAR the contribution of the supply shock increased for Germany and decreased for the US. For Belgium the contribution of supply shocks became less important than in the bivariate case, presumably as a result of the identification of the energy shock that accounts for about 25 p.c. of the long-run forecast error variance for prices. Disregarding the supply shocks, aggregate demand shocks and energy shocks were important for US inflation, while the monetary and foreign exchange shocks were relatively important for Germany. The relative weight of these two shocks depends evidently on the specification of the German model.

The case of Belgium merits some special attention, as in this country the effect of the energy shocks on consumer prices was more pronounced than in the two other economies and significantly different from zero. It indicates that a possible core inflation measure which eliminates the effect of oil price shocks must be interpreted carefully. If only the direct effect on consumer prices is excluded, this measure may be useful as a supplementary indicator of inflation. Indeed, the theoretical model of the previous section showed that a monetary policy reaction to the direct effect was not desirable. Moreover many oil price movements in the recent past were of a temporary nature. However, if an energy shock has important second round effects, a reaction seemed justified. These second round effects worked in the typical Belgian context of the seventies and the early eighties in the opposite sense than in the theoretical model. Given the automatic wage indexation, real wages in Belgium appeared to be very inflexible and the oil price shocks became the driving force behind the increase in inflation that took place at that time. Recently the vulnerability of the Belgian economy to oil price increases has been reduced by introducing the so-called "health index" instead of the total CPI as the reference for the wage indexation mechanism. This "health index" does not take the price changes for oil products into account.

Figure 21 shows that supply shocks also contributed to a large extent and in a significant way to the forecast error variance of the German short-term interest rate, although the impact effect of the two monetary innovations taken together is more important. The demand shock represents some 20 p.c. of the forecast error variance, while the energy shocks were not important in explaining the German short interest rates. For the short-term interest rates in the US, the monetary shock is definitely the driving force at shorter horizons, while the demand shock is important at longer horizons. Nevertheless, some 25 p.c. of the forecast error decomposition is accounted for by the supply shock. The fact that the Belgian short-term interest rate differential vis-à-vis Germany is mainly driven by the exchange rate shock results directly from the exchange rate policy of the monetary authorities. Consequently, the other shocks, including the supply shock, are less important to explain the interest rate *differential* with Germany. However, this does not mean that supply shocks were not important for the Belgian interest rate *level*, as these shocks, which are, given the cointegration of Belgian and German output, to a large extent common to both countries, may have influenced Belgian interest rates through their effect on German rates.

3. Conclusion

In this paper, a real business cycle model for an open economy and SVARs for the US, Germany and Belgium are presented, in order to study the underlying sources of inflation movements, both from a theoretical and from an empirical point of view. An examination has been made of whether the monetary authorities should diversify their policy response, according to the type of structural shock that is at the origin of the observed inflation. It has been argued that the core inflation concept should incorporate those components of measured inflation that are caused by structural shocks which ask for a monetary policy reaction, while the effects of shocks that do not justify a monetary policy reaction should be removed from the core inflation measure. As such, the core measure should represent the information concept on inflation that is optimal for monetary policy purposes.

The theoretical and the empirical approach both lead to the following conclusion. Positive demand shocks and negative supply shocks have important and similar effects on inflation, as they pass through the same channel. The monetary policy reaction to these shocks should be identical. The empirical part indicates that this has been the case, in particular in Germany. Hence, the core inflation measure should incorporate the effects on inflation of the demand shock, as well as those of the supply shock. This tends to contradict the Quah and Vahey approach, that excludes from measured inflation the effect of the shock that has permanent output effects.

Shocks of flexible prices are less important for monetary policy purposes and should, as far as their direct effect on CPI inflation is concerned, be removed from the core measure. However, if these flexible price shocks have important indirect effects a monetary policy reaction seems to be justified, as is evidenced by the significant impact that the energy shocks have had on Belgian inflation. This result goes into the direction of the traditional approach to core inflation, whereby flexible prices, such as energy or seasonal food prices, are removed from headline inflation. However, this approach has the disadvantage that the choice of the removed component is made on an arbitrary basis. The core inflation measures proposed by Bryan and Pike (1991) and by Bryan and Cechetti (1994), may overcome this problem as discretionary judgement is eliminated when the removed components are selected.

Table 1

Summary of stochastic simulations [1]

Relative standard deviation for a list of selected macro-economic variables
strong interest rate instrument reaction rule versus weak interest rate instrument rule [2]
for inflation driven by different types of shocks

	supply shock	demand shock	energy shock as input in production	energy shock as consumption good	exchange rate shock	cost-push shock
CPI inflation	0.39	0.42	0.47	0.75	0.56	0.53
domestic inflation	0.47	0.26	0.18	1.02	0.25	0.83
exchange rate	0.42	0.40	0.40	0.87	0.50	0.41
interest rate	0.28	0.41	0.54	2.04	0.80	1.32
output	1.08	0.66	0.84	1.12	1.67	1.28
employment	0.87	0.64	0.82	1.14	1.79	1.29
consumption	1.05	0.86	0.94	1.04	1.29	1.21
investment	1.16	0.58	0.85	1.12	1.86	1.39
export	1.10	0.98	1.16	0.94	0.94	1.35
import	1.07	0.99	0.97	1.01	1.12	1.22
real consumption wage	1.05	0.79	0.92	1.01	1.35	0.97
nominal wage	0.24	0.16	0.33	1.10	0.22	0.79
CPI price level	0.07	0.11	0.11	0.62	0.15	0.26
real marginal cost	0.83	0.44	0.72	1.13	0.38	0.93

1. the standard deviations are calculated as averages over ten simulations for 120 quarters each and dropping the first 20 observations
2. the two instrument rules are

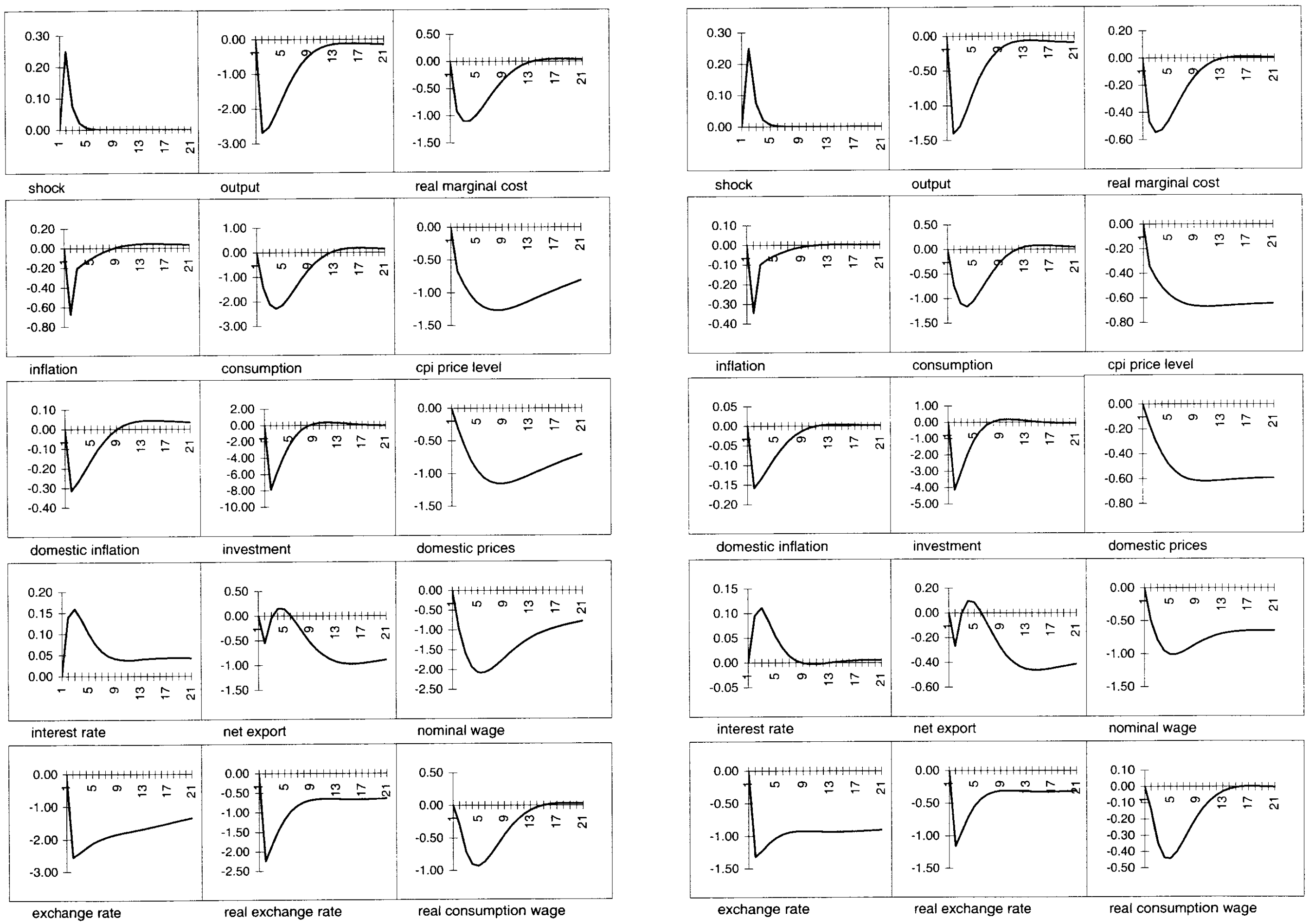
$r(t) = 0.165*\pi(t)+0.85*r(t-1)$

$r(t) = 0.450*\pi(t)+0.85*r(t-1)$

a relative standard deviation smaller then one implies that the standard deviation was smaller under the strong reaction rule

Figure 1 Impulse-response functions for a monetary policy shock (25 basispoint increase in interest rate[1] - autocorrelation 0.3)

weak reaction / strong reaction



[1] interest rate expressed on a quarterly basis, inflation calculated as a percentage quarter to quarter change in the price level

Figure 2

Impulse-response functions for a demand shock (increase in ROW demand - autocorrelation 0.9)

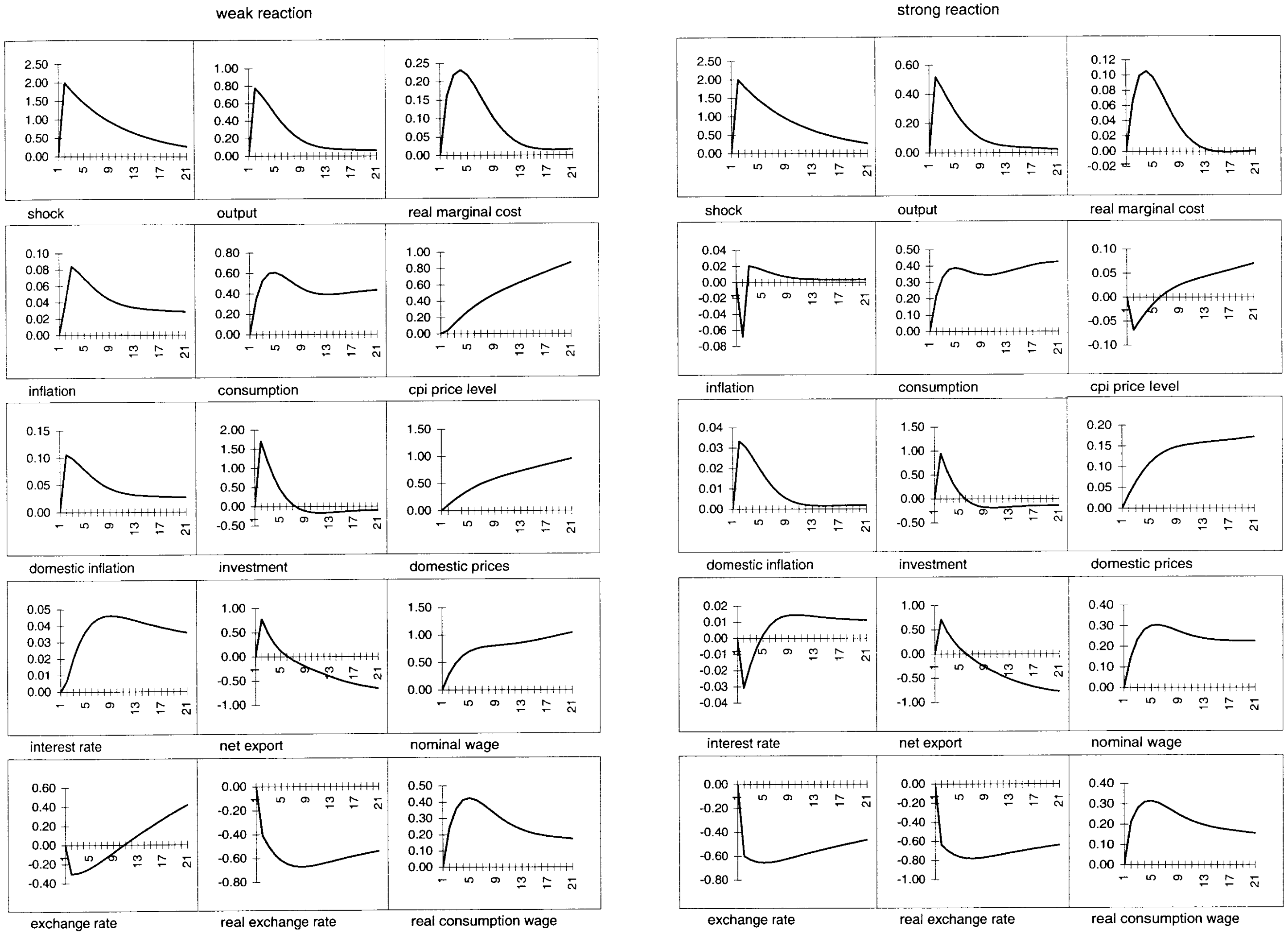


Figure 3 Impulse-response functions for a supply shock (increase in productivity - autocorrelation 0.95)

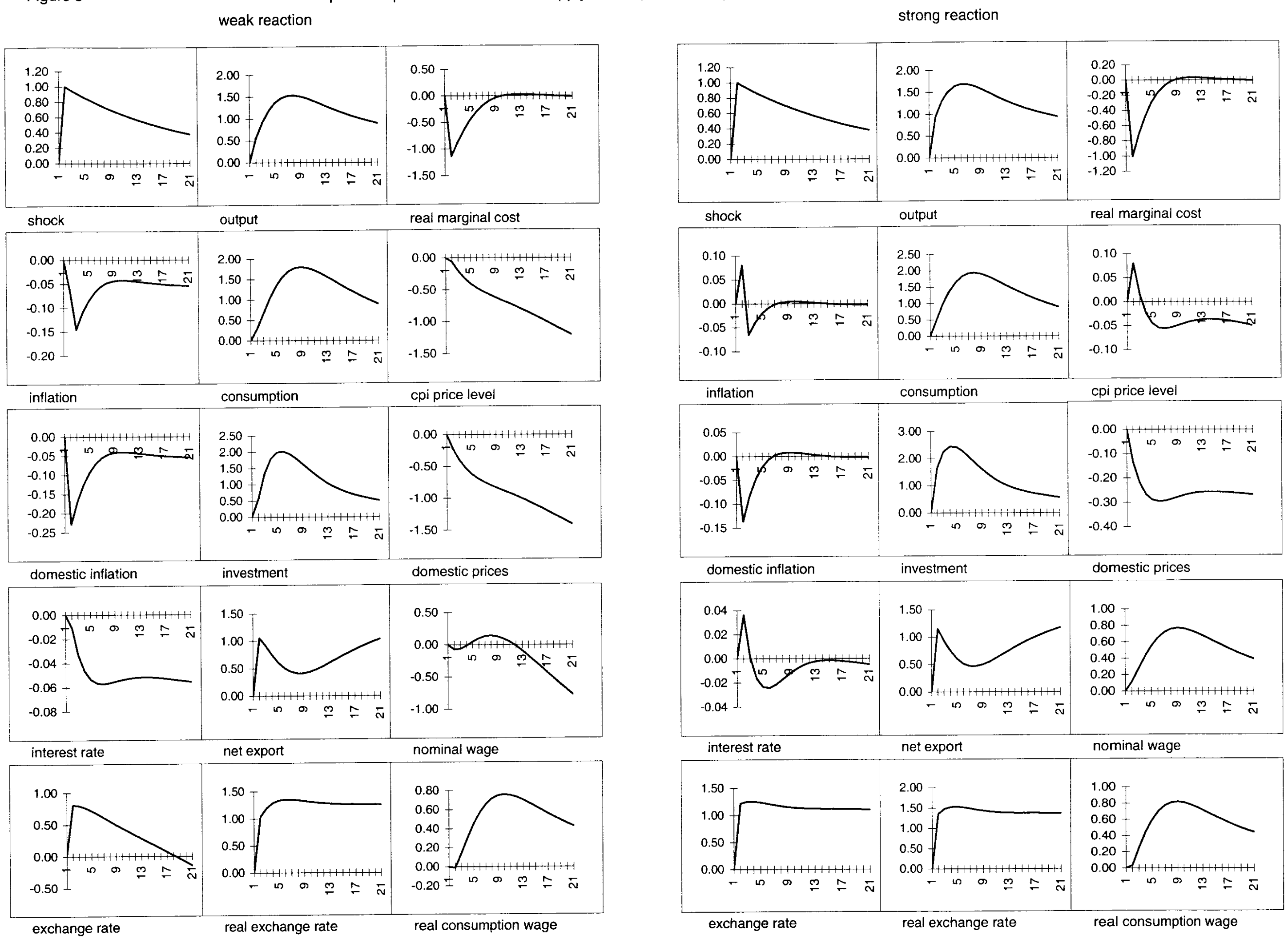
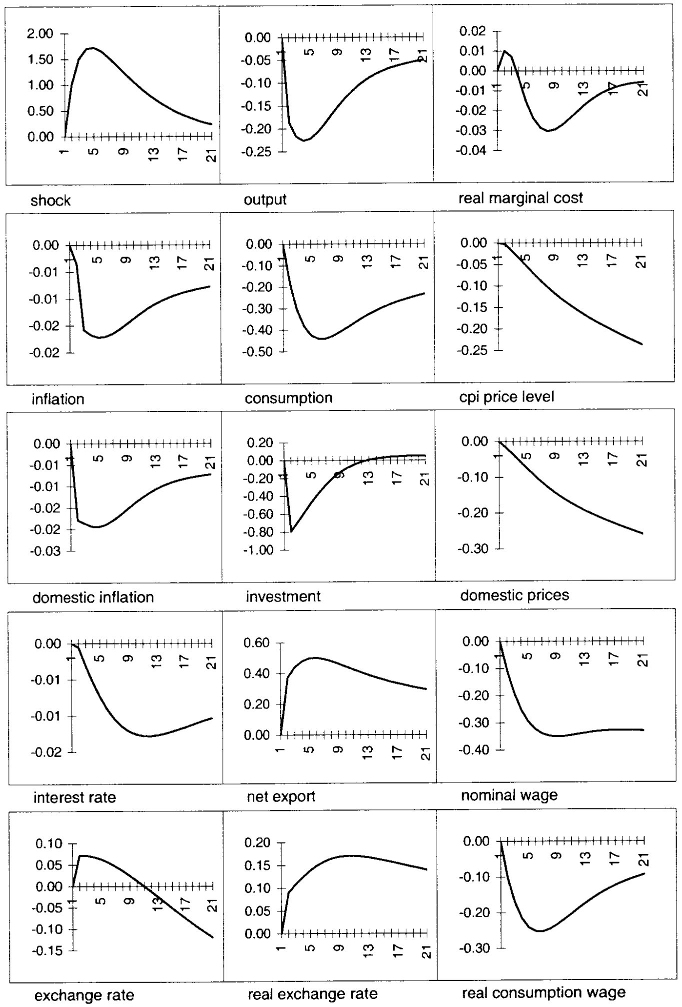


Figure 4 Impulse-response functions for an energy price shock : energy as intermediate input (second order autocorrelation (1.5,-0.55))

weak reaction



strong reaction

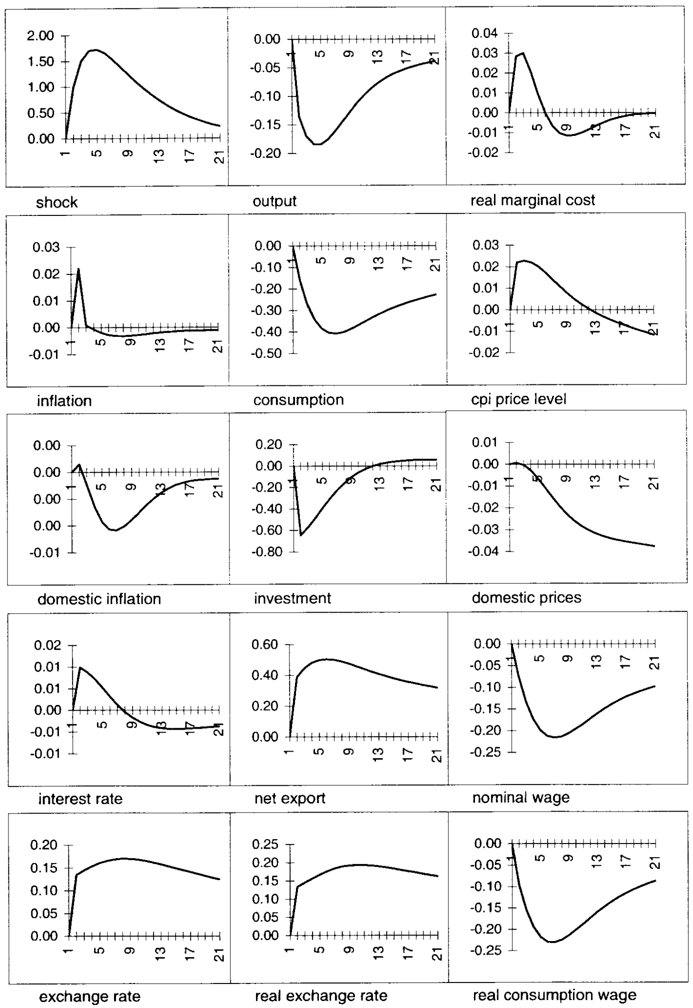


Figure 5 Impulse-response functions for an energy price shock : energy as final consumption good (second order autocorrelation (1.5,-0.55))

weak reaction | strong reaction

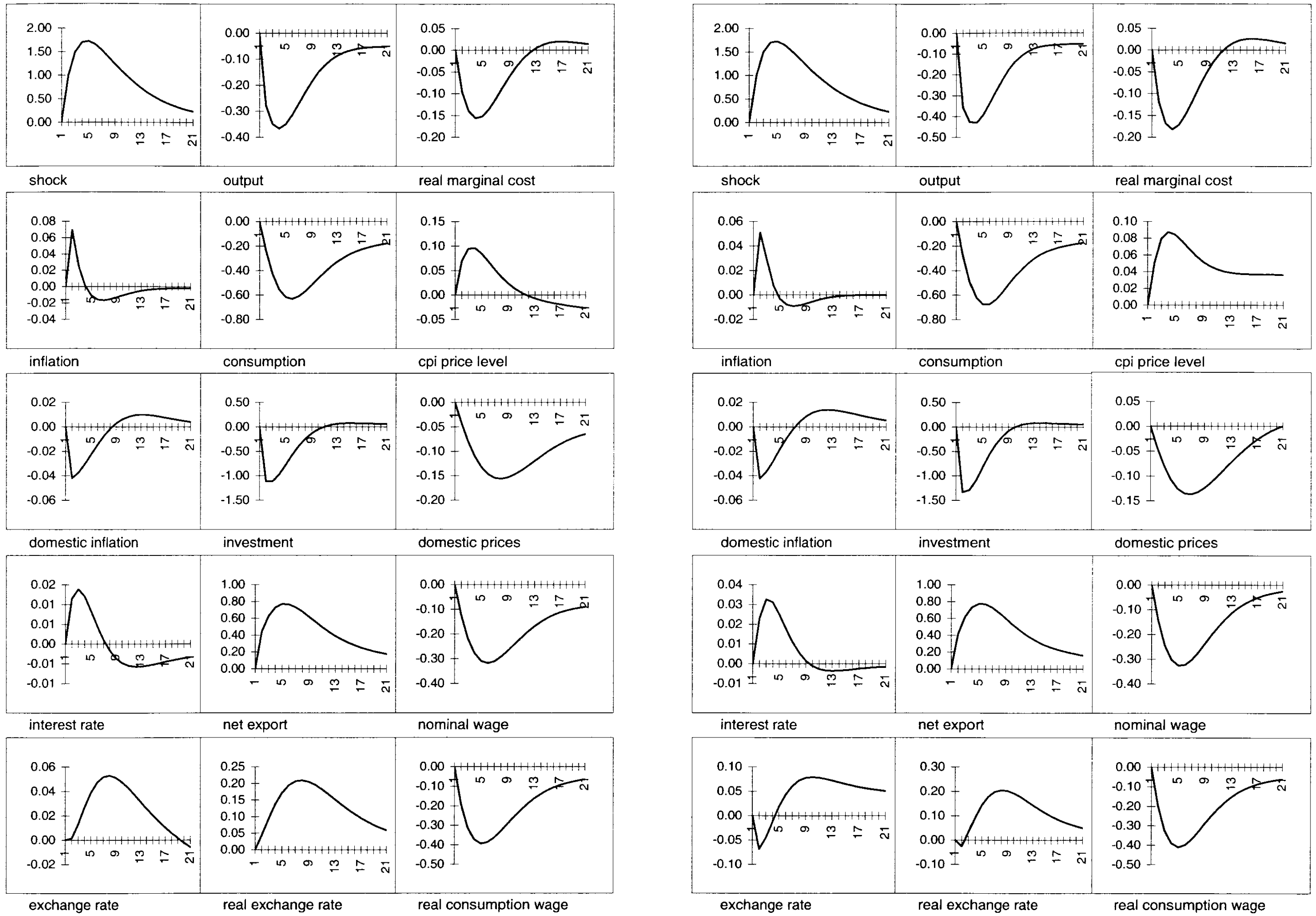


Figure 6 Impulse-response functions for an exchange rate shock (increase in risk premium - autocorrelation 0.9)

