

Identifying Domestic and Imported Core Inflation*

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Abstract: This paper estimates core inflation in Norway, identified as that component of inflation that has no long-run effect on GDP. The model distinguishes explicitly between domestic and imported core inflation. The results show that (domestic) core inflation is the main component of CPI inflation. However, CPI inflation misrepresents core inflation during some periods. The differences are well explained by the other shocks identified in the model, in particular the oil price shocks of the 1970s when Norway imported inflation, and the negative non-core (supply) shocks of the late 1980s which pushed inflation up temporarily relative to core inflation.

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I. INTRODUCTION

Since the early 1990s, several countries (like Canada, New Zealand, United Kingdom, Finland and Sweden), have introduced explicit inflation targets for monetary policy (see e.g. Haldane, 1995, and McCallum, 1996, for descriptions). The main argument for an inflation targeting regime is that in a small open industrialized economy, inflation targeting allows monetary policy to focus directly on the goal of achieving low and stable inflation (see e.g. Svensson, 1997). In Norway, monetary policy aims to stabilize the nominal exchange rate. The pressure on the Norwegian currency in several periods throughout the 1990s, have led many to argue that the central bank should abandon the target of stable exchanges rates in favor of an explicit target of low inflation rate (see e.g. Isachsen and Røste, 1999, and Leitemo, 1998).

However, if a central bank wants to keep the aggregate inflation rate at a specific target, it needs to have a precise measure of the inflationary pressure in the economy, that it can control. The consumer price index (CPI) may not be a good measure of the inflationary pressure, as the CPI is affected by other factors than just monetary policy, like one time changes in VAT and other indirect taxes, that induce temporary noise in the overall price index. Many central banks that have adopted an inflation target therefore also calculate the so called “core” (also referred to as “underlying”) inflation rate, by adjusting the consumer price index for some of these noisy price signals that should not respond to monetary policy.

There are many ways the central bank can adjust the CPI for random inflation developments, that should be disregarded for the purpose of setting the stance of monetary policy. Although some of these “adjustment” methods may yield useful additional information about the inflation process, they might just as well misrepresent core inflation. Especially, as no precise definition of core inflation is put forward, there is no formal criteria by which one can judge the accuracy of the measured inflation rate. This paper identifies instead the core inflation component by imposing dynamic restrictions implied by economic theory, on a structural vector autoregression (VAR) model. The empirical analysis is applied to Norway. In the event that the Norwegian authorities would want to switch to an explicit inflation target, this paper then addresses questions about the appropriate measure of inflation to use.

Several definitions of core inflation have been put forward in the economic literature. Eckstein (1981, pp. 7–8) defined core inflation as the trend increase in the cost of the factors of production. More recently, Bryan and Cecchetti (1993, p. 3) have argued that it is common to think of core inflation as the “*long-run, or persistent component of the measured price index, which is tied in some way to money growth.*” The definition by Bryan and Cecchetti echoes Milton Friedman’s view that “inflation is always and everywhere a monetary phenomenon.” The idea that inflation is a monetary phenomenon in the long-run has recently been used in many studies to argue that, if inflation is non-stationary, then the permanent component of inflation can be associated with permanent changes in the growth rate of money (see e.g. Roberts, 1993, and Bullard and Keating, 1995).

However, if the permanent component of inflation is caused by monetary changes, then the transitory component of inflation will be made up of (exogenous) non-monetary disturbances. Clearly, this definition excludes the possibility that other shocks, say energy price changes, can have very persistent effects on inflation. Further, the assumption that the permanent component of inflation is due to monetary changes will not be a valid assumption if monetary shocks are also important sources behind the temporary variation in inflation. This could well be the case if prices adjust quickly to monetary disturbances, so the temporary effects of monetary shocks on inflation are more important than the long-run effects.

This paper identifies core inflation as the component of inflation that has no long-run effect on real output. This identifying assumption allows all types of shocks (including monetary disturbances) to drive core inflation, as long as they are output neutral in the long-run. The neutrality restriction relies on the assumption of a vertical long-run Phillips curve, although in the short-run the Phillips curve may be positively sloped, allowing for a temporary trade off between core inflation and real output.

The econometric model builds on Quah and Vahey (1995). By specifying a VAR model containing the growth rates of output and inflation, Quah and Vahey identify two types of uncorrelated shocks; core and non-core shocks. The core shocks can have no long-run effects on real output. Non-core shocks will then be the impulses that can affect output in the long-run, typically supply shocks like productivity changes, energy shocks, taxes and price controls. No restrictions are placed on the response of inflation to core or non-core shocks. An estimate of core inflation will be calculated from the core impulses.

This paper goes further than that of Quah and Vahey (1995), in that it distinguishes explicitly between domestically generated core inflation and the components of inflation that are imported. The idea is that in a small open economy, a large part of inflation is imported, and the central bank needs to separate the imported part from the domestically generated inflation when it shall react to observed price signals. This paper isolates foreign price signals in two different ways. First, it disentangles the effects of foreign oil price shocks from the core and non-core shocks, by including oil prices directly into the structural VAR model. Second, it specifies a model where instead of oil prices, the price level of Norway's trading partners is included in the VAR model. This allows one to distinguish between domestic and imported core inflation (including that generated by oil price changes).

Below, the concept of core inflation is discussed more thoroughly in Section II, and the structural VAR models are identified in Section III. Section IV displays the empirical results and Section V concludes.

II. INFLATION TARGETING AND CORE INFLATION

It is well known that the consumer price index may not necessarily be a good indicator of underlying inflation in an economy, as noise in some of the price indices will shift the inflation rate around randomly. Several procedures are available for correcting noisy price signals. One of the most subjective methods, is to extract extreme outliers in the CPI, (after each shock has occurred). Another subjective method is to (permanently) exclude the most volatile price components in the CPI, by giving them zero weight. For instance, the CPI is often reported excluding “food and energy.” Countries that have included interest cost in the CPI, also often exclude these components (in particular mortgage interest payments), as the way they are included makes the CPI sensitive to cyclical movements in interest rates.¹ A more mechanical method that has recently become more popular, is to compute the median inflation rate across the individual prices in the CPI. The motivation for doing so is the observation that the components of the CPI are positively skewed (see Bryan and Pike, 1991).

Many central banks that have adopted inflation targets, calculate core inflation using some of the adjustment procedures described above. For instance, in **New Zealand**, the Policy Targets Agreement (PTA), established between the Minister of Finance and the Governor of the Bank, gives the Reserve Bank responsibility for the control of *trend or ongoing inflation*. Embodied in the PTA is the idea that “*The appropriate measure of underlying inflation for policy purposes, ... is one which is able to*

distinguish between one-off shocks to prices arising from supply-side developments as opposed to shocks to the ongoing inflation rate arising from demand-side developments.” Roger (1995, p. 2).

