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Estimating Core Inflation
– The Role of Oil Price Shocks and Imported Inflation

Abstract:
This paper calculates core inflation, by imposing long run restrictions on a structural vector autoregression (VAR) model containing the growth rate of output, inflation and oil prices. Core inflation is identified as that component in inflation that has no long run effect on output. No restrictions are placed on the response of output and inflation to the oil price shocks. The analysis is applied to Norway and the United Kingdom, both oil producing OECD countries. A model that distinguishes between domestic and imported inflation, is also specified for Norway. In both countries, core inflation is a prime mover of CPI (RPI) inflation. However, CPI (RPI) inflation overvalues or undervalues core inflation in many periods, of which oil price shocks are important sources behind this deviation for prolonged periods

Keywords: Core inflation, inflation target, long-run neutrality, oil price shocks, imported inflation, structural VAR.

JEL classification: C32, E31, E61

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1. 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 a description of the individual inflation target arrangements). The arguments for an inflation target regime are that in a small open industrialised economy, inflation targeting allows monetary policy to focus directly on the goal of achieving low and stable inflation (see e.g. Svensson, 1996)[1]. In Norway, monetary policy is set so as to stabilise the exchange rate. The pressure on the Norwegian currency in many periods throughout the 1990s, have led some to argue that the Central Bank should abandon the target of stable exchanges rates in favour of a target of low inflation rate.

However, if the Central Banks want to keep aggregate inflation rate within a specified band, they need to have a precise measure of the inflation pressure in the economy, that they can control. The consumer price index (CPI) may not be a good measure of the inflation pressure, as the CPI is affected by other factors than just monetary policy, like one time changes in e.g. 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 ‘underlying’ or ‘core’ inflation rate, by adjusting the consumer price index for some of these noisy price signals (that should not respond to monetary policy)[2].

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 analysis will be applied to Norway and the United Kingdom, both oil exporting OECD countries.

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

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[1] See also Rødseth, (1996), for an argument for the use of price level targets to achieve output stability.

[2] In the remaining analysis, we will use the terms underlying or core inflation interchangeably.

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 nonstationary, 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 by (exogenous) non-monetary disturbances. Clearly, this definition excludes the possibility that other shocks, say energy price changes, can have long run effect 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 money shocks on inflation are more important than the long run effects.

In this paper we follow Quah and Vahey (1995), and identify core inflation as that component of inflation that has no long run effect on real output. This identifying assumption is essentially weak, allowing all types of shocks (including monetary disturbances) to drive core inflation, as long as they are output neutral in the long run.[3] The neutrality restriction relies on the assumption of a vertical long run Phillips curve, although the short run Phillips curve may be positively sloped, allowing for a temporary trade off between 'core inflation' and real output. By specifying a VAR model containing the growth rates of output and inflation, two types of shocks can be identified; core and non-core shocks. Non-core shocks will then be the impulses that are allowed to 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.

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[3] Bullard and Keating (1995) have tested for long run neutrality of 'money shocks' on output in several countries, by examining whether the permanent component of inflation (assumed to be due to monetary changes) has any long run effects on output. Generally they do not find much evidence that the permanent inflation shocks have significant long run effects on output. One exception is a high inflation country (Bolivia), where a permanent increase in inflation leads to a permanent negative long run response of output.

This paper differs from that of Quah and Vahey (1995) in two important aspects. First, Quah and Vahey argue that if the identifying assumption shall be meaningful, the non-core disturbances (that are allowed to have a long run effect on output), are not expected to contribute significantly to the inflation movements. That is, core shocks (that have only temporary effects on output) shall be the main driving force of inflation. However, some shocks have been observed to have had both prolonged effects on output and inflation. Typically, the large adverse oil price shocks in the 1970s, may have had both a negative long run real effect on output, as well as have had a persistent inflationary effect (see e.g. Fama, 1981, Burbidge and Harrison, 1984, Gisser and Goodwin, 1986, Ahmed et. al, 1988, and Barrell and Magnussen, 1996)[4].

To be able to study the effects of oil prices directly, we disentangle the effects of oil price shocks from the two other shocks, by including oil prices into the structural VAR model for Norway and the UK. No restrictions are placed on the response of output and inflation to the oil price shocks. In addition, we also specify a model for Norway where instead of oil prices, we include the price level of Norway's trading partners in the VAR model, to distinguish between «domestic» and «imported» core inflation. The idea is that in a small open economy, a large part of inflation is imported (including that generated by oil price changes).