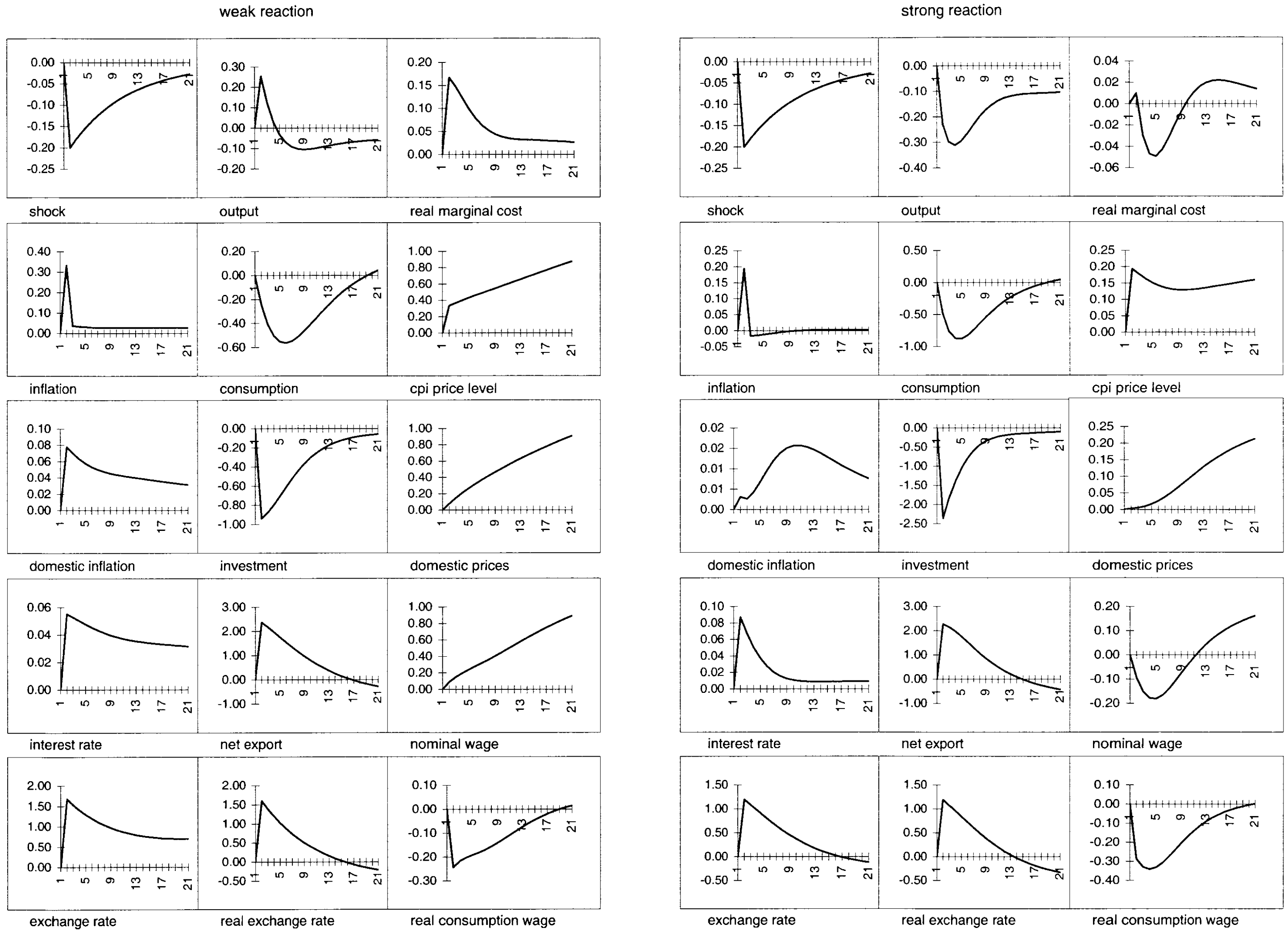


Figure 7 Impulse-response functions for a cost-push shock (wage increase shock)

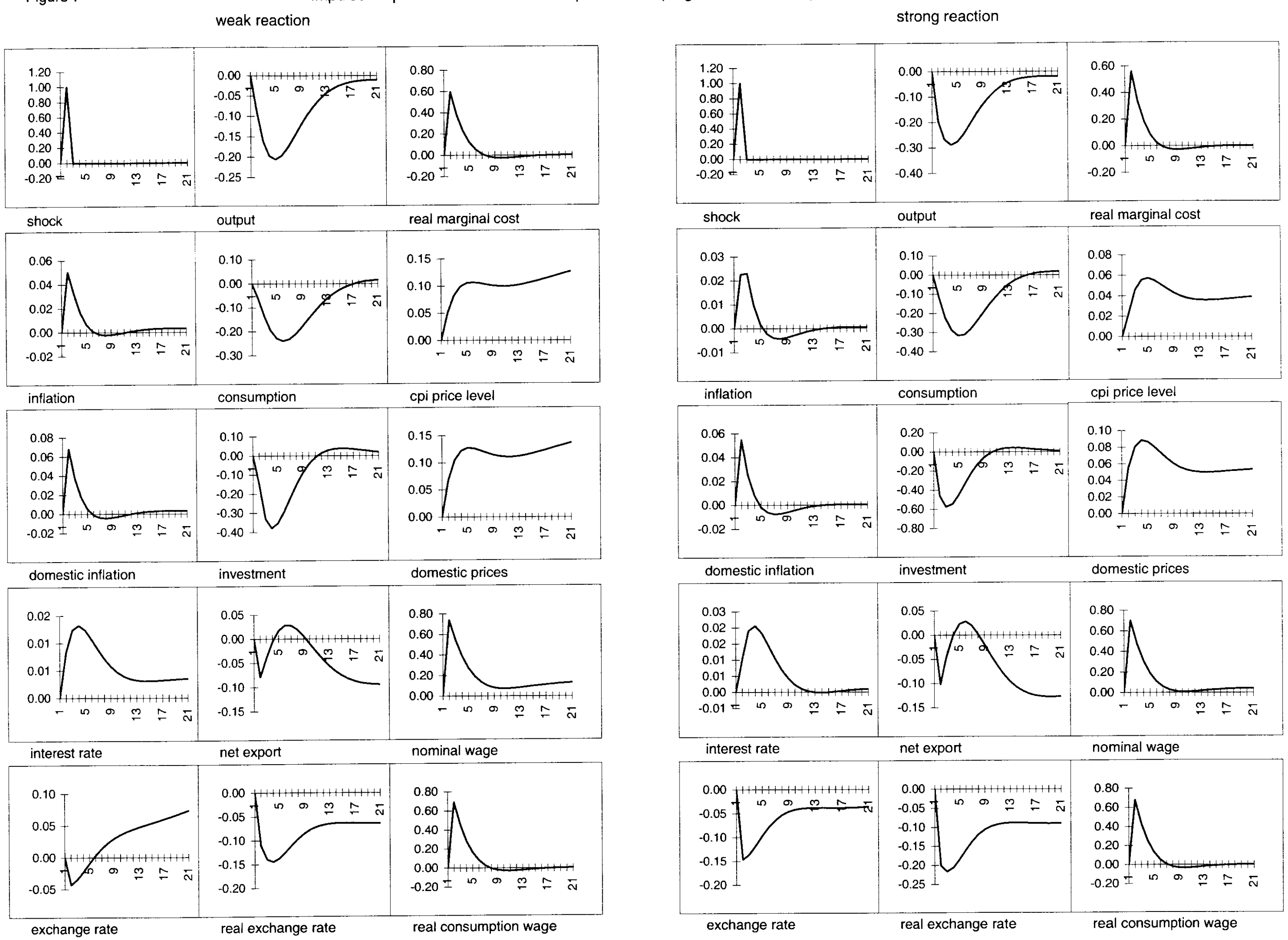
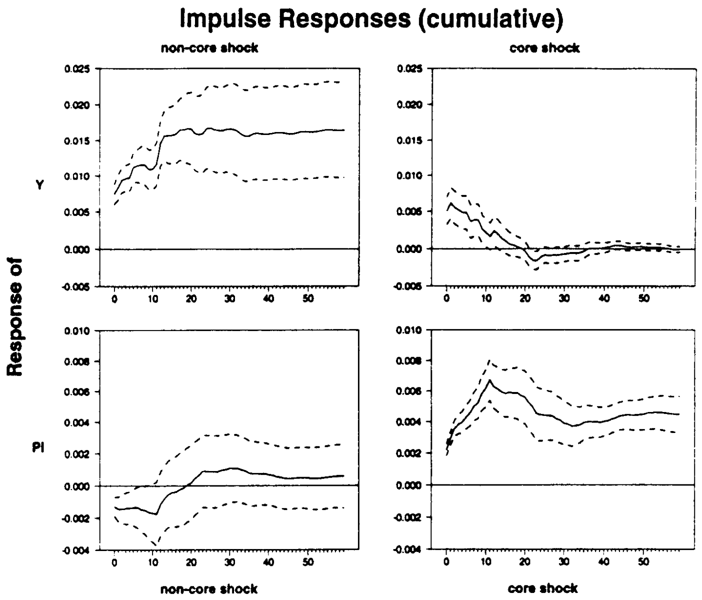


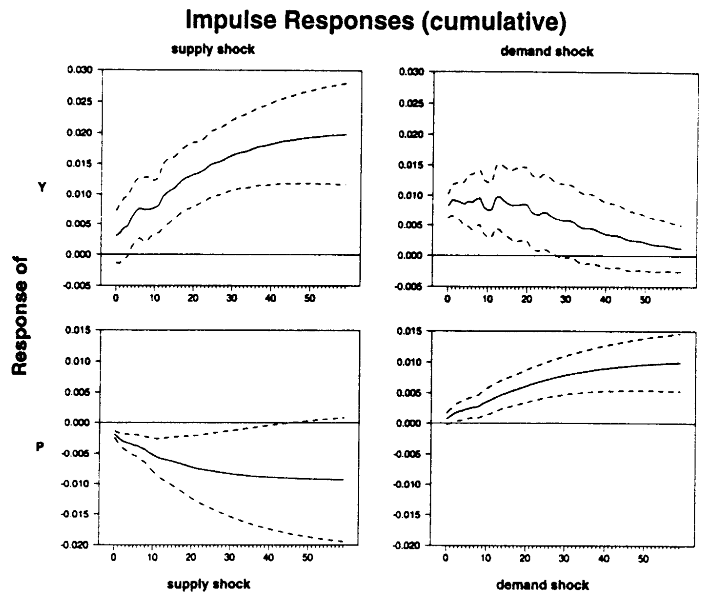
Figure 8

USA : IMPULSE RESPONSE IN A BIVARIATE VAR WITH

1. OUTPUT GROWTH AND CHANGE IN MEASURED INFLATION



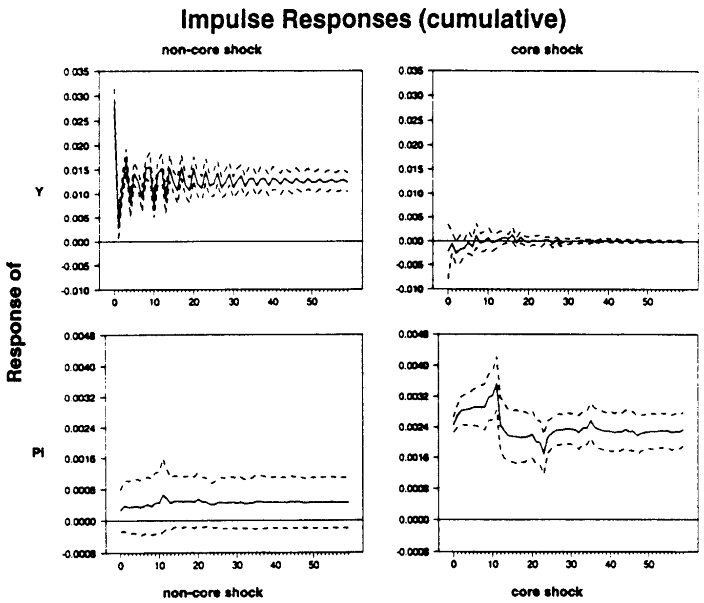
2. OUTPUT GROWTH AND MEASURED INFLATION



GRAF 2VAR.doc

GERMANY : IMPULSE RESPONSE IN A BIVARIATE VAR WITH

1. OUTPUT GROWTH AND CHANGE IN MEASURED INFLATION



2. OUTPUT GROWTH AND MEASURED INFLATION

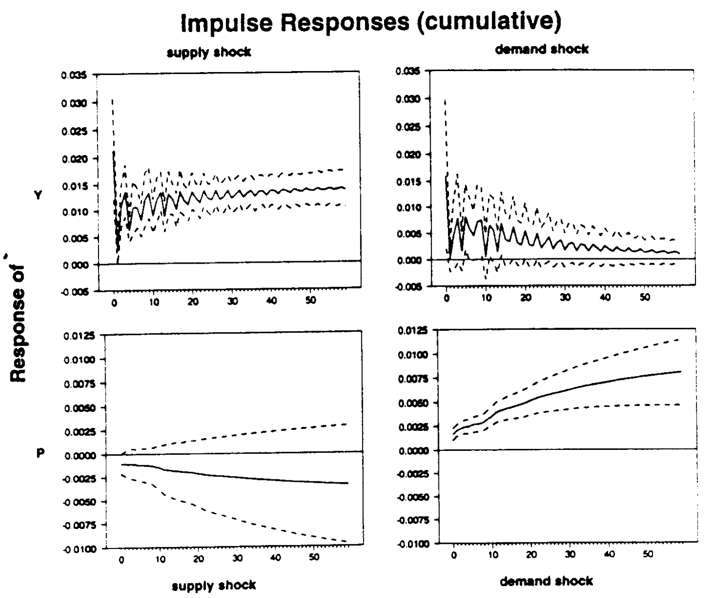


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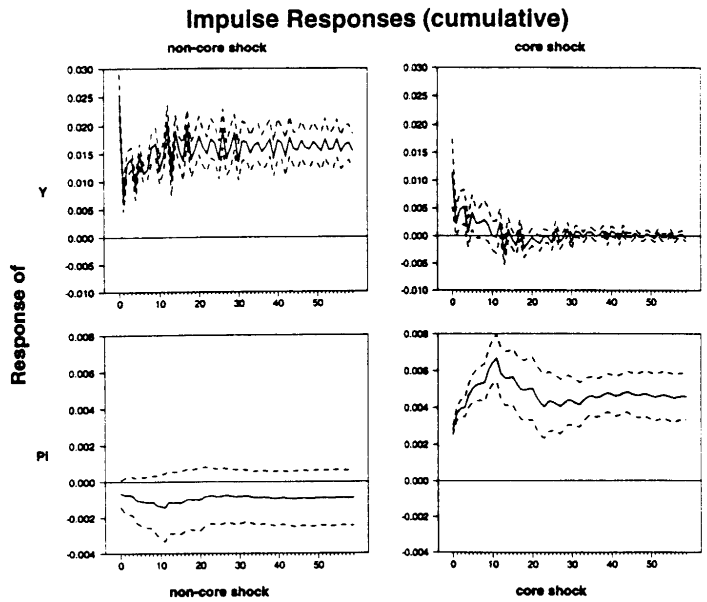
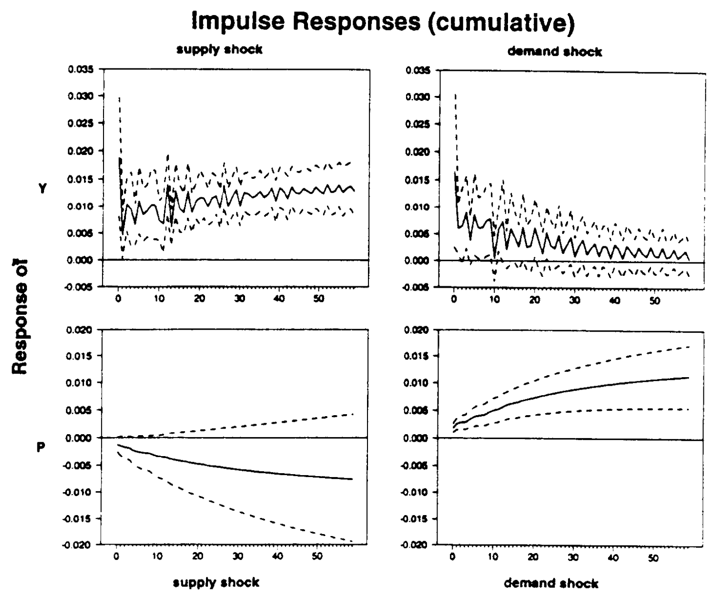
Figure 10

BELGIUM : IMPULSE RESPONSE IN A BIVARIATE VAR WITH

1. OUTPUT GROWTH AND CHANGE IN MEASURED INFLATION



2. OUTPUT GROWTH AND MEASURED INFLATION



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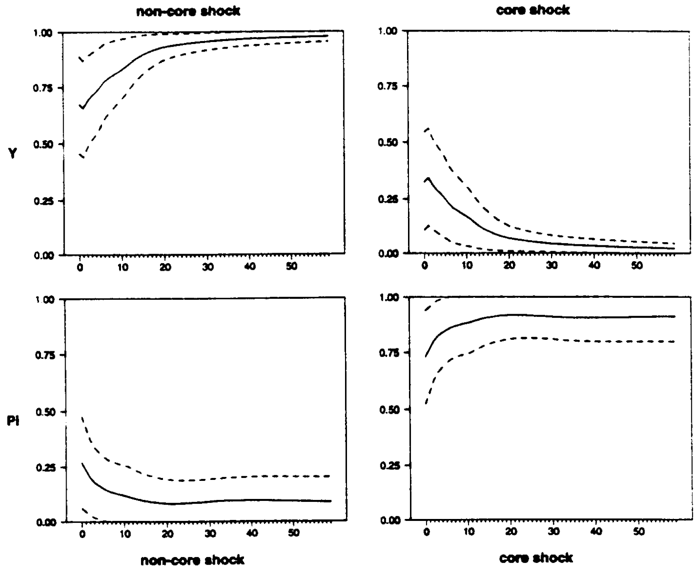
USA : FORECAST ERROR DECOMPOSITION IN A BIVARIATE VAR WITH

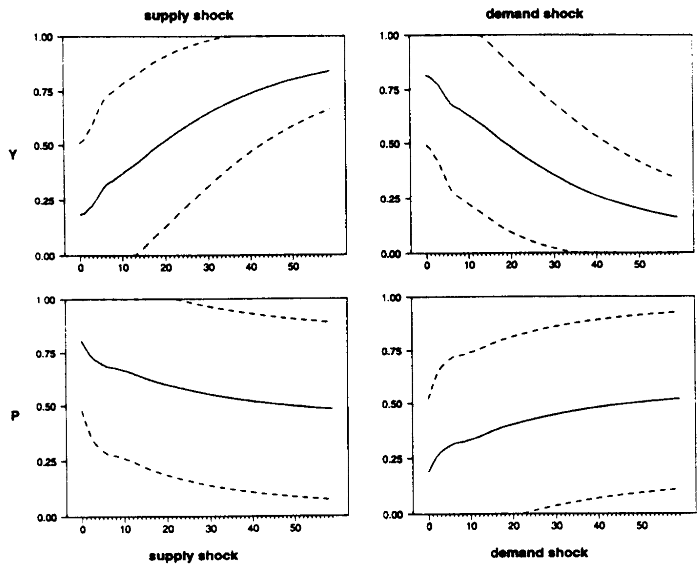
1. OUTPUT GROWTH AND CHANGE IN MEASURED INFLATION

Forecast Error Variance Decomp. (cumulative)



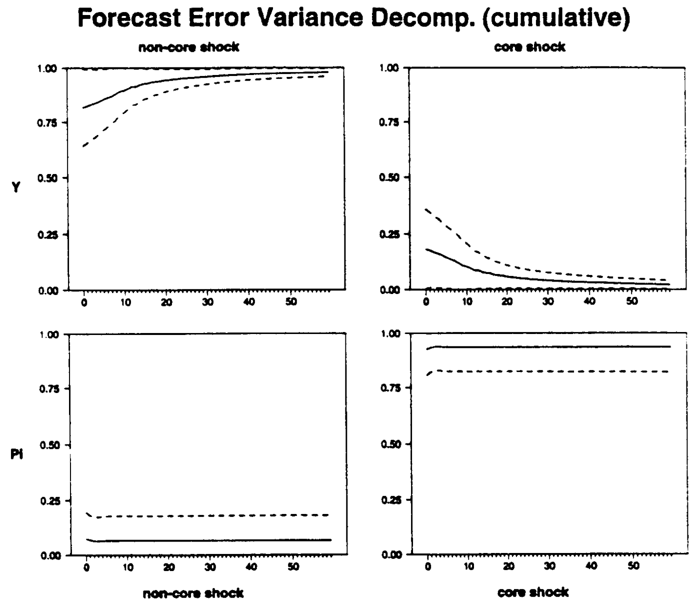
2. OUTPUT GROWTH AND MEASURED INFLATION

Forecast Error Variance Decomp. (cumulative)

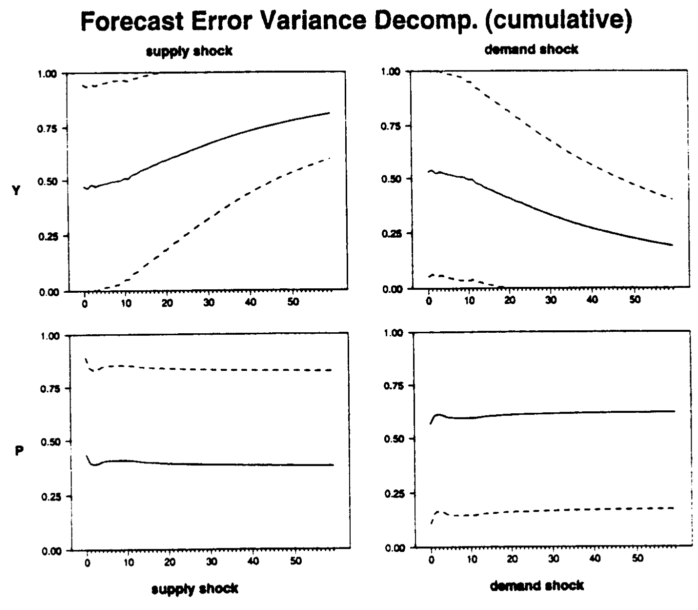


BELGIUM : FORECAST ERROR DECOMPOSITION IN A BIVARIATE VAR WITH

1. OUTPUT GROWTH AND CHANGE IN MEASURED INFLATION

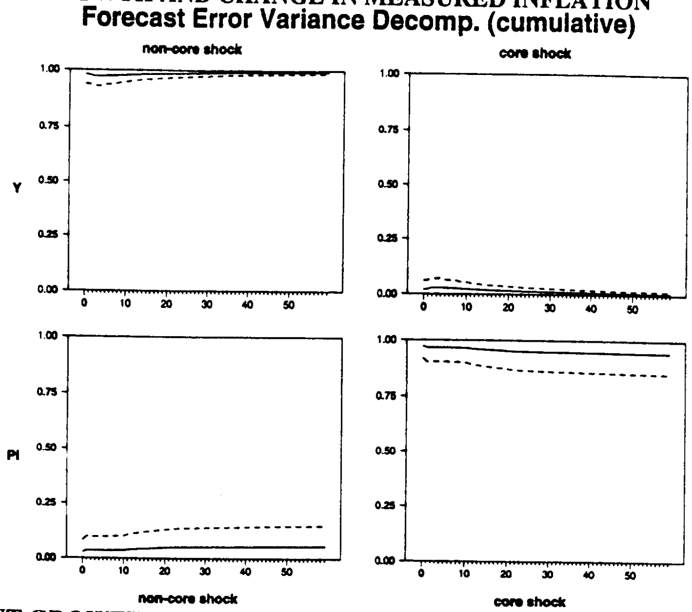


2. OUTPUT GROWTH AND MEASURED INFLATION



GERMANY : FORECAST ERROR DECOMPOSITION IN A BIVARIATE VAR WITH

1. OUTPUT GROWTH AND CHANGE IN MEASURED INFLATION



2. OUTPUT GROWTH AND MEASURED INFLATION

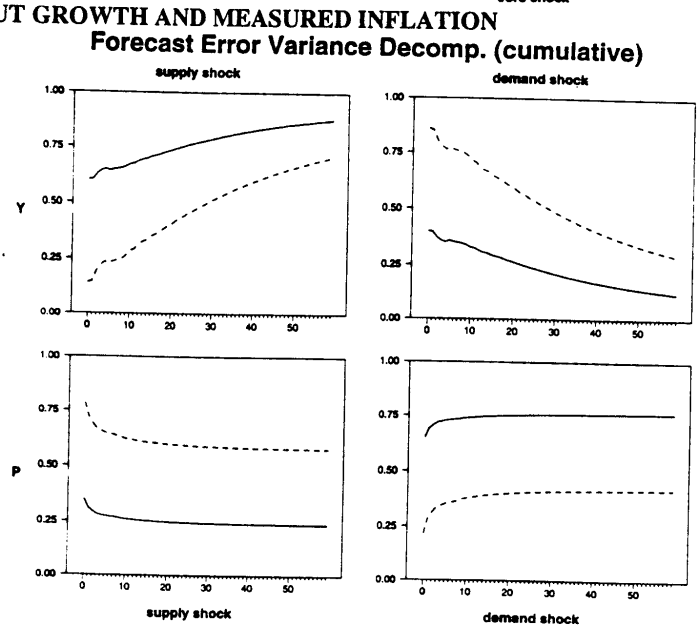
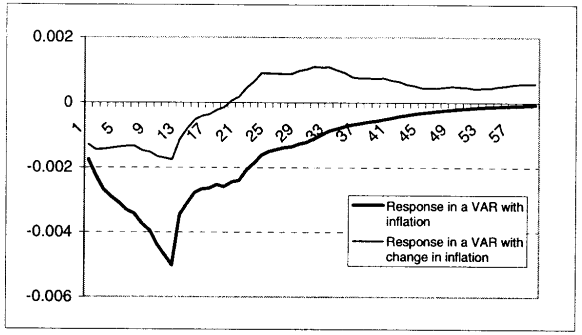


