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by his colleague, Raphael Solomon.

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## **Abstract**

The author constructs a measure of core inflation using a structural vector autoregression containing oil-price growth, output growth, and inflation. This “macro-founded” measure of inflation forecasts total inflation at least as well as other, atheoretical measures.

*JEL classification: E31, C53*

*Bank classification: Inflation and prices*

## **Résumé**

L’auteur construit une mesure de l’inflation sous-jacente à l’aide d’un modèle vectoriel autorégressif structurel qui comprend le taux de variation du prix du pétrole, la croissance de la production et l’inflation. Cette mesure de l’inflation fondée sur la théorie macroéconomique permet de prévoir l’inflation globale aussi bien que des mesures non théoriques.

*Classification JEL : E31, C53*

*Classification de la Banque : Inflation et prix*

# 1 Introduction

The goal of monetary policy in Canada is to contribute to solid economic performance and rising living standards for Canadians. To reach this goal, the Bank of Canada committed to explicit, quantitative inflation targets.<sup>1</sup> By specifying the inflation-control target explicitly in terms of change in the total consumer price index (or headline inflation), inflation targeting makes monetary policy more transparent to the public, and thereby reinforces the accountability of central banks.

The usefulness of headline inflation for monetary policy is limited, since this measure is not perfectly controllable by the central bank. Its susceptibility to specific disturbances, reflecting relative price shocks rather than the underlying inflationary process, makes headline inflation a noisy signal of genuine inflationary pressures.<sup>2</sup> This drawback requires the use of an operational guide, in the conduct of monetary policy, that reflects only the underlying inflation process: “core inflation.”

In practice, however, there is no consensus on the definition of core inflation; implicitly, then, all methods used to measure it generate different meanings. Nevertheless, as stated by Roger (1998), all measures follow one of two broad concepts of core inflation: the generalized or the persistent component of measured inflation. Adopted by most central banks, the generalized approach views inflation as comprising a core component, associated with expected inflation and monetary growth, and a relative price change component.<sup>3</sup> If price changes are pervasive and if supply shocks are the main source of relative-price shocks that blur the underlying process, core inflation is obtained by “excluding” items whose price movements create the so-called noise. Usually, this noise is removed by reweighting the components that are likely to be affected by supply disturbances.<sup>4</sup>

The part of measured inflation that is integrated into expectations by economic agents is

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1. Many central banks have adopted this policy framework. See Bernanke (2003) for a recent discussion.
  2. Folkertsma and Hubrich (2000) mention other drawbacks associated with the use of headline inflation for monetary policy purposes.
  3. According to Fase and Folkertsma (1997), the origin of the concept of generalized inflation can be linked to the notion of inner value of money in the work of Carl Menger in the 1920s. Nevertheless, the concept is more frequently associated in the literature with Arthur Okun’s definition of inflation as “a condition of generally rising prices.”
  4. Armour (2006) provides an interesting statistical evaluation of various measures of core inflation for Canada entering into this category. She concludes that “CPIW,” which weights each component of headline inflation by a factor that is inversely proportional to the component’s variability, seems to have a slight advantage over other measures, including “CPIX,” which is the official measure of core inflation at the Bank of Canada. This latter is obtained by excluding eight of the most volatile components, which are frequently in the tails of the cross-sectional distribution of price changes.

essentially what the persistent approach is trying to capture. This time, there is no formal consensus on how to distinguish the persistent component – “trend” inflation – from shocks at an aggregated level. Relying more or less explicitly on Eckstein’s (1981) traditional definition of core inflation, some economists obtain long-run inflation using a basic univariate method.<sup>5</sup> In practice, economists use either a simple moving average, the Hodrick-Prescott filter, Kalman filter, or Beveridge-Nelson decomposition.

According to Quah and Vahey (1995), if core inflation is related to inflation expectations, it must be defined as “that component of measured inflation that has no medium to long-run impact on real output.” Relying on this widely accepted verticality of the long-run Phillips curve, this approach is the only one to identify core inflation using economic theory. Both approaches to “persistent” inflation in fact conceptually exclude transient disturbances (supply shocks) and include long-run inflation. Nevertheless, and unlike Eckstein, Quah and Vahey explicitly include cyclical excess-demand pressure to identify core inflation. When they do so, their measure of core inflation is potentially more cyclical than the one obtained using procedures consistent with Eckstein’s view. Again, the work of Roger (1998) is extremely useful to understand the distinction.

Consider the following short-run supply curve:

$$\pi_t = \pi_t^{lr} + g * (x_{t-1}) + \nu_t, \tag{1}$$

where:

- $\pi_t$  is the inflation rate,
- $\pi_t^{lr}$  is the trend (or long-run) inflation rate,
- $x_{t-1}$  is a measure of cyclical excess demand pressure, and
- $\nu_t$  is a measure of transient disturbances.

Table 1 characterizes the effects of the conceptual difference between the two approaches on core and non-core inflation.

The inclusion of cyclical pressures,  $g * (x_{t-1})$ , should make the Quah and Vahey definition of core inflation more volatile than Eckstein’s. On these grounds, as mentioned by Roger

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5. Eckstein specified core inflation as “the trend increases of the cost of the factors of production.” According to him, core inflation “originates in the long-term expectations of inflation in the minds of households and businesses, in the contractual arrangements which sustain the wage-price momentum, and in the tax system.”

(1998), only policy-makers with a short- or medium-term horizon will find Quah and Vahey’s definition theoretically appropriate, though this temporal distinction can be somewhat arbitrary. In both definitions, however, the core inflation rate exhibits less variability than headline inflation, given that they exclude transient disturbances.

The Quah and Vahey approach is implemented via a structural vector autoregression (SVAR). Structural shocks are distinguished by their long-run impact on the level of real output. Core shocks are constrained to be output-neutral in the long run, while non-core shocks can affect output permanently. The core inflation measure is then obtained from the effects of the core shocks on inflation. The goal of this paper is to expand the set of inflation measures used by the Bank of Canada. This goal is achieved by measuring underlying inflation in a way consistent with the theoretical considerations of Quah and Vahey. More specifically, we follow the approach of Bjørnland (2001), which modifies the original framework by adding an energy price shock.

In order for a measure of core inflation to be useful as an “operational guide,” it is important that it be able to predict total inflation. It is useful to compare the efficacy of these forecasts for different measures of core inflation. We mimic the methodology of Cogley (1998) as extended by Armour (2006) for these comparisons.

The remainder of the paper has the following structure. Section 2 explains the SVAR framework. Section 3 reviews the recent literature. Section 4 discusses some important issues. Section 5 explains our approach and highlights our main findings. Section 6 examines the predictive power of the new core measure. Section 7 concludes and suggests directions for future research.