Second, the assumption of a vertical long run Phillips curve, relies on the fact that both output and inflation are nonstationary variables (contain stochastic trends). However, if instead inflation is stationary (but prices are nonstationary), the assumption of a vertical long run Phillips curve may no longer be required. Instead, we can then define core inflation as the component in prices that has no long run effect on the level of GDP. This is equivalent to assuming a long run vertical supply schedule, where positive «demand shocks» are output neutral in the long run, but increase prices permanently. On the other hand, a positive supply shock that shifts the long run vertical supply schedule outwards will increase output and reduce prices permanently. Note that although inflation is stationary, core inflation shocks can still be the most important factors explaining inflation movements for prolonged periods, but due to for instance institutional factors like the wage bargaining process, the accumulated effects on the inflation rate of core shocks will eventually die out. In fact, below we will show that although the inflation process turned out to be very different in Norway and the UK, the concept of core inflation can be sensibly interpreted in both countries.

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[4] 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.

Below we will discuss more thoroughly the concept of core inflation, before we identify the structural VAR models in section three. Section four displays the empirical results for Norway and the UK, and section five concludes.

2. 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». 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 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[5]. 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, p.2, 1995). Consistent with this idea, the Reserve Bank has defined three categories of inflation disturbances that it can omit when calculating underlying inflation. In the **United Kingdom**, the Government rely on the retail price index (RPI) excluding mortgage interest payments, (RPIX), when choosing 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).

[5] For a full description of the different adjustment methods used in each country, see e.g. McCallum (1996).

All of these methods may yield some useful information about the underlying inflation process. However, they are either subjective or mechanical, and as there is no formal criteria by which to judge the accuracy of the measured inflation rate, it could in fact turn out that none of them represent the 'underlying' inflation rate any more than the CPI itself. In addition, 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. Especially, as both the processes of defining and measuring underlying inflation involve elements of judgement, it is difficult to verify the result as that who conscientiously represents underlying inflation[6].

Here, we use 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 describe above, in that it avoids the problem of having to determine subjectively which shocks to adjust for. In addition, we have a precise definition of underlying inflation we can judge the results from.

The restriction that core inflation has no long run effect on real output can be tested (informally) by investigating the short run properties of the model. Typically, if long run output neutrality shall prevail, we 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 also discussed in King and Watson (1992) and Vredin and Warne (1994) as a plausible way to test for neutrality[7].

2.1. 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 long run effects on output. No restrictions were imposed on the response of inflation to these two shocks. Yet, if the measure of core inflation should be an useful indicator of the inflation pressure in the economy, the non-core shocks are not expected to contribute significantly to the inflation movements.

[6] See also Roger, (1995), and Svensson, (1996), for problems with the implementations of inflation targeting.

[7] Vredin and Warne (1994) especially criticise Fisher and Seater's (1993) non-structural methodology, that test for long run neutrality (between money, prices and output) by examining univariate time series properties.

However, some shocks have been observed to have had persistent effects on both output and inflation. Especially, the two adverse oil price shocks in 1973/1974 and 1979/1980 are believed to have reduced world trade permanently, (mainly by reducing the net amount of energy used in the production) as well as have had a persistent effect on inflation. 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, so oil price shocks convert themselves into higher inflation. Eckstein (1981, pp. 36-37) also emphasised that «Gradually via the expectations of workers and investors, higher energy prices converted themselves into core inflation ... The energy crisis was also largely responsible for the poor investment and productivity results from 1974-1980».

The effects of oil price shocks on the economy, will also naturally depend on the policy responses of the government to these shocks. If the government follows an non-accomodating policy, they aim explicitly to eliminate any extra inflation caused by the supply shocks, by e.g. reducing nominal GDP growth through tight monetary policies. Alternatively, the government can decide to follow an accommodating policy response by raising nominal GDP so as to maintain the original output growth. Especially, in a small oil exporting country like Norway, the extra income from higher oil prices allowed the government to follow expansionary polices, which although it boosted aggregate demand, may have fuelled inflation expectations further. To be able to also capture the real income effect of higher oil prices on the two energy exporting countries Norway and the UK, we use real (as opposed to nominal) oil prices in the VAR model. However, in the end, we also compare the results with a VAR model containing nominal oil prices. Oil price shocks are identified by assuming that as both Norway and the UK are small countries, no other shocks than oil price shocks can influence (nominal or real) oil prices in the *long run*.