Consistent with this idea, the Reserve Bank therefore has defined a few categories of inflation disturbances that it can omit when calculating underlying inflation.ⁱⁱ In the **United Kingdom**, the Government relies on the retail price index (RPI) excluding mortgage interest payments, (RPIX), when conducting monetary policy. In **Canada**, the CPI is reported excluding food and energy and the contribution of changes in indirect taxes, whereas **Sweden** reports the CPI excluding effects of indirect taxes and subsidies. Many of these methods have recently also been evaluated and applied to the Norwegian CPI, (see Bråten and Olsen, 1997).

All of these methods may yield some useful information about the underlying inflation process. However, they are either subjective and involve elements of judgement (in addition to having to decide which shocks to adjust for, one also has to make sure that there are no second order effects of these shocks that the CPI will react to), or mechanical where one has no formal criteria by which to judge the accuracy of the measured inflation rate. Hence, it could in fact turn out that none of the “adjusted inflation rates” represent the “underlying” inflation rate any more than the CPI itself. Finally, the central banks may find it problematic to use a subjective adjustment method, as it is difficult to identify a measure of underlying inflation that serves both policy purposes and is accountable at the same time.ⁱⁱⁱ

This paper uses instead an econometric model to identify core inflation as the component of inflation that has no long-run effect on real output. The econometric model has the advantage over many of the adjustment methods described above, as the removal of the different shocks will be intrinsic to the modeling. Hence, one avoids having to determine subjectively which shocks to adjust for. In addition, one has a precise and economically interpretable definition of underlying inflation one can judge the results from.

The restriction that the core inflation shock has no long-run effect on real output can be tested (informally) by investigating the short-run properties of the model. In particular, given that one does not restrict *how* fast the core shocks shall be output neutral, but let the data decide, one can examine the plausibility of the short-run responses, given the long-run restriction. Typically, if long-run output neutrality shall prevail, one should expect the short-run effects of the core shocks on output to die out fairly quickly. The approach of imposing long-run neutrality and testing its implications on the short-run properties of the model, was discussed in King and Watson (1992) and Vredin and Warne (1994) as a plausible way to test for neutrality.^{iv}

Finally, note that the assumption of a vertical long-run Phillips curve relies on the fact that both output and inflation are non-stationary variables. However, if instead inflation is stationary (but prices are non-stationary), the assumption of a vertical long-run Phillips curve may no longer be required. Instead, one can then define core inflation from the assumption of a long-run vertical supply schedule, where positive demand shocks are output neutral in the long-run, but increase prices permanently. Nevertheless, although inflation is stationary, the core inflation shocks can still be the most important factors explaining inflation movements for prolonged periods, but the accumulated effects of core shocks on the inflation rate will eventually die out.

A. The role of oil prices and imported inflation

In the model specified in Quah and Vahey (1995), core disturbances were identified as those shocks that had no long-run effects on output, whereas non-core disturbances were allowed to have

permanent effects on output. No restrictions were imposed on the response of inflation to these two shocks. Yet, if the measure of core inflation was to be an useful indicator of the inflationary pressure in the economy, then non-core shocks should not contribute significantly to the inflation movements. However, some shocks have been observed to have had prolonged effects on both output and inflation. In particular, the two successive adverse oil price shocks in 1973/1974 and 1979/1980 are believed to have reduced world trade permanently, as well as have had a persistent effect on inflation (see e.g. Fama, 1981, Burbidge and Harrison, 1984, Gisser and Goodwin, 1986, and Ahmed et al., 1988).^v An oil price shock may typically have real effects, as a higher energy price may affect output via the aggregate production function, by reducing the net amount of energy used in the production. The persistent effect on inflation may come about as agents observe higher fuel prices, they revise their price expectations upwards by among other demanding higher wages. Eventually then, via the expectations of agents, higher oil prices convert themselves into higher inflation, (c.f. Eckstein, 1981).

The effects of oil price shocks on the economy, will also depend on the policy responses of the government to these shocks. In a small oil exporting country like Norway, the extra income from higher oil prices allowed the government to follow expansionary policies, in particular throughout the 1970s and parts of the 1980s, which although it boosted aggregate demand, may have fuelled inflation expectations further. To be able to study the effects of oil prices directly, this paper therefore disentangles the effects of oil price shocks from the two other shocks, by including oil prices into the structural VAR model. No restrictions are placed on the response of output and inflation to the oil price shocks, but only oil price shocks can affect the oil price in the long-run. To emphasize the real income effect of higher oil prices on an energy exporting country, real (as opposed to nominal) oil prices are used in the VAR model, although in the end, the results are compared to a VAR model containing nominal oil prices.

Finally, this paper distinguishes between domestic and imported core inflation by including the foreign price of Norway's trading partners instead of the real oil price in the VAR. The model now allows one to distinguish between three types of shocks: non-core, domestic core, and imported core inflation shocks. Neither domestic nor imported core shocks are assumed to have long-run effects on real output, and given the small country assumption for Norway, domestic core shocks can have no long-run effects on the foreign price level. However, alternative identifying restrictions are also tried out. By comparing the results using imported inflation with those where oil price shocks were identified, one can also investigate the extent to which oil price shocks are reflected in the imported inflation shocks. The identifying restrictions used to orthogonalize the different shocks, will be discussed further below.

III. IDENTIFYING THE STRUCTURAL VARs

Below, the identification scheme for the VAR model containing oil prices is first discussed, before focusing on the VAR model with imported prices. In the analysis, real GDP and real oil prices will be taken to be non-stationary, integrated, $I(1)$, variables, whereas inflation is either $I(1)$ or $I(0)$. Below one will see how these three variables will be sufficient to identify the three structural shocks: core, non-core and oil price shocks. Assume for now that inflation is $I(0)$. One can then define z_t as a vector of stationary macroeconomic variables: $z_t = (\Delta o_t, \Delta y_t, \Delta p_t)'$ where Δo_t is the first difference of the log of oil prices, Δy_t is the first differences of the log of output and Δp_t is the inflation rate, calculated as the first differences of the log of the price index.^{vi} A reduced form of z_t can be modeled as:

$$\begin{aligned} z_t &= \alpha + A_1 z_{t-1} + \dots + A_p z_{t-p} + e_t \\ A(L)z_t &= \alpha + e_t \end{aligned} \quad (1)$$

where $A(L)$ is the matrix lag operator. e_t is a vector of reduced form residuals with covariance matrix Ω . To go from the reduced form to the structural model, a set of identifying restrictions must be imposed. As all the variables defined in z_t are assumed to be stationary, z_t is a covariance stationary vector process. The Wold Representation Theorem implies that under weak regularity conditions, a stationary process can be represented as an invertible distributed lag of serially uncorrelated disturbances. The implied moving average representation of (1) can be found and written as (ignoring the constant term for now):