## 2 The Structural VAR Framework

The structural VAR methodology assumes that movements in variables come from the cumulated effect of current and past shocks. The structural moving average representation and the long-run coefficient matrix of these shocks are:

$$y_t = \nu + A_0 e_t + A_1 e_{t-1} + A_2 e_{t-2} + \dots + A_\infty e_{t-\infty}, \quad (2)$$

$$A(1) = A_0 + A_1 + A_2 + \dots + A_\infty. \quad (3)$$

The problem of simultaneity makes it impossible to identify the contemporaneous impact matrix  $A_0$ . To solve this problem, we first estimate the reduced-form vector-autoregressive representation:

$$y_t = \mu + D_1 y_{t-1} + D_2 y_{t-2} + \dots + D_p y_{t-p} + \varepsilon_t,$$

where  $E(\varepsilon_t \varepsilon_t') = \Sigma$ , the variance-covariance matrix of the residuals. Assuming that the stochastic process is stationary, the reduced form can be rewritten in its moving average representation:

$$y_t = \nu + \varepsilon_t + C_1 \varepsilon_{t-1} + C_2 \varepsilon_{t-2} + \dots + C_\infty \varepsilon_{t-\infty}, \quad (4)$$

$$C(1) = I + C_1 + C_2 + \dots + C_\infty. \quad (5)$$

The innovations from the reduced form may be linked to the structural residuals by:

$$\varepsilon_t = A_0 e_t. \quad (6)$$

The variance-covariance matrices of the residuals from both forms are then related:

$$E(\varepsilon_t \varepsilon_t') = A_0 \Omega A_0' = \Sigma. \quad (7)$$

The key assumption that structural shocks are uncorrelated and the normalization of their variances imply that  $\Omega$  is an identity matrix. This allows us to establish a direct link between the unidentified matrix  $A_0$  and the variance-covariance matrix of the reduced form:

$$E(\varepsilon_t \varepsilon_t') = \Sigma = A_0 A_0'. \quad (8)$$

Finally, both matrices of long-run effects can be linked together through the following relationship:

$$A(1) = C(1) A_0. \quad (9)$$

$A_0$  is undetermined, although some information on it is contained in the variance-covariance matrix of the reduced form. Hence, we need to impose supplementary



restrictions to identify the structural VAR.<sup>6</sup> One possibility is to impose short-run restrictions on the impact matrix  $A_0$  (i.e., to constrain some shocks to have no immediate effects on some variables). Another possibility, the long-run identifying restrictions developed by Blanchard and Quah (1989), consists of imposing that the cumulative effects of a shock on some variables are zero. This second set of restrictions is perfectly suited to implementing the long-run verticality of the Phillips curve.

### 3 Literature Review

This literature review focuses explicitly on an identification problem. Hence, instead of reporting on specific results, we review the theoretical identification of core inflation in a short but diverse list of papers. The literature shows a clear divergence of opinions on the choice of the relevant shocks, and on the way to model the interaction between the same set of variables in some cases.<sup>7</sup> The literature also demonstrates that the debate over the stationarity of the inflation rate has profound implications for the identification of core inflation; it explicitly affects the long-run properties of the Phillips curve.

The seminal paper of Quah and Vahey (1995) implies a straightforward framework implemented in a basic bivariate structural VAR<sup>8</sup>:

$$\begin{bmatrix} \Delta \ln Y_t \\ \Delta \pi_t \end{bmatrix} = \begin{bmatrix} \nu_1 \\ \nu_2 \end{bmatrix} + \sum_{j=0}^{\infty} \begin{bmatrix} a_{11,j} & a_{12,j} \\ a_{21,j} & a_{22,j} \end{bmatrix} \begin{bmatrix} e_{1,t-j} \\ e_{2,t-j} \end{bmatrix}. \quad (10)$$

The structural shocks are then distinguished by their long-run effects on the level of output.

To constrain the core shock to be output neutral, the authors use the long-run constraint:

$$\sum_{j=0}^{\infty} a_{12,j} = 0.$$

The component of measured inflation that is output-neutral in the long run (i.e., core inflation) is obtained from the effects of the core shock on inflation:

$$\Delta \pi_t^c = \nu_2 + \sum_{j=0}^{\infty} a_{22,j} e_{2,t-j},$$

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6.  $A_0$  contains  $n^2$  elements ( $n$  = the number of dependent variables). The assumption that the variance-covariance matrix of the reduced form is symmetric supplies only  $(n(n+1))/2$  restrictions.

7. See Folkertsma and Hubrich (2000) for a highly useful classification of the various approaches used to identify core inflation.

8. For the United Kingdom, the specification uses the retail price index and monthly industrial output.

Quah and Vahey assume that only two types of shocks affect inflation and output. Their conclusion about the non-stationarity of the inflation rate can also raise some concerns, because the superneutrality of money is used to identify the structural VAR. This potential drawback implies that the *level* of core inflation is not identified in this scheme, but only its *change*.

Gartner and Wehinger (1998) assess the restrictiveness of the two-shock approach outlined above by estimating a trivariate structural VAR for selected European countries. In fact, they refine the composition of the core shock by adding the short-term nominal interest rate into the system.<sup>9</sup> Unit-root tests do not reject the assumption that output and the nominal interest are I(1) and, contrary to Quah and Vahey's results for a similar sample, suggest that the inflation rate is I(0). These results imply the following specification:

$$\begin{bmatrix} \Delta \ln Y_t \\ \Delta R_t \\ \pi_t \end{bmatrix} = \begin{bmatrix} \nu_1 \\ \nu_2 \\ \nu_3 \end{bmatrix} + \sum_{j=0}^{\infty} \begin{bmatrix} a_{11,j} & a_{12,j} & a_{13,j} \\ a_{21,j} & a_{22,j} & a_{23,j} \\ a_{31,j} & a_{32,j} & a_{33,j} \end{bmatrix} \begin{bmatrix} e_{1,t-j} \\ e_{2,t-j} \\ e_{3,t-j} \end{bmatrix}. \quad (11)$$

Headline inflation is thus potentially generated by three shocks: a supply shock, a monetary policy shock, and a real demand shock. Relying on economic theory, the authors achieve identification by imposing three supplementary restrictions on the two related demand shocks. Neither a monetary policy shock nor a real demand shock has a long-run effect on the level of output. The real demand shock does not also affect the level of the nominal interest rate in the long run. Hence,  $\sum_{j=0}^{\infty} a_{12,j} = 0$ ,  $\sum_{j=0}^{\infty} a_{13,j} = 0$ , and  $\sum_{j=0}^{\infty} a_{23,j} = 0$ .

Summing the effects of these two demand shocks, one obtains the core inflation rate:

$$\pi_t^c = \nu_3 + \sum_{j=0}^{\infty} a_{32,j} e_{2,t-j} + \sum_{j=0}^{\infty} a_{33,j} e_{3,t-j}.$$

Gartner and Wehinger conclude that refining the approach used by Quah and Vahey has very small implications for the identification of core inflation. Hence, empirically speaking, the core inflation measure obtained from a bivariate structural VAR remains relevant. One must note that the neutrality of money is sufficient to identify the core inflation rate in their framework given that the inflation rate is I(0). Unfortunately, concluding simultaneously that the nominal interest rate is I(1) implies that the real interest rate is I(1). This by-product raises some concerns, because there is no clear consensus on this issue.