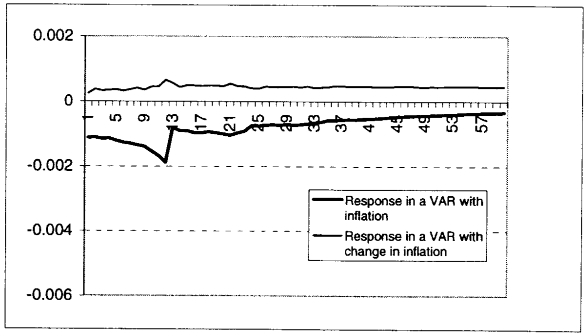
Figure 14

CONSEQUENCES OF THE VAR SPECIFICATION FOR THE IMPULSE RESPONSES OF A SUPPLY SHOCK ON INFLATION

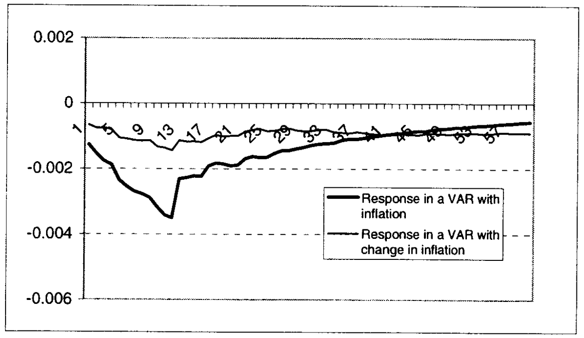
USA



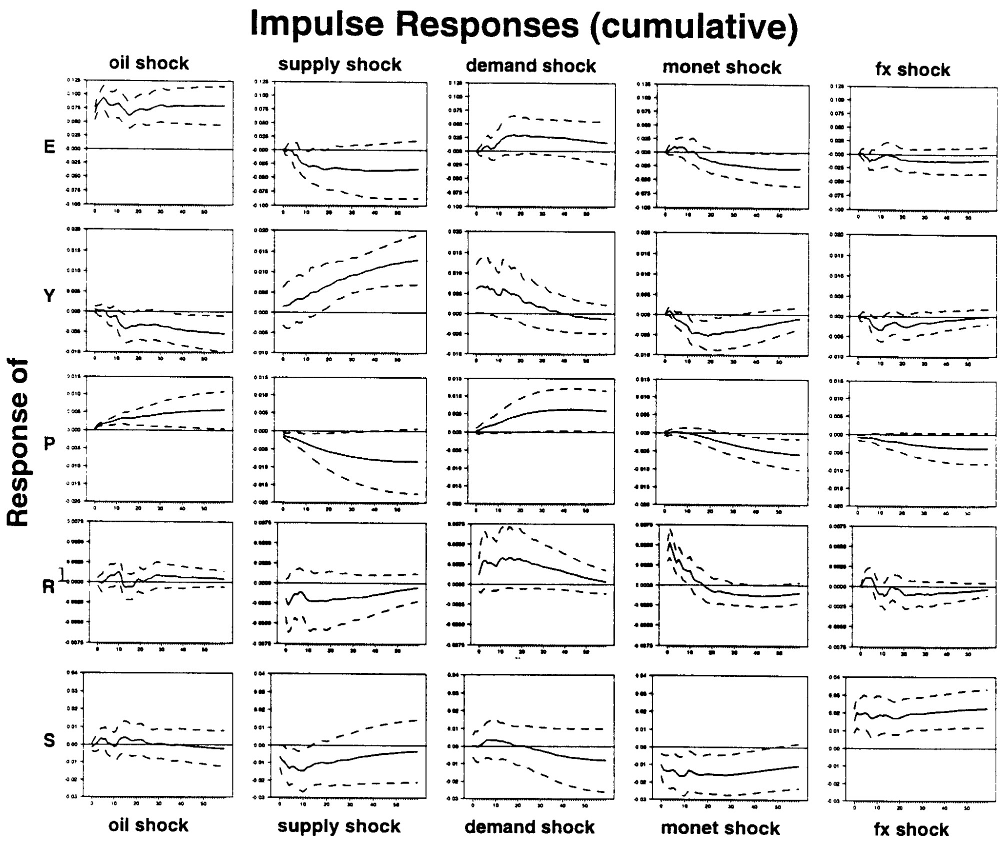
GERMANY



BELGIUM

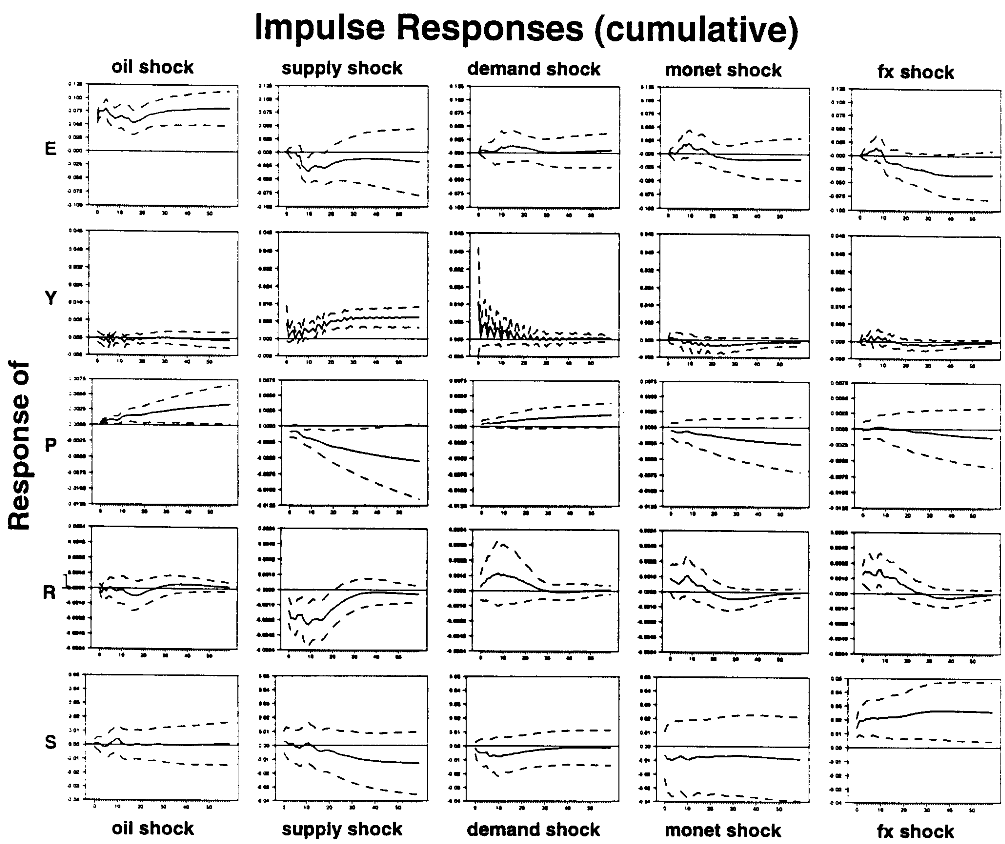


A SVAR WITH 5 VARIABLES : USA



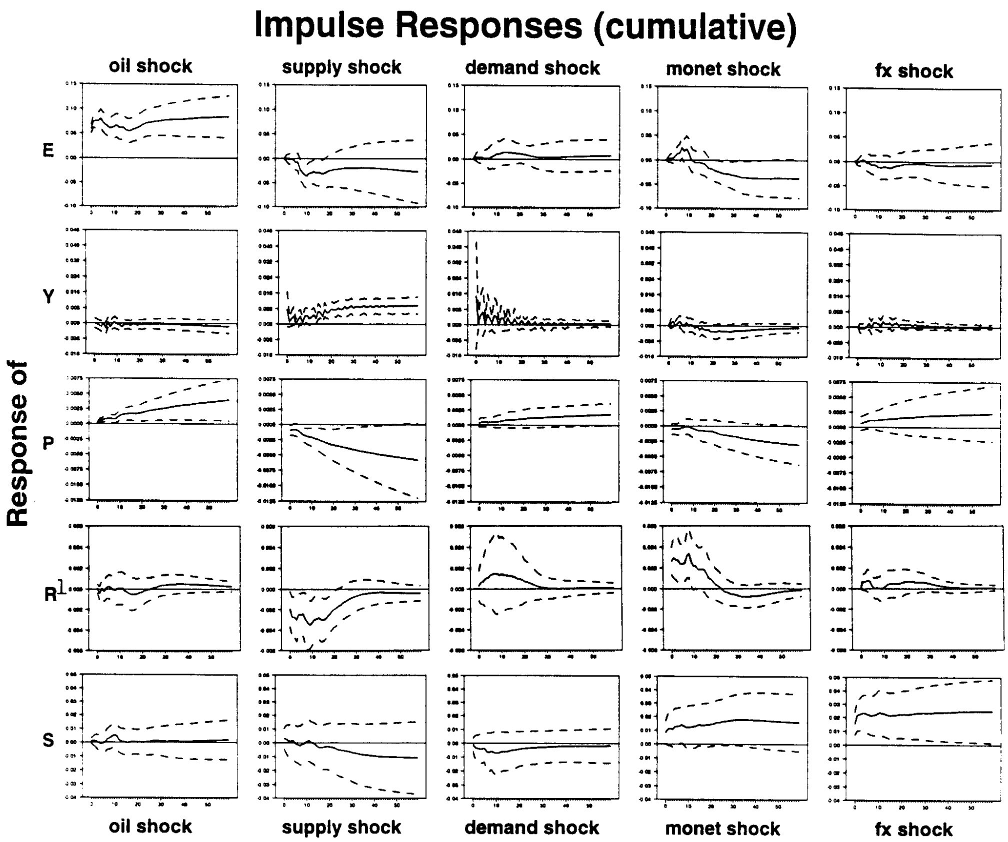
1 Not cumulative.

A SVAR WITH 5 VARIABLES : GERMANY WITH SOME WEIGHT ON EXCHANGE RATE STABILISATION



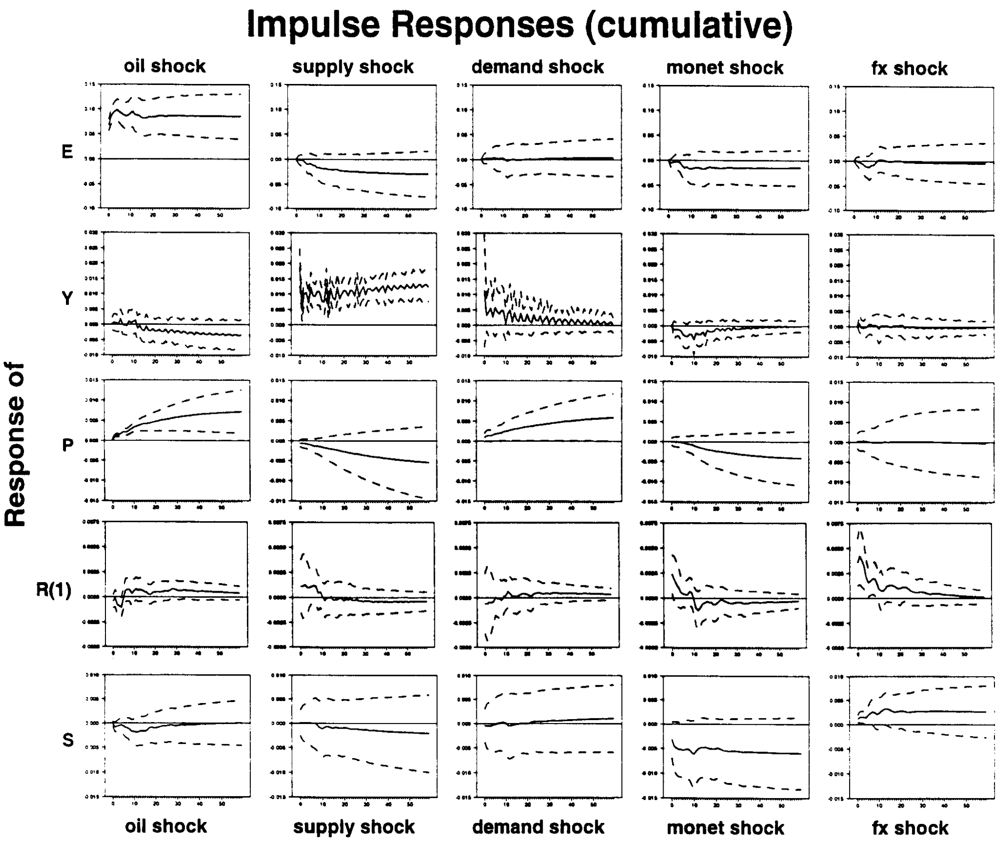
1 Not cumulative.

A SVAR WITH 5 VARIABLES : GERMANY WITHOUT WEIGHT ON EXCHANGE RATE STABILISATION



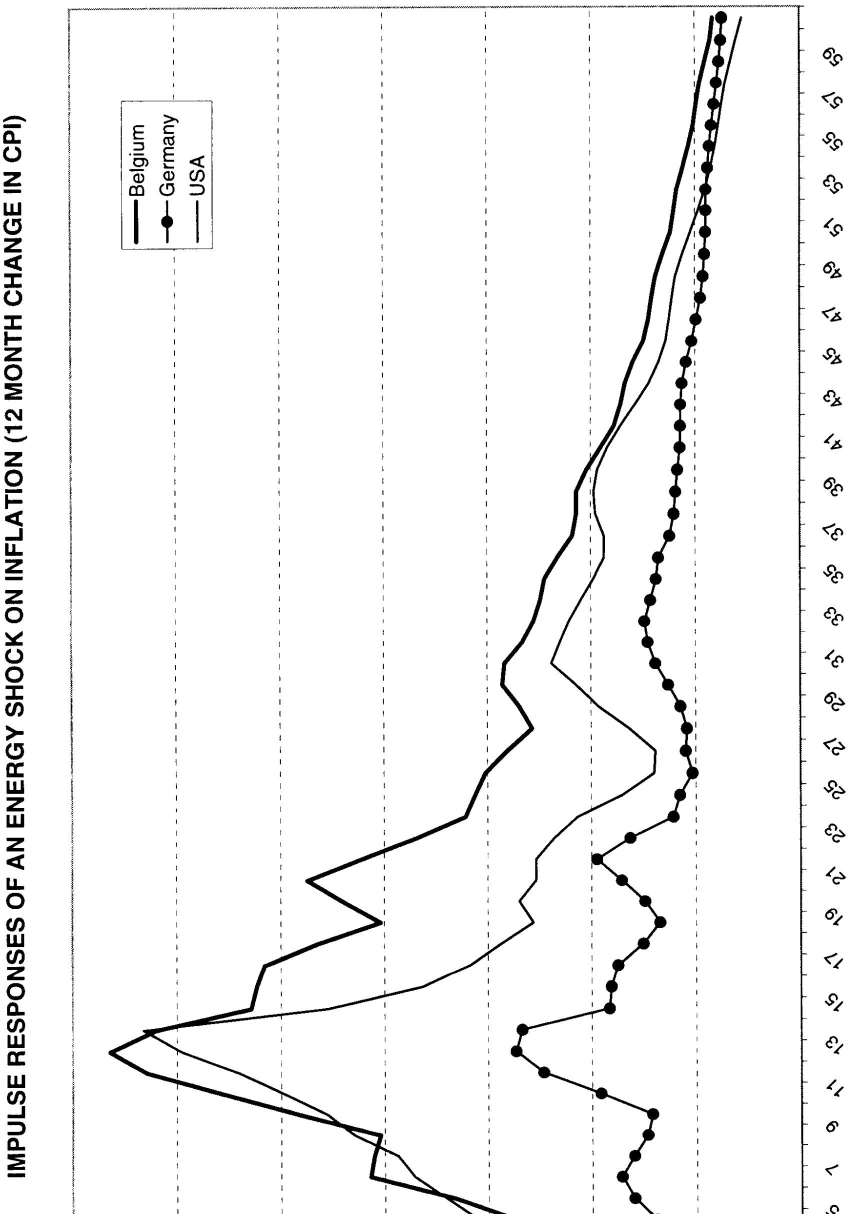
1 Not cumulative.

A SVAR WITH 5 VARIABLES : BELGIUM USING THE BEF-DEM EXCHANGE RATE AND THE INTEREST RATE DIFFERENTIAL VIS-A-VIS GERMANY



(1) Short-term interest rate differential vis-à-vis Germany. Not cumulative.

Figure 19


IMPULSE RESPONSES OF AN ENERGY SHOCK ON INFLATION (12 MONTH CHANGE IN CPI)
Belgium
Germany
USA
0.003500
0.003000
0.002500
0.002000
0.001500
0.001000
0.000500
0.000000
1
3
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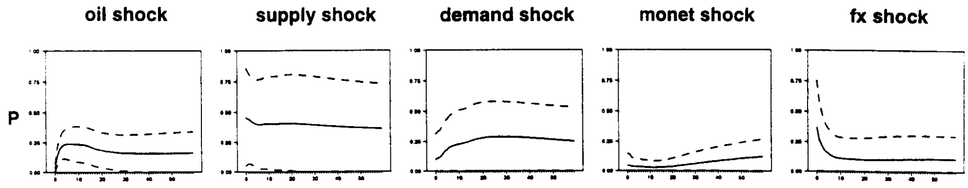
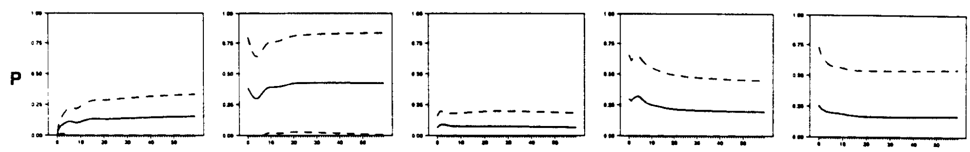
FORECAST ERROR VARIANCE DECOMPOSITION FOR CONSUMER PRICES

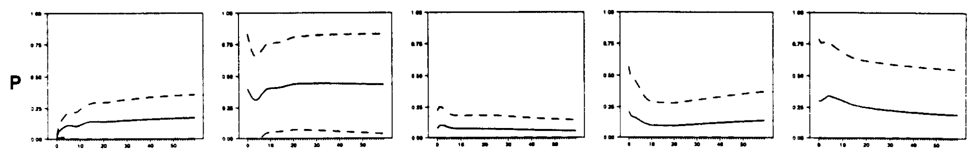
1. USA



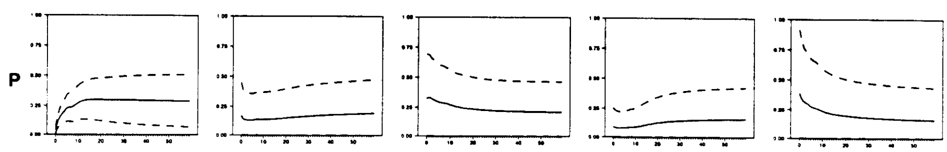
2. Germany, with some weight on exchange rate stabilisation



3. Germany, without weight on exchange rate stabilisation

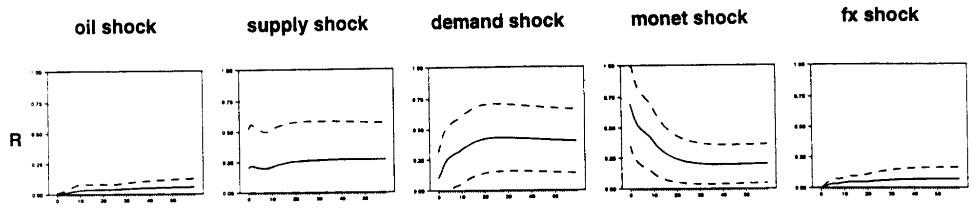


4. Belgium

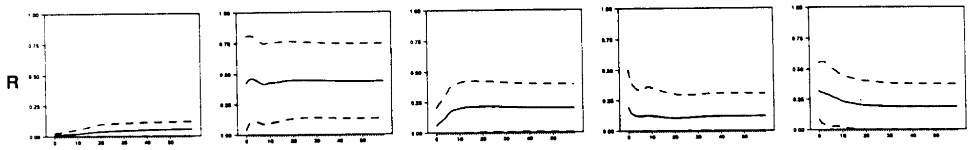


FORECAST ERROR VARIANCE DECOMPOSITION FOR SHORT INTEREST RATES

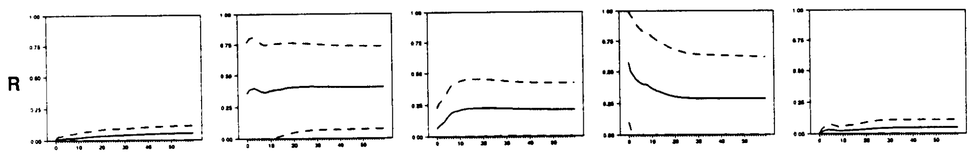
1. USA



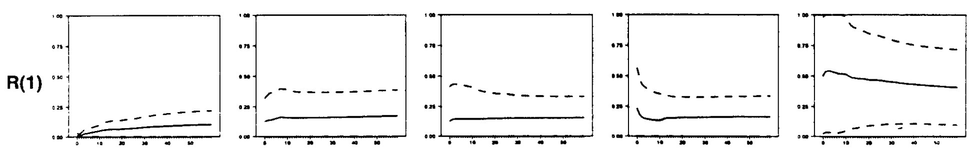
2. Germany, with some weight on exchange rate stabilisation



3. Germany, without weight on exchange rate stabilisation



4. Belgium



(1) Short term interest rate differential vis-à-vis Germany.

Appendix: parameterisation of the theoretical model

In the standard simulation of the theoretical model the following values for the coefficients are assumed. The share of capital is set at 0.35 and the parameter for the cost of capital adjustment is 10. The parameter determining the marginal cost of higher capacity utilisation (King and Rebelo (1998)) is set at 0.1. In the utility function, we set the coefficient of relative risk aversion at 1. The habit variable moves with consumption lagged one period with a coefficient equal to 0.8. The macroeconomic labour supply elasticity with respect to real wages is 0.5.

The structure of final demand is given by the following steady-state assumptions: final import/gdp = 0.15, energy import/gdp = 0.10, export/gdp = 0.25, consumption/gdp = 0.58, investment/gdp = 0.22, government expenditures/gdp = 0.20, public debt/gdp = 2.4 and net foreign assets/gdp = 0.4. The discount factor β is set at 0.99, the rate of depreciation is 0.02 and capital/gdp ratio is 11.0. The import and export price elasticity is set at 0.75.

In order to get a specification in which monetary expansions result in persistent effects on real growth and inflation, we set the probability of price and wage changes at 0.2 which falls within the acceptable region of empirical estimates. In this case the average duration for a fixed price and wage contract is equal to (1 - 0.2)/0.2 or four quarters, which is comparable with one-year Taylor-type contracts. In similar models, King and Watson (1996) use a value of 0.1 for the price adjustment coefficient, whereas Gali and Gertler (1998) estimate a value of 0.2 in an empirical model for the US.

These parameters can reflect the economic structure of a large open economy such as Germany. The model is linearized around the steady state growth path. This results in a simple linear model that is solved numerically using the Troll software.

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NETHERLANDS BANK

MEASURING INFLATION: AN ATTEMPT TO OPERATIONALIZE CARL MENGER'S CONCEPT OF THE INNER VALUE OF MONEY

M.M.G. Fase and C.K. Folkertsma

ABSTRACT

This paper attempts to operationalize Carl Menger's concept of the 'innerer Tauschwert des Geldes', i.e. the inner value of money. Since the change in the inner value of money is the component of price movements which is due to monetary influences, the operationalization provides an alternative measure of inflation. We consider several approaches for gauging the change in the inner value of money. Of these, we use Quah and Vahey's structural VAR model to identify the price movements in the Netherlands and the EU due to monetary shocks.

Key words: core inflation, monetary policy, European Monetary Union
JEL codes: E31

1 INTRODUCTION

The main objective of this paper is to identify the component of observable price changes, which is due to monetary as opposed to real shocks. It attempts to operationalize Carl Menger's old concept of the inner value of money as the true measure for inflation. This operationalization is applied to the Netherlands and the European Union, yielding a measure of price changes, which reflects more closely the theoretical notion of inflation as a monetary phenomenon.

According to the definition adopted here, inflation is any increase in prices induced by monetary factors. Contrary to Friedman's well-known definition of inflation as 'a steady and sustained rise in prices' (Friedman (1963) p. 1), a non-recurring price change is considered as (short-term) inflation as long as it is due to monetary influences. Clearly, without stating that the price changes are induced by monetary factors, inflation would not be 'always and everywhere a monetary phenomenon' (Friedman (1963), p. 17), since short periods of rising prices may, after all, be due to real factors alone. The adoption of the broader inflation concept seems justified since in economic theory the important distinction is not between the effects of a temporary and a sustained price increase but between anticipated and unanticipated changes. Furthermore, from the perspective of monetary policy, it is interesting to measure any movement in prices brought about by monetary shocks, irrespective of whether the movements are temporary or sustained.

This paper is organised as follows. Section 2 argues why the change in the consumer price index (CPI) and comparable indices are inappropriate for measuring inflation. Section 3 goes into Carl Menger's distinction between 'innerer' and 'äußerer Tauschwert des Geldes' which is our main inspiration for this research (Fase (1986, pp. 9-10)). Section 4 proposes a decomposition of price changes. Four possible inflation gauges are examined, the aim being to establish which components of price changes they identify. Section 5 discusses a method to identify the change in the inner value of money insofar as price rises are caused by monetary shocks. Section 6 applies this method to Dutch and European data. Conclusions are drawn in the final section.

2 CHANGES IN PRICE INDICES AS INFLATION GAUGE

The change in the CPI published monthly is seen by the public and by politicians as the measure of inflation on an annual basis. The change in this index gauges the increase in expenditure on a package of goods and services consumed by the representative household. Roughly, the rise in the CPI reflects the loss of purchasing power of money as the representative household experiences it. Application of this index is justifiable if the aim is to determine changes in the spending potential of households, which are caused by price movements ensuing from changes in monetary policy, or from changes in fiscal policy and other real causes. However, this gauge is inappropriate for measuring inflation as defined by Friedman or price level changes brought about by monetary shocks as the CPI reflects every change in consumer prices.

Several attempts have been made to restructure the CPI into a better measure of inflation. For instance, in addition to the ordinary CPI, a price index is published in the Netherlands, which has been adjusted for changes in indirect taxation and subsidies, and various statistical methods have been developed to identify the trend component in the change in prices. But even when an adjustment is made for the direct influence of changed taxes and subsidies on expenditure, the index still reacts to price changes which have been generated by second-order effects of tax and subsidy adjustments and other real influences. Furthermore, weighting the price index means that some prices will determine the general price level thus measured to a greater extent than others. For an assessment of changes in purchasing power, the weighting scheme has a theoretical foundation but there is no clear rationale for gauging inflation by means of weighting. Finally, the basket of goods consumed by households is but a sub-set of the goods marketed within the economy. Notably the prices of the various factors of production are left out of account.

Its partial nature, the weighting aspect and the impossibility to distinguish between real and monetary causes of price changes make the CPI an unsuitable instrument for gauging inflation. For similar reasons, other frequently used price indices such as the producer price index or the implicit deflator of gross domestic product do not constitute better tools for measuring inflation either.