$$z_t = C(L)e_t \quad (2)$$

where $C(L) = A(L)^{-1}$ and $C_0 = I$. As the elements in e_t are contemporaneously correlated, they can not be interpreted as structural shocks. The elements in e_t are orthogonalized by imposing restrictions. A (restricted) form of the moving average containing the vector of original disturbances as linear combinations of the Wold innovations can be found as:

$$z_t = D(L)\varepsilon_t \quad (3)$$

where ε_t are orthogonal structural disturbances which for convenience are normalized so they have unit variance, e.g. $\text{cov}(\varepsilon_t) = I$. With C_0 as the identity matrix, (2) and (3) imply that $e_t = D_0\varepsilon_t$, and $C_j D_0 = D_j$ so:

$$C(L)D_0 = D(L) \quad (4)$$

If D_0 is identified, one can derive the *MA* representation in (3) since $C(L)$ is identifiable through inversions of a finite order $A(L)$ polynomial. Consistent estimates of $A(L)$ can be found by applying *OLS* to (1). However, with a three variable system, the D_0 matrix contains nine elements. To orthogonalize the different innovations, nine restrictions are needed. First, from the normalization of $\text{var}(\varepsilon_t)$ it follows that:

$$\Omega = D_0 D_0' \quad (5)$$

This imposes six restrictions on the elements in D_0 because of the symmetry of the covariance matrix Ω . Three more restrictions are then needed to identify D_0 . These will come through long-run restrictions on the $D(L)$ matrix.

The three serially uncorrelated orthogonal structural shocks are first ordered as: $\varepsilon_t = (\varepsilon_t^{OP}, \varepsilon_t^{NC}, \varepsilon_t^C)'$, where ε_t^{OP} is the oil price shock, ε_t^{NC} is the non-core disturbance, and ε_t^C is the core shock. The long-run expression of (3) can then be written in matrix format as:

$$\begin{bmatrix} \Delta o \\ \Delta y \\ \Delta p \end{bmatrix}_t = \begin{bmatrix} D_{11}(1)D_{12}(1)D_{13}(1) \\ D_{21}(1)D_{22}(1)D_{23}(1) \\ D_{31}(1)D_{32}(1)D_{33}(1) \end{bmatrix} \begin{bmatrix} \varepsilon^{OP} \\ \varepsilon^{NC} \\ \varepsilon^C \end{bmatrix}_t \quad (6)$$

where $D(1) = \sum_{j=0}^{\infty} D_j$ indicate the long-run matrix of $D(L)$. The three long-run restrictions on $D(1)$ can now be imposed in the following way. The first restriction, that core shocks have no long-run effect on the level of GDP, is simply found by setting $D_{23}(1) = 0$. The two other restrictions are used to identify oil price shocks, and essentially state that only oil price shocks can influence real oil prices in the long-run, hence, $D_{12}(1) = D_{13}(1) = 0$. However, in the short-run, core and non-core shocks are free to influence real oil prices. The long-run restrictions on oil prices are plausible given that Norway is a small oil producer, that has had only limited influence on the price of oil. In addition, oil prices have been dominated by a few exogenous developments, like the OPEC embargo in 1973 and the collapse of OPEC in 1986. With the three long-run restrictions, the $D(1)$ matrix will be lower triangular. Writing the long-run expression of (4) as $C(1)D_0 = D(1)$, expression (4) and (5) together imply:

$$C(1)\Omega C(1)' = D(1)D(1)' \quad (7)$$

This matrix can be computed from the estimate of Ω and $C(1)$. As $D(1)$ is lower triangular, the expression in (7) implies that $D(1)$ will be the unique lower triangular Choleski factor of $C(1)\Omega C(1)'$. Let M denote the lower triangular Choleski decomposition of (7), then D_0 can be easily obtained from:

$$D_0 = C(1)^{-1} M \quad (8)$$

Having identified D_0 , the systems structural shocks and their dynamics in (3) can be found.

A. Imported inflation

In the VAR model with foreign prices, oil prices are replaced with CPI of Norway's trading partners (f_t). Assume for now that f_t is $I(1)$, but the first differences are stationary. The vector of stationary macroeconomic variables can then be defined and ordered as: $z_t = (\Delta f_t, \Delta y_t, \Delta p_t)'$. These three variables, will be sufficient to identify the three structural shocks: $\varepsilon_t = (\varepsilon_t^{IC}, \varepsilon_t^{NC}, \varepsilon_t^{DC})'$, where ε_t^{IC} is the imported (core) inflation shock, ε_t^{DC} now refers to the domestic core shock and ε_t^{NC} is defined as above. The long-run expression of (3), using instead foreign inflation in the VAR model, then becomes:

$$\begin{bmatrix} \Delta f \\ \Delta y \\ \Delta p \end{bmatrix}_t = \begin{bmatrix} D_{11}(1)D_{12}(1)D_{13}(1) \\ D_{21}(1)D_{22}(1)D_{23}(1) \\ D_{31}(1)D_{32}(1)D_{33}(1) \end{bmatrix} \begin{bmatrix} \varepsilon^{IC} \\ \varepsilon^{NC} \\ \varepsilon^{DC} \end{bmatrix}_t \quad (9)$$

To identify D_0 , again it is assumed that domestic core disturbances have no long-run effects on y , hence $D_{23}(1) = 0$. Consistent with the idea of a long-run vertical Phillips curve (or a vertical aggregate supply schedule), this paper assumes that neither the imported core shocks can have a long-run effect on output, hence $D_{21}(1) = 0$. In addition, it is assumed that for a small country as Norway, domestic core shocks can have no long-run effects on the foreign price level, hence $D_{13}(1) = 0$. That is, there are two types of core inflation shocks that have no long-run effects on output; domestic and imported core shocks. Of these two shocks, only imported core shocks can have a long-run effect on the foreign price level. However, the non-core shocks are allowed to have a long-run effect on the foreign price level, through possible productivity spill over effects.

To investigate the robustness of the results using this restriction, another set of restrictions were tried out, by now allowing imported core shocks to have a long-run effect on output (this way one can test whether the assumption of a long-run vertical Phillips curve holds with regard to the imported inflation shocks). Instead, the same type of (small country) restriction imposed on real oil prices above is assumed, namely that the non-core shocks (in addition to the domestic core shocks) can have no long-run effects on the foreign price level, hence $D_{12}(1) = 0$, and $D_{13}(1) = D_{23}(1) = 0$ as above.

Interestingly, the results were almost identical using either set of restrictions. In particular, the effects of the imported (core) price shocks turned out to be the same whether one imposed the restriction that they had no long-run effect on output, or not. To be consistent with the model using oil prices, it was therefore continued with the second set of restrictions ($D_{12}(1) = D_{13}(1) = D_{23}(1) = 0$).^{vii} The $D(1)$ matrix in (9) will now be lower triangular, and D_0 can again be recovered using (7)–(8).