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9. Relying on quarterly data, their specifications use the consumer price index (or a comparable index), the real gross domestic product, and the 3-month interest rate.

Dewachter and Lustig (1997) also add the short-term nominal interest rate to test the restrictiveness of the two-shock approach.<sup>10</sup> Unit-root tests imply that the nominal interest rate and the inflation rate are both I(1).<sup>11</sup> Assuming that the real interest rate is I(0), the authors impose a cointegration relationship between the inflation rate and the nominal interest rate in their framework:

$$\begin{bmatrix} \Delta \ln Y_t \\ R_t - \pi_t \\ \Delta R_t \end{bmatrix} = \begin{bmatrix} \nu_1 \\ \nu_2 \\ \nu_3 \end{bmatrix} + \sum_{j=0}^{\infty} \begin{bmatrix} a_{11,j} & a_{12,j} & a_{13,j} \\ a_{21,j} & a_{22,j} & a_{23,j} \\ a_{31,j} & a_{32,j} & a_{33,j} \end{bmatrix} \begin{bmatrix} e_{1,t-j} \\ e_{2,t-j} \\ e_{3,t-j} \end{bmatrix}. \quad (12)$$

To identify the aggregate-supply shock correctly, Dewachter and Lustig use the same two restrictions outlined above:  $\sum_{j=0}^{\infty} a_{12,j} = 0$  and  $\sum_{j=0}^{\infty} a_{13,j} = 0$ . To discriminate between the effects of the two demand shocks, Dewachter and Lustig follow Bernanke and Blinder (1992) and Galí (1992) and constrain the monetary shock to have no contemporaneous impact on output:  $a_{13,0} = 0$ . This combination of short- and long-run restrictions implies a more complicated calculation for the core inflation rate:

$$\begin{aligned} \Delta \pi_t^c = & \nu_3 + (a_{32,0} - a_{22,0})e_{2,t} + (a_{33,0} - a_{23,0})e_{3,t} + \\ & \sum_{j=1}^{\infty} (a_{32,j} + a_{22,j-1} - a_{22,j})e_{2,t-j} + \sum_{j=1}^{\infty} (a_{33,j} + a_{23,j-1} - a_{23,j})e_{3,t-j}. \end{aligned} \quad (13)$$

They also conclude that refining the demand shock has limited implications for the identification of core inflation. Nevertheless, one should note that the method used to discriminate between the two demand shocks is not problem-free, since many central bankers argue that monetary policy has no contemporaneous effect on prices.

Bjørnland (2001) tests the restrictiveness of the bivariate system by adding an energy price shock that could permanently affect output and prices, in light of the historic effects of oil-price shocks.<sup>12</sup> Unit-root tests suggest the following specification:

$$\begin{bmatrix} \Delta \ln O_t \\ \Delta \ln Y_t \\ \pi_t \end{bmatrix} = \begin{bmatrix} \nu_1 \\ \nu_2 \\ \nu_3 \end{bmatrix} + \sum_{j=0}^{\infty} \begin{bmatrix} a_{11,j} & a_{12,j} & a_{13,j} \\ a_{21,j} & a_{22,j} & a_{23,j} \\ a_{31,j} & a_{32,j} & a_{33,j} \end{bmatrix} \begin{bmatrix} e_{1,t-j} \\ e_{2,t-j} \\ e_{3,t-j} \end{bmatrix}. \quad (14)$$

10. They use real industrial output because of the monthly frequency of the model.

11. This result implies superneutrality of money.

12. Bjørnland estimates her specification for Norway and the United Kingdom. On a quarterly basis, she uses real GDP, real oil prices, and the consumer price index or the retail price index (U.K.).

The oil-price shock is easily identified by imposing the restriction that no other shock can influence oil prices in the long run ( $\sum_{j=0}^{\infty} a_{12,j} = 0$  and  $\sum_{j=0}^{\infty} a_{13,j} = 0$ ). The remaining constraint is obtained from the traditional property of the long-run Phillips curve ( $\sum_{j=0}^{\infty} a_{23,j} = 0$ ). Core inflation is defined as:

$$\pi_t^c = \nu_3 + \sum_{j=0}^{\infty} a_{33,j} e_{3,t-j}.$$

## 4 Issues and Data

If inflation is non-stationary, the researcher must assume monetary superneutrality, which is controversial. There is no consensus on the stationarity of inflation. Recent working papers from the Bank of Canada shed light on Canadian data. Demers (2003) and Binette and Martel (2005) find three different regimes in the inflation process, using either the traditional measure of core inflation or the implicit price index of personal expenditure on consumer goods and services.<sup>13</sup> Results obtained from a Bai-Perron (1998) test on headline inflation suggest the same pattern.<sup>14</sup> Based on these, we use the filtered inflation rate, which we obtain by subtracting the regime-specific mean from the original series. As suggested by Chart 1 and unit-root tests, this new series is clearly  $I(0)$ . Since the core inflation rate obtained from the structural VAR has zero mean, we add the means that we previously subtracted to obtain our core measure.<sup>15</sup>

The other key issue concerns the choice of shocks to implement in the structural VAR to identify core inflation. As explained earlier, the potential restrictiveness of the two-shock approach has been a clear source of concern in the literature. Nevertheless, research conducted by Dewachter and Lustig (1997) concludes that adding a monetary policy shock has no significant implication for their results. Gartner and Wehinger (1998, 17) reach the same conclusion in a study covering many countries: “Even though the core-CPI differentials differ somewhat from those obtained in the bivariate approach, the pattern of deviations closely matches the one from the previous results. In almost every case, the cyclical pattern of over- and underestimations is remarkably similar across both

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13. The presence of break points does not necessarily imply that the inflation rate in Canada is  $I(1)$ . In fact, the breaks reduce the probability of correctly identifying a stationary process.

14. The three break dates (1972Q2, 1982Q4, and 1991Q1) are similar to those found in Demers (2003) and Binette and Martel (2005).