3 MENGER'S CONCEPT OF 'INNERER TAUSCHWERT'

At the end of the nineteenth century, Carl Menger (Menger (1923)) introduced the dual concept of the 'innerer' (i.e. inner) and the 'äußerer Tauschwert' (i.e. outer value) of a commodity, and of money in particular. By the outer value of a commodity, he meant the price of that commodity or the amount of money, which is to be exchanged for the commodity in equilibrium. Analogously, the outer value of money is its purchasing power, viz. the commodity bundle that can be exchanged for one unit of account. In Menger's terminology the CPI thus measures the change in the outer value of money. While Menger stressed that the ratio at which two goods are exchanged in equilibrium is ultimately determined by the (marginal) subjective valuation of the goods involved, he avers that a change in the relationship may be caused by changes affecting only one of the goods. He calls these changes movements in the inner value of a good. Analogously, changes in the inner value of money are those price changes, which are due to purely monetary factors.

According to Menger, a decrease in the inner value of money must lead to a proportional increase in all goods prices. After all, if the changes relate solely to money, the relative goods prices will, in his view, remain unchanged. However, he does acknowledge that a proportional rise in all prices need not necessarily constitute a fall in the inner value of money, because this may also be caused by real factors affecting the production of all commodities simultaneously. That is why Menger is sceptical about the possibility of measuring changes in the inner value of money. He mentions measurement based on the distribution of price changes as a possible way of operationalization. If all prices rise by the same percentage, the hypothesis that the inner value of money has fallen is more likely than the hypothesis that the inner value of all goods has gone up to the same extent. The likelihood of this conclusion rests on the fact that the first explanation relates to the changes in the value of fewer objects of exchange. If not all goods prices go up by the same percentage, then the change in the inner value of money could, on the basis of the same argument, be estimated with the aid of the mode of the frequency distribution of the price changes. However, Menger indicates himself that the method becomes less convincing as the spread of the price changes increases.

Menger's concept of the inner value of money is closely related to the definition of inflation used in this paper. Inflation *is* the change in the inner value of money. Thus Menger's classical concept of the inner value of money turns out to have a very modern interpretation. This was already observed by Hayek (1934, p. XXXI) who noted that 'the actual terms employed are somewhat misleading' but 'the underlying concept of the problem is extra-ordinarily modern'. In the light of the relevance of Menger's concept it is interesting to search for a more convincing operationalization. The main characteristic of Menger's concept should, however, remain intact. This characteristic is that a change in the inner value of money should ultimately lead to a proportional rise in all commodity prices. As suggested by Menger, a suitable starting point for operationalization is the frequency distribution of price changes. The following section deals with this approach and discusses possible gauges for the change in the inner value of money.

4 INNER VALUE OF MONEY: A FRAMEWORK FOR THE DECOMPOSITION OF PRICE CHANGES

The observed change in the price of a good may be caused by various factors. The change in relative and absolute prices may be due to monetary or real causes or an error of measurement may have occurred. If P_{kt} is the price of good *k* at time *t* and

$$\pi_{kt} = \ln P_{kt} - \ln P_{k(t-1)}$$

is the increase in the price of good *k*, then the observed price change may be broken down into

$$\pi_{kt} = \alpha_t^M + \alpha_{kt} + \beta_{kt} + \varepsilon_{kt} \qquad k = 1,...,K. \tag{1}$$

$\alpha_t^M + \alpha_{kt}$ is the price rise at time *t* of good *k*, which is underlain by monetary factors, such as an expansion of the money supply. Although an expansion of the money supply should, at least in the long run, lead to a proportional rise in all prices, the transmission of monetary shocks will, at least temporarily, disturb relative prices. α_t^M is the change in the inner value of money, i.e. the proportional rise in all goods prices as a result of a monetary shock following the completion of all adjustment processes. α_{kt} reflects the temporary deviation of the relative prices from the new long-run equilibrium during the transmission of a monetary shock [1]. ε_{kt} is the error of measurement which may arise in the observation of prices. β_{kt} is the price change in period *t* which is caused by real factors. Real shocks may effect a change in supply and demand in all markets. This disturbance of the general equilibrium of the economy will, if the equilibrium is stable, lead to new relative prices.

The component of the price changes that must be identified is the change in the inner value of money α_t^M. The decomposition of price changes according to (1) may help to examine to what extent the measuring results obtained with the aid of various inflation gauges will approximate the change in the inner value of money. The first gauge to be considered here is the change in the CPI as the gauge most commonly used in practice. For the change in the CPI, say π_t^C, which is defined as the weighted sum of individual price changes by

$$\pi_t^C = \sum_k w_{kt}\pi_{kt} \ , \tag{2}$$

with $w_{kt} = \frac{x_{k0}P_{k(t-1)}}{\sum_i x_{i0}P_{i(t-1)}} > 0$ and $\sum_k w_{kt} = 1$, one has, in view of the decomposition (1) that

$$\pi_t^C = \alpha_t^M + \sum_k w_{kt}\alpha_{kt} + \sum_k w_{kt}\beta_{kt} + \sum_k w_{kt}\varepsilon_{kt} \ . \tag{3}$$

We see that the change in the CPI does not simply measure the change in the inner value of money α_t^M. We note that, generally speaking, neither the weighted sum of the relative price effects of transmission $\sum_k w_{kt}\alpha_{kt}$, nor the sum of the budget-share weighted price changes caused by real factors $\sum_k w_{kt}\beta_{kt}$ equal 0 [2]. Finally, it cannot be ruled out that measurement errors — the term $\sum_k w_{kt}\varepsilon_{kt}$ — affect π_t^C.

[1] In his discussion of the inner value of money, Menger abstracted from the problem that monetary shocks might lead to a temporary disturbance in relative prices.

[2] $\sum_k w_{kt}\beta_{kt} = 0$ holds only if the demand and supply functions of the economy fulfill highly exceptional conditions.

However, other inflation gauges based on, for instance, the frequency distribution of price changes, may be considered. As the change in the inner value of money is a component of the general price rise, the average, the median or, as Menger proposed, the modal price changes form alternative ways of measuring inflation.

The average price change π_t^A would only identify the change in the inner value of money if it may be assumed that the average price rise caused by real factors and transmission equals nil. After all $\pi_t^A = \frac{1}{K}\sum_k \pi_{kt}$, and, on the basis of decomposition (1)

$$\pi_t^A = \alpha_t^M + \frac{1}{K}\sum_k \alpha_{kt} + \frac{1}{K}\sum_k \beta_{kt} + \frac{1}{K}\sum_k \varepsilon_{kt}$$

or, if the calculation of the average price changes is based on a large number of goods

$$\pi_t^A \approx \alpha_t^M + \frac{1}{K}\sum_k \alpha_{kt} + \frac{1}{K}\sum_k \beta_{kt} . \tag{4}$$

The latter equation follows under mild conditions from the law of large numbers [3]. There are, however, no arguments in economic theory to justify the hypothesis that the relative price changes caused by real or monetary factors average nil. In fact, it is extremely unlikely that $\frac{1}{K}\sum_k \beta_{kt}$ equals zero after an increase in VAT by 1%. Therefore, the average price change as such is not a suitable statistic for the change in the inner value of money.

The *median* and the *modal* price change, too, lead to a breakdown of the changes in the inner value of money and price changes caused by real factors only on the basis of certain ad hoc assumptions. For the median price change π_t^M , and the modal price change π_t^X ,

$$\pi_t^M = \alpha_t^M + z_t \tag{5}$$

and

$$\pi_t^X = \alpha_t^M + s_t \tag{6}$$

respectively, with z the median and s the mode of the joint distribution of α_{kt}, β_{kt} and the measurement errors ε_{kt} . Like the change in the CPI and the average price change, the median and the modal price change are also on the whole unable to identify the change in the inner value of money. It is clear from this discussion that the changes in the inner value of money cannot be gleaned with the aid of purely descriptive statistics. None of the gauges is capable of distinguishing between general price level increases caused by monetary factors and those resulting from real shocks. In addition, all gauges, except the average price change, are sensitive to errors of measurement. Therefore, we follow another route to identify the changes in the inner value of money.

5 THE MODEL OF QUAH AND VAHEY AND THE INNER VALUE OF MONEY

5.1 The model

Quah and Vahey (1995) recently proposed a model for solving the problem of measuring monetary inflation. This is a structural VAR model. The approach of Quah and Vahey is underlain by the notion that in the long run inflation, being a monetary phenomenon, is output-neutral, with the proviso that unexpected inflationary shocks in the short and medium term may influence real income. Measuring

[3] Where the change in the CPI is concerned, the law of large numbers applies only under highly implausible assumptions with regard to the budget shares w_{kt} .

inflation by means of the CPI or other price indices can, however, be misleading as has been shown in the previous section, since price changes brought about by real factors are not eliminated. Therefore, Quah and Vahey suggest decomposing measured inflation into so-termed core inflation and a residual. Core inflation is defined as the component of measured inflation, which is output-neutral in the long run.

Quah and Vahey assume that the first differences of (the logarithm of) output and measured inflation are stationary stochastic processes. Furthermore, they assume that the change in measured inflation, $\Delta\pi$, and the growth rate of output, Δy, can be explained by contemporaneous and lagged effects of two types of shocks ε_1 and ε_2. Therefore,

$$\begin{pmatrix}\Delta\pi_t\\ \Delta y_t\end{pmatrix} = A_0\begin{pmatrix}\varepsilon_{1t}\\ \varepsilon_{2t}\end{pmatrix} + A_1\begin{pmatrix}\varepsilon_{1t-1}\\ \varepsilon_{2t-1}\end{pmatrix} + A_2\begin{pmatrix}\varepsilon_{1t-2}\\ \varepsilon_{2t-2}\end{pmatrix} + A_3\begin{pmatrix}\varepsilon_{1t-3}\\ \varepsilon_{2t-3}\end{pmatrix} + \ldots \qquad (7)$$

The shocks ε_{it} of this structural VAR model are serially and contemporarily uncorrelated with zero expectation and unit variance [4]. Finally, they assume that one of the shocks, the 'core inflation shock', ε_{1t}, does not affect the level of output in the long run. The change in the output-neutral component of measured inflation, i.e. the change in core inflation, is then defined as $\Delta\pi_t^c = \sum_{j=0}^{\infty} A_{j,11}\varepsilon_{1,t-j}$, with $A_{j,11}$ the element (1,1) of matrix A_j.

The parameters of the stochastic process generating inflation and output are, however, unknown and must be determined empirically. Here an identification problem arises: only the reduced form of the vector autoregressive representation of (7)

$$\begin{pmatrix}\Delta\pi_t\\ \Delta y_t\end{pmatrix} = D_1\begin{pmatrix}\Delta\pi_{t-1}\\ \Delta y_{t-1}\end{pmatrix} + D_2\begin{pmatrix}\Delta\pi_{t-2}\\ \Delta y_{t-2}\end{pmatrix} + \ldots + D_p\begin{pmatrix}\Delta\pi_{t-p}\\ \Delta y_{t-p}\end{pmatrix} + \begin{pmatrix}\upsilon_{1t}\\ \upsilon_{2t}\end{pmatrix} \qquad (8)$$

can be estimated. The moving average representation of (7), however,

$$\begin{pmatrix}\Delta\pi_t\\ \Delta y_t\end{pmatrix} = \begin{pmatrix}\upsilon_{1t}\\ \upsilon_{2t}\end{pmatrix} + C_1\begin{pmatrix}\upsilon_{1t-1}\\ \upsilon_{2t-1}\end{pmatrix} + C_2\begin{pmatrix}\upsilon_{1t-2}\\ \upsilon_{2t-2}\end{pmatrix} + C_3\begin{pmatrix}\upsilon_{1t-3}\\ \upsilon_{2t-3}\end{pmatrix} + \ldots \qquad (9)$$

shows that the shocks e in the structural form (7) are not identified. Indeed, comparing the coefficients in (7) and (9) shows that $\upsilon_t = A_0\varepsilon_t$ and $C_i A_0 = A_i$, $i = 1,2,\ldots$ with the matrix A_0 unknown.

With the aid of the estimated covariance matrix of the reduced-form disturbances $\mathrm{E}\,\upsilon_t\upsilon_t^T = \Omega$ and the hypothesis that in the long run core inflation is output-neutral, all elements of A_0 can be identified. After all, $\mathrm{E}\,\upsilon_t\upsilon_t^T = A_0A_0^T$ so that the covariance matrix yields three restrictions for the four elements of A_0. The neutrality of core inflation implies that the model parameters must meet a fourth restriction: after *k* periods, a core inflation shock leads to a change in the output *level* of size $\varepsilon_{1t+k}\sum_{j=0}^{k} A_{j,21}$. On the basis of neutrality, $\sum_{j=0}^{\infty} A_{j,21} = 0$ should therefore hold. In other words, the element (2,1) of matrix $\sum_{i=0}^{\infty} C_i A_0$ must equal zero.

Once the matrix A_0 has been determined with the aid of these restrictions, the structural form (7) can be constructed using the residuals and the estimated parameters from the reduced form (8).

[4] The normalization of the variance of the structural shocks does not have any consequences for the estimations of other outcomes of the model.

Subsequently, core inflation or the output-neutral component of measured inflation, which is not directly observable, may be derived from the parameters and the shocks of the structural form.

5.2 A closer look at the model

Quah and Vahey assume that observed inflation and output are explained by no more than two types of exogenous shocks. The reasons why core inflation depends on just one type of exogenous shock are that it is due entirely to monetary influences and that monetary policy is conducted by a single institution, viz. the central bank. The assumption that all other changes in measured inflation and output may be explained by a single second type of shock which invariably influences the two endogenous variables in the same way may be seen as no more than an approximation. The latter assumption can, however, be relaxed if the number of endogenous variables in the model is increased by the number and nature of possible structural shocks. A desirable extension of the model would consist of the explicit treatment of indirect tax rate changes. It seems unlikely that the effect of a changed VAT rate is identical to that of an oil price change or of a variation in government spending.

In Quah and Vahey's model, the identification of structural shocks is underlain by the economic hypothesis that in the long run inflation does not affect output. There seems to be a consensus among economists about this property of inflation. Inflation is a monetary phenomenon and thus, in the absence of money illusion, it has no long-run real impact. The bone of contention lies mainly with the short-run effects of inflation or the speed with which the short-run turns into the long-run Phillips curve. The influence that inflation may have in the short and the medium run on the level of output is, however, not restricted by the identification method. The model of Quah and Vahey also permits the validity of the identification method to be tested. As inflation is a monetary phenomenon, the second type of shocks, viz. output shocks, should, in the long run, not affect measured inflation. However, should measured inflation be found to be influenced by output shocks even in the long run, doubts would arise about the validity of the identification procedure proposed by Quah and Vahey.

Finally, there is an identification problem related to the model of Quah and Vahey. As the model is estimated in first differences of the endogenous variables, it is not core inflation itself that is identified, but the change in core inflation. The level of core inflation itself remains unknown and undetermined.

5.3 The relationship between the inner value of money and core inflation

The main question that arises upon consideration of Quah and Vahey's model is what relationship exists between the change in the inner value of money and Quah and Vahey's concept of core inflation.

Quah and Vahey's core inflation is that part of measured inflation which is output-neutral in the long run. The decompositions of two possible inflation gauges, viz. the change in the CPI of equation (3) and the average price change of equation (4), indicate that in the long run three components do not affect the level of output, and may therefore be identified as part of core inflation. These components are

- the change in the inner value of money
- the (weighted) average of temporary relative price changes brought about by monetary shocks, and
- measurement errors.

Of course, the (weighted) average of the relative price changes generated by monetary shocks is output-neutral in the long run because these price effects will disappear if the equilibrium is stable.

Consequently, it may be concluded that the method of Quah and Vahey is, in theory, capable of decomposing the influence of real and monetary shocks on inflation, measured by one of these two gauges. However, for both gauges, Quah and Vahey's core inflation does not correspond wholly to the change in the inner value of money. Core inflation derived from the CPI or the average price change at time t is the (weighted) average of the price changes at that time, insofar as caused by monetary factors, but not the change in the inner value of money, i.e. the proportional change in all prices following a monetary shock after the new long-run equilibrium is reached. Thus, in the absence of measurement errors, the difference between core inflation and the decrease in the inner value of money depends on transitory relative price changes due to monetary shocks.

The use of the unweighted average price change as the inflation series which is to be decomposed by Quah and Vahey's model probably yields the least distorted estimation of the change in the inner value of money because, on the one hand, weighting the CPI in order to measure inflation is theoretically unfounded and, on the other, errors of measurement have a negligible effect on this inflation gauge. Moreover, when calculating the average price, one is in principle not limited to consumer commodities only. For the other two gauges, the median and the modal price change, it is not possible to determine, without the aid of further and highly detailed assumptions, which components would be identified as core inflation by the Quah and Vahey method.

Although Quah and Vahey's core inflation does not exactly correspond to the change in the inner value of money, core inflation derived from the average price change is thus far the best available operationalization to measure Menger's concept. In the next section we use this operationalization to calculate the change of the inner value of money for the Netherlands and for the European Union.

6 MEASURING THE INNER VALUE OF MONEY

6.1 The Netherlands

Quah and Vahey's VAR model (8) for the Netherlands is estimated with monthly data from the period 1991-1995. For real output the deseasonalized average daily output of the production industries excluding construction was chosen. For observed inflation we used the average price change, calculated on the basis of the 200 price series which also underlie the CPI.

Before estimating Quah and Vahey's VAR model, we tested if the non-stationarity assumptions are indeed satisfied by the Dutch data. The results of the tests for the non-stationarity of the average price change and real output, summarised in Table 1 of Appendix I, indicate that the series are integrated of order one. Completing the specification of the model, we determined the order of the VAR model. Based on preliminary estimations we included 3 lagged variables in our final model [5]. The results of the estimation are presented as impulse-response functions shown in Figure 1 and 2, which indicate how real output and measured inflation respond to the structural shocks. Note that these impulse-responses show the movements in the *level* of *measured* inflation and output.

Figure 1 shows that a core inflation shock leads to a permanent increase in inflation, while after less than a year output has returned to its initial level. The speed with which the effect of an unanticipated inflation impulse on real output wears off is not determined by the identification method. Indeed, the identification implies solely that core inflation has become output-neutral after an infinite number of periods. It is noteworthy that an inflation shock decreases output in the first month, while the opposite was to be expected on the basis of the short-run Phillips curve. The confidence intervals are, however, so large that there is no telling whether this effect is significant.

Figure 2 shows that an output shock leads to a permanent rise in measured inflation, too. This effect is, however, not significant. This confirms the hypothesis that core inflation shocks do indeed reflect monetary influences. Finally, Figure 2 shows that an output shock has a permanent impact on real output.

[5] Details are provided in Appendix I.

Response to core inflation shock

Figure 1a Measured inflation

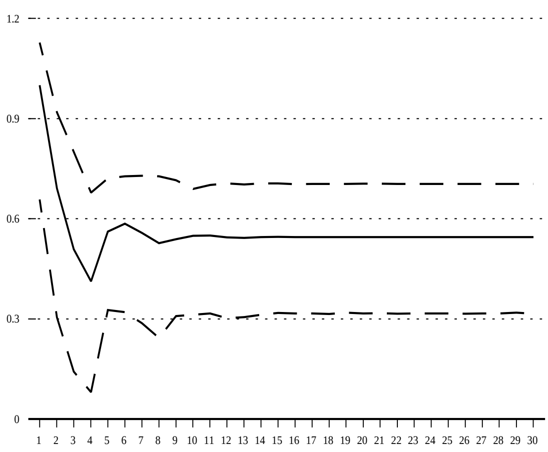
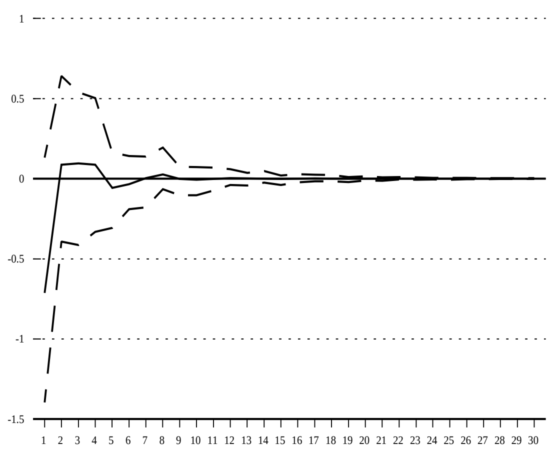


Figure 1b Output



Response to output shock

Figure 2a Measured inflation

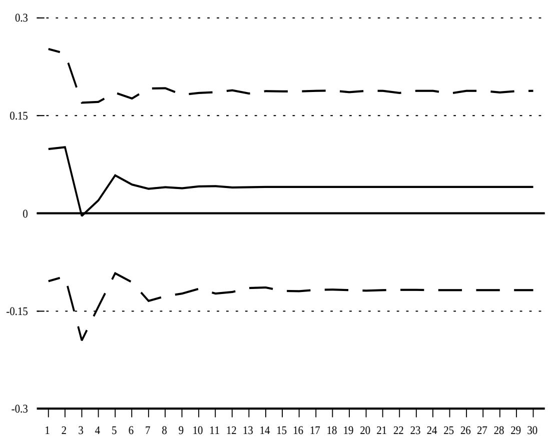
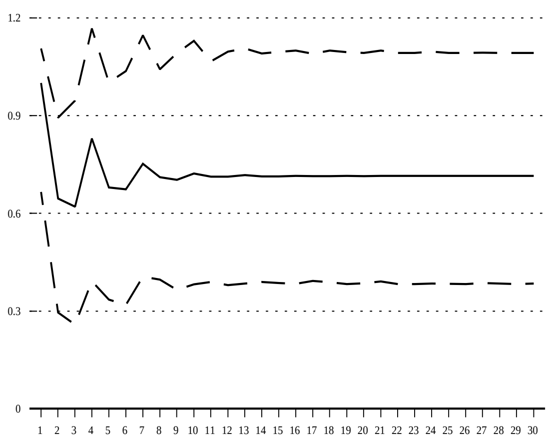


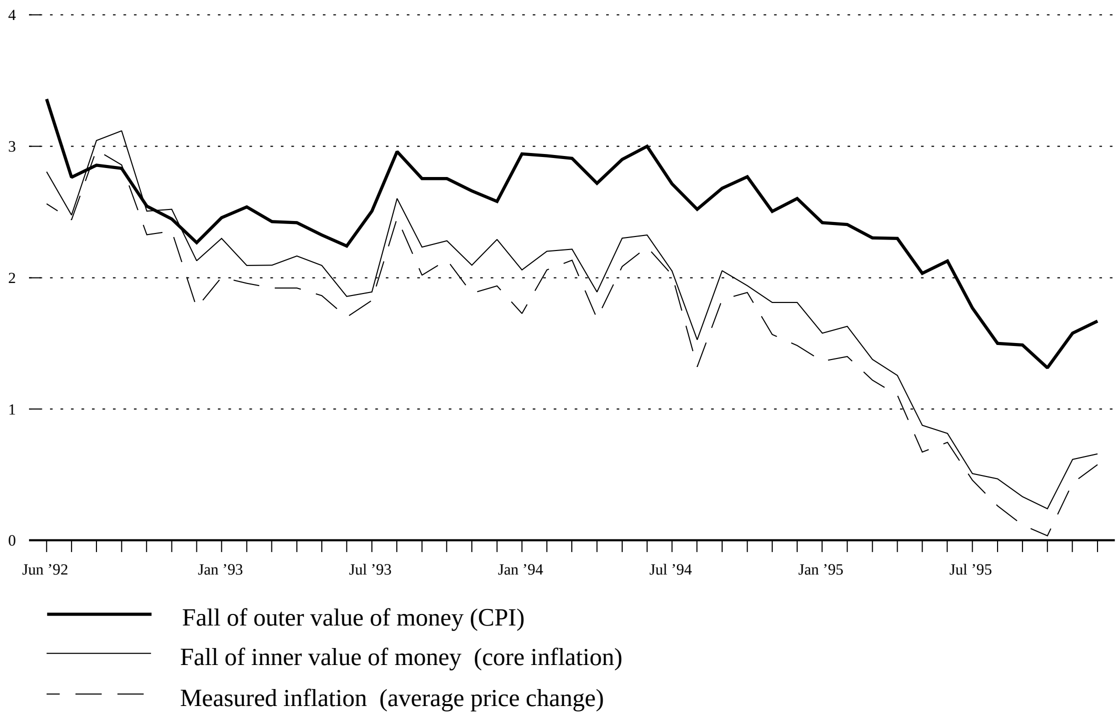
Figure 2b Output



Explanatory note: The horizontal axis shows time in months. The vertical axis shows the deviation (in percent) of inflation and (log-)output, respectively, from the initial level. The core inflation shock ε_1 and the output shock ε_2 have been so chosen that in the first period measured inflation would be up by one percentage point, and the level of (log-)output by one percent. The shock lasts but one period. The 95% confidence intervals — based on 1000 replications — for the impulse-response functions are also shown (see Runkle (1987) for details).

The ultimate objective of the model is the identification of price changes, which have been caused by monetary factors. Figure 3 shows the average price change or measured inflation, the core inflation derived from the average price change and the conventional measure of inflation based on the CPI. Phrased differently, using core inflation based on the average price change to operationalize the decrease in the inner value of money, Figure 3 depicts the movement in the outer and inner value of money. As noted before, the level of core inflation cannot be identified, merely the change in that level. The chart is therefore based on the assumption that in the month preceding the sample period core inflation coincides with the average price change.