Finally, in a small open country like Norway, we distinguish between domestic and imported inflation by including the foreign prices of Norway's trading partners in the VAR, instead of real oil prices. The model now allows us to distinguish between three types of shocks; Non-core, domestic core, and imported (core) inflation shocks. The domestic core shocks are still identified as having no long run effects on output. To identify imported inflation shocks, we assume that domestic core and non-core shocks have no long run effect on the foreign price level, which is a similar small country assumption as that used to identify oil price shocks. By comparing the results using imported inflation with those where we identified oil price shocks, we can also investigate to which extent the oil price shocks are reflected in the imported inflation shocks. The identifying restrictions used to identify the different shocks, will be discussed further below.

3. Identifying the Structural VARs

In this 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 we will show how these three variables will be sufficient to identify three structural shocks: core, non-core and oil price shocks. Assume for now that inflation is I(0). We can then define z_t as a vector of stationary macroeconomic variables: $z_t = (\Delta o_t, \Delta y_t, \pi_t)'$ 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 π_t (=Δp_t) is the log of the inflation rate, calculated from the fist differences of a price index[8]. A reduced form of z_t can be modelled as:

(1)
$$z_t = \alpha + A_1 z_{t-1} + \ldots + A_p z_{t-p} + e_t$$
$$A(L) z_t = \alpha + e_t$$

where A(L) is the matrix lag operator, A_j refers to the autoregressive coefficient at lag j and $A_0 = I$, (the identity matrix). 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):

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

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:

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

[8] If inflation is instead non-stationary, π_t would be represented in first differences in z_t.

where ε_t are orthogonal structural disturbances which for convenience are normalised so they all have unit variance, e.g. cov(ε_t)=I. With C_0 as the identity matrix, (2) and (3) imply that $e_t=D_0\varepsilon_t$, and $C_jD_0=D_j$ so:

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

If D_0 is identified, we 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 orthogonalise the different innovations, nine restrictions are needed. First, from the normalisation of var(ε_t) it follows that:

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

This imposes six restrictions on the elements in D_0, Three more restrictions are then needed to identify D_0. These will come through long run restrictions on the D(L) matrix.

We first order the three serially uncorrelated orthogonal structural shocks as: $\varepsilon_t = (\varepsilon_t^{OP}, \varepsilon_t^{NC}, \varepsilon_t^{C})'$, where ε_t^{OP} is the oil price shock, ε^{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:

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

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 easily be found. 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 allowed to influence real oil prices. The long run restrictions on oil prices are plausible given that both Norway and the UK are small oil producers, that have 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[9]. With the three long run restrictions, the D(1) matrix will be lower triangular, and we can use this to recover D_0. Writing the long run expression of (4) as $C(1)D_0=D(1)$, expression (4) and (5) together imply:

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

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

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

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

3.1. Imported inflation

Finally, in a model for Norway, we replace oil prices (o_t) with CPI of Norway's trading partners (pi_t). We assume for now that CPI for the trading partner is I(1), but the first differences are stationary. The vector of stationary macroeconomic variables can then be defined as: $z_t = (\Delta pi_t, \Delta y_t, \pi_t)'$. 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^{NC} is defined as above. The long run expression of (3), using instead «imported» inflation in the model, then becomes:

(6') $$\begin{bmatrix} \Delta pi \\ \Delta y \\ \pi \end{bmatrix}_t = \begin{bmatrix} D_{11}(1) & D_{12}(1) & D_{13}(1) \\ D_{21}(1) & D_{22}(1) & D_{23}(1) \\ D_{31}(1) & D_{32}(1) & D_{33}(1) \end{bmatrix} \begin{bmatrix} \varepsilon^{IC} \\ \varepsilon^{NC} \\ \varepsilon^{DC} \end{bmatrix}_t$$

To identify D_0, again we assume that domestic core disturbances have no long run effect on y, hence $D_{23}(1)=0$. In addition, we assume that for a small country, domestic core shocks and non-core shocks

[9] In Bjørnland (1996a, 1996b), I allowed demand and supply shocks to affect the real price of oil in the long run. However, by examination, none of these shocks turned out to have significant long run effects on real oil prices in Norway or the UK.

have no long run effects on the foreign price level, hence $D_{12}(1)=D_{13}(1)=0$[10]. This is a similar to the (small country) restriction imposed on real oil prices above.

To investigate the robustness of the results using this restriction, we also tried another set of restrictions, by allowing non-core shocks to have long run effects on the foreign price level (through productivity spill over effects), but assuming instead that imported core shocks can have no long run effects on output. That is, we impose explicitly that there will be two types of core inflation shocks that can have no long run effect 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. Hence, $D_{13}(1)=0$ and $D_{21}(1)=D_{23}(1)=0$.