IV. EMPIRICAL RESULTS

Below, the results from estimating the “oil price VAR model” are first presented, before focusing on the “foreign price VAR model”. For each model, the properties of the different shocks identified are first investigated, before computing the core inflation rate. This is done so that one can judge whether the different impulses identified have meaningful economic interpretations.

A. Data analysis and model specifications

The variables are first assessed to see whether the model specifications outlined above are consistent with their time series properties. The data and their sources are described in Appendix I. Standard unit-root tests (c.f. Table A.1) confirm that for neither GDP, the real oil price nor consumer prices can one reject the hypothesis of a unit-root in favor of the (trend) stationary alternative. However, one can reject the hypothesis that their first differences are $I(1)$. By testing for cointegration between GDP, oil prices and prices, one can confirm that none of the variables in the VAR model are cointegrated (see Table A.2.a), hence they can be specified in their first differences as described above.

Likelihood ratio tests for model lag reductions accept two lags at the 5 percent level. However, four lags were required in the model to reject the hypothesis of auto-correlation and heteroscedasticity at the 5 percent level, although one could not reject the hypothesis of non-normality in any of the equations. Plots of the data also suggest that there are at least three outliers in the oil price and at least one outlier in inflation. Inclusion of appropriate dummies to take care of the outliers, the non-normality tests in the equation for CPI can be rejected, although there is some evidence of non-normality in the remaining system, most likely due to remaining non-normality in the equation for oil prices.^{viii} However, as the focus is on inflation and one wants to use as few dummies as possible, the remaining non-normality in the system is ignored.

B. Dynamic responses to core, non-core, and oil price shocks

Below, the impulse responses are first presented (Figure 1), before focusing on the variance decomposition (Table 1). The impulse responses give the accumulated responses of inflation and real output to each shock, with a one standard deviation band around the point estimates, reflecting uncertainty of estimated coefficients.^{ix} A positive core disturbance increases inflation, and the effect dies out after approximately four years, when inflation returns to its long-run (stationary) level. GDP is temporarily stimulated from the core shock, but the effect is not significantly different from zero after a year. The output-neutrality assumption seems therefore valid. A positive non-core shock reduces inflation temporarily, but has a strong stimulating effect on GDP, that reaches its long-run equilibrium after two years. Hence positive non-core shocks act as beneficiary supply shock, by increasing GDP permanently and reducing inflation temporarily. The quick adjustment in inflation also implies that non-core disturbances are not fundamental to the inflationary process.

[Figure 1 somewhere here]

An oil price shock reduces inflation the first quarter, but thereafter inflation increases. The inflationary effect is quite persistent and lasts for approximately two to three years. A real oil price shock has a beneficiary effect (but not necessarily significant in the long-run) on GDP, which is consistent with the fact that Norway is a small oil exporting country, whose wealth and demand increase when oil prices are high (see also Bjørnland, 1998).

The variance decomposition for the level of GDP and inflation are reported in Table 1. Core shocks explain approximately 70 percent of the variance in inflation after two years, whereas almost 10 percent of the variation in inflation is explained by oil price shocks. Non-core shocks are the main source behind the variation of GDP, explaining 80 percent of GDP movements the first year, increasing to 90 percent after two years. Core shocks explain 15–20 percent of GDP variation the first year, but thereafter the effect eventually dies out. Less than 5 percent of the variation in GDP is explained by real oil price shocks at all horizons.

[Table 1. somewhere here]

In the analysis above, real oil prices were used in the VAR model. Using instead nominal oil prices in the VAR, the main conclusions drawn above are essentially the same, except that a nominal oil price shock has a larger impact on inflation but a smaller effect on GDP than a real oil price shock (as one now captures less of the real income effects of a higher energy price). Hence, an oil price shock (whether real or nominal) have a more persistent effect on inflation than on real output in the Norwegian economy.

C. Core inflation

Above, the average responses of inflation and GDP to the different shocks were analyzed. Overall, the shocks have the effects as expected, and one can therefore continue by computing the core inflation rate from the identified core shocks. Below, the core inflation rate is computed as the CPI inflation rate absent all other shocks than the core disturbances (“core” in the Figures below). The component of inflation that would prevail if both core plus oil price shocks occurred is also calculated (“core including oil”).

The main properties of the different components of inflation are first summarized in Table 2. Clearly, standard deviation (in percent) falls for core inflation relatively to CPI inflation. All components of

CPI inflation behave procyclically with the inflation rate, most so core inflation. In the left column in the two final rows in Table 2, the cross correlation between the growth rates in GDP and the CPI inflation rate are calculated, over the whole sample and from 1985–1994. The correlation between inflation and GDP growth is negative, suggesting a countercyclical behavior between the growth in GDP and inflation. This has by many economists been taken to support the real business cycle theory, where productivity shocks are the predominant sources behind output fluctuations (c.f. Kydland and Prescott, 1982). However, the contributions from the different components of inflation in Table 2 emphasize that the negative correlation between output growth and inflation stems mainly from the non-core component of inflation as core inflation is positively correlated with output growth.

[Table 2 somewhere here]

These results emphasize that presenting stylized facts of business cycles using simple correlations, may clearly hide information if there are several shocks hitting the economy with very different effects on the variables under study. The cross correlations between output growth and the different components of inflation presented here suggest in fact the case for both a Keynesian sticky wage and a real business cycle view of output fluctuations, where in the former, the core component of prices and output growth are positive correlated, and in the latter, the productivity (non-core) component of inflation is negatively correlated with output growth.

In Figure 2, core inflation and the one quarter change in the CPI (inflation rate) are plotted together, whereas Figure 3 shows “core including oil price shocks” together with the CPI inflation rate. Overall, the CPI inflation rate follows core inflation closely, although CPI inflation misrepresents core inflation during many specific periods. During the 1970s and early 1980s, Norway pursued price and wage controls. In these periods, inflation is below core, reflecting the fact that non-core shocks push inflation down relative to core inflation. Hence, the price and wage controls can be interpreted as beneficial supply shocks that reduce inflation temporarily. The difference between core and “core including oil” is also most noticeable in the 1970s, especially in 1973–1976 and 1979–1983, as inflation is (eventually) pushed up vis-à-vis core after the two oil price shocks for prolonged periods (cf. Figure 2 versus Figure 3).