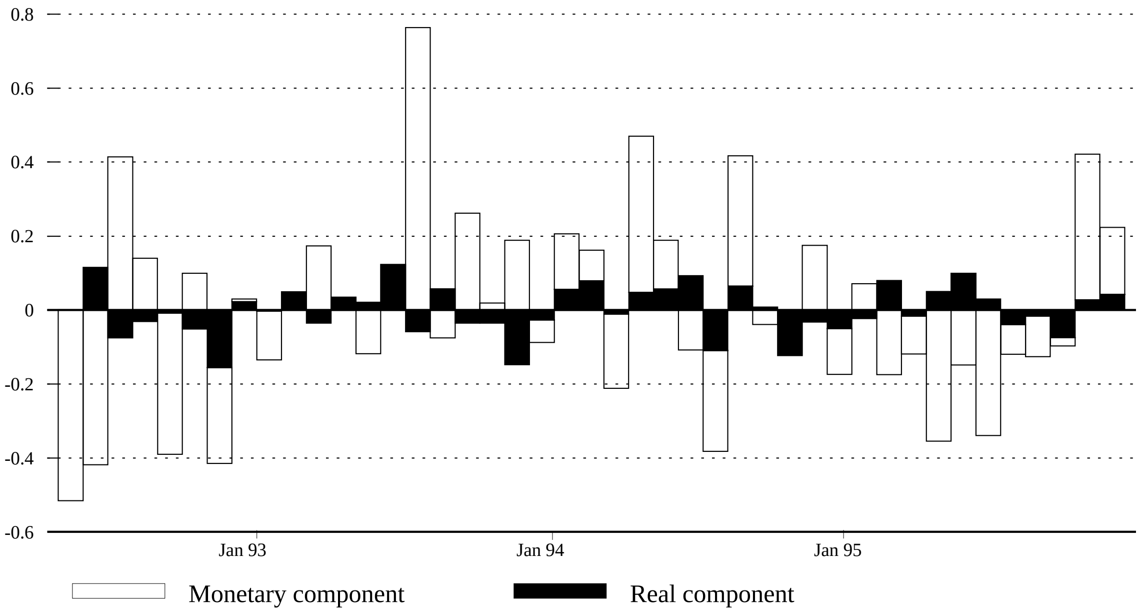
Figure 3 Change of inner and outer value of money (percent)



The remarkable thing about the pattern in Figure 3 is that the discrepancy between measured inflation and core inflation does not show any trend over time. This means that the average price change is either relatively insensitive to price changes generated by real factors or - and this is more likely - that over the sample period real shocks had but a relatively small influence on the price level. This second interpretation is also supported by the breakdown of the impulses on *measured* inflation υ_{1t}. The shocks υ_{1t} relating to measured inflation, i.e. the average price change, are, after all, related to the structural shocks ε_{1t} and ε_{2t} through $\upsilon_{1t} = A_{0,11}\varepsilon_{1t} + A_{0,12}\varepsilon_{2t}$. Figure 4 shows, for every month of the sample period, the monetary component $A_{0,11}\varepsilon_{1t}$, and the real component $A_{0,12}\varepsilon_{2t}$ of the inflation shock υ_{1t}. The chart shows that the effect of real shocks on measured inflation has indeed been fairly small over the past three years by comparison with the effect of monetary shocks.

The movements in the average price change and derived core inflation in Figure 3 shows that a number of periods stand out where the average price change over- or underestimates the monetary influences on inflation. Figure 4 shows, for example, that the drop in the average price change in December 1992 is only partially the result of monetary policy. Simultaneous real impulses lead to a drop in the average price change as well. On the other hand, the increase in the average price change in February and March 1994 is not caused by a monetary shock only, but real factors drove prices up as well. Finally, in the second half of 1995, the average price change first dropped more substantially and then rose more considerably than core inflation. Again real and monetary impulses worked in the same direction leading to an overestimation of the monetary effects on measured inflation.

Figure 4 Historical decomposition of inflation shocks υ_{1t}



From a comparison of the movements in the inner and the outer value of money, i.e. core inflation and the change in the CPI, it becomes evident that a notable difference between the two is that from July 1993 onwards the fall in the outer value of money is much more pronounced than that in the inner value of money. It goes without saying that the weighting of the CPI explains this phenomenon, because certain goods and services whose prices continued to rise after July 1993 figure fairly prominently in the CPI, such as actual and imputed rents. In the case of the average price change and derived core inflation, the marked rise in the prices of these items is partially offset by the smaller increase or even fall in prices of the bulk of goods and services.

6.2 European Union

Attempting to measure the inner and outer value of money on a European level by the methods described so far presents problems of its own, most notably the problem that a common European currency does not yet exist. Therefore, in order to measure the value of money, one first has to define a European concept of money. Here we define European money as the aggregated money stocks of the various nations using purchasing power parities to convert all nominal values into ecu. Thus, the European money stock at time *t* is defined as

$$M_{tEU} = \sum_i e_{ti} M_{ti} \ , \qquad (10)$$

with e_{ti} denoting the purchasing power parity of country *i* at time *t* and M_{ti} the money stock of country *i* at time *t*. A matching definition of the outer value of European money takes the form

$$P_t^L = \sum_i w_i \frac{e_{ti}}{e_{0i}} P_{ti}^L \text{, with } w_i = \frac{\sum_j e_{oi} p_{0ij} x_{0ij}}{\sum_{lj} e_{0l} p_{0lj} x_{0lj}} , \qquad (11)$$

which is a weighted average of the national CPI's P_{ti}^L of the various countries, with weights w_i equal to the countries, shares in aggregate European final consumption in 1985. Finally, as European average price change we use

$$\pi(\text{avg.}) = \frac{1}{IJ} \sum_{ij} \ln e_{ti} p_{tij} - \ln e_{(t-1)i} p_{(t-1)ij} \qquad (12)$$

where *I* denotes the number of countries considered and *J* the number of commodities per country.

In order to estimate Quah and Vahey's VAR model (8) for Europe we used monthly data for the period January 1985 to December 1995 for Austria, Belgium, France, Germany, Italy, the Netherlands, Spain, Sweden and the United Kingdom. As the series reflecting real output, the deseasonalized average daily output of the national production industries, excluding construction, was chosen. European real output was constructed as the weighted average of national real output, with weights equal to each country's share in European gross added value on the basis of factor prices. Measured inflation in this application is the European average price change, calculated on the basis of the 11 price series per country which also underlie the national CPI's.

Before we estimated the model for the European Union we tested if the series for measured inflation and real output show non-stationary behaviour. The test results indicate that for the European Union these conditions for the identification method are satisfied. For the model specification to be complete, the lag order of the VAR model must be chosen. Based on preliminary estimates and several standard criteria we choose a lag length of three [6]. The estimation results for the structural VAR model are again presented as impulse-response functions for measured inflation, i.e. European average price change, and European (log-)output, shown in Figures 5 and 6.

A core inflation shock leads to a permanent increase in inflation. In the same way as for the Netherlands it is observed that the effect of an inflation impulse on output wears off quickly and that output returns to its initial level within 12 months. Similarly, the European results suggest that an inflation shock may decrease output in the first month. The confidence intervals reveal, however, that this effect is not significant.

Contrary to the model for the Netherlands, however, the model for the European Union implies that a real shock has a significant and permanent effect on inflation. This casts some doubt on the hypothesis that monetary effects are correctly identified by this approach applied to European data. Indeed, the prediction that a permanent rise in the output level by 0.5% implies a permanent rise in inflation in the absence of any monetary effects, contradicts economic theory.

This failure of the model to decompose the European average price change into a purely monetary and a purely real component can probably be explained by the assumptions underlying the structural VAR model. Implicitly the model assumes that only two types of shocks drive inflation and output. Furthermore, it is assumed that each realisation of a shock has the same effect on the endogenous variables. If applied to one country, the assumption of a single typical inflation shock is justifiable because of the existence of a single monetary base. For Europe, however, a single monetary base does not yet exist. Moreover, the transmission of monetary shocks may differ between countries due to diverging institutional arrangements. Both facts may imply that a monetary shock originating in e.g. Italy leads to a different effect on European output than an unanticipated inflation shock in, for instance, Germany.

Although the identification of the monetary component of the average price change by the structural VAR model applied to the European Union is less convincing compared to the application to the Netherlands, we present in Figure 7 the change in the inner and outer value of European money. The chart shows that the inner value of money decreased less than the outer value of money in 1988-89, catching up in 1990-91. In the third and fourth quarters of 1992, however, the fall in the inner value of money was more marked than that in the outer value. In the last quarter of 1993 and 1994 the fall of the inner value decelerated once more, catching up with the decrease in the inner value of European money. Incidentally, in 1992 the year when the changes in the inner and the outer value diverged quite sharply, the UK and Italy moved out of the EMS.

[6] Details are presented in Appendix I.

Response to core inflation shock

Figure 5a Measured inflation

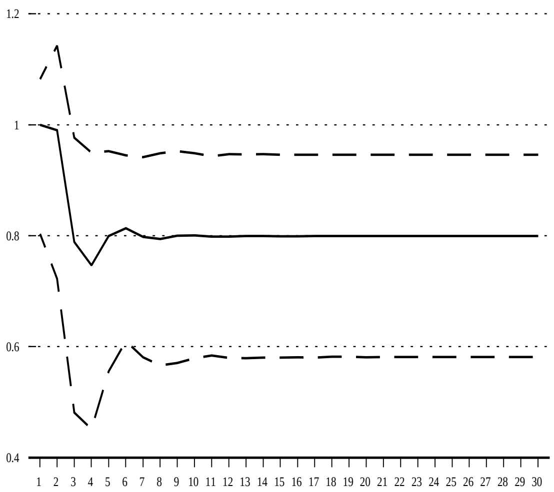
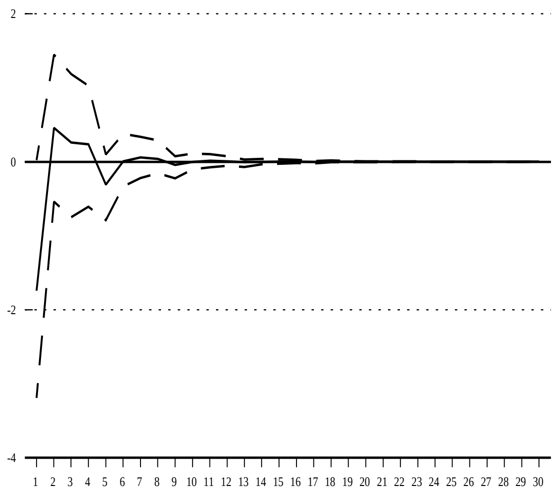


Figure 5b Output



Response to output shock

Figure 6a Measured inflation

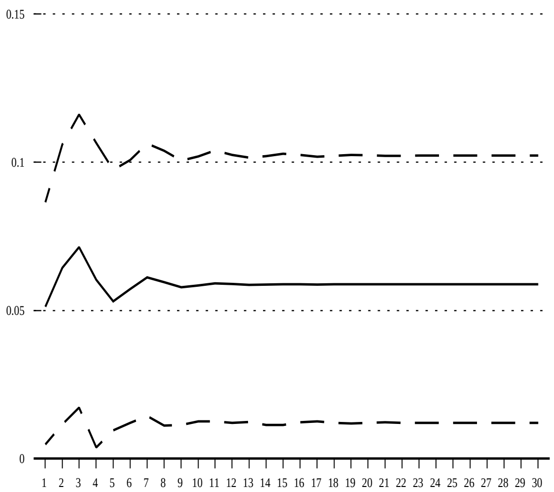
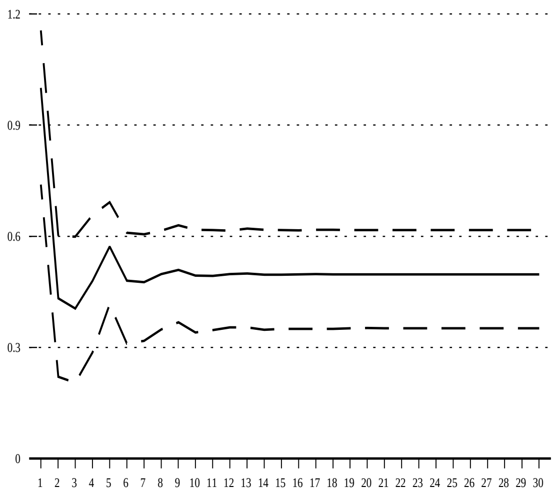
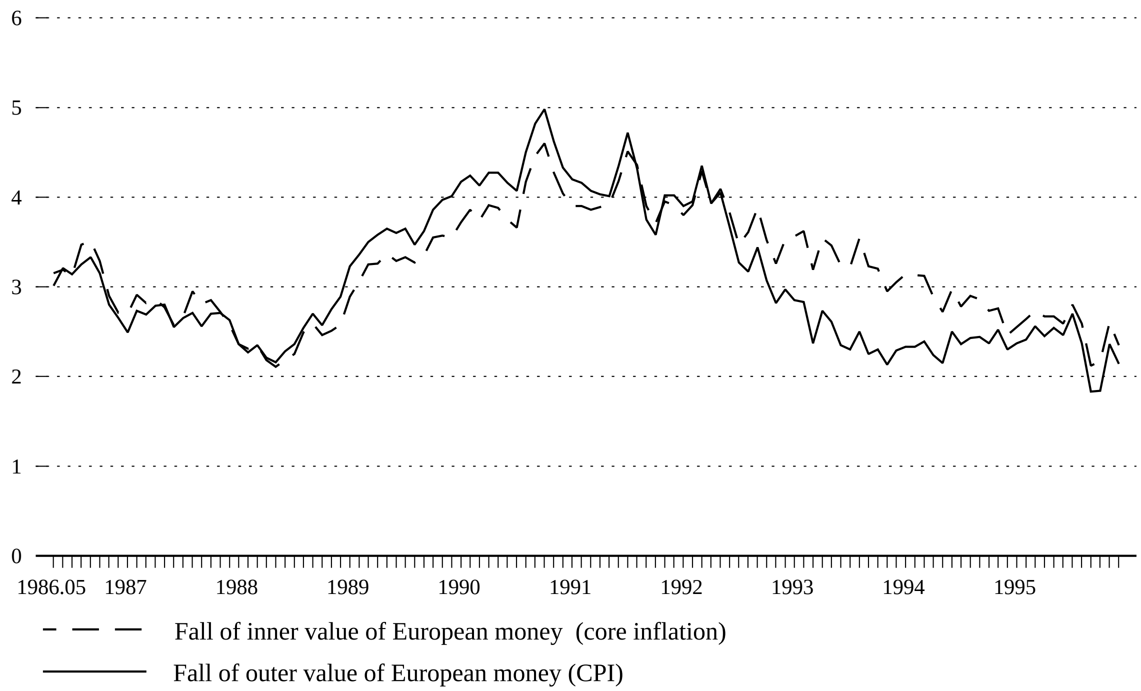


Figure 6b Output



Explanatory note: The horizontal axis shows time in months. The vertical axis shows the deviation (in percent) of inflation (log-)output, respectively, from the initial level. The core inflation shock ε_1 and the output shock ε_2 have been so chosen that in the first period measured inflation would be up by one percentage point, and the level of (log-)output by one percent. The shock lasts but one period. The 95% confidence intervals for the impulse-response functions are also shown.

Figure 7 Change of inner and outer value of European money



7 CONCLUSIONS

This paper was motivated by the fact that the most commonly used measure of inflation, the change in the CPI, does not match the concept of inflation used in economic theory: it cannot distinguish between monetary and real causes leading to price changes nor between a one-off and a permanent price rise. From the point of view of a monetary authority which aims to stabilize the value of money, the former shortcoming is especially disturbing since the central bank may be held accountable for price rises which are not caused by monetary policy or it may take inappropriate policy actions on the basis of a biased inflation measure.

This paper investigated possible operationalizations of Carl Menger's concept of the inner value of money. A change in the inner value of money is defined as the change in prices, which is solely brought about by monetary causes. On examining different descriptive statistics of price changes more closely, we found that neither the change in the CPI, nor the average price change or the mode or median of the price change frequency distribution is capable of identifying changes in the inner value of money. Furthermore, we also tried to decompose the price changes measured by the average price change into a real and monetary component using the economic hypothesis that inflation is output-neutral in the long run. It was argued that this approach, which is based on a model of Quah and Vahey, does indeed identify the monetary component of price changes but not the inner value of money. The difference between the two is that the former responds to price changes which are caused by the transmission of monetary shocks, whereas the latter is defined in terms of price changes following a monetary shock after all adjustment processes have been completed. Despite this difference, core inflation or the monetary component of the average price change is the best available operationalization of the decrease in the inner value of money and is wholly in accordance with economic theory.

Applying the approach to the Netherlands and the European Union, we found that the change in the inner and that in the outer value of money have diverged considerably and persistently in the periods examined. This finding indicates that using the CPI as a gauge for inflation is not only theoretically inappropriate but that even in practical applications it yields distorted information on the actual inflationary tendencies. The change in the inner value of money may be seen as an alternative measure that matches the concept of inflation used in economic theory more closely than the change in the CPI. Moreover, from the point of view of monetary policy, it seems to be the more adequate measure of inflation in terms of accountability.

APPENDIX I

I.1 **The model for the Netherlands: non-stationarity tests and lag order**

With the aid of the two augmented Dickey-Fuller tests, the stationarity of the base series and their first differences were examined. For the (log-)output series *y*, the test statistic $T(\rho-1)$, with *T* the sample size and ρ the autocorrelation between successive observations, and the Dickey-Fuller *t*-test $\frac{\rho-1}{\sigma_\rho}$ indicate the existence of non-stationarity; the first differences Δy, however, do form a stationary process. The hypothesis that the output series is integrated of order one is thus confirmed. The hypothesis that the average price change is also integrated of order one may also be accepted.

Table 1 Results of the Augmented Dickey-Fuller test

Variabele	Lag length	Excluding trend $T(\rho-1)$	Excluding trend $(\rho-1)/\sigma_\rho$	Including trend $T(\rho-1)$	Including trend $(\rho-1)/\sigma_\rho$
y	5	0.46***	0.05***	-9.91***	-0.94***
Δy	4	-231.39	-6.41	-238.87	-6.78
π(aver.)	1	-3.04***	-1.16***	-15.36***	-2.68***
$\Delta\pi$(aver.)	1	-66.66	-6.64	-66.32	-6.51

Notes: The number of lagged variables in the test regression has been so chosen that the disturbance term is not serially correlated. ***/**/* means that the hypothesis that a unit root is present cannot be rejected at a significance level of 10%/5%/1%, respectively.

The number of lagged variables to be included in the VAR model is determined with the aid of various criteria and test statistics. The criteria of Akaike, Hannan-Quinn and Schwartz indicate a lag length of 1 to 3. Although the Box-Pierce Portmanteau test and Godfrey's Lagrange multiplier test do not indicate serial correlation of the residuals if the model includes but one lagged variable, and the log-likelihood ratio test, too, does not show that, by comparison with a lag length of 3, this specification is overly restrictive, three lagged variables were included. It seems unlikely that the change in inflation and the growth rate of output can be explained by current inflation and output as well as inflation and output of the previous month only. It also turned out that a deterministic trend is not significant, so that, apart from the lagged variables, only a constant term was added to the model.

I.2 **The model for the European Union: non-stationarity tests and lag order**

The results of the test for the non-stationarity of the European average price change and European real output are summarised in Table 2. With the aid of the two augmented Dickey-Fuller tests, the stationarity of the base series and their first differences were examined. For the (log-)output series *y*, the test statistic $T(\rho - 1)$, and the Dickey-Fuller *t*-test indicate the existence of non-stationarity; the first differences Δy, however, do form a stationary process. The hypothesis that the output series is integrated of order one is thus confirmed. The hypothesis that the average price change is also integrated of order one may also be accepted.

Table 2 Results of the Augmented Dickey-Fuller test

Variabele	Lag length	Excluding trend		Including trend	
		$T(\rho - 1)$	$(\rho - 1)/\sigma_\rho$	$T(\rho - 1)$	$(\rho - 1)/\sigma_\rho$
y	3	-5.21***	-1.58***	-7.89***	-1.43***
Δy	3	-307.70	-8.19	-311.77	-8.22
π(aver.)	2	-3.58***	-1.16***	-4.03***	-1.28***
$\Delta\pi$(aver.)	2	-140.69	-7.69	-141.03	-7.69

Notes: The number of lagged variables in the test regression has been so chosen that the disturbance term is not serially correlated. ***/**/* means that the hypothesis that a unit root is present cannot be rejected at a significance level of 10%/5%/1%, respectively.

As in the model for the Netherlands, the number of lagged variables to be included in the VAR model is determined with the aid of the criteria of Akaike, Hannan-Quinn and Schwartz. The criterion of Schwartz points towards a lag length of 1, whereas the other two criteria indicate a lag length of 3. The model with 1 lagged variable is, however, not correctly specified since the Box-Pierce Portmanteau test and Godfrey’s Lagrange multiplier test indicate serial correlation of the residuals. The log-likelihood ratio test, too, rejects a lag length of 1 maintaining the model with three lagged variables.

APPENDIX II: INFLATION IN THE NETHERLANDS AND EUROPE MEASURED BY DIFFERENT GAUGES

In this appendix the numerical values underlying Figure 3 and 7 as well as some additional series are presented. Table 3a contains the monthly series for the Netherlands depicted in Figure 3. Table 3b shows the annual averages of these series. Furthermore, Table 3a presents the series for the change in the derived CPI, endogenous inflation and underlying inflation. The derived CPI excludes changes in indirect taxes and consumption-based taxes, such as motor vehicle tax. The endogenous inflation is the change in the derived CPI excluding the prices, which are administered in the Netherlands, e.g. gas, rents and imputed rents. Finally, the underlying inflation is calculated as the change in the CPI excluding the prices of vegetables, fruits and energy.

Table 4a contains the monthly series depicted in Figure 7 and Table 4b presents the annual averages of these series.

Table 3a Inflation in the Netherlands measured by different gauges (percent)

Month		Change in the CPI	Change in the derived CPI	Endogenous inflation	Under-lying Inflation	Average price change	
						measured	core inflation
1992	June	3.36	2.61	2.12	3.56	2.56	2.80
	July	2.76	2.21	1.78	3.64	2.44	2.47
	August	2.85	2.31	1.91	3.72	2.97	3.04
	September	2.83	2.29	1.61	3.78	2.86	3.12
	October	2.54	2.28	1.64	3.59	2.33	2.51
	November	2.45	2.28	1.64	3.59	2.35	2.52
	December	2.26	1.90	1.13	3.21	1.77	2.13
1993	January	2.46	2.29	1.76	3.40	2.00	2.30
	February	2.54	2.28	1.75	3.47	1.96	2.09
	March	2.43	2.26	1.73	3.26	1.92	2.09
	April	2.42	2.16	1.60	3.34	1.92	2.16
	May	2.32	2.07	1.47	3.25	1.86	2.09
	June	2.24	1.98	1.35	3.17	1.70	1.86
	July	2.51	2.44	2.04	3.24	1.83	1.89
	August	2.96	3.00	2.80	3.59	2.45	2.60
	September	2.75	2.70	2.67	3.37	2.02	2.23
	October	2.75	2.41	2.24	3.37	2.13	2.28
	November	2.66	2.23	1.99	3.19	1.88	2.09
	December	2.58	2.33	2.13	3.11	1.94	2.29
1994	January	2.94	2.42	1.76	3.20	1.73	2.06
	February	2.93	2.50	1.88	3.00	2.06	2.20
	March	2.91	2.49	1.86	2.98	2.13	2.22
	April	2.72	2.30	1.61	2.70	1.69	1.89
	May	2.90	2.48	1.85	2.70	2.08	2.30
	June	3.00	2.58	1.99	2.71	2.23	2.32
	July	2.71	2.29	1.47	2.69	2.02	2.05

Table 3a (continued)

Month		Change in the CPI	Change in the derived CPI	Endogenous inflation	Under-lying Inflation	Average price change	
						measured	core inflation
	August	2.52	2.10	1.21	2.41	1.32	1.53
	September	2.68	2.36	1.57	2.57	1.83	2.05
	October	2.77	2.36	1.56	2.66	1.89	1.94
	November	2.50	2.18	1.32	2.48	1.57	1.81
	December	2.60	2.19	1.33	2.58	1.48	1.81
1995	January	2.42	2.28	1.53	2.40	1.36	1.58
	February	2.40	2.17	1.39	2.39	1.40	1.63
	March	2.30	2.16	1.38	2.46	1.22	1.38
	April	2.30	2.16	1.38	2.46	1.11	1.26
	May	2.03	1.98	1.13	2.20	0.67	0.87
	June	2.13	1.98	1.14	2.38	0.75	0.81
	July	1.77	1.71	1.05	2.02	0.46	0.51
	August	1.50	1.43	0.67	1.75	0.26	0.47
	September	1.49	1.42	0.67	1.73	0.12	0.33
	October	1.31	1.25	0.42	1.56	0.03	0.24
	November	1.58	1.51	0.79	1.74	0.44	0.62
	December	1.67	1.52	0.79	1.66	0.58	0.66

Table 3b Inflation in the Netherlands measured by different gauges (percent)

Year	Change in the CPI	Change in the derived CPI	Endogenous inflation	Under-lying Inflation	Average price change	
					measured	core inflation
1992*)	2.72	2.27	1.69	3.58	2.47	2.66
1993	2.55	2.35	1.96	3.31	1.97	2.16
1994	2.77	2.35	1.62	2.72	1.84	2.02
1995	1.91	1.80	1.03	2.06	0.70	0.86

*) For 1992 the averages are based on the figures for June – December.

Table 4a European inflation measured by different gauges (percent)

Month		Change in European CPI	European average price change	
			measured	core inflation +)
1986	May	2.67	3.01	3.15
	June	2.70	3.21	3.19
	July	2.49	3.14	3.12
	August	2.53	3.25	3.47
	September	2.64	3.33	3.51
	October	2.34	3.15	3.29
	November	2.16	2.80	2.90
	December	2.11	2.65	2.71
1987	January	2.19	2.49	2.70
	February	2.24	2.73	2.91
	March	2.37	2.69	2.82
	April	2.43	2.79	2.86
	May	2.40	2.80	2.77
	June	2.31	2.55	2.57
	July	2.59	2.65	2.67
	August	2.63	2.71	2.95
	September	2.55	2.56	2.81
	October	2.78	2.70	2.85
	November	2.72	2.71	2.72
	December	2.58	2.63	2.58
1988	January	2.31	2.36	2.36
	February	2.31	2.27	2.31
	March	2.45	2.35	2.35
	April	2.50	2.21	2.18
	May	2.62	2.16	2.11
	June	2.72	2.28	2.18
	July	2.82	2.36	2.25
	August	3.10	2.54	2.49
	September	3.17	2.70	2.59
	October	3.20	2.57	2.46
	November	3.38	2.75	2.51
	December	3.61	2.89	2.58
1989	January	3.94	3.23	2.89
	February	4.19	3.36	3.06
	March	4.20	3.50	3.25
	April	4.44	3.58	3.26
	May	4.55	3.65	3.37
	June	4.52	3.60	3.29
	July	4.45	3.65	3.33
	August	4.22	3.47	3.27
	September	4.24	3.62	3.35
	October	4.36	3.86	3.55
	November	4.36	3.97	3.57
	December	4.34	4.01	3.55
1990	January	4.26	4.17	3.72
	February	4.24	4.24	3.86
	March	4.32	4.13	3.74
	April	4.36	4.27	3.91

Table 4a (continued)

Month		Change in European CPI	European average price change: measured	core inflation +)
	May	4.32	4.27	3.88
	June	4.25	4.16	3.75
	July	4.28	4.07	3.66
	August	4.68	4.50	4.17
	September	4.94	4.82	4.46
	October	5.10	4.98	4.60
	November	4.73	4.62	4.27
	December	4.51	4.33	4.04
1991	January	4.47	4.20	3.90
	February	4.51	4.16	3.90
	March	4.36	4.07	3.86
	April	4.02	4.03	3.89
	May	4.09	4.01	3.92
	June	4.32	4.35	4.18
	July	4.55	4.72	4.51
	August	4.17	4.32	4.36
	September	3.84	3.75	3.90
	October	3.92	3.58	3.71
	November	4.41	4.02	3.95
	December	4.37	4.02	3.91
1992	January	4.31	3.90	3.80
	February	4.28	3.95	3.91
	March	4.35	4.35	4.29
	April	4.39	3.93	3.93
	May	4.33	4.05	4.09
	June	4.03	3.67	3.83
	July	3.62	3.27	3.47
	August	3.51	3.17	3.61
	September	3.50	3.44	3.88
	October	2.96	3.07	3.52
	November	2.70	2.82	3.26
	December	2.68	2.97	3.53
1993	January	2.80	2.85	3.56
	February	2.81	2.83	3.62
	March	2.82	2.37	3.19
	April	2.70	2.73	3.54
	May	2.64	2.61	3.46
	June	2.68	2.35	3.24
	July	2.85	2.30	3.22
	August	2.97	2.50	3.54
	September	2.89	2.25	3.23
	October	2.87	2.30	3.20
	November	2.84	2.13	2.95
	December	2.94	2.29	3.05
1994	January	2.74	2.33	3.14
	February	2.68	2.33	3.13
	March	2.56	2.39	3.12

Table 4a (continued)

Month		Change in European CPI	European average price change measured	core inflation +)
	April	2.57	2.24	2.89
	May	2.62	2.15	2.72
	June	2.58	2.50	2.97
	July	2.45	2.36	2.78
	August	2.51	2.43	2.90
	September	2.45	2.44	2.86
	October	2.41	2.37	2.73
	November	2.36	2.52	2.76
	December	2.48	2.30	2.46
1995	January	2.53	2.37	2.55
	February	2.63	2.41	2.64
	March	2.76	2.56	2.73
	April	2.80	2.45	2.67
	May	2.71	2.54	2.67
	June	2.86	2.46	2.59
	July	2.69	2.70	2.80
	August	2.75	2.37	2.59
	September	2.83	1.83	2.12
	October	2.69	1.84	2.17
	November	2.74	2.36	2.60
	December	2.75	2.14	2.35

+) Cf. note to Table 4b.