15. Our approach is not totally problem-free, because regime shifts are modelled to occur in only one period. A more gradual approach could be better suited, but remains, in practice, quite difficult to implement.

specifications.” On these grounds, and given the present effects of oil prices, it seems appropriate to use a trivariate structural VAR that includes an energy shock, as in Bjørnland.<sup>16</sup>

For the sample period 1961Q1-2005Q2, the data used are  $\pi^f$ , which is the filtered headline inflation rate. Headline inflation is measured as the first differences of the log of the consumer price index multiplied by 400,  $Y$  is the first difference of the log of real GDP multiplied by 400, and  $Ener$  is the annualized growth rate of the energy component of the Bank of Canada commodity price index deflated by the U.S. GDP price deflator. The following specification uses the same restrictions as Bjørnland ( $\sum_{j=0}^{\infty} a_{12,j} = 0$ ,  $\sum_{j=0}^{\infty} a_{13,j} = 0$ , and  $\sum_{j=0}^{\infty} a_{23,j} = 0$ ):

$$\begin{bmatrix} \Delta \ln Ener_t \\ \Delta \ln Y_t \\ \pi_t^f \end{bmatrix} = \begin{bmatrix} \nu_1 \\ \nu_2 \\ \nu_3 \end{bmatrix} + \sum_{j=0}^{\infty} \begin{bmatrix} a_{11,j} & a_{12,j} & a_{13,j} \\ a_{21,j} & a_{22,j} & a_{23,j} \\ a_{31,j} & a_{32,j} & a_{33,j} \end{bmatrix} \begin{bmatrix} e_{1,t-j} \\ e_{2,t-j} \\ e_{3,t-j} \end{bmatrix}, \quad (15)$$

$$\pi_t^{fc} = \nu_3 + \sum_{j=0}^{\infty} a_{33,j} e_{3,t-j}.$$

## 5 Trivariate Structural VAR: Empirical Results

In this section we describe the impulse responses and the variance decompositions. We also describe the core inflation measure and the resulting short-term inflation.

### 5.1 Impulse responses

All nine impulse responses are consistent with economic theory, as Charts 2, 3, and 4 suggest. An energy price shock implies a sharp increase in the price of energy in the first year, but this effect is somewhat muted thereafter. The resulting higher long-run equilibrium is reached after two years. This shock also has a clear initial stimulating effect on output, but its long-run effect is slightly negative. That is consistent with the fact that

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16. As in Bjørnland, we treat energy prices as an endogenous variable. Results associated with the variance decomposition demonstrate that the effects of the other variables on energy prices are extremely marginal, even in the short run.

past increases in investment in non-residential structures followed oil-price shocks in Canada. (Canada became a net exporter of crude oil only in the second half of the sample.) As expected, oil-price shocks quickly increase prices in Canada. The new higher equilibrium price level generates a stable rate of inflation after two to three years.

A positive supply shock in Canada coincides with a decrease in energy prices. The importance of this result must not be overstated, given that Canada has no significant impact on energy prices. This shock reduces inflation temporarily, but has a strong and persistent stimulating effect on output, suggesting a beneficial productivity shock. The quick adjustment in inflation also suggests that supply shocks are not very important to the inflation process.

A positive demand shock (core shock) generates a temporary increase in energy prices that dies out quite rapidly. The same disturbance increases prices permanently, although the effect is somewhat stronger in the short run. Core shocks also stimulate output, but the effect dies out very rapidly. The speed of this adjustment suggests the existence of a nearly vertical short-run Phillips curve.

## 5.2 Variance decomposition

Variance decompositions for inflation and GDP are reported in Tables 2 and 3, respectively. As expected, core shocks are the key driver of inflation, explaining more than 60 per cent of its variance. Energy price shocks are quite insignificant in the short run, but they generate almost 10 per cent of the variation in the long run. Supply shocks explain between 25 and 30 per cent of the variation.

In our framework, output fluctuations are driven by supply shocks. These shocks explain more than 80 per cent of the variation in the first year and later become the only source of movements. Hence, our results are compatible with the real business cycle theory. Nevertheless, one must note that the formal interpretation of this “supply shock” is not straightforward.<sup>17</sup> Core shocks explain about 15 per cent of changes in output the first year, but thereafter the effect disappears very rapidly. Hence, energy price shocks are not really important to explain output movements at any horizon.

For both variance decompositions, our results are in line with the ones obtained by

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17. As Aucremanne and Wouters (1999) note, many terminologies, including technology shock (Blix 1995), are used in the literature: non-core shock (Quah and Vahey 1995), supply shock (Dewachter and Lustig 1997; Gartner and Wehinger 1998), and output shock (Fase and Folkertsma 1997).

Bjørnland. The results are also highly satisfactory for inflation. It seems reasonable to believe that inflation is driven mainly by a single shock: a core shock. Common to Bjørnland, Quah and Vahey, and this study is the fact that there is a small transitory component of GDP. A second common result is more problematic: demand shocks are not so important in the short term. Theoretically, our measure of core inflation could be biased if the supply shocks reflect some effects that should be included in core shocks. Nevertheless, as mentioned earlier, this theoretical concern has no serious empirical implications, according to many researchers.

### 5.3 Core and headline inflation

Chart 5 shows core inflation, the annualized quarterly change in headline inflation, and changes in these two series on a year-over-year basis given the usual focus of monetary authorities.<sup>18</sup> The two series are quite similar at first glance, suggesting that headline inflation tracks the underlying rate of inflation relatively well.<sup>19</sup> This result is not surprising, given that core shocks are the key driver of headline inflation, as the variance decomposition suggested earlier. However, during many periods, headline inflation tracks core inflation poorly. Chart 6 shows the difference between headline and core inflation on a quarterly basis: this is short-term inflation. In our framework, movements in short-term inflation are driven by the effects of energy and supply shocks on headline inflation.

Headline inflation is persistently above core during periods of oil-price shocks, including those of the Gulf War of 1991. As energy price shocks die out, headline inflation falls below core, although the effects are not symmetric. This result is confirmed in Chart 7, which shows that the effects of energy price shocks are the key determinant of short-term inflation in the first half of the sample. The effects of supply shocks on headline inflation were small during the 60s, but became more important thereafter. Since the mid-80s, these effects are clearly more symmetric and volatile. They have been the main determinant of short-term inflation in the past 10 years. These shocks almost perfectly match sharp movements in short-term inflation during key periods of low inflation, including the Asian financial crisis and the terrorist attacks of 11 September 2001. As expected, headline inflation remains below core in such periods of low inflation.

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18. Series displayed on a year-over-year basis come from a mathematical transformation, and not from a re-estimation of the SVAR, given concerns with overlapping data.

19. As one would expect, core inflation has a smaller standard deviation (3.07 per cent) than headline inflation (3.39 per cent). The discrepancy is even bigger on a year-over-year basis (0.42 per cent). One should also note that our measure of core inflation has virtually the same standard deviation as CPIX over the available common sample period (1979Q1 to 2005Q2).