[Figure 2 and 3 together somewhere here]

During the 1980s, the Norwegian currency was devalued several times (1982, 1984 and 1986). This seems to have been picked up by core inflation, which increases above CPI inflation on several occasions, indicating that there is more inflationary pressure in the economy than what the CPI captures. From 1984/1985, a financial deregulation initiates a demand led boom, pushing core inflation and eventually (after almost a year), CPI inflation upwards. The fall in oil prices in 1986 reduced CPI inflation rate temporarily, but core inflation remained high until 1987 (cf. Figure 2 versus Figure 3). In the late 1980s, Norway experienced a severe recession, due to a series of negative permanent (supply) shocks (see e.g. Bjørnland, 1998). During this period, CPI inflation overpredicts core inflation, as the negative non-core shocks increase inflation temporarily.

To sum up, the core inflation rate seems to be a more accurate measure of the inflationary pressure in the economy than what the CPI represents, and the differences between these two measures are well interpreted in terms of the other shocks identified in the VAR model (non-core and oil price shocks).

D. Domestic and imported core inflation

The effects of imported core inflation shocks on inflation are examined below, before the domestic core inflation rate is calculated. Figure 4 presents the impulse responses for inflation, whereas Table 3 give the variance decomposition for both inflation and GDP.

[Figure 4 somewhere here]

Using foreign prices in the VAR model instead of oil prices, the three shocks identified; domestic core, imported core and non-core shocks, have the effects as expected.^{x,xi} The impulse responses emphasize that domestic and imported core inflation shocks increase inflation for prolonged periods. However, it takes some time before the imported core shocks affect the domestic price level (as the imported prices will not have an impact before new goods and intermediates are bought), but after two years, domestic core and imported core account for 70 percent and 15 percent of inflation movements, respectively. Both domestic and imported core shocks increase GDP temporarily, accounting each for 6–7 percent of the GDP movements the first year. The effects of both shocks thereafter die out. Non-core shocks essentially behave as above.

[Table 3 somewhere here]

In Figure 5, the component of inflation that is due to “domestic core” together with the component that is due to both domestic and imported core (denoted “total core”) are graphed together with CPI inflation. Clearly, during the first two oil price shocks (1973/1974) and (1979/1980), total core is above domestic core, hence Norway imported inflation. On the other hand, from 1986–1990, imported core shocks work to reduce total core inflation, first from the fall in oil prices in 1986, but thereafter as international prices fell at a much higher rate than in Norway. From 1987, total core inflation lies below the CPI (as core inflation in Figure 2), suggesting again that negative non-core (productivity) shocks reduce GDP permanently, thereby pushing CPI upwards vis-à-vis (total) core inflation.

[Figure 5 somewhere here]

In Figure 6, the component of inflation that is due to total core is compared with the component of inflation that is due to core and oil price shocks (“core including oil” from Figure 3) and the one quarter change in the CPI. Clearly, “core including oil” and total core behave very similarly in many periods, indicating how oil price shocks are imported into the total core inflation rates.

Hence, although the two VAR models are specified differently with regard to the imported inflation impulses, they are nevertheless consistent with each other in the sense that the oil price shocks (identified in the “oil price VAR model”) are reflected in the imported inflation impulses (identified in the “foreign price VAR model”). However, as more information is portrayed in the imported inflation impulses rather than in the oil price impulses, it will be more informative for the central bank to use the core concept identified by the “foreign price VAR model,” when it shall specify an inflation target.

[Figure 6 somewhere here]

Finally, in Figure 7, the annual rate of domestic core inflation is compared with the median inflation rate and the CPI in Norway from 1984 to 1994 (see Bråten and Olsen, 1997, for details on calculating the median). Median inflation clearly undervalues core inflation, except for the period 1991-1992,

when both CPI inflation and median inflation lie above core inflation. Hence, the median inflation rate does not seem to be an accurate measure of the estimated core inflation rate. In particular, as the distribution of price changes has displayed a positive skewness, more large price increases have been excluded from the CPI than large price decreases, with the result that the median tracks systematically below the CPI.

[Figure 7 somewhere here]

V. CONCLUSIONS AND SUMMARY

A central bank that uses an inflation target, needs to have a precise measure of the inflation rate that reflects the overall inflationary pressure in the economy. The CPI is not such a measure, as one time noise in some of the price indices (due to e.g. VAT or tax changes) will shift the overall inflation rate temporarily. Many central banks therefore calculate the so-called core (or underlying) inflation rate by adjusting the CPI for “noise” that is out of their control. Although many of these adjustment methods may yield some useful information about the underlying inflation process, the fact that there is no formal criteria by which to judge the accuracy of the measured inflation rate makes it difficult to evaluate the results. In addition, as both the process of defining and measuring underlying inflation using many of these methods involve elements of judgement, it becomes difficult to identify a measure of underlying inflation that serves both policy purposes and is accountable at the same time.

Here, core inflation is instead calculated by imposing long-run restrictions on a vector autoregression model. Core inflation is identified as the component in inflation that has no long-run effect on GDP. By using the econometric methodology outlined here rather than more subjective methods, one avoids having to determine subjectively which shocks to adjust for, as the removal of the different shocks will be intrinsic to the modeling. In addition, one has a precise definition of underlying inflation that one can judge the results from.

The model specified here distinguishes explicitly between domestic and imported core inflation. The idea is that in a small open economy, a large part of inflation is imported, and the central bank needs to distinguish the imported part from the domestically generated inflation when it shall react to observed price signals. Both the effects of oil price shocks and a measure of foreign price shocks are analyzed explicitly as imported inflation impulses.

The analysis is applied to Norway. In the event that the Norwegian authorities would want to switch from an exchange rate target to an explicit inflation target, this paper addresses questions about the appropriate measure of inflation to use. The results show that (domestic) core inflation is the main component of CPI inflation. However, CPI inflation misrepresents core inflation during many specific periods, and the differences are well interpreted in terms of the other shocks identified; non-core (productivity) and imported core inflation shocks.

Adverse oil price shocks are important sources behind the overvaluation of CPI inflation relative to domestic core inflation in the late 1970s and early 1980s, when Norway imported inflation. Positive non-core (productivity) shocks push inflation downwards relatively to core inflation in the first part of the 1980s, whereas negative non-core shocks are responsible for the overvaluation of inflation relative to core inflation in the late 1980s. During the same period, imported core shocks work to reduce total core inflation.

The two different models (using oil prices or foreign prices) investigated here, are consistent with each other in the sense that the oil price shocks (identified in the oil price VAR model) are captured by the imported core impulses (identified in the foreign price VAR model).