Table 4b European inflation measured by different gauges (percent)

Year	Change in European CPI	European average price change measured	core inflation +)
1986 *)	2.46	3.07	3.17
1987	2.57	2.66	2.74
1988	3.08	2.53	2.40
1989	4.38	3.73	3.41
1990	4.60	4.47	4.10
1991	4.21	4.10	4.05
1992	3.41	3.31	3.65
1993	2.83	2.34	3.24
1994	2.48	2.38	2.77
1995	2.75	2.28	2.49

*) For 1986 the averages are based on the figures for May – Dec.
+) As in Table 3, it is assumed that in April 1992 core inflation coincided with measured average price change.

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RESERVE BANK OF NEW ZEALAND

Targeting alternative measures of inflation under uncertainty about inflation expectations and exchange rate pass-through

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1. Introduction

It has become increasingly common among central banks to specify the operational goal of monetary policy as the maintenance of price stability. For example, the European Central Bank (ECB) recently announced that its goal for monetary policy is to keep inflation below two percent per annum over the medium term. In translating the operational goal into practice, it must be decided which price index is to be targeted. Theory suggests that if the primary cost of inflation arises from consumers' uncertainty regarding the future purchasing power of their incomes, then monetary policy should strive to stabilise a utility-constant consumer price index. In the absence of such ideal indices, central banks have opted to target some available index of consumer prices.

As consumer price indices are independently calculated by statistical agencies, they are seen as credible targets for policy. This is perhaps their primary advantage. However, the disadvantage of targeting consumer prices is that the aggregate index is often affected by price movements in sub-components that do not reflect the 'underlying' trend in inflation. Setting policy at all times based upon movements in aggregate consumer prices could then lead to sub-optimal outcomes. In recognition of this problem, central banks do not in practice strive to meet their CPI inflation targets at all times (see Debelle (1997)). Instead, operational flexibility is afforded to the central bank, arising in two main guises. The first is to target CPI inflation subject to 'caveats' for price movements in the index that are seen as extraordinary (for example, as in New Zealand and Canada). The second is to allow the central bank to meet the inflation target over a somewhat flexible period of time (for example, in the 'medium' term at the ECB, and 'over the cycle' at the Reserve Bank of Australia).

A central bank afforded operational flexibility in policy making, explicitly or implicitly, needs to take into account what is often termed underlying or 'core' inflation. Many alternative methodologies have been proposed to measure core inflation. The key concept behind these measures is that the central bank should counter only *persistent* sources of inflationary pressures, as these become ingrained into inflation expectations. Consequently, the inflation control problem is difficult to manage if core inflation 'gets away' from the inflation target. In contrast, by definition temporary inflation shocks will not have ongoing effects, and therefore the consequences for the monetary authority of ignoring them are less severe.

In the macro model that lies at the heart of the Reserve Bank of New Zealand's *Forecasting and Policy System*, FPS, core inflation is defined as the rate of inflation in the price of domestically produced and consumed goods. This rate of inflation is driven principally by the deviation of aggregate demand for goods and services from the economy's supply capacity. However, for small open economies, movements in the nominal exchange rate, via their direct effect on the price of imported goods, cause a significant part of the variation in consumer price indices. The model's definition of CPI inflation incorporates these direct exchange rate effects, while the core inflation measure does not.

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If exchange rate movements affect only the *level* of the CPI, and not inflation expectations, then exchange rate pass-through constitutes the type of shock that core inflation measures aim to remove. In this case, *a priori,* we would expect that 'looking through' these short-lived effects would lead to superior macroeconomic outcomes. This is examined in Svensson (1998), where a model of a small open economy is used to compare 'flexible' policy rules that target CPI inflation, against those that target domestic price inflation. Svensson's results largely confirm our intuition - the variance in CPI inflation and the real exchange rate is lower when targeting CPI inflation, whilst the variance in real output and nominal interest rates are lower when targeting domestic price inflation.

We might expect that agents face a signal extraction problem in the real world as to how much of observed inflation constitutes 'core' inflation. Given this problem, we do not know exactly how agents form their expectations of inflation. Hence, there is no guarantee that agents' perceptions of core inflation are the same as that of the monetary authority. In Conway *et al.* (1998), stochastic simulations of FPS are used to explore the implications of this uncertainty in the context of CPI versus core domestic price inflation targeting. The result found in Svensson (op. cit.) was largely upheld. That is, whether direct exchange rate price effects influence inflation expectations or only the level of CPI inflation, and regardless of whether the monetary authority perceives this correctly, targeting domestic inflation reduces the variability in all macro variables except for CPI inflation.

This paper extends the work presented in Conway *et al.* in several dimensions. Firstly, following recent development of the FPS core model, the stochastic disturbances applied are a more complete representation of the shocks the New Zealand economy has faced historically. Secondly, we examine the performance of the model economy under a broader range of policy rules. Finally we add another important dimension of uncertainty to the problem – that of the speed of exchange rate pass-through. Reflecting conventional 'stylised facts', the exchange rate transmission channel of monetary policy in FPS affects CPI inflation more quickly than the aggregate demand transmission channel. Nevertheless, the exchange rate transmission channel is still slow relative to other stylised models such as that in Svensson (1998). This reflects only New Zealand's *recent* experience. The transmission of exchange rate or foreign price movements into domestic import prices has been quite variable over time. Given this uncertainty about the speed of exchange rate pass-through, coupled with uncertainty about how agents form their inflation expectations, we examine whether it is still the case that preferable macroeconomic outcomes are attainable under domestic price inflation targeting.

Our results suggest that under the standard forward-looking inflation targeting policy rule used in FPS – a rule that is used to prepare the Bank's economic projections – it is indeed still the case that targeting core inflation results in superior macroeconomic outcomes. We also examine the performance of the model economy under three alternative, descriptively accurate policy rules.[1] In particular, we consider an inflation-targeting rule that is less forward-looking than the standard FPS rule, an inflation-targeting rule that explicitly seeks to smooth output, and the standard 'Taylor rule'. Under a policy rule with a shorter policy horizon than the standard FPS rule, it is found that targeting core inflation reduces variability in output, core inflation, *and* CPI inflation, at a cost of higher instrument variability, relative to targeting CPI inflation. The results under the forward-looking inflation targeting rule with an explicit concern for smoothing output are similar to those found with the standard FPS policy rule, except that core inflation variability is largely the same regardless of whether CPI or core inflation is targeted. Finally, the results under the Taylor rule run against the qualitative results seen under the forward-looking policy rules. The Taylor rule that targets output and core inflation results in *more* variability in output and the real exchange rate relative to the Taylor rule that targets output and CPI inflation.

[1] These rules are descriptively accurate in the sense that they can explain movements in actual policy over history quite well.

The remainder of the paper is structured as follows. In Section 2 a very brief description of FPS, and the technique employed for performing stochastic simulations of the model, are presented. In Section 3, alternative methodologies for constructing core inflation are outlined and we discuss how the model's definition of core inflation fits within these methodologies. Section 4 contains a discussion of exchange rate pass-through in New Zealand. The stochastic simulation results are presented in Section 5. Section 6 contains a brief summary and conclusion.

2. The FPS core model[2]

2.1 The core model

The FPS core model describes the interaction of five economic agents: households, firms, government, a foreign sector, and the monetary authority. The model has a two-tiered structure. The first tier is the underlying steady-state structure that determines the long-run equilibrium to which the model will converge. The second tier is the dynamic adjustment structure that traces out how the economy converges towards that long-run equilibrium.

The long-run equilibrium is characterised by a neo-classical balanced-growth path. Along that growth path, consumers maximise utility, firms maximise profits and government achieves exogenously-specified targets for debt and expenditures. The foreign sector trades in goods and assets with the domestic economy. Taken together, the actions of these agents determine expenditure flows that support a set of stock equilibrium conditions underlying the balanced growth path.

The dynamic adjustment process overlaid on the equilibrium structure embodies both "expectational" and "intrinsic" dynamics. Expectational dynamics arise through the interaction of exogenous disturbances, policy actions and private agents' expectations. Policy actions are introduced to re-anchor expectations when exogenous disturbances move the economy away from equilibrium. Because policy actions do not immediately re-anchor private expectations, other real variables in the economy must follow disequilibrium paths until expectations return to equilibrium. To capture this notion, expectations are modelled as a linear combination of a backward-looking autoregressive process and a forward-looking model-consistent process. Modelling expectations in this way partially addresses the critique, initially raised in Lucas (1976), that examining alternative policy actions in reduced form econometric models gives misleading conclusions.[3]

Intrinsic dynamics arise because adjustment is costly. The costs of adjustment are modelled using a polynomial (up to fourth order) adjustment-cost framework (see Tinsley (1993)). In addition to expectational and intrinsic dynamics, the behaviour of both the monetary and fiscal authorities also contributes to the overall dynamic adjustment process.

On the supply side, FPS is a single-good model. That single good is differentiated in its use by a system of relative prices. Overlaid on this system of relative prices is an inflation process. Although inflation can potentially arise from many sources in the model, inflation in domestic goods prices is determined fundamentally by the difference between the economy's supply capacity and the demand for goods and services. Further, the relationship between goods markets disequilibrium and inflation

[2] See Black *et al*. (1997) for a full account of the FPS.

[3] The Lucas critique states that the estimated parameters of reduced-form models are dependent on the policy regimes in place over the estimation period. Consequently, simulating reduced-form models in which behaviour is invariant to policy actions produces misleading policy conclusions. Although FPS has partially addressed the Lucas critique, a more explicit modelling of agents' learning behaviour would be required to fully address it.

is specified to be asymmetric. Excess demand generates more inflationary pressure than an identical amount of excess supply generates deflationary pressure.

The monetary authority effectively closes the model by enforcing a nominal anchor. Its behaviour is modelled by a forward-looking reaction function that moves the short-term nominal interest rate in response to projected deviations of inflation from an exogenously-specified target rate. Although the reaction function is *ad hoc* in the sense that it is not the solution to a pre-defined optimal control problem as in Svensson (1996), its design is not arbitrary. The forward-looking nature of the reaction function takes account of the lags in the economy between policy actions and subsequent implications for inflation outcomes. Further, the strength of the policy response to projected deviations in inflation implicitly embodies the notion that the monetary authority is not single-minded in its pursuit of the inflation target. Other factors such as the variability of its instrument and the real economy are also of concern.

2.2 Stochastic simulations of the core model[4]

Performing stochastic simulations requires a distribution from which to draw the shocks that are applied to the model economy. In small macroeconometric models, the distributions of the shocks applied to the model are usually based upon the properties of the residuals from the estimated equations (see, for example, Fillion and Tetlow (1994) for an application of this approach). Given the paucity of data in New Zealand, and the size of the model, FPS has been calibrated. Consequently, there are no historical errors from which we can draw shocks to use for stochastic simulations of the model. Instead, impulse response functions (IRFs) from an estimated VAR are used to define disturbances to the FPS core model. These disturbances include shocks to:

- world output
- world commodity prices
- domestic demand
- core inflation
- the real exchange rate.

The impulse response functions arising from the VAR are used to determine the serial and cross correlation structure of the macro disturbances. This is the primary advantage of using the VAR model – the shocks applied in the stochastic simulation experiments presented in Section 5 do not have independence arbitrarily imposed.[5]

As discussed in Conway *et al.* (1998), there are two main weaknesses that arise in using the VAR to define the macro disturbances. The first is that the data could not support a large enough VAR to capture foreign interest rate and inflation effects. To rectify this problem, an extension has recently been made to the FPS core model. The core model now contains an endogenous foreign sector consisting of an aggregate IS curve, a Phillips curve, a policy reaction function, a long-term interest rate equation and a terms of trade relationship. Given this extension, shocks to world output and commodity prices now directly influence foreign inflation and interest rates. As such, the behaviour of the model economy under stochastic simulations is arguably now more realistic.

The properties of the foreign model have been calibrated using the behaviour of New Zealand's terms of trade as suggested by the VAR, evidence regarding commodity price variability over United States

[4] See Drew and Hunt (1998a) for a complete description on how stochastic simulations of the FPS core model are performed.
[5] Note however that the disturbances are seeded, so that for each experiment considered an identical battery of shocks hit the core model.

business cycles,[6] and the properties of the FRB/US model as outlined in Brayton and Tinsley (1996). (See Appendix 1 for further details and an illustration of the properties of the foreign sector of the FPS core model).

The second main difficulty with using the VAR is that there is insufficient stochastic information in the New Zealand potential output series to produce sensible impulse response functions when it is included. As such, there are no permanent disturbances in the stochastic simulation experiments, implying that important sources of macro variability in the New Zealand economy may be missing in the analysis. Mitigating this is the fact that innovations in the economy's level of productive capacity will in part be captured by the shock terms of the other variables of the system. Stochastic innovations in the domestic price level, for example, can be partially attributed to temporary aggregate supply shocks. Furthermore, as seen in Drew and Hunt (1998b), the moments of key macro variables generated by the FPS core model are reasonably close to the relevant historical moments.

3. Alternative measures of core inflation and FPS

3.1 Alternative measures of core inflation

With the advent of inflation targeting by several central banks around the world, there has been increasing recognition and acceptance of the idea that it may be preferable to stabilise a measure of inflation other than the simple mean inflation rate in the 'general' level of consumer prices. A "core inflation" measure, if more closely influenced by monetary policy, may comprise a superior target inflation rate.

Measures of core inflation aim to exclude temporary shocks and leave only shocks that 'permanently' affect inflation[7]. These latter shocks have the potential to feed through into inflationary expectations, and thus into a generalised inflation process. Temporary shocks, by comparison, tend to be out of line with 'typical' price changes and might be expected to have little or no effect on inflation expectations. The core component is therefore the component of inflation that the monetary authority should focus on controlling.

There are a number of different methods of extracting underlying inflation from measured inflation. These can be generally classified under statistical and model-based approaches. Statistically-based procedures apply some type of filter to exclude from the CPI index 'unusual' price movements. Model-based procedures impose some economic theory onto the problem of extracting core inflation.

The simplest statistically-based approach is simply to exclude from the series those prices that move significantly differently from the general level of prices. This can be done on a quarter-by-quarter basis, based on actual price changes, or, more commonly, by removing the same prices each quarter. Such prices typically include very volatile series, such as fresh food and oil prices, or prices that are little affected by demand, such as those set administratively by government.

The problem with the approach identified above is that it is relatively *ad hoc*, and may be subject to changes in definition. If this is the case then the measure is not externally verifiable, and hence may be seen as a non-credible policy target. An alternative statistically-based procedure that does not suffer from this problem is to rank price changes within a CPI regimen using a weighting scheme that affords less influence to extreme price movements than a simple mean. Roger (1995, 1997)

[6] This relationship was taken in part from evidence contained in Hunt (1995).
[7] Under inflation targeting, all shocks to prices are allowed to be only levels effects in the long run. Over the near term, the distinction is really about the degree of persistence in prices.

investigates median-based and trimmed mean measures for New Zealand.[8] A similar approach is to weight price changes according to their estimated information content with respect to the 'true' general rate of inflation. Dow (1993) assigns weights to price changes by solving a static filtering problem, and alternatively by using a Kalman filter, to produce an index with less volatility. The idea behind the calculation is that there is an underlying 'average' inflation rate, unaffected by relative price shocks and affecting all prices evenly.

Quah and Vahey (1995) use a VAR identified by long-run restrictions to extract core inflation.[9] Specifically, they assume that observed changes in consumer price inflation are the result of two types of disturbances, uncorrelated with each other. The first has no impact on real output in the medium to long run, while the second has unrestricted effects on both measured inflation and real output, but is assumed not to affect core inflation. That is, core inflation is defined as that part of inflation that has no medium to long-run impact on output. This reflects the notion of a vertical long-run Phillips curve in output and inflation. An advantage of this measure is that it is based on economic theory, but a drawback is that the addition of a new data point requires re-estimation. The historical series is therefore subject to revision, which makes it an undesirable target inflation rate.

In the literature, these different measures of core inflation use varying terminology, being defined in terms of 'level' or 'rate' shocks, 'permanent' versus 'temporary' shocks, 'typical' versus 'extreme' shocks, or 'demand' versus 'supply' shocks. Despite these different approaches, the key aim of all the measures is to extract a measure of that component of CPI inflation that can be most closely influenced by monetary policy, yet still purport to represent 'the price level' in an economy. This does come at a cost, however: a conceptual difficulty with any core inflation measure is that there may be valid information regarding the future path of core inflation contained within the excluded price movements. This reflects the fact that we do not know exactly how agents form their expectations of inflation.

3.2 Core inflation in FPS

In the Reserve Bank of New Zealand's Forecasting and Policy System (FPS) the counterpart of core inflation is inflation in the price of domestically produced and consumed goods and services (domestic price inflation). This rate of inflation is determined according to a Phillips curve relationship:

$$\begin{aligned}\pi_t &= (1-\alpha)\mathbf{B}_1(L)\cdot\pi_t + \alpha\cdot\pi_t^e + \mathbf{B}_2(L)\left(y_t - y_t^p\right) + \mathbf{B}_3(L)\left(y_t - y_t^p\right)^+ \\ &\quad + f(tot) + g(w) + h(ti),\end{aligned} \tag{1}$$

where π represents domestic price inflation, π^e represents expected inflation, y represents output, y^p represents potential output, α is a coefficient, $\mathbf{B}(L)$ denotes a polynomial in the back-shift operator, $(\cdot)^+$ is an annihilation operator (in this case filtering out negative values of the output gap), $f(tot)$ is a function of the terms of trade, $g(w)$ represents a function of the real wage, and $h(ti)$ a function of indirect taxes.

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[8] Rather than simply choosing the median, an alternative percentile can be chosen if it as seen as desirable for credibility reasons that the measure should have the same mean as the published CPI. For example, Roger finds that the 56th or 57th percentile is appropriate for New Zealand.

[9] Gartner and Wehinger (1998) use Quah and Vahey's methodology to estimate core inflation for selected European Union countries. They find that inflation is primarily demand-driven, and that therefore the resulting core inflation indicator could potentially be useful when formulating monetary policy.

Inflation expectations are given by a linear combination of past and model-consistent values of *domestic price inflation*:

$$\pi_t^e = (1-\gamma)\mathbf{B}(L)\cdot \pi_t + \gamma \cdot \mathbf{C}(F)\cdot \pi_t \qquad (2)$$

where γ is a coefficient and $\mathbf{C}(F)$ is a polynomial in the forward-shift operator.

Full CPI inflation, by comparison, incorporates direct exchange rate effects. The base-case version of FPS is structured such that direct exchange rate effects on import prices affect only the level of the CPI. That is, direct exchange rate effects in the CPI do *not* impact on inflation expectations. CPI inflation is built up by adding imported consumption goods price inflation to inflation in domestic prices:

$$\pi_t^{cpi} = \pi_t \cdot \mathbf{B}(L)\cdot \left(pc_t / pc_{t-1}\right) \qquad (3)$$

where π_t^{cpi} represents CPI inflation and pc is the consumption price deflator relative to the price of domestically-produced and consumed goods. The consumption price deflator is a linear combination of the prices of both domestically-produced and imported consumption goods. The latter term includes the direct price effects of movements in the exchange rate.

The base-case version of the model implies that there is little persistence in inflation arising from direct exchange rate effects. Foreign price shocks and real exchange rate movements have only very small effects on the domestic price level. If the price of exports increases, for example, resources will shift away from the production of goods for domestic consumption, towards the production of exports. This will have supply implications for the domestic market, and hence domestic prices. Similarly, an increase in import prices, due to either a foreign price shock or exchange rate depreciation, will increase the cost of a significant number of inputs to production, thereby also affecting the domestic price level through supply-side effects. However, the magnitude of such effects is extremely small in the FPS model relative to the direct CPI price effects of such foreign shocks.

In addition to exchange rate movements, domestic price inflation in FPS is also largely insulated from the first round effects of changes in consumption taxes and government charges. The measure *is* affected directly by wage pressures, the output gap and inflationary expectations, a characteristic well-suited to a core inflation measure, as these can be influenced by monetary policy. Inflation in domestic prices in the FPS model can therefore be interpreted as a measure of core inflation.

3.3 Uncertainty and core inflation in FPS

It is likely to be the case that agents in the real world are unable to distinguish how much movement in the CPI is attributable to exchange rate effects, how much other 'temporary' shocks, and how much reflects core inflationary pressures.[10] If this is the case, then there is uncertainty over how agents form their expectations of inflation. To examine the implications of this uncertainty, two model structures for inflation expectations are considered. The first structure is the standard characterisation of expectations seen in equation (2) above. The second structure is as follows:

[10] In New Zealand, this assumption may be reasonable since the data is unable to reveal whether or not direct exchange rate effects influence agents' expectations of generalised inflation. This is presented formally in Conway and Hunt (1997), who find that when both first and second differences of the exchange rate are included as explanatory variables in a standard Phillips curve relationship, both are significant.

$$\pi_t^e = (1-\gamma)\mathbf{B}(L)\cdot \pi_t^{cpi} + \gamma \cdot \mathbf{C}(F)\cdot \pi_t^{cpi} \qquad (4)$$

That is, inflation expectations are made a function of historical CPI inflation, and model-consistent expectations of future CPI inflation. Movements in the exchange rate or foreign prices under this specification of inflation expectations then directly enter into inflation expectations, and consequently, also affect core inflation.

If the exchange rate affects both the level of CPI inflation *and* inflation expectations, then the exchange rate channel of policy is potentially a powerful lever for the monetary authority to use. However, if the monetary authority sets policy believing that it can affect inflation expectations via the exchange rate channel, and this turns out to be incorrect, we might expect that potentially undesirable macroeconomic outcomes could occur. Alternatively, what are the macroeconomic outcomes of setting policy believing that the exchange rate only has price *level* effects, when in fact it also affects core inflation via inflation expectations? These issues are examined in section 5 of this paper. Before we turn to this however, the influence of uncertainty about the speed of exchange rate pass-through onto CPI inflation is discussed.

4. Exchange rate pass-through in New Zealand

In open economies, the exchange rate plays an important role in the monetary policy transmission process, particularly under an inflation-targeting regime. By utilising the impact of exchange rate movements on import prices, monetary authorities have a relatively fast and direct channel through which changes in policy can feed through into inflation. Indirectly, movements in the exchange rate can also affect inflation through economic activity and inflation expectations, as per the interest rate channel.

The emphasis placed by the monetary authority upon the direct versus the indirect transmission channel can be thought of as a reflection of its policy horizon. For example, a monetary authority targeting CPI inflation with a relatively short horizon will rely more on the direct channel. During the early period of inflation targeting at the RBNZ, the concern was to build credibility. Given the uncertainty regarding the relationship between interest rates and inflation, the Bank used primarily movements in the exchange rate to maintain CPI inflation within its target band.[11] Policy was set to ensure that the trade-weighted exchange rate remained within a 'comfort zone' consistent with keeping inflation on target. The width of the exchange rate comfort zone was determined by estimates of the degree of pass-through from exchange rate movements to CPI inflation.

A substantial amount of research has been carried out at the RBNZ to determine the strength of exchange rate effects on CPI inflation given its importance in the policy process. Most of this research involved estimating 'mark-up' equations based on a cost-plus view of price setting. These equations specify inflation as a function of economic activity, unit labour costs, world import and export prices and the exchange rate. The degree of exchange rate pass-through is measured by the sum of the coefficients on the exchange rate variables. This work is surveyed by Beaumont *et al*. (1994), who find that the *magnitude* of exchange rate pass-through into CPI inflation over the medium run is quite stable at around -0.3 (i.e. a 1 percent appreciation reduces inflation by 0.3 percent).[12] This

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[11] See Orr *et al.* (1998) for a discussion of the role of the exchange rate in New Zealand monetary policy. More recently, the role of the exchange rate has expanded to incorporate the indirect effects on inflation through economic activity and inflation expectations also.