Interestingly, the results were almost identical using either set of restrictions. Especially, the effects of imported (core) price shocks turned out to be the same whether we imposed the restriction that they had no long run effect on output, or not[11]. To be consistent with the model using oil prices, we continued with the first set of restrictions ($D_{12}(1)=D_{13}(1)= D_{23}(1)=0$). The D(1) matrix in (6') will now be lower triangular, and D_0 can again be recovered using (7)-(8).

4. Empirical results

Below we first present the results using the VAR model containing oil prices for both Norway and the UK, before we display the results for Norway using imported prices. In the VAR model specified in (1) above, the variables were assumed to be stationary and the levels of the variables were not cointegrating. We therefore start by assessing whether the variables are specified according to their time series properties. Misspecification tests are thereafter carried out.

4.1. Data analysis and model specifications

The data used is $\boldsymbol{\pi}$, the log of the inflation rate, measured as the log of the first differences of the CPI in Norway and the first differences of the RPI in UK, $\boldsymbol{y}$ is the log of real GDP (mainland GDP in Norway) and $\boldsymbol{o}$ is the log of real oil prices (nominal oil prices converted into each country's currency and deflated by the GDP deflator) [12,13]. All data are quarterly and seasonally adjusted.

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[10] Imported prices are given in foreign currencies, to avoid that a domestic currency devaluation (a core shock) that increases the domestic price level, also has a long run effect on imported prices.

[11] These results can be obtained from the author on request.

[12] Nominal oil prices; Saudi Arabian Light-34, USD per barrel, fob- (n.s.a.). Prior to 1980, posted prices, thereafter spot prices. Source: OPEC BULLETIN and Statistics Norway.

[13] Due to the large contribution of oil in Norway's GDP, real oil prices are deflated using the GDP deflator for mainland Norway.

Unit root tests for both countries confirm that for neither GDP nor real oil prices can we reject the hypothesis of a unit root in favour of the (trend) stationary alternative. Further, for the UK, we can not reject the hypothesis that inflation contains a unit root, whereas in Norway, we can reject the hypothesis that inflation is I(1) in favour of the stationary alternative, (c.f. table A.1). Hence, inflation in Norway will be represented in their levels, whereas inflation in UK will be represented by their first differences. Comparing the plot of some measures of inflation in Norway (the CPI index versus the implicit GDP deflator for the mainland economy) and in the UK (the RPI index versus the implicit GDP deflator), also indicates that inflation in the UK is non-stationary, whereas in Norway, inflation is (at the most trend) stationary (see figure A.1).

The lag orders of the VAR-models are determined using the F-forms of likelihood ratio tests for model reductions as suggested by Doornik and Hendry (1994). A lag reduction to four lags in Norway and five lags in the UK could be accepted at the 5 pct. level in both countries (see table A.2-A.3). Using four lags in the model for Norway and five lags in the model for UK, we could reject the hypothesis of autocorrelation and heteroscedasticity in both countries. However, we could not reject the hypothesis of non-normality in any of the equations in both countries. Plots of the data, also suggest that there are three ouliers in the oil prices, and an outlier in inflation in each country, (see figure A.1).

To take care of the outliers in the equation for real oil prices, three dummies are specified for both countries. The first dummy is one in 1974Q1, (the OPEC embargo), the second is one in 1986Q1, (the collapse of OPEC) and the third dummy is one in 1990Q3 and minus one in 1991Q1, (the Gulf War). In addition, to take care of the non-normality in the equations for inflation, we specify a dummy that is one in 1979Q1 in Norway, corresponding to a prize and wage freeze. The non-normality in the equation for inflation in the UK may stem from the VAT increase in September 1979, suggesting a construction of a dummy that is one in 1979Q3. A deterministic trend is also included to take care of possible long run exogenous growth in GDP not appropriately accounted for by the models. The results are now more satisfactory, as non-normality tests in the equation for CPI (RPI) can be rejected for both countries, 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 (c.f. table A.4 and A.5)[14].

[14] As we try to use as few dummies as possible, the remaining non-normality in the system is ignored.

Further, in the VAR model specified above, there are no cointegration relations. By testing for cointegration between oil prices, output and (prices or) inflation, we can confirm that none of the variables in the VAR models are cointegrated (see table A.6).

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

Below we first present the impulse responses and thereafter the variance decompositions. 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[15].