## 6 The Predictive Power of Core Inflation

Armour (2006, equation (2)) quotes Cogley’s (1998) test for the predictive power of core inflation:

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

The null hypothesis of  $\alpha = 0$  corresponds to an unbiased forecast, whereas the null hypothesis of  $\beta = 1$  corresponds to a measure of core inflation that perfectly captures transitory movements in total inflation. We report results of this regression for the core measure derived in this paper (hereafter, CPICV). For the purposes of comparison, we also report the results for two other core measures: CPIX and CPIW. CPIX is the exclusion-based measure used by the Bank of Canada as its “operational guide;” this measure excludes the prices of eight volatile components and the effects of changes to indirect taxes. CPIW is a double-weighted measure; rather than excluding volatile components, it reweights the components by the inverse of their variances.<sup>20</sup> We consider the forecasting power of these three measures at horizons of two, four, and six quarters for a sample from 1992Q1 through 2004Q1; results are shown in Tables 4 through 6.<sup>21</sup>

At the two-quarter horizon, the core measure derived from the SVAR (14), CPICV, forecasts better than CPIX and CPIW, both in-sample and out-of-sample. Each of the three measures forecasts best at one of the longer horizons, either in-sample or out-of-sample. Also, while it is not possible to reject the hypothesis that  $\beta = 1$  at a four-quarter horizon for CPIX (at the 5 per cent significance level), it is possible to reject the hypothesis that  $\beta = 1$  for all other measure-horizon pairs. Fortunately, we are not able to reject the hypothesis that  $\alpha = 0$  for any of the three measures and any of the three horizons; all of these measures are unbiased forecasters of total inflation. Wald tests reveal that it is not possible to reject the joint hypothesis of  $\alpha = 0, \beta = 1$  for CPIX at either the four-quarter or six-quarter horizon.

Armour (2006) follows Macklem (2001), who recommends that the Cogley (1998) equations be reversed. This test is related to the work of Granger (1969). If core inflation can be used to forecast total inflation but total inflation can also be used to forecast core inflation, one

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20. For more on CPIX and CPIW, see Armour (2006).

21. Data through 2005Q2 are used for the out-of-sample calculations such as root mean squared error.



might reasonably ask the question whether the measure called “core” is really appropriate as a guide for policy.

We replicate Armour’s results for CPIX and CPIW. As she reports, the in-sample fit of total as a predictor for core is essentially zero (she does not report measures of out-of-sample fit). But this test is inappropriate for CPICV, which is the mean of total inflation plus past shocks to inflation. It is therefore unsurprising that CPICV predicts total inflation well. In fact, total inflation can predict core inflation with an in-sample fit of almost 40 per cent after four quarters!

To determine whether any of these measures of inflation forecast better than the others, we need to examine their out-of-sample fit, measured by the root mean squared error (RMSE). Diebold and Mariano (1995) tests allow the researcher to state whether the differences in RMSE are statistically significant. CPICV forecasts significantly better than either exclusion measure at the two-quarter horizon, and significantly better than CPIX at the six-quarter horizon (although we cannot reject the hypothesis of equal forecast accuracy for CPICV and CPIW at that horizon). At the four-quarter horizon, CPIW forecasts significantly better than either of the other two measures.

Overall, we show that there are horizons for which CPICV forecasts better than the existing exclusion measures out-of-sample. This measure is potentially useful for policy purposes. Some data used to construct CPICV are revised. Determining whether this measure is actually useful requires a real-time analysis, which is beyond the scope of the present paper.

## 7 Conclusion

Our main goal in this paper has been to develop a measure of core inflation for Canada based on macroeconomic theory. We get this measure by imposing the long-run verticality of the Phillips curve in a slightly modified version of Quah and Vahey (1995), a trivariate SVAR including an energy price shock. As with many other researchers, we conclude that headline inflation can diverge significantly and persistently from the underlying rate of inflation. A detailed analysis suggests that the effects of supply shocks on headline inflation explain most of the discrepancy at the end of the sample period, implying that the relative importance of energy price shocks diminishes over time.

This macroeconomic-founded measure of core inflation is not problem-free. One must consider that possible revisions to the measure complicate its use, even if the absence of

revisions for classical measures of core inflation is not necessarily a sign of perfection. This problem is not only a quantitative drawback but also a conceptual one, since core inflation should be related to inflation expectations based on the available information. Future research could try to reduce the uncertainty associated with this issue.

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**Table 1****Core Inflation and Non-Core Inflation**

Quah and Vahey		Eckstein	
Core	Non-core	Core	Non-core
$\pi_t^{lr} + g^*(x_{t-1})$	$\nu_t$	$\pi_t^{lr}$	$g^*(x_{t-1}) + \nu_t$

**Table 2****Trivariate SVAR: Variance Decomposition of Inflation**

Quarter	Energy price shocks	Supply shocks	Core shocks
1	2.15	28.96	68.90
2	6.23	24.93	68.84
3	9.47	24.83	65.70
4	9.31	25.74	64.95
8	9.87	25.56	64.57
16	9.91	25.56	64.53
32	9.91	25.56	64.53
64	9.91	25.56	64.53
100	9.91	25.56	64.53

**Table 3****Trivariate SVAR: Variance Decomposition of GDP**

Quarter	Energy price shocks	Supply shocks	Core shocks
1	1.99	76.11	21.90
2	1.28	83.15	15.58
3	0.95	88.53	10.52
4	0.93	91.19	7.88
8	0.39	96.58	3.02
16	0.21	98.39	1.40
32	0.11	99.22	0.68
64	0.06	99.61	0.33
100	0.04	99.75	0.21

**Table 4****Two-Quarter-Ahead Cogley Regressions**

	CPICV	CPIW	CPIX
$\hat{\alpha}$	0.08	0.17	-0.02
s.e. ( $\alpha$ )	0.14	0.78	0.14
$\hat{\beta}$	0.42	-0.05	0.50
s.e. ( $\beta$ )	0.11	0.22	0.17
$R_a^2$	<b>0.25</b>	-0.02	0.14
RMSE	<b>0.51</b>	0.54	0.56

**Table 5**  
**Four-Quarter-Ahead Cogley Regressions**

	CPICV	CPIW	CPIX
$\hat{\alpha}$	0.08	-0.19	-0.01
s.e. $(\alpha)$	0.20	1.07	0.18
$\hat{\beta}$	0.55	0.07	0.98
s.e. $(\beta)$	0.17	0.30	0.22
$R_a^2$	0.17	-0.02	<b>0.31</b>
RMSE	0.71	<b>0.66</b>	0.78

**Table 6**  
**Six-Quarter-Ahead Cogley Regressions**

	CPICV	CPIW	CPIX
$\hat{\alpha}$	0.14	-0.32	0.07
s.e. $(\alpha)$	0.17	0.87	0.16
$\hat{\beta}$	0.34	0.13	0.65
s.e. $(\beta)$	0.17	0.25	0.20
$R_a^2$	0.07	-0.02	<b>0.18</b>
RMSE	<b>0.65</b>	0.78	0.72