[12] The 'medium-run' is defined to be around 2 years. More disaggregated analysis by Winkelman (1996) shows that the degree of exchange rate pass-through varies greatly between commodities.

finding is consistent with the share of consumption allocated to imported items in FPS.[13] However, the *speed* of the pass-through varies considerably. In particular, recent empirical evidence suggests that exchange rate pass-through is slower presently than it was in the early 1990s.[14]

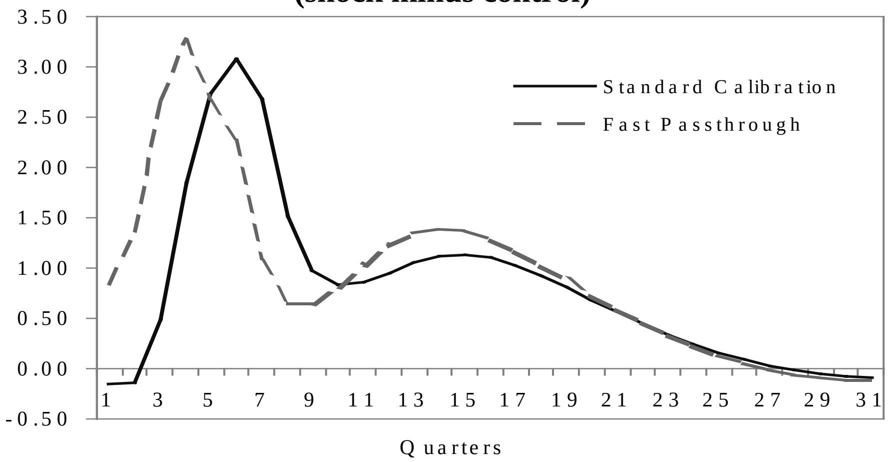
Reflecting recent empirical evidence, the transmission of a shock to the exchange rate into CPI inflation is slower in FPS than the mark-up equation previously used to generate the Bank's medium-term inflation projections. This is shown in Table 1 below.[15]

Table 1 Impact of Temporary Exchange Rate Shock

	Mark-up equation	***FPS***
Peak effect after	3 Quarters	6 Quarters
Proportion of cumulative 18 month impact achieved after 1 year	78 %	25 %

It may be the case, however, that in the future exchange rate pass-through is quicker than that currently calibrated into FPS. To examine the implications of the exchange rate pass-through speed uncertainty, a faster pass-through is calibrated in the FPS core model to be more consistent with that estimated in the mark-up equation. This is illustrated in Figure 1 below which presents the impact of a 1-quarter exchange rate shock under the standard FPS calibration, and an alternative faster pass-through calibration. Both the standard calibration of the exchange rate pass-through and the alternative calibration are used in the stochastic simulation experiments presented next.

Figure 1: Impact of Exchange Rate Shock on CPI Inflation (shock minus control)



13 Twelve percent of consumption goods are imported directly and the remaining 17 percent are imported intermediate goods, used to produce consumer goods in New Zealand.

14 This is discussed in Orr *et al.* (1998). Note that it *may* also be the case that the magnitude of exchange rate pass-through has also declined, all else equal, implying that the CPI is less influenced by movements in the exchange rate today than historically. Examining uncertainty about the magnitude of policy transmission effects (or policy multipliers) is outside the scope of this paper, but part of the Bank's current research agenda.

15 In order to compare meaningfully the properties of the FPS GE model with the partial equilibrium mark-up equation, the endogenous evolution of relevant FPS variables were used as inputs into the mark-up equation.

5. Results

5.1 Overview of the experiments

Before discussing the results it is useful to provide a 'roadmap' of the experiments conducted for this paper. Stochastic simulations of the model economy are performed under both domestic price and CPI inflation targeting. In the simulation experiments two sources of uncertainty are considered:

1) Uncertainty over whether exchange rate effects enter into agents' inflation expectations; combined with
2) Uncertainty over the speed of the pass-through from domestic import consumption prices into CPI inflation.

Table 2 below shows the complete dimension of the problem. For the first source of uncertainty two model structures, as presented in Section 3, are considered: exchange rate effects are level effects (L) or they affect inflation expectations (E). Similarly, for the second source of uncertainty two model structures, as presented in Section 4, are considered: exchange rate pass-through is normal (N) or it is fast (F). The monetary authority targets core inflation (πc), or CPI inflation (πcpi). In setting policy to meet the inflation target, it believes the real world is given by B, which may or may not conform to the true representation of the world, given by R.

For each source of uncertainty there are then four distinct (B/R) cases to consider. As in Conway *et al.*, in order to capture uncertainty about how the exchange rate affects expectations, we examine cases where the monetary authority sets policy on the belief that the exchange rate affects:

1) only the level of the CPI, when in reality it affects inflation expectations (L/E);
2) inflation expectations, when in reality it affects only the level of the CPI (E/L);
3) only the level of the CPI, and this is true in reality (L/L); and,
4) inflation expectations, and this is true in reality (E/E).

Similarly, for uncertainty regarding exchange rate pass-through the monetary authority sets policy on the belief that exchange rate pass-through is:

1) normal when in reality it is fast (N/F);
2) fast when in reality it is normal (F/N);
3) normal, and in reality it is normal (N/N); and,
4) fast, and in reality it is fast (F/F).

Table 2: Outline of Stochastic Simulation Experiments

	L/L		L/E		E/E		E/L	
N/N	πc	πcpi	πc	πcpi	πc	πcpi	πc	πcpi
F/F	πc	πcpi	πc	πcpi	πc	πcpi	πc	πcpi
N/F	πc	πcpi	πc	πcpi	πc	πcpi	πc	πcpi
F/N	πc	πcpi	πc	πcpi	πc	πcpi	πc	πcpi

Key:

πc The monetary authority targets core inflation
πcpi The monetary authority targets CPI inflation

L The exchange rate affects only the level of the CPI
E The exchange rate affects inflation expectations
N Exchange rate pass-through is normal
F Exchange rate pass-through is fast

B/R The authority sets policy assuming world **B**, but the real world is given by **R.**

The two sources of uncertainty are *not restricted* to be mutually exclusive, as there may well be interesting dynamics that arise from the interaction of the uncertainties. Hence, the total number of cases to consider is 16. For each case, the authority can target core inflation or CPI inflation. The total number of experiments conducted is therefore 32 for each policy rule examined.[16]

[16] In practice, examining the macro variability of the model economy under the alternative configurations of the 'real' world is computationally very expensive. A forward solution of endogenous model variables is conducted at each point in time, conditional upon the information set at that point in time. Using the methodology described in Drew and Hunt (1998a), approximately 300,000 simulations are conducted for each rule employing the "stacked-time" algorithm for forward-looking non-linear models (see Armstrong *et al.* (1995)). With this in mind, employing grid-search techniques to search for so called 'efficient policy rules' was not possible given time constraints.

The analysis is restricted to examining the performance of the model economy under four descriptively accurate policy rules:

I. The **standard FPS policy rule**, used in the formulation of the Reserve Bank's economic projections, is a forward-looking inflation forecast-based rule. This policy rule is characterised as follows:

$$rn_t = rn\_eq + 1.4 * \sum_{k=6}^{8} (tpdot_{t+k} - 1.5) \qquad (4)$$

where: rn_t is the actual nominal 90 day interest rate at time t,
rn_eq is the equilibrium 90 day interest rate,
$tpdot_{t+k}$ is the projection for inflation at time t, k quarters into the future,
1.5 is the target rate of inflation, representing the mid-point of the inflation target-band for New Zealand monetary policy.

II. An **inflation-targeting rule with a shorter policy horizon** than the standard rule. This policy rule is identical to that presented in (4), except that k = 2 to 4. Our motivation for examining this rule is that it may be more indicative of the way policy was run in the early period of inflation targeting at the Reserve Bank.[17] Furthermore, it is closer to the 'strict' inflation targeting rules discussed in Svensson (1998).

III. The **standard 'Taylor' rule**. This rule has been found to be descriptively accurate for the conduct of policy in the United States (see Taylor (1993)). The formulation of this rule is as follows:

$$rn_t = rn\_eq + 0.5 * (tpdot_t - 1.5) + 0.5 * (ygap_t) \qquad (5)$$

where $ygap_t$ is the deviation of output from potential at time t. The weights of 0.5 on inflation and output deviations from the target and potential respectively are as in Taylor (1993).

IV. A rule with the same policy horizon and weight on inflation as the standard FPS rule, but also with a weight of 0.5 on contemporaneous deviations of output from potential. We can think of this as a **'forward-looking' Taylor rule**.

Finally, to evaluate the performance of the model economy under the alternative inflation targets, the root mean squared deviations (RMSDs) of output, the nominal interest rate, the real exchange rate, core inflation, and CPI inflation are compared.[18] Significance tests are conducted by constructing *t*-test statistics to examine the hypothesis that differences between the RMSDs over the alternative inflation targets are not significantly different from zero.[19] We turn now to the results.

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[17] See Orr e*t al.* (1998).

[18] RMSDs are calculated rather than SDs because in a model such as FPS with a non-linear Phillips curve, under stochastic simulations the long-run average outcome for output will be less than the deterministic level of potential output and the average outcome for inflation will be above target. RMSDs penalise deviations from the deterministic level and target and hence 'reward' outcomes that are closer. See Laxton *et al.* (1994) for further elaboration on this point.

[19] In other terms, the second moments of the model economy are evaluated only. As Luppi (1998) shows, the welfare benefit of stabilising the economy in terms of consumption utility is very small relative to the welfare benefits of permanently increasing an economy's growth potential. Although not explicitly incorporated into the analysis, we would argue that reducing the volatility in macro variables such as inflation, interest rates, the exchange rate, and output *may* also permanently increase an economy's supply capacity. Furthermore, it is certainly the case that most political pressure placed upon central bankers in the conduct of monetary policy concerns the management of the economy over the business cycle.

5.2 Results

5.2.1 The standard FPS policy rule

The first set of results, presented in the N/N block in Table 3 below, repeat the analysis presented in Conway *et al.* (1998). The stochastic behaviour of the model economy is evaluated under the alternative inflation targets, given uncertainty about the way in which exchange rate movements affect inflation expectations. Exchange rate pass-through is normal and the monetary authority correctly perceives this.

As we might expect, given the richer structure of the external sector in the present FPS core model, the results are quantitatively different from those seen in Conway *et al*. The qualitative story remains unaltered however: targeting core domestic price inflation results in lower macroeconomic variability for all variables considered with the exception of CPI inflation. Furthermore, whether targeting domestic price inflation or CPI inflation, there is *less* variability in the macro variables when expectations of core inflation are a function of CPI inflation. This is seen in comparing columns 1 with 2, and 3 with 4. These results stem from the fact that in a small open economy, the exchange rate is to some degree influenced by the policy instrument via uncovered interest parity (UIP). Since CPI-based expectations include the effects of exchange rate movements, this means that the monetary authority now finds it *easier* than before to sway expectations because of the effect of UIP in exchange rate dynamics. Effectively, this gives the monetary authority more control over inflation. On average, the relative importance of this channel is greater than the effect of the exchange rate and external price shocks that are hitting the economy.

The impact of exchange rate movements on inflation expectations creates an interesting dynamic when the monetary authority misperceives these effects. The worst outcome for both CPI and core inflation variability, under both core and CPI inflation targeting, occurs when the authority believes inflation expectations are CPI-based and in fact they are not (the E/L case). In this case the authority consistently overestimates the impact of the transmission of policy onto inflation, and consequently, is not vigorous enough with policy to achieve the inflation control it achieves in the absence of the misperception. Conversely, the lowest inflation variability occurs when the monetary authority believes expectations are not CPI-based and they in fact are (L/E). In this case, the authority sets policy quarter-by-quarter in a manner that gives it more control over inflation than it had counted upon. The variability of all macro variables is in fact lower than if expectations are formed in line with central bank beliefs (L/L). In *Conway et al.* (1998) it is shown this result is not a general result. Instead, it reflects the fact that the standard FPS policy rule is not an ‘efficient policy rule’: lower variability in inflation and output can be obtained by being more aggressive with the policy instrument (see Appendix 2 for details). For all rules on the efficient policy frontier, as we might expect, the monetary authority makes no mistakes about the structure of the model economy.

Table 3: Performance of the model economy under the standard FPS rule

		L/L		L/E		E/E		E/L	
		πc	πcpi	πc	πcpi	πc	πcpi	πc	πcpi
N/N	**rmsd y**	2.74	3.22*[a]	2.58	2.97*[a]	2.59	2.91*[a]	2.78	3.18*[a]
	rmsd rn	3.55	3.87*[a]	3.41	3.54*[a]	3.15	3.26*[a]	3.36	3.62*[a]
	rmsd z	4.45	4.98*[a]	4.42	4.93*[a]	4.23	4.59*[a]	4.26	4.64*[a]
	rmsd πc	1.48	1.59*[a]	1.31	1.40*[a]	1.39	1.48*[a]	1.58	1.70*[a]
	rmsd πcpi	1.11	1.05*[b]	0.96	0.91*[b]	1.02	1.00	1.19	1.18
F/F	**rmsd y**	2.74	3.31*[a]	2.57	3.01*[a]	2.60	2.94*[a]	2.80	3.23*[a]
	rmsd rn	3.55	4.09*[a]	3.43	3.69*[a]	3.20	3.37*[a]	3.38	3.74*[a]
	rmsd z	4.45	5.21*[a]	4.40	5.16*[a]	4.24	4.73*[a]	4.27	4.77*[a]
	rmsd πc	1.48	1.64*[a]	1.31	1.44*[a]	1.40	1.55*[a]	1.59	1.77*[a]
	rmsd πcpi	1.11	1.09	0.99	0.95*[b]	1.03	1.05	1.21	1.23*[a]
N/F	**rmsd y**	2.74	2.99*[a]	2.57	2.92*[a]	2.58	2.87*[a]	2.78	3.17*[a]
	rmsd rn	3.55	3.72*[a]	3.43	3.49*[a]	3.18	3.25*[a]	3.36	3.61*[a]
	rmsd z	4.45	4.71*[a]	4.41	4.91*[a]	4.21	4.56*[a]	4.24	4.61*[a]
	rmsd πc	1.48	1.53*[a]	1.31	1.38*[a]	1.39	1.47*[a]	1.58	1.70*[a]
	rmsd πcpi	1.11	1.08*[b]	0.99	0.90*[b]	1.03	0.98*[b]	1.20	1.17*[b]
F/N	**rmsd y**	2.74	3.32*[a]	2.58	3.07*[a]	2.62	3.00*[a]	2.80	3.25*[a]
	rmsd rn	3.55	4.10*[a]	3.41	3.76*[a]	3.18	3.41*[a]	3.38	3.76*[a]
	rmsd z	4.45	5.23*[a]	4.41	5.18*[a]	4.26	4.77*[a]	4.29	4.81*[a]
	rmsd πc	1.48	1.64*[a]	1.31	1.45*[a]	1.40	1.56*[a]	1.59	1.77*[a]
	rmsd πcpi	1.11	1.09	0.96	0.95	1.03	1.08*[a]	1.20	1.25*[a]

[a] ([b]) indicates that variability under core inflation targeting is less (more) than under CPI inflation targeting at the 95 percent level of confidence.

The second, third, and fourth set of results, shown in the F/F, F/N and N/F blocks, show that under the standard FPS policy rule, the additional factor of alternative exchange rate pass-through speeds does not substantively alter the conclusions reached in *Conway et al*. For all cases, the variability in output, the interest rate, the exchange rate and core inflation is lower under core inflation targeting than under CPI inflation targeting. In fact, in contrast to the case of normal exchange rate pass-through, there are four cases (as highlighted) where CPI inflation variability is *also lower* under core inflation targeting. Under the standard FPS policy rule, then, our results further strengthen the case for targeting core inflation over CPI inflation.

The four cases that result in higher CPI inflation variability when targeting CPI inflation, occur when exchange rate pass-through is perceived to be fast (F/F or F/N), and exchange rate movements are perceived to affect expectations (E/E or E/L). In these cases, the monetary authority believes that it has a channel with which it can quickly affect both CPI inflation, through price level effects, and core inflation, via inflation expectations. Under core inflation targeting the authority counts upon the latter channel; under CPI inflation targeting it counts upon both. Whether or not the beliefs are correct, core inflation targeting results in lower CPI inflation variability.

When the authority, in fact, has neither channel but does not realise it (the F/N E/L case), under both CPI and core inflation targeting the monetary authority consistently sets policy too loosely relative to when it knows the true state of the economy. Hence, both CPI and core inflation variability is higher than in the correct-information N/N L/L case. However, under CPI inflation targeting policy is set even *more* loosely.[20] In fact, the highest variability for CPI inflation under the standard FPS rule is then observed. Similarly, when the authority makes no mistakes about inflation expectations, but believes exchange rate pass-through is faster than it actually is (the F/N E/E case), policy is again set too loosely under CPI inflation targeting, and higher CPI inflation variability results.

The more puzzling cases are when the authority correctly perceives exchange rate pass-through is fast (F/F), and rightly or wrongly believes that movements in the exchange rate affect inflation expectations (E/E or E/L). Under these cases, regardless of the inflation target, the authority believes it can sway inflation expectations via movements in the exchange rate. As such, we might expect that the general result that CPI inflation variability is lower under CPI inflation targeting would hold. However, it does not. This may reflect the fact that the standard FPS policy rule is not an efficient policy rule. Alternatively, it may reflect that under the standard FPS policy horizon, the monetary authority is unable to exploit fully a fast exchange rate transmission channel. This issue is examined next.

5.2.2 The short-horizon policy rule

The standard policy rule used in FPS sets policy given forecast deviations of inflation from the target 6, 7, and 8 quarters ahead. Over this horizon, policy affects inflation primarily through the output gap channel. Therefore, even under CPI inflation targeting the transmission of exchange rate movements into CPI inflation is 'looked-through' to some extent. With a shorter policy-horizon of 2 to 4 quarters, movements in the exchange rate affect CPI inflation more over the horizon in which policy is reacting to forecasted inflation deviations from target. Hence under CPI inflation targeting the authority relies upon the direct exchange rate transmission channel to a greater extent. This may afford the authority better control over CPI inflation. It is of interest then to examine the macroeconomic implications of targeting core versus CPI inflation when the authority has a less forward-looking policy horizon; that is, when it is trying to stabilise inflation more quickly.

The results of the stochastic simulation experiments are presented in Table 4 below. Relative to the results observed for the standard FPS policy rule, it is seen that policy is far more aggressive. This can be seen by comparing the variability in the nominal interest rate, for any configuration of the model economy and any inflation target, in Table 4 with Table 3. This result reflects that if policy seeks to stabilise inflation at a shorter-horizon, it needs to be aggressive. In being more aggressive, the monetary authority reduces the variability in CPI inflation when targeting CPI inflation, and both

[20] Note that setting policy 'more loosely' does not imply that the RMSD of policy variables will be less. In fact, as observed in table 3, the RMSD of the nominal interest rate and the exchange rate is higher under the CPI inflation targeting cases. Setting policy consistently too loosely implies that the authority does not act strongly or soon enough to inflation deviations from the target. As such, greater secondary cycles are put through the model economy and policy instruments stay away from control for longer. The RMSD statistic explicitly penalises this.

CPI and core inflation, when targeting core inflation. However, the cost of this is greater output variability. This result is observed more generally in a host of other research including Black *et al.* (1997), Svensson (1998), and Drew and Hunt (1998b).

An interesting result observed is that for the short-horizon policy rule, policy is far *more* aggressive under core inflation targeting relative to CPI inflation targeting, where instrument variability is around 1.5 percentage points higher.[21] This result stems from the fact that when targeting CPI inflation at short horizons, the monetary authority can rely more upon the direct price effects of exchange rate movements onto CPI inflation. Hence it does not need to be as aggressive with policy as if it were targeting core inflation, which excludes these effects.

In being more aggressive under core inflation targeting, the monetary authority not only reduces core inflation variability relative to the CPI inflation targeting rules, but also reduces CPI inflation variability.[22] This result is substantively different from the broad result obtained under the standard policy rule. Furthermore, although the monetary authority is more aggressive under core inflation targeting, output variability is *still less* than that observed under CPI inflation targeting for any configuration of the model economy and monetary authority beliefs. This result re-enforces the efficacy of targeting core over CPI inflation. That is, even when exchange rate pass-through is fast, within the policy horizon of the monetary authority *and* affecting core inflation expectations, when targeting CPI inflation the monetary authority induces unnecessary volatility into the economy by reacting to the price level effects of movements in the exchange rate.

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[21] If the RMSD of the nominal interest rate is 1.5 percentage points more under core inflation targeting, then the 95 per cent confidence band about the interest rate is +/-3 percentage points greater than that under targeting CPI inflation. This is of a magnitude likely to be of concern for any real world monetary authority.

[22] There is one case in table 4 where CPI inflation variability is actually lower when targeting CPI inflation (the L/E and N/F case as highlighted). We see this result as an anomaly that would possibly not be robust under a broader range of policy rules.

Table 4: Performance of the model economy under the short-horizon rule

		L/L		L/E		E/E		E/L	
		πc	πcpi	πc	πcpi	πc	πcpi	πc	πcpi
N/N	**rmsd y**	3.29	3.72*[a]	3.10	3.26*[a]	2.94	3.16*[a]	3.17	3.62*[a]
	rmsd rn	5.61	4.40*[b]	5.50	3.81*[b]	4.99	3.81*[b]	5.18	4.40*[b]
	rmsd z	5.52	4.95*[b]	5.48	4.81*[b]	5.12	4.58*[b]	5.18	4.74*[b]
	rmsd πc	1.30	1.71*[a]	1.15	1.42*[a]	1.19	1.45*[a]	1.37	1.75*[a]
	rmsd πcpi	0.75	0.93*[a]	0.67	0.74*[a]	0.70	0.82*[a]	0.81	1.04*[a]
F/F	**rmsd y**	3.29	3.90*[a]	3.04	3.32*[a]	2.90	3.19*[a]	3.19	3.67*[a]
	rmsd rn	5.61	4.48*[b]	5.46	3.73*[b]	4.90	3.74*[b]	5.14	4.35*[b]
	rmsd z	5.52	5.12*[b]	5.44	4.93*[b]	5.02	4.58*[b]	5.10	4.73*[b]
	rmsd πc	1.30	1.85*[a]	1.11	1.51*[a]	1.18	1.52*[a]	1.39	1.84*[a]
	rmsd πcpi	0.75	0.96*[a]	0.73	0.75	0.68	0.82*[a]	0.81	1.06*[a]
N/F	**rmsd y**	3.29	3.75*[a]	3.04	3.19*[a]	2.87	3.10*[a]	3.15	3.61*[a]
	rmsd rn	5.61	4.46*[b]	5.46	3.76*[b]	4.91	3.80*[b]	5.15	4.42*[b]
	rmsd z	5.52	4.99*[b]	5.45	4.75*[b]	5.05	4.53*[b]	5.14	4.71*[b]
	rmsd πc	1.30	1.73*[a]	1.11	1.39*[a]	1.16	1.42*[a]	1.37	1.76*[a]
	rmsd πcpi	0.75	0.88*[a]	0.73	0.67*[b]	0.68	0.74*[a]	0.81	0.98*[a]
F/N	**rmsd y**	3.29	3.91*[a]	3.10	3.42*[a]	2.98	3.26*[a]	3.20	3.69*[a]
	rmsd rn	5.61	4.49*[b]	5.50	3.82*[b]	4.99	3.77*[b]	5.17	4.34*[b]
	rmsd z	5.52	5.15*[b]	5.47	4.99*[b]	5.09	4.64*[b]	5.15	4.77*[b]
	rmsd πc	1.30	1.85*[a]	1.15	1.54*[a]	1.21	1.55*[a]	1.38	1.84*[a]
	rmsd πcpi	0.75	1.03*[a]	0.67	0.83*[a]	0.71	0.90*[a]	0.82	1.12*[a]

[a] ([b]) indicates that variability under core inflation targeting is less (more) than under CPI inflation targeting at the 95 percent level of confidence.

5.2.3 The Taylor rule

The Taylor rule differs from the previous policy rules examined for two key reasons. Firstly, only observed *contemporaneous* information is used to guide policy. Therefore, the monetary authority's beliefs about the structure of the real world are irrelevant. Policy is set mechanically in response to the actual deviations of output and inflation from their targets. In contrast, under the inflation-targeting rules examined previously, the monetary authority exploits its knowledge of the economy to project the future outlook of the economy in order to set policy. Even given the uncertainties examined in this paper, the monetary authority is still better informed about the structure of the economy than is likely in the real world.[23] As such, we might expect that superior macroeconomic outcomes would be attainable when policy is forward looking.[24]

The second point of difference between the Taylor rule and the inflation targeting rules, is the obvious fact that weight is placed not only on inflation deviations from the target, but also on deviations of output from potential. As such policy *explicitly* seeks to smooth output. In contrast, inflation forecast-based rules only *implicitly* smooth output via the output gap channel of policy, given shocks to demand. A core inflation-targeting rule does this to a *greater* extent than a CPI inflation-targeting rule as the core inflation rule works primarily via the output gap channel, rather than the direct exchange rate channel. That is, shocks to aggregate demand move core inflation and output in the same direction. Hence stabilising core inflation has the ancillary benefit of stabilising output in a world where demand shocks are important. This is one of the reasons why under the inflation targeting rules examined previously, output variability is lower under core inflation targeting.

Turning to the results, in Table 5 below there are only four cases considered, given that the authority's beliefs about the real world are irrelevant. These cases are that exchange rate pass-through is:

1. normal and exchange rate movements affect only the level of CPI inflation
2. fast and exchange rate movements affect only the level of CPI inflation
3. normal and exchange movements affect inflation expectations
4. fast and exchange movements affect inflation expectations

Whatever the structure of the world, the qualitative results presented in Table 5 are the same. Output and exchange rate variability is marginally *higher* under core inflation targeting, whilst core and CPI inflation variability is lower. Variability in the policy instrument is largely the same under either core or CPI inflation targeting.

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[23] In the real world the monetary authority must also contend with uncertainty about the current state of the economy and more generalised model uncertainties than those considered here.

[24] This result is seen in Drew and Hunt (1998b), even when the monetary authority makes errors about the level of potential output.

Table 5: Performance of the model economy under the Taylor Rule

		L/L		E/E	
		πc	πcpi	πc	πcpi
N/N	**rmsd y**	2.39	2.34*[b]	2.36	2.31*[b]
	rmsd rn	3.39	3.39	3.22	3.21
	rmsd z	4.24	4.15*[b]	4.28	4.19*[b]
	rmsd πc	2.69	2.76*[a]	2.44	2.50*[a]
	rmsd πcpi	2.49	2.58*[a]	2.23	2.31*[a]
F/F	**rmsd y**	2.39	2.34*[b]	2.37	2.32*[b]
	rmsd rn	3.39	3.37	3.34	3.31*[b]
	rmsd z	4.24	4.10*[b]	4.32	4.17*[b]
	rmsd πc	2.69	2.74*[a]	2.53	2.57*[a]
	rmsd πcpi	2.49	2.58*[a]	2.34	2.39*[a]

[a] ([b]) indicates that variability under core inflation targeting is less (more) than under CPI inflation targeting at the 95 percent level of confidence.

The fact that variability in output is higher under core inflation targeting runs directly against the results obtained under the previous two policy rules examined. This result at first glance seems counterintuitive. As discussed, setting policy to stabilise core inflation will stabilise output under shocks that also affect aggregate demand. It is true that setting policy in response to temporary shocks to the Phillips curve will move output in the opposite direction. However, given the previous stochastic simulation results it must be the case that *on average* the shocks to demand are more important than shocks to the Phillips curve.