The impulse responses for Norway, are presented in figure 1 A-F. A positive core disturbance has a temporary positive effect on inflation, which dies out after approximately 3-4 years. Output is also stimulated from core shocks. However, the effect eventually dies out as the long run restriction bites, and already after one year does the standard error band include zero. Hence, the output-neutrality assumption seems valid. Positive non-core disturbances reduce inflation temporarily, but have strong stimulating effects on output, that reaches its long run equilibrium after approximately one and a half year. Hence positive non-core shocks act as beneficiary supply shock, by increasing output permanently and reducing inflation temporarily. The quick adjustments in inflation also imply that the non-core disturbances are not fundamental to the inflationary process.

An oil price shock reduces inflation in Norway at first, but eventually inflation increases. The inflationary effects of oil price shocks last for approximately 2-3 years. The fact that prices initially fall after a real oil price shock was also found in Bjørnland (1996b), and may be due to the fact that the Norwegian currency is partly a petrocurrency, which appreciates when oil prices are high (1970s) and depreciates (devaluates) when oil prices are low (1986). Real oil price shocks have also beneficiary effects (but not necessarily significant in the long run) on output, 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 1996a,b).

The impulse responses for the UK are seen in figure 2 A-F. A core disturbance increases inflation in the UK permanently, although the initial effect is much larger than the long run effect. Core shocks also increase output initially, but the effect quickly dies out, and after a year, the impulse response is

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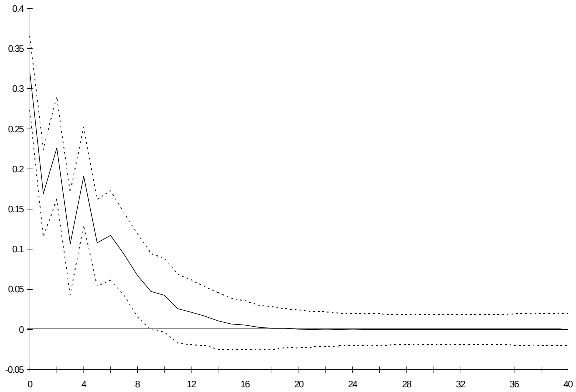
[15] The standard errors reported are calculated using Monte Carlo simulation based on normal random drawings from the distribution of the reduced form VAR. The draws are made directly from the posterior distribution of the VAR coefficients. The standard errors that correspond to the distributions in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

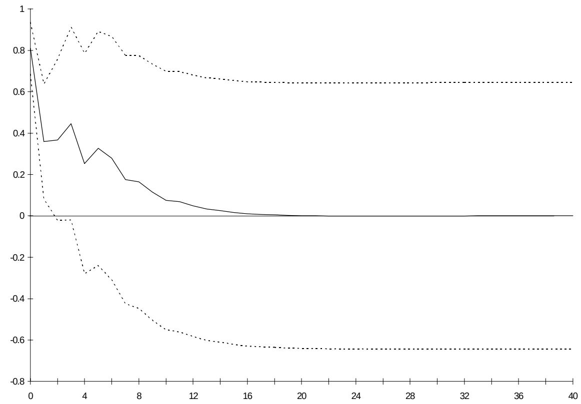
Figure 1. Impulse responses in Norway with one standard error band

Response to Core shock:

A) Inflation

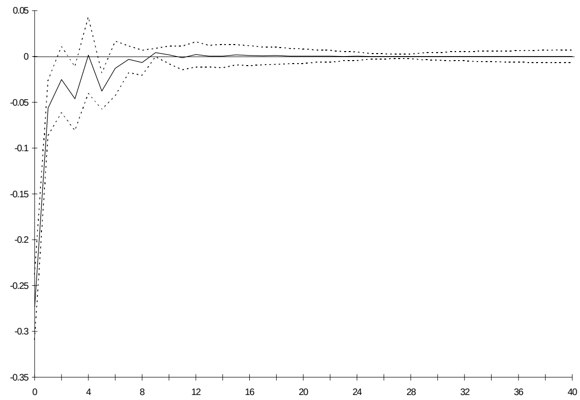


B) GDP

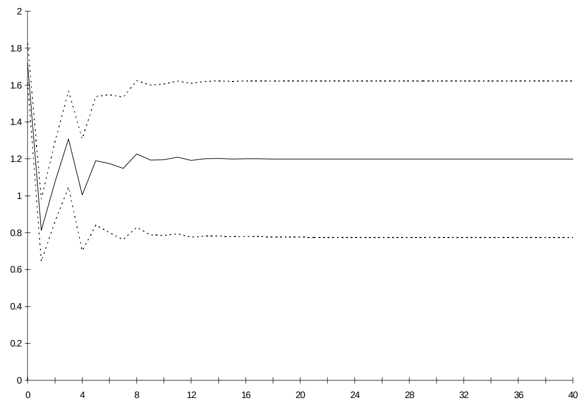


Response to Non-core shock:

C) Inflation

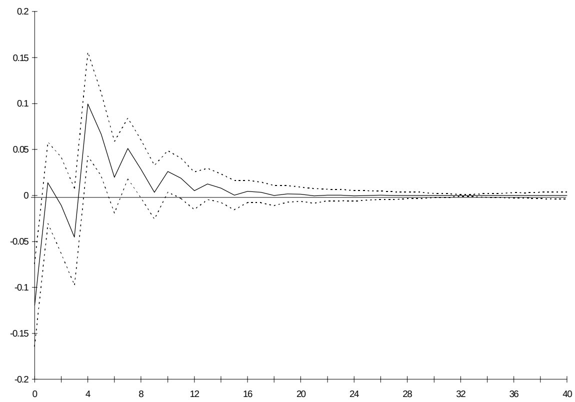


D) GDP



Response to Oil price shock:

E) Inflation



F) GDP

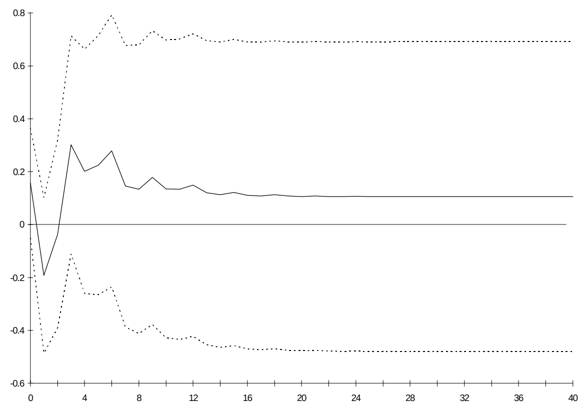
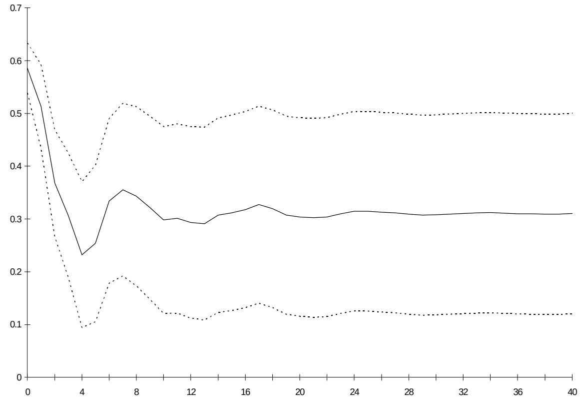


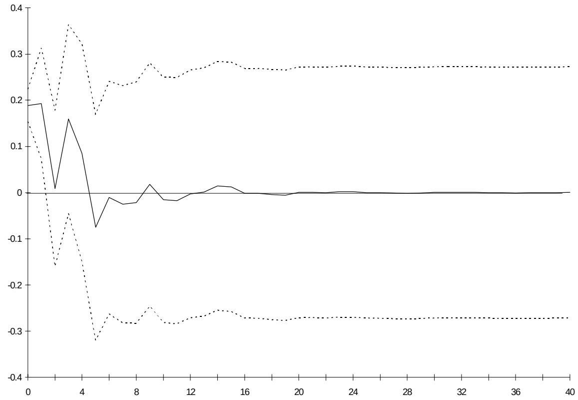
Figure 2. Impulse responses in UK with one standard error band

Response to Core shock:

A) Inflation

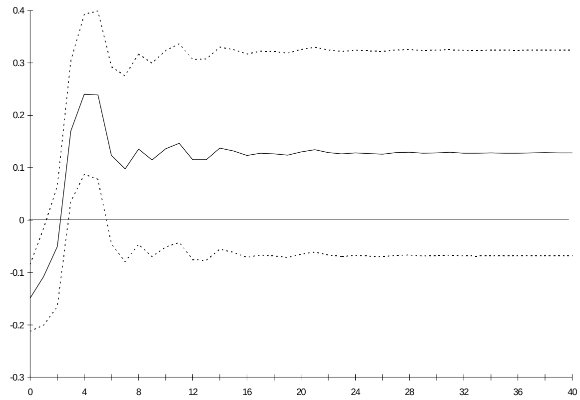


B) GDP

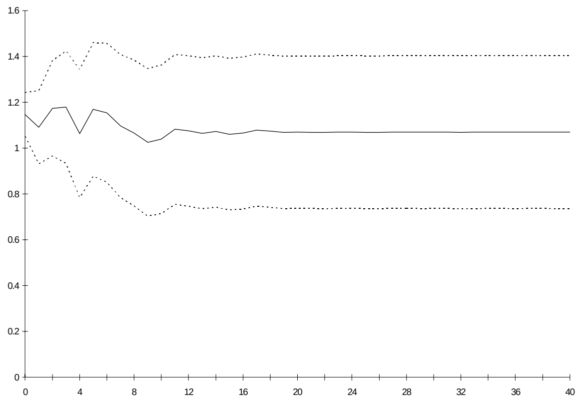


Response to Non-core shock:

C) Inflation

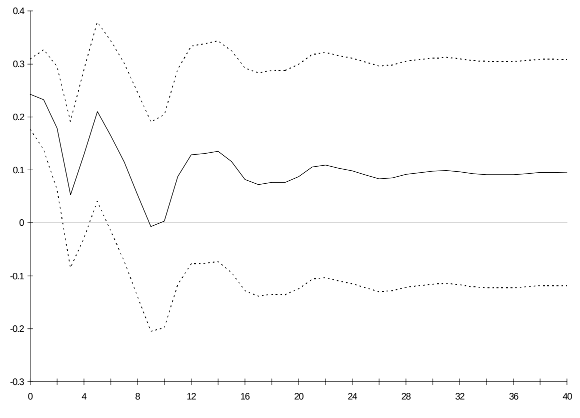


D) GDP

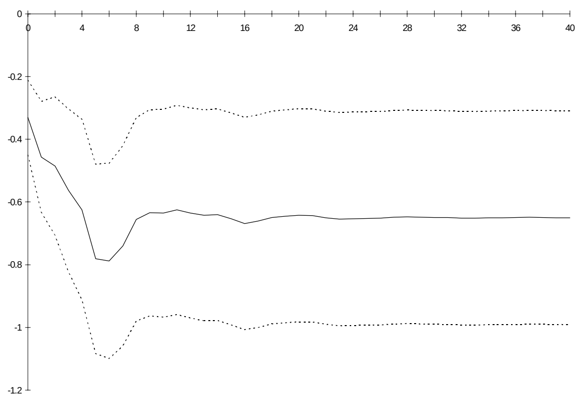


Response to Oil price shock:

E) Inflation



F) GDP



close to zero. Hence, the output-neutrality assumption seems also valid in the model for the UK. The positive non-core disturbance has a strong stimulating effect on output, that reaches its long run equilibrium after approximately two years, whereas the effects of non-core on inflation are temporary negative (suggesting again a beneficiary productivity shock). The quick adjustments of inflation to non-core shocks also imply that the non-core disturbances are not fundamental to the inflationary process. Oil price shocks increase inflation and reduce output in the UK, suggesting the response of an oil importing country rather than an oil exporting country (see also Bjørnland 1996a,b).

The variance decomposition for output and inflation in Norway are reported in table 1. Core shocks explain approximately 70 pct. of the variance in inflation after two years, whereas almost 10 pct. of the variation in inflation is explained by oil price shocks. Non-core shocks are the main source behind the variation of output, explaining 80 pct. of output movements the first year, increasing to 90 pct. after two years. Core shocks explain between 15 and 20 pct. of output variation the first year, but thereafter the effect eventually dies out. Less than 3 pct of the variation in output is explained by real oil price shocks at all horizons.

Table 1. Norway; Variance Decompositions of inflation and GDP

	Inflation			GDP		
Quarters	Core	Non-Core	Real Oil Price	Core	Non-Core	Real Oil Price
1	53.4	39.1	7.5	18.1	81.2	0.7
2	58.6	34.9	6.5	17.6	81.0	1.4
4	66.5	27.8	5.7	14.5	83.6	2.0
8	69.6	21.4	9.0	9.6	88.0	2.4
16	69.8	21.0	9.2	5.5	92.6	1.9
32	69.8	21.0	9.2	2.4	96.4	1.3