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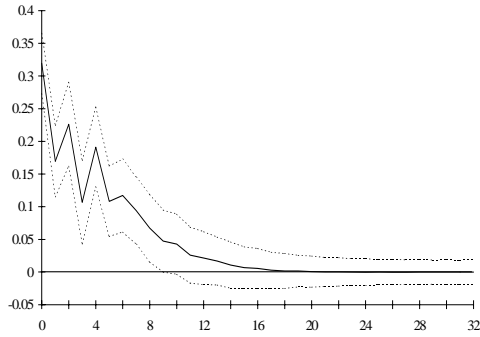
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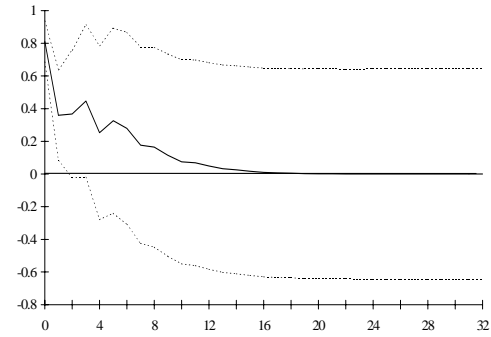
Figure 1. Impulse responses with one standard error band

Response to core shock:

A) Inflation

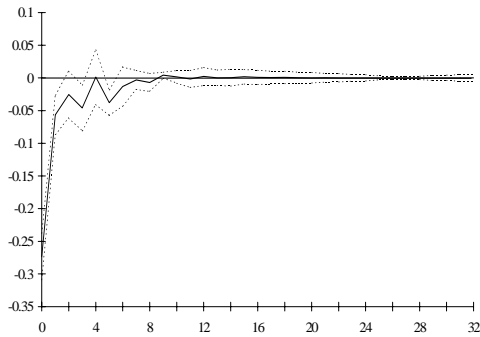


B) GDP

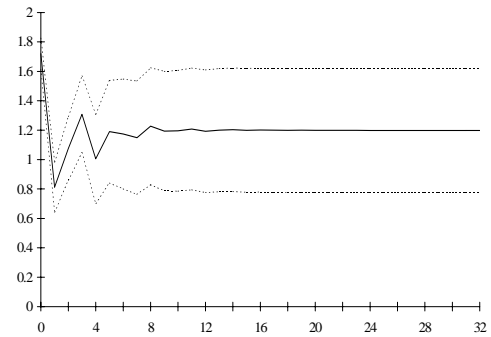


Response to non-core shock:

C) Inflation

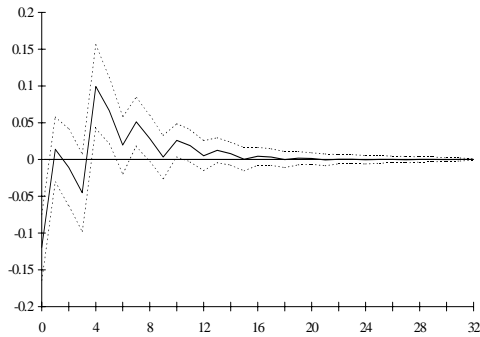


D) GDP



Response to oil price shock:

E) Inflation



F) GDP

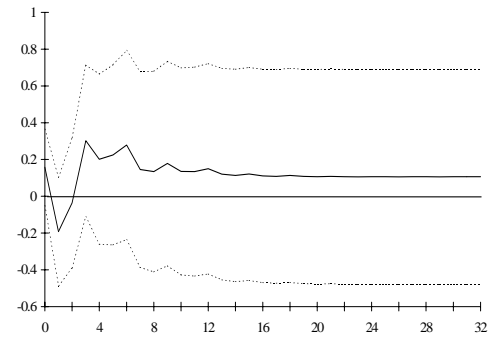


Figure 2. Core inflation and measured CPI inflation

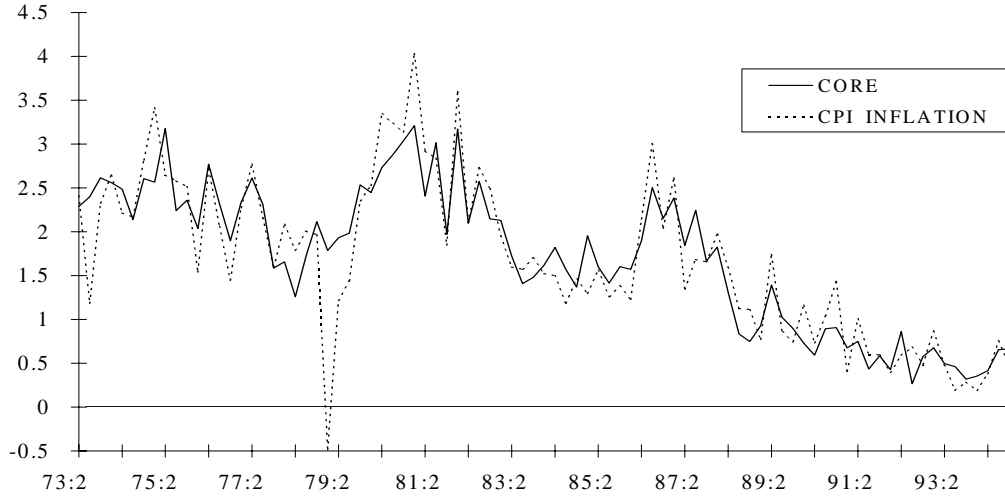


Figure 3. Core including oil and measured CPI inflation

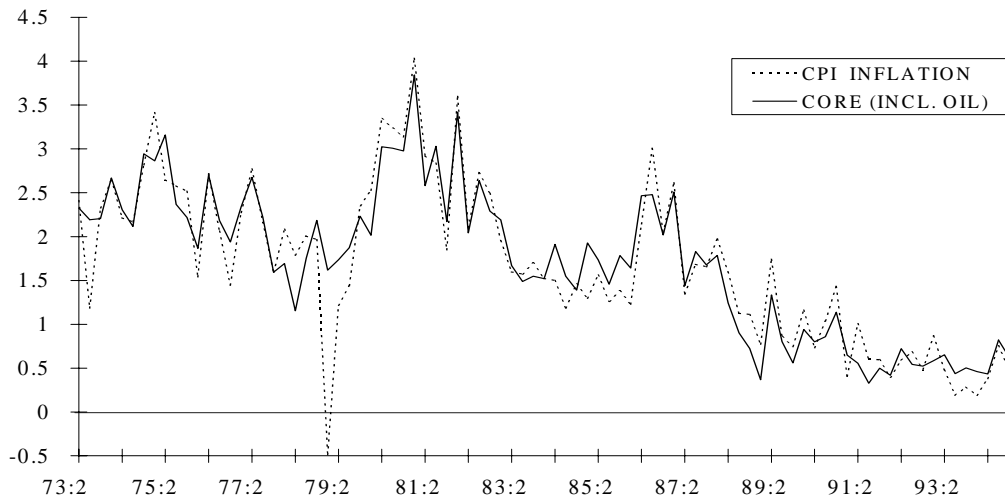


Figure 4. Impulse responses of inflation

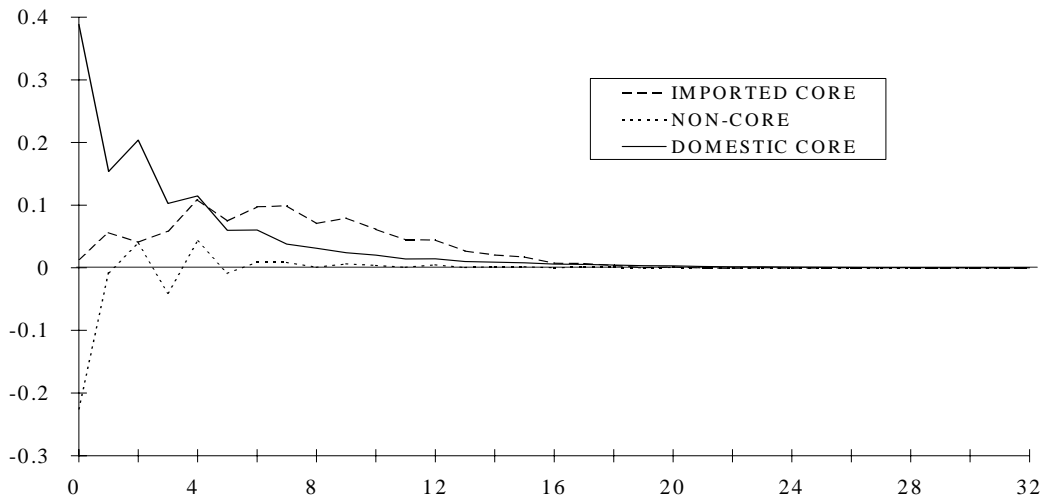


Figure 5. Total core, domestic core, and measured CPI inflation

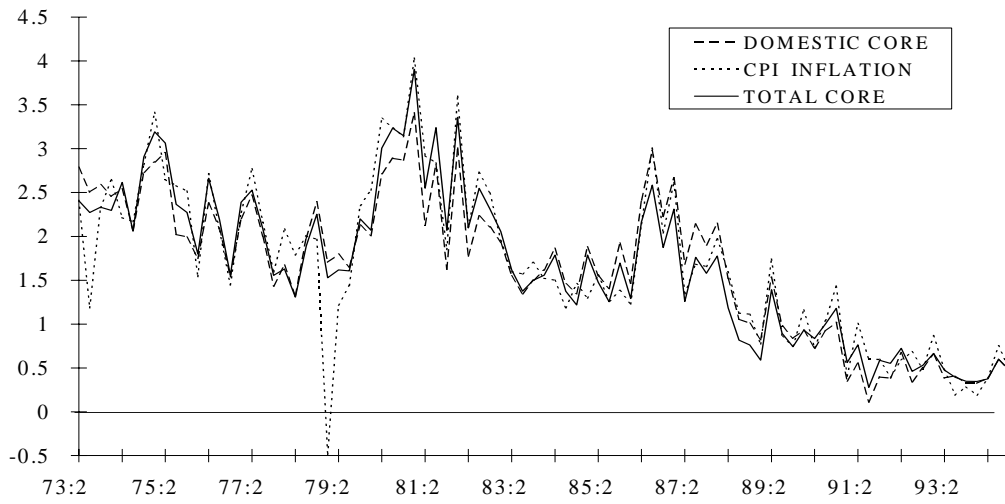


Figure 6. Total core, core including oil, and measured CPI inflation

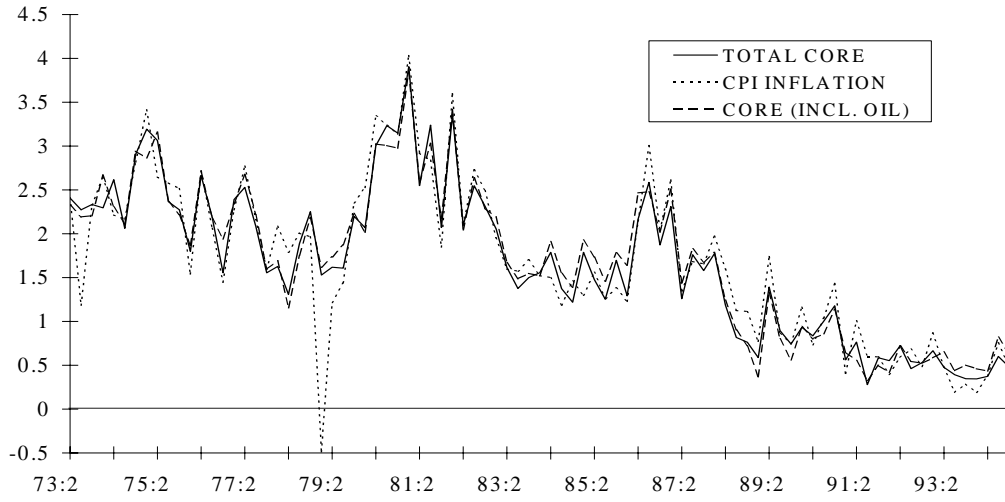


Figure 7. Domestic core, median, and measured CPI inflation; (1984–1994)
Annually, pct. change

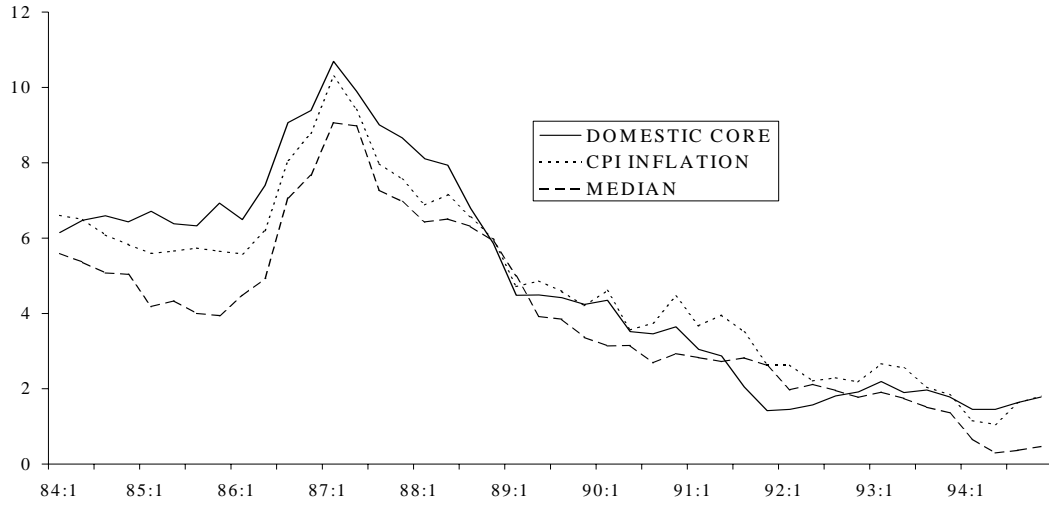


Table 1. Variance decompositions of inflation and GDP

Quarters	Inflation			GDP		
	Core	Non-core	Real oil price	Core	Non-core	Real oil price
1	53	39	8	18	81	1
2	59	35	7	18	81	1
4	66	28	6	15	84	2
8	70	22	9	10	88	3
16	70	21	9	6	93	2
40	70	21	9	2	97	1