Chart 1  
Filtered and Headline Inflation

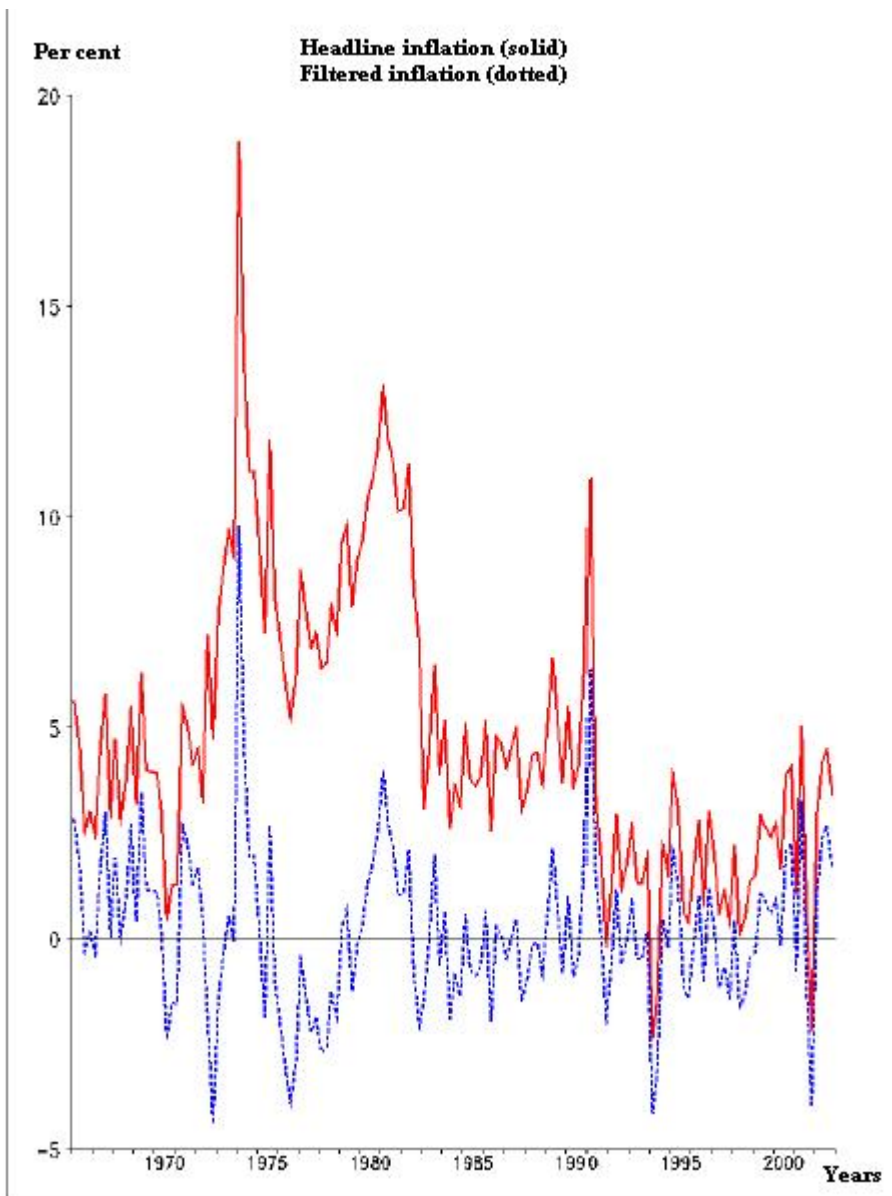


Chart 2  
 Trivariate SVAR: Impulse Responses

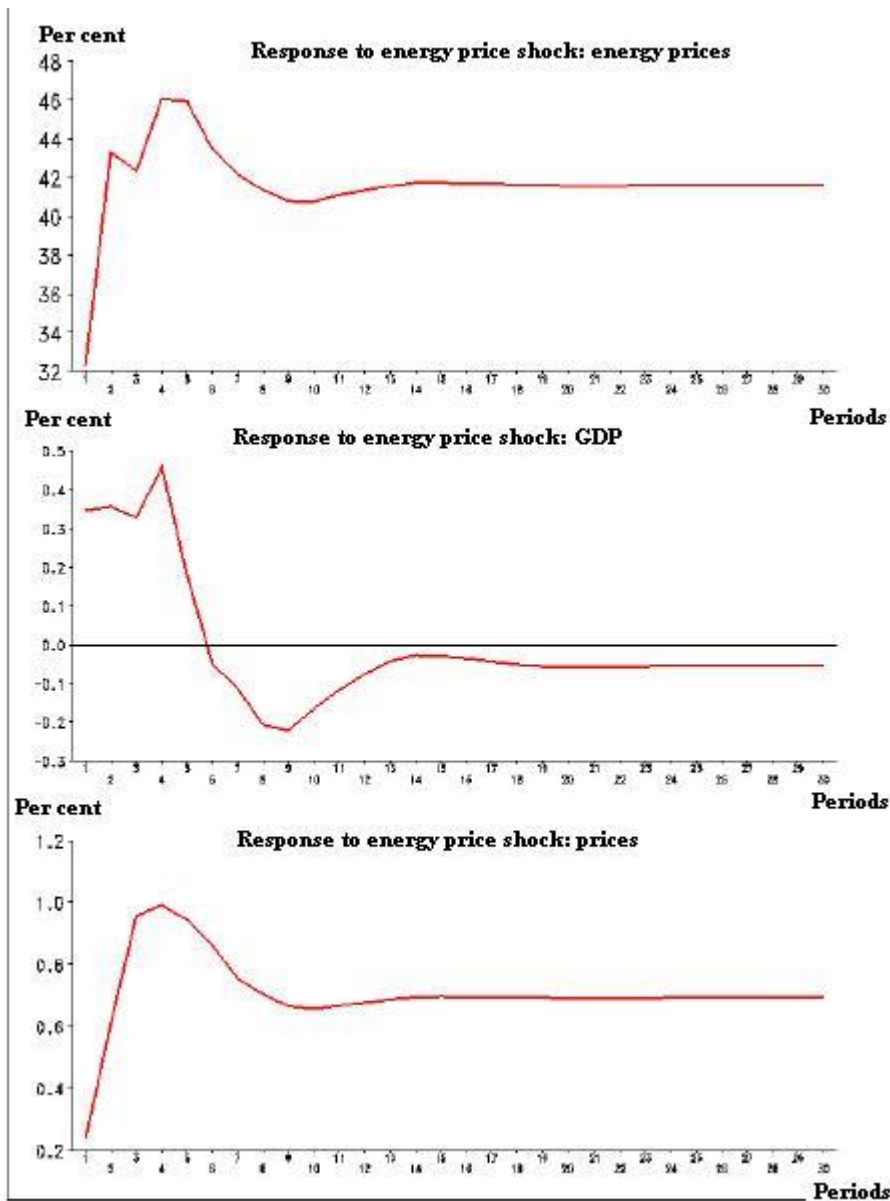




Chart 3  