To shed some light on the Taylor rule results a simple deterministic demand shock is presented under both core and CPI inflation targeting, for both the Taylor rule and the standard FPS rule. The results of these simulations are given in Appendix 3. The dashed lines are the outcomes under core inflation targeting, the solid lines outcomes under CPI inflation targeting. All outcomes are expressed as deviations from control. For the Taylor rule with a core inflation target, the paths for both CPI and core inflation deviate less from control than under CPI targeting, while the paths for the real exchange rate and the output gap appear to deviate more. In contrast, for the standard FPS rule, it is clear that the output gap and domestic price inflation is less variable under core inflation targeting in the case of the demand shock.

The results under the deterministic demand shock are then similar to the results observed under the stochastic simulation experiments. It would therefore appear that the differences between the Taylor results and the inflation targeting results stem from the differing response of the monetary authority to shocks to demand. These responses are fundamentally a function of the policy horizon of the monetary authority. Under the Taylor rule with a CPI inflation target, the monetary authority sees more quickly the impact of its policy actions on CPI inflation, via the impact of the exchange rate. It therefore eases policy slightly more rapidly than under the core inflation Taylor rule. The real exchange rate returns to control more quickly and the cycle in output is less. However, as policy is effectively looser, both CPI and core inflation variability are higher.

Conversely, under a Taylor rule with a core inflation target the authority does not see the impact of its policy actions until later, as policy works through the slower output channel. Policy is kept tighter for longer, and via UIP the real exchange rate deviates from control for a longer period.

In contrast, when the authority is forward-looking, by definition it sets policy based upon the projected outlook of the economy. With a core inflation target under the demand shock, it sees through the temporary effect of the exchange rate appreciation on CPI inflation and keeps policy initially tighter for longer. Further out, it is able to ease back on monetary conditions more quickly than under the CPI inflation target. That is, by being forward-looking and targeting core inflation the authority more quickly arrests the inflationary consequences of the demand shock.

In comparison to the forward-looking inflation targeting rules, both CPI and core inflation variability is far greater under both Taylor rules examined. For example, the variability of CPI inflation under the CPI inflation targeting Taylor rule is roughly 2.5 times greater than that of the standard CPI inflation targeting policy rule. In contrast, output variability under the Taylor rule is consistently lower than under the forward-looking rules, although not by the same order of magnitude as that observed for CPI inflation variability. This result is observed more generally in Drew and Hunt (1998b), where a broader range of policy rules are examined that that presented here.

In summary, under the core inflation targeting Taylor rule output variability is higher relative to the CPI inflation targeting Taylor rule. This result is a function of the policy horizon of the monetary authority. It may also be because the standard Taylor rule is not efficient (See Drew and Hunt (1998b)), hence it will be interesting to see in future research whether the result still holds when considering efficient policy rules. The benefit of including an output gap term into the policy reaction function, is however, clearly seen. We turn now to examine a rule that combines features of both types of rules examined thus far; that is, a rule that is forward-looking in inflation, but also has a concern for the current output gap.

5.2.4 Inflation forecast-based rule with explicit output smoothing

In Table 6 below, the results of targeting core versus CPI inflation are seen in the context of a rule that is forward-looking in inflation, but also has a concern for the current output gap. The broad result from these experiments is that output and instrument variability is lower when targeting core inflation, whilst CPI inflation variability is slightly higher. These results match those observed for the standard FPS policy rule and hence oppose the results observed under the Taylor rule examined here. An interesting point of departure from the standard results, however, is that core inflation variability is largely the same regardless of whether CPI or core inflation is targeted. This reflects the fact that by including an output argument into the policy reaction function, forward-looking CPI inflation targeting becomes closer to core inflation targeting. The analysis presented here, however, suggests that this is true only up to a point. It is still the case that the monetary authority is better able to stabilise output and its instruments by not reacting as strongly to exchange rate effects.

The hybrid nature of the policy rule examined here is clearly seen in comparison of the results with the previous policy rules examined. Relative to the Taylor rule, inflation variability is far lower. Relative to the inflation targeting rules, output variability is lower. As in Drew and Hunt (1998b), this result suggests that a forward-looking inflation-targeting rule could be well complemented by also having a concern for current output.

Two further points of comparison with the previous policy rules examined are also worth mentioning. Firstly, the four cases identified using the standard policy rule (in section 5.2.1), in which under core inflation targeting CPI inflation variability is also reduced, are overturned here. That is, the more robust general result that under core inflation targeting, CPI inflation variability is slightly higher, holds. Secondly, the specification of inflation expectations qualitatively affects the outcome of the stochastic experiments in the same way as observed under the other forward-looking policy rules examined. That is, better macroeconomic outcomes are observed when movements in the exchange rate do affect inflation expectations. Again, reflecting that the policy rule is not efficient, the best outcomes for inflation, and often output, are observed when the authority acts as if the exchange rate affects only the level of CPI inflation when it in fact affects inflation expectations (L/E). The worst results for output and inflation are observed in the converse case (E/L).

Table 6: Performance of the model economy under an inflation forecast-based rule with explicit output smoothing

		L/L		L/E		E/E		E/L	
		πc	πcpi	πc	πcpi	πc	πcpi	πc	πcpi
N/N	rmsd y	2.50	2.81*[a]	2.38	2.69*[a]	2.37	2.59*[a]	2.60	2.84*[a]
	rmsd rn	3.80	3.97*[a]	3.75	3.83*[a]	3.43	3.50*[a]	3.58	3.71*[a]
	rmsd z	4.40	4.84*[a]	4.39	4.85*[a]	4.22	4.55*[a]	4.32	4.63*[a]
	rmsd πc	1.42	1.43	1.27	1.25*[b]	1.33	1.34	1.46	1.50*[a]
	rmsd πcpi	1.12	1.02*[b]	0.99	0.85*[b]	1.02	0.95*[b]	1.10	1.06*[b]
F/F	rmsd y	2.50	2.84*[a]	2.37	2.66*[a]	2.39	2.62*[a]	2.53	2.82*[a]
	rmsd rn	3.80	4.28*[a]	3.77	4.13*[a]	3.48	3.71*[a]	3.55	3.89*[a]
	rmsd z	4.40	5.03*[a]	4.38	5.02*[a]	4.24	4.72*[a]	4.25	4.73*[a]
	rmsd πc	1.42	1.45*[a]	1.28	1.29	1.33	1.38*[a]	1.49	1.55*[a]
	rmsd πcpi	1.12	1.06*[b]	1.03	0.95*[b]	1.05	0.99*[b]	1.20	1.14*[b]
N/F	rmsd y	2.50	2.80*[a]	2.44	2.64*[a]	2.37	2.56*[a]	2.51	2.77*[a]
	rmsd rn	3.80	3.97*[a]	3.79	3.78*[b]	3.46	3.49*[a]	3.53	3.67*[a]
	rmsd z	4.40	4.83*[a]	4.46	4.81*[a]	4.21	4.53*[a]	4.21	4.55*[a]
	rmsd πc	1.42	1.43	1.24	1.24	1.33	1.33	1.49	1.52*[a]
	rmsd πcpi	1.12	1.05*[b]	0.97	0.86*[b]	1.05	0.96*[b]	1.20	1.12*[b]
F/N	rmsd y	2.50	2.85*[a]	2.38	2.70*[a]	2.40	2.67*[a]	2.53	2.83*[a]
	rmsd rn	3.80	4.28*[a]	3.75	4.16*[a]	3.46	3.74*[a]	3.56	3.91*[a]
	rmsd z	4.40	5.05*[a]	4.38	5.03*[a]	4.26	4.76*[a]	4.28	4.77*[a]
	rmsd πc	1.42	1.44	1.27	1.30*[a]	1.33	1.39*[a]	1.50	1.55*[a]
	rmsd πcpi	1.12	1.04*[b]	0.99	0.92*[b]	1.02	0.99*[b]	1.17	1.14*[b]

[a] ([b]) indicates that variability under core inflation targeting is less (more) than under CPI inflation targeting at the 95 percent level of confidence.

6. Summary and conclusion

This paper has sought to address whether preferable macroeconomic outcomes are attainable under core as opposed to CPI inflation targeting when there is uncertainty about exchange rate pass-through and/or uncertainty about how agents form their expectations of inflation. To answer this question, stochastic simulations of the model economy are performed and the macroeconomic stability of the economy is assessed. Under the standard FPS policy rule, the broad result is that targeting core inflation reduces the variability in output, the interest rate and the exchange rate, and that of core inflation itself. However, CPI inflation variability is, in most instances, slightly more variable. Under a policy rule with a shorter policy horizon than the standard FPS rule, it is found that targeting core inflation reduces variability in output and both core and CPI inflation; however, instrument variability is higher. The results under a forward-looking Taylor rule are similar to those found with the standard FPS policy rule, except that core inflation variability is largely the same regardless of whether CPI or core inflation is targeted. Finally, the results obtained under the standard core inflation targeting Taylor rule are that core and CPI inflation variability is lower, whilst output and exchange rate variability is higher.

In summary, as in Svensson (1998), the results are somewhat dependent upon the formulation of the policy rule. If policy is forward-looking there is broad support targeting core inflation over CPI inflation. Under the Taylor rule, the efficacy of targeting core inflation is less clear as output and exchange rate variability is higher.

The motivation for examining the behaviour of the economy under the policy rules presented in this paper is that they are descriptively accurate representations of actual policy practice. The results, however, may not be general even for the FPS model economy. To answer this question our future research agenda will be to perform grid-search techniques to search for efficient policy rules.

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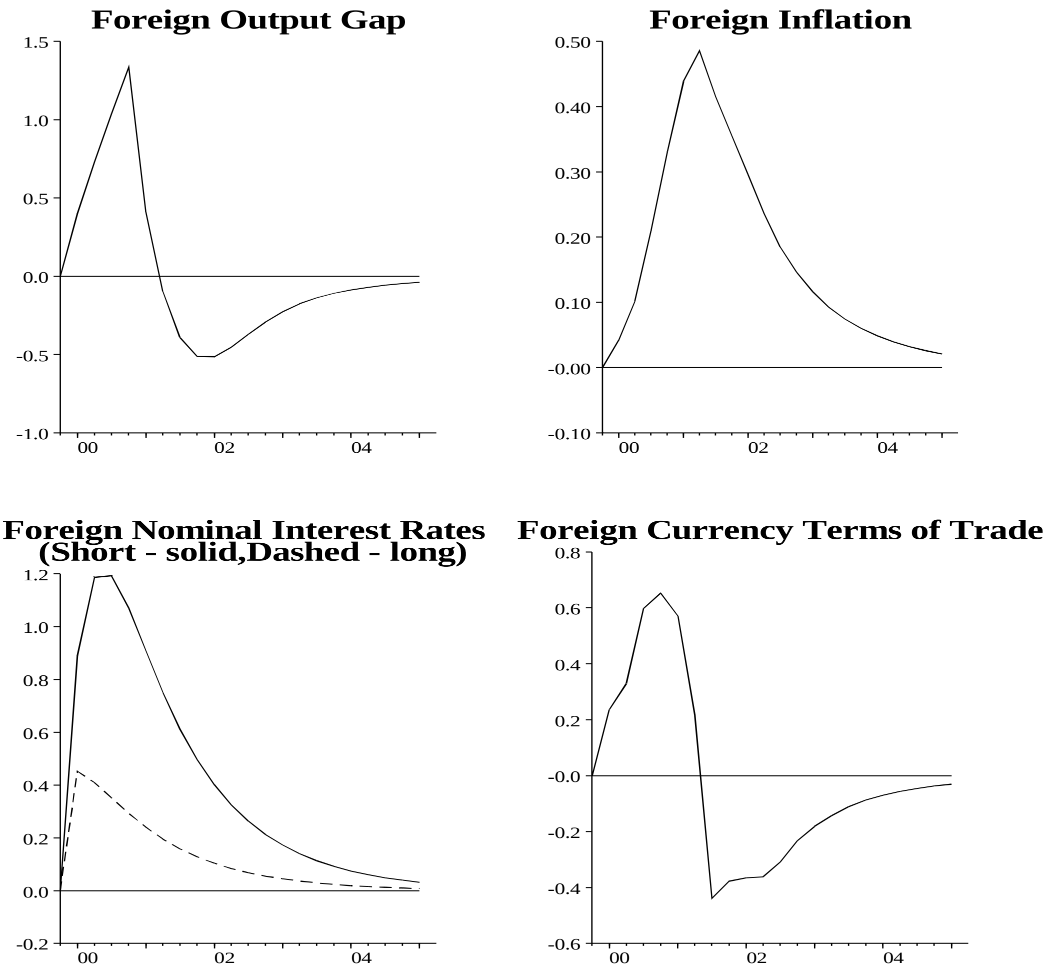
Appendix 1 The endogenous foreign sector

The response of the foreign sector to a demand shock is traced out in the figure below. Two points are worth noting. Unlike the FPS core model, the foreign Phillips curve is symmetric in goods market disequilibrium. The sacrifice ratio has been calibrated to be 2. This is roughly the mid-point of the range of sacrifice ratios (1.3 to 2.6) that result in FRB/US under the alternative structures for expectations and disinflation credibility assumptions presented in Brayton and Tinsley (1996). A forward-looking inflation-targeting policy reaction function determines the short-term nominal interest rate, while the behaviour of the foreign long-term interest rate is given by the expectations theorem. The behaviour of the foreign-currency terms of trade relevant for New Zealand has been calibrated to match the behaviour of New Zealand's terms of trade as suggested by the VAR.

Foreign Demand Shock
(Shock minus Control)



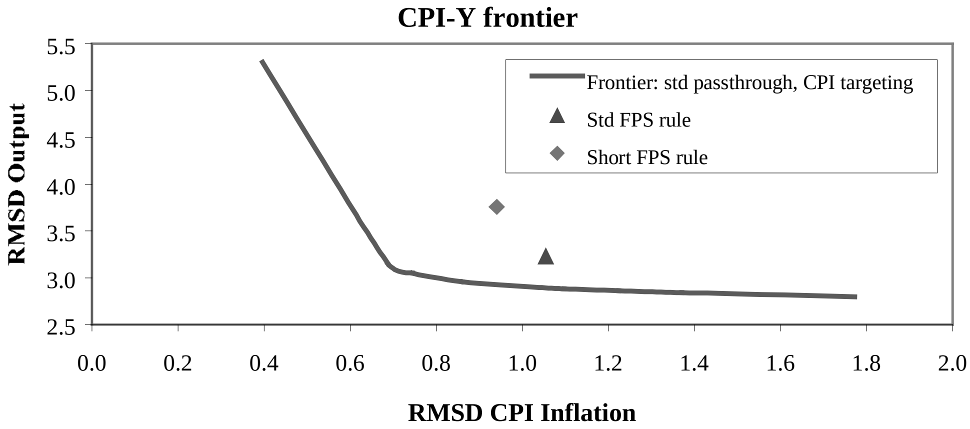
The changes in the stochastic properties of the New Zealand economy that result from endogenising the foreign sector under the standard FPS reaction function are evident in the Table below. The variability of real output remains virtually unchanged. However, the variability of inflation and the real exchange rate falls and the variability of the nominal short-term interest rate rises. The direction of these changes is quite intuitive. Because the foreign short-term interest rate is now variable over the cycle, the domestic interest rate must do more of the work. Given the positive correlation between foreign and domestic business cycles, movements in the domestic short rate and the foreign short rate are positively correlated (on average), producing less variability in the exchange rate via the UIP condition. Additionally, the response of the foreign monetary authority in order to return foreign inflation to control also helps to return domestic inflation to control via import and export prices.

Root Mean Squared Deviations

	Output	**Exchange rate**	**Nominal interest rate**	**CPI Inflation**
Exogenous foreign sector	3.19	5.24	3.59	1.19
Endogenous foreign sector	3.22	4.97	3.89	1.05

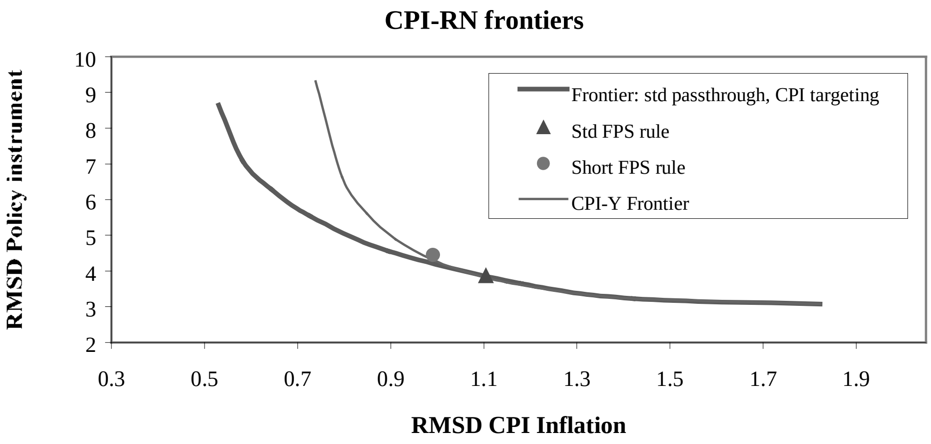
Appendix 2 Efficient Policy Frontiers

As defined in Taylor (1994), efficient policy rules are those rules that deliver the lowest achievable combinations of inflation and output variability, given the structure of the model economy under consideration and the stochastic disturbances applied. In the graph below, the efficient policy frontier is traced out for forward-looking CPI inflation targeting policy rules.[25] The two policy rules of the same class examined in this paper are also shown. These rules lie to the north east of the efficient policy frontier. This illustrates that the policy rules examined are not efficient: other policy rules exist that the monetary authority could use to achieve lower combinations of both output and inflation.

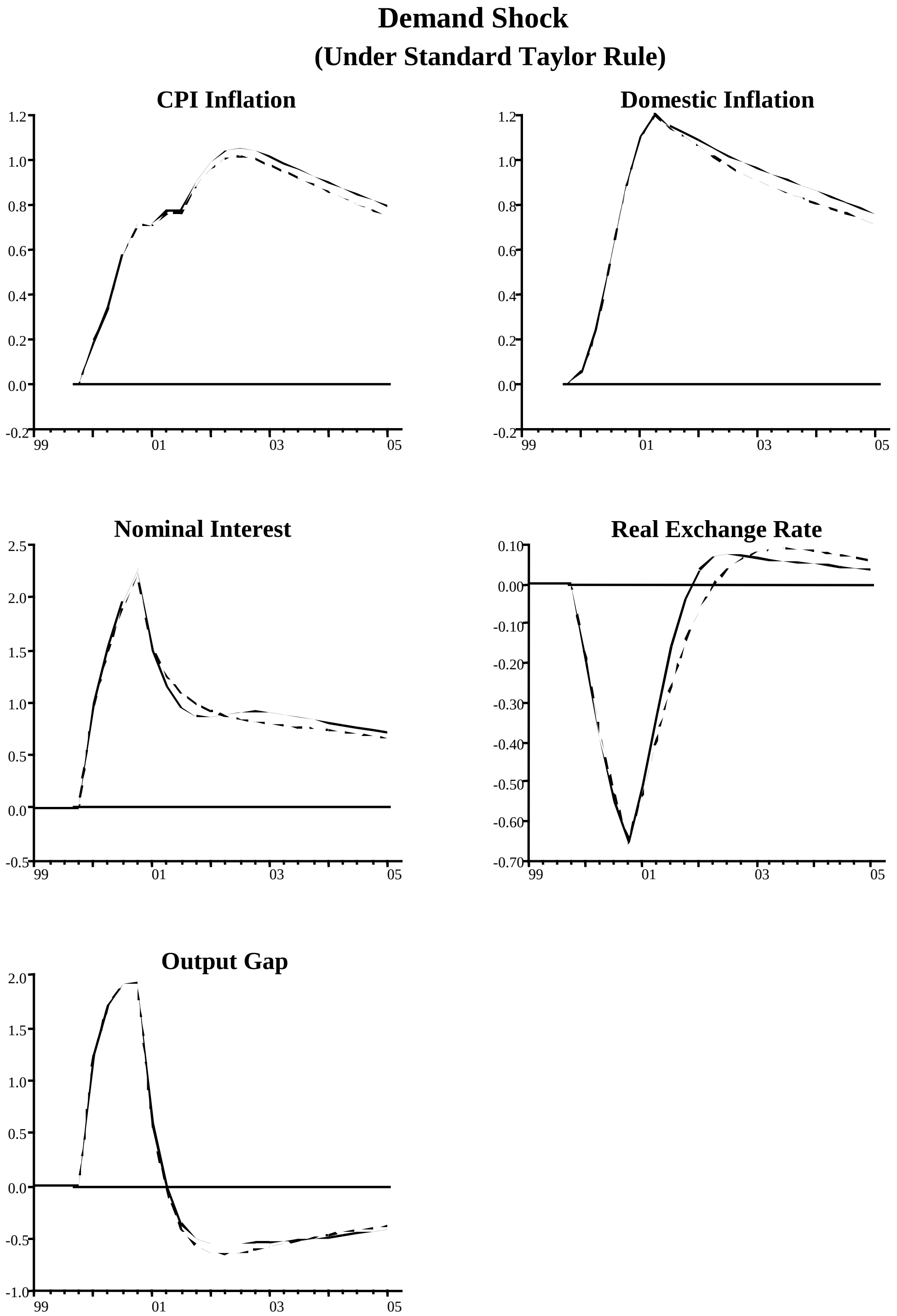


The policy rules that lie upon the efficient policy frontier tend to penalise forecast inflation deviations from target far more vigorously than the standard FPS policy rule, or the alternatives presented in this paper. This is illustrated in the second graph below which shows the trade-off between instrument and inflation variability. Note that the policy rules presented here all have relatively low instrument variability. This finding is common in the extensive literature on policy rules (see Drew and Hunt (1998b)). That is, it is often found that descriptively accurate policy rules, such as the Taylor rule, fare poorly in terms of the inflation/output variability trade-off, but well in terms of instrument variability. In other words, policy makers have a high revealed preference for being cautious in adjusting policy. The classic Brainard (1966) article offers a plausible insight into this revealed preference: if there is also uncertainty about policy multipliers, it may better to act cautiously.

[25] See Drew and Hunt (1998b) for a description of the techniques employed to trace out efficient policy frontiers, and a general discussion on the stochastic behaviour of the FPS model under alternative policy rules.

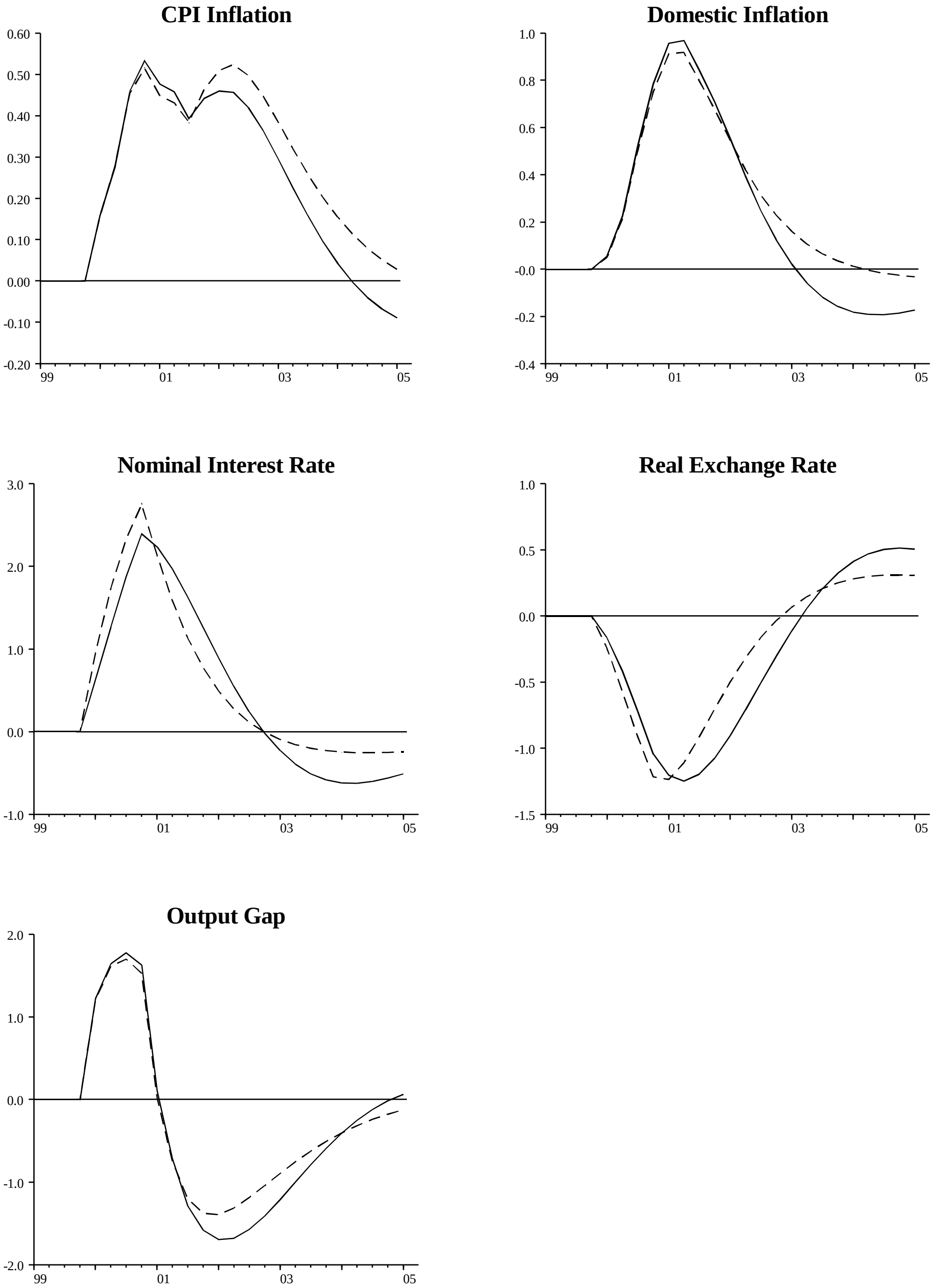

CPI-RN frontiers
RMSD Policy instrument
RMSD CPI Inflation
10
9
8
7
6
5
4
3
2
0.3
0.5
0.7
0.9
1.1
1.3
1.5
1.7
1.9
Frontier: std passthrough, CPI targeting
Std FPS rule
Short FPS rule
CPI-Y Frontier

Appendix 3 Deterministic Demand Shocks



Demand Shock

(Under Standard FPS Rule)



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