Table 2. Sample moments

	Δ CPI	Core	Core (incl. Oil)	Non-core
Std. Error	0.91	0.81	0.84	0.29
Mean	1.69	1.71	1.71	0.00
Cross-corr; Δ CPI	1.00	0.89	0.91	0.29
Cross-corr; Δ GDP				
1973–1994	-0.11	0.12	0.09	-0.69
1985–1994	-0.23	0.08	0.06	-0.69

Table 3. Variance decomposition of inflation and GDP

Quarters	Inflation			GDP		
	Domestic Core	Imported Core	Non- core	Domestic Core	Imported Core	Non- core
1	75	0	25	5	6	89
2	76	2	22	7	5	88
4	78	3	19	5	5	89
8	70	14	16	3	4	93
16	67	18	15	2	2	96
40	67	18	15	1	2	97

Appendix: Data sources and model specifications

All data are quarterly, and, (except for the oil price), seasonally adjusted. The estimation sample runs from 1971Q3-1994Q4. All data are in logarithms.

- p* The log of the CPI. Source: Statistics Norway.
- y* The log of real GDP (*mainland* GDP). Source: Statistics Norway.
- o* The log of the real oil price (nominal oil prices converted into domestic currency and deflated by the implicit GDP deflator). Nominal oil prices; Saudi Arabian Light-34, USD per barrel, fob- (n.s.a.). Prior to 1980, posted prices, thereafter spot prices. Due to the large contribution of oil in Norway's GDP, real oil prices are deflated using the GDP deflator for *mainland* Norway. Source: OPEC BULLETIN, OECD and Statistics Norway.
- f* The log of the price level of (a weight of) Norway's trading partners. Source: Norges Bank.

Table A.1. Augmented Dickey-Fuller unit-root tests

Series ^a	ADF(lags) ^c	ADF
<i>y</i>	ADF(2)	-1.71
<i>o</i>	ADF(4)	-1.76
<i>p</i>	ADF(2)	0.41
Δy	ADF(5)	-5.00**
Δo	ADF(3)	-5.76**
Δp	ADF(1)	-3.63*
Δy^b	ADF(1)	-10.06**
Δo^b	ADF(3)	-5.54**
Δp^b	ADF(0)	-3.88**

^a A constant and a time trend are included in the regression except for (b).

^b A constant is included in the regression.

^c The number of lags are chosen to be the highest lag length with a significant t-value.

** Rejection of the unit-root hypothesis at the 1 percent level.

* Rejection of the unit-root hypothesis at the 5 percent level.

Table A.2(a). Johansen cointegration tests¹
 Cointegrating vector: (y_t, o_t, p_t) ²

H ₀	H ₁	Critical value 5 percent λ_{max}	Critical value 5 percent λ_{trace}	λ_{max}	λ_{trace}
r=0	r≥1	25.54	42.44	18.11	34.98
r≤1	r≥2	18.96	25.32	11.89	16.87
r≤2	r≥3	12.25	12.25	4.98	4.98

¹ All test-statistics are calculated using PcFiml 8.0 (see Doornik and Hendry, 1994). Critical values are taken from Table 2* in Osterwald-Lenum (1992), where the trend is restricted to be in the cointegration space.

² The VAR in levels contains 5 lags

Table A.2(b). Johansen cointegration tests¹
 Cointegrating vector: (y_t, f_t, p_t) ²

H ₀	H ₁	Critical value 5 percent λ_{max}	Critical value 5 percent λ_{trace}	λ_{max}	λ_{trace}
r=0	r≥1	25.54	42.44	15.43	33.55
r≤1	r≥2	18.96	25.32	13.16	18.13
r≤2	r≥3	12.25	12.25	4.97	4.97

¹ See table A.2(a).

² See table A.2(a).

ⁱ The main argument for excluding the direct price level effects of interest rate movements from the concept of underlying inflation is the problem of interest instability. In particular, an interest rate increase induced by the central bank in order to curb emerging inflation, will have the perverse initial effect of boosting inflation, thereby possibly leading the central bank to rise interest rates further and so on, (see Roger, 1995, pp. 11–12).

ⁱⁱ Recently, the Reserve Bank has adjusted the inflation target focusing now on a broader definition of the price index. The new measure of core inflation is calculated by excluding “credit services” from the headline index (CPIX). However, as described above, the Reserve Bank can still omit certain temporary supply-side disturbances from the CPI, when they are considered to mask the underlying trend in prices.

ⁱⁱⁱ See also Roger (1995), and Svensson (1997), for problems with the implementations of inflation targeting.

^{iv} Vredin and Warne (1994) especially criticise Fisher and Seater’s (1993) non-structural methodology of testing for long-run neutrality (between money, prices and output) by examining univariate time series properties.

^v However, Ahmed et al. (1988) also show how the degree of persistence of the effects of energy shocks depends on the ordering of the variables in the VAR model.

^{vi} If inflation is instead non-stationary, p_t would be represented in second differences in z_t .

^{vii} The results using the first set of restrictions can be obtained from the author on request.

^{viii} To take care of the non-normality in the oil price equations, the following dummies are specified: A dummy that is one in 1974Q1 (the OPEC embargo), a dummy that is one in 1986Q1 (the collapse of OPEC), and a dummy that is one in 1990Q3 and minus one in 1991Q1 (the Gulf War). To take care of the non-normality in the equations for inflation, a dummy that is one in 1979Q1 (the start of a prize freeze) is included. The dummies are included in their respective equations only. A deterministic trend is also included to take care of possible long-run exogenous growth in GDP not appropriately accounted for by the model.

^{ix} The standard errors reported are calculated using Monte Carlo simulation based on normal random drawings from the distribution of the reduced form VAR. The draws are made directly from the posterior distribution of the VAR coefficients. The standard errors that correspond to the distributions in the $D(L)$ matrix are then calculated using the estimate of D_0 .

^x The imported price (of Norway’s trading partners) are given in foreign currencies, thereby avoiding that a domestic currency devaluation (a domestic core shock) also has a long-run effect on imported prices.

^{xi} To be consistent with the model above, four lags and the dummy in CPI are used. The model satisfies tests of autocorrelation, heteroscedasticity and non-normality in all equations. Standard tests confirm that one can reject the hypothesis that the first differences of imported prices are $I(1)$ against the (trend) stationary alternative at the 5 percent level ($t_{ADF} = -3.46$). Finally, the variables are not cointegrating (cf. Table A.2.b).