 Trivariate SVAR: Impulse Responses

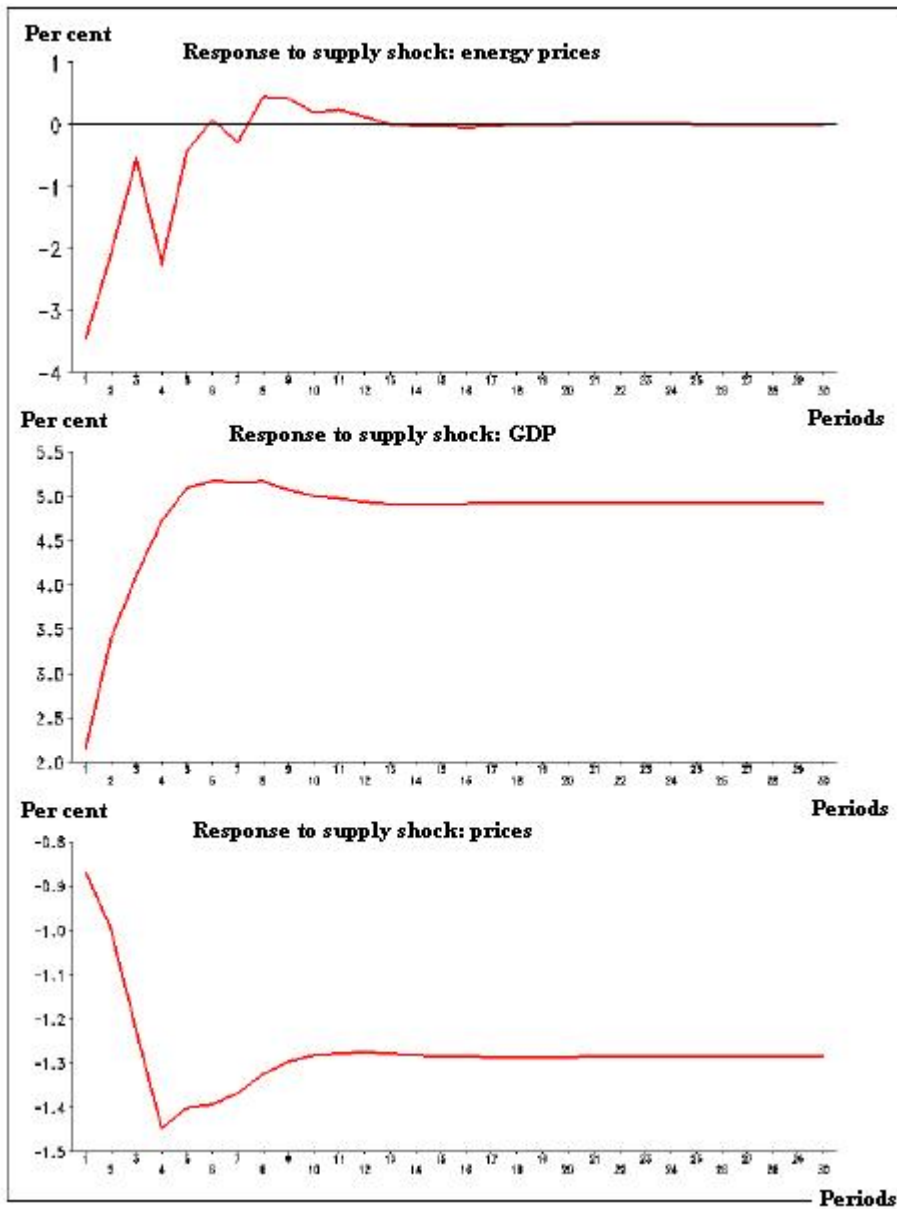


Chart 4  
 Trivariate SVAR: Impulse Responses

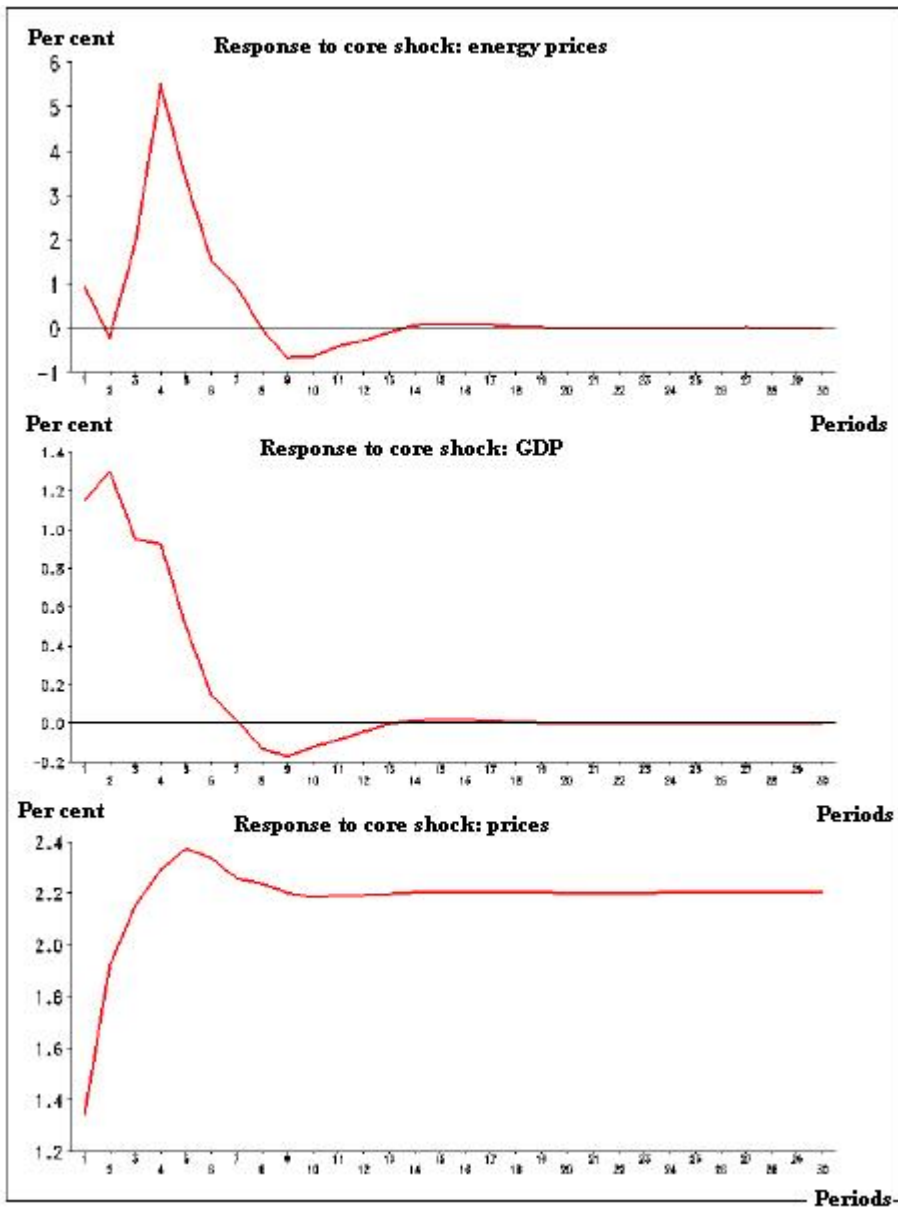
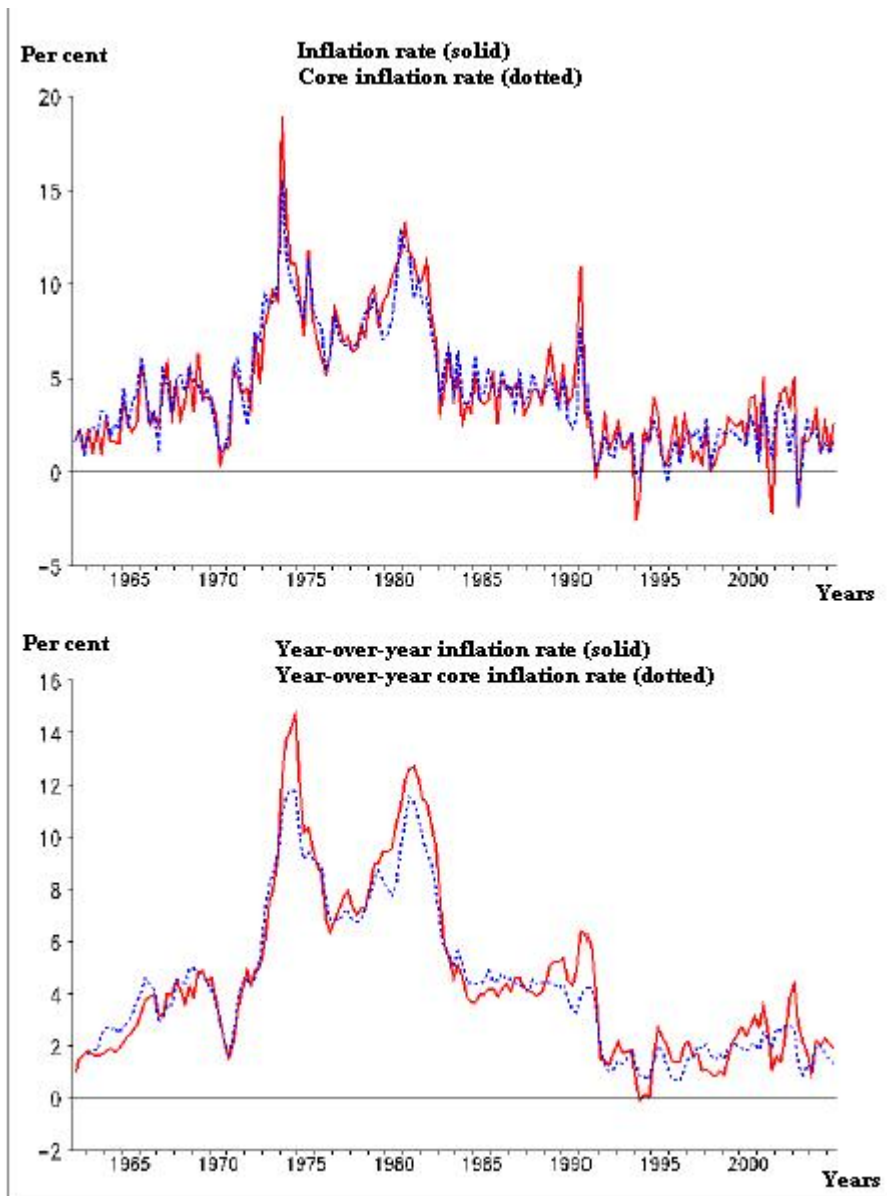


Chart 5  
Core and Headline Inflation



**Chart 6**  
**Short-Term Inflation**

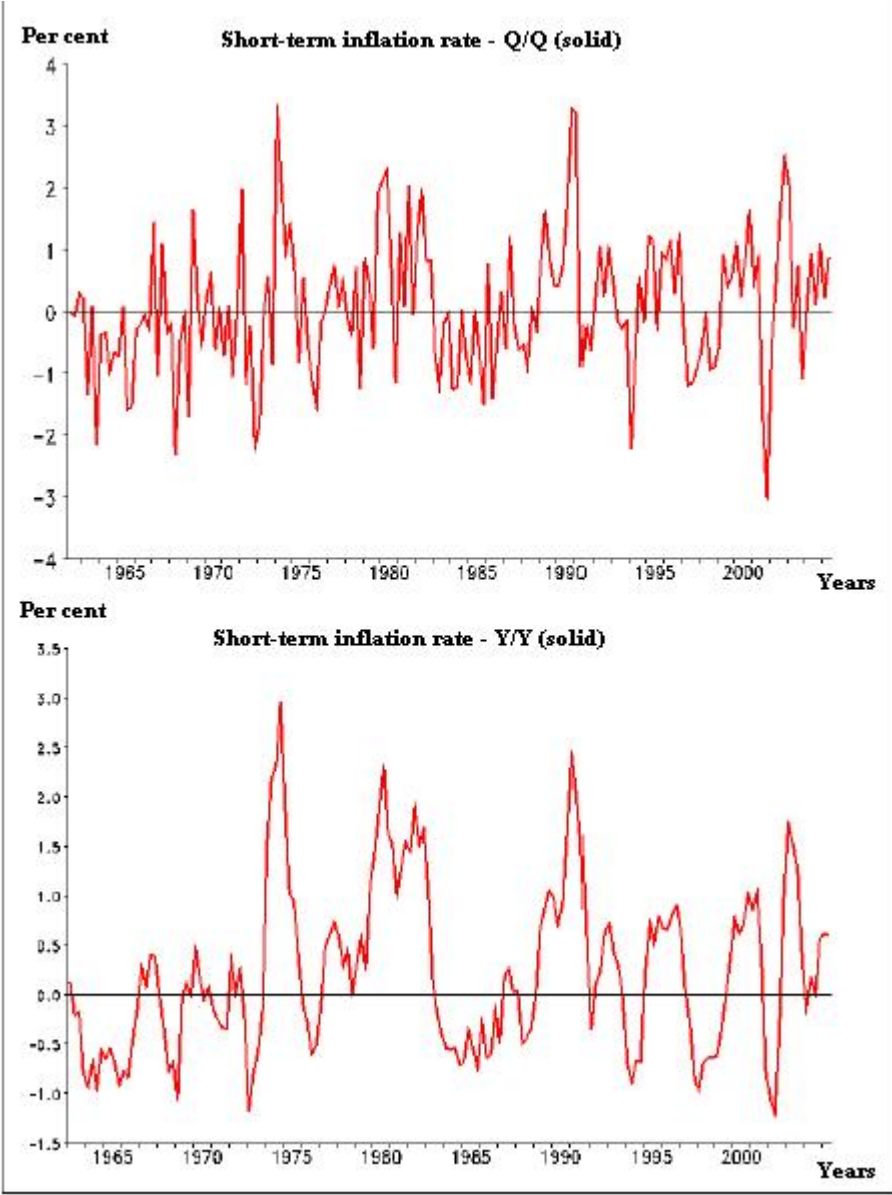


Chart 7  
Short-Term Inflation and the Effects of Non-Core Shocks on Headline Inflation