Table 2. UK; Variance Decompositions of inflation and GDP

	Inflation			GDP		
Quarters	Core	Non-Core	Real Oil Price	Core	Non-Core	Real Oil Price
1	80.9	5.2	13.9	2.4	90.1	7.5
2	80.5	4.5	15.0	2.5	86.5	11.0
4	79.7	6.2	14.1	1.6	84.5	14.0
8	73.4	12.5	14.1	0.7	76.1	23.1
16	75.0	12.9	12.1	0.4	74.8	24.8
40	77.3	13.2	9.5	0.2	73.8	26.0

Table 2 indicates that core shocks explain almost 80 pct. of the variance in inflation in the UK at all horizons, whereas oil price shocks turn out to be more important than non-core shocks, explaining approximately 15 pct. of the inflation variance the first four years. Non-core is the most important factor behind the variation in output, explaining more than 85 pct. of the variance of output the first year. The effect thereafter decreases somewhat, as oil price shocks become more important over the horizon. After four years, almost 25 pct of the variation in output is accounted for by real oil price shocks.

In the analysis above, we used real oil prices in the VAR. Finally, in table 3 and 4, we show the variance decomposition of GDP and inflation, using instead nominal oil prices in the VAR. The main conclusions drawn above are essentially the same. However, there are two things to note. First, as we now capture less of the real income effects of a higher energy price, a nominal oil price shock has a larger impact on inflation but a smaller effect on real output, than a real oil price shock. Further, nominal oil price shocks now explain more of the inflation variance than output variance at all horizons in *both* countries, (whereas previously, in the UK, real oil price shocks explained more of the output variance than inflation variance already after a year, cf. table 2).

Table 3. Norway; Variance Decompositions of inflation and GDP
Nominal oil prices in the VAR model

	Inflation			GDP		
Quarters	Core	Non-Core	Nominal Oil Price	Core	Non-Core	Nominal Oil Price
1	46.6	38.6	14.8	17.8	82.2	0.0
2	53.2	34.1	12.7	17.7	81.8	0.5
4	63.1	26.9	10.0	14.6	84.8	0.6
8	69.4	19.8	10.8	9.5	90.1	0.4
16	69.5	19.6	10.9	5.4	94.3	0.3
32	69.5	19.6	10.9	2.9	96.9	0.2

Table 4. UK; Variance Decompositions of inflation and GDP
Nominal oil prices in the VAR model

	Inflation			GDP		
Quarters	Core	Non-Core	Nominal Oil Price	Core	Non-Core	Nominal Oil Price
1	75.5	6.6	17.9	1.4	98.5	0.0
2	74.8	5.7	19.5	1.8	97.3	0.9
4	71.5	8.9	19.6	1.2	95.0	3.8
8	59.6	13.9	26.5	0.6	86.2	13.2
16	60.0	16.2	23.8	0.4	84.0	15.6
32	60.2	17.1	22.7	0.2	83.0	16.8

Hence, the effects of core and non-core shocks on output and inflation are very similar in Norway and the UK, despite the different inflation processes in the two countries. Especially, although core shocks have a permanent positive effect on inflation in the UK but a zero long run effect in Norway, the responses of inflation to core shocks are very similar the first few years in both countries, with the initial effect being much larger than the long run effect. Further, the prolonged inflationary effects of oil price shocks in both countries, emphasise the importance of oil price shocks in explaining inflation movements. On the other hand, the different behaviour of output in Norway and UK following the oil price shocks, emphasises how two oil producing countries can react very differently to energy price changes. Especially, macroeconomic policies have been conducted very differently in light of the two major oil price shocks, as the government in Norway has used the high income from the North Sea to pursue expansionary policies.

4.3. Estimating core inflation

Until now, we have discussed the responses of inflation and output to the different shocks on average over the whole period. In the remaining part, we focus instead on short term fluctuations in each historical period. This allows us to compute the core inflation rate (denoted core), that is the inflation rate absent all other shocks than the core disturbances. We also calculate the component of inflation that would prevail if both core plus oil price shocks occurred ('core including oil').

We first summarise the main properties of the different components of inflation for Norway and the UK in table 5 and 6 respectively. Clearly, standard deviation (in pct.) falls for core inflation relatively to CPI (RPI) inflation. All components of CPI (RPI) inflation behave procyclically with the inflation rate, most so core inflation. In the left column in the two final rows in table 5 and 6, the cross correlation between the growth rates in GDP and the CPI (RPI) inflation rate in each country is calculated, over the whole sample and from 1985-1994. In both countries, the correlation between inflation and GDP growth is negative, suggesting a countercyclical behaviour between the growth in GDP and inflation. This has by many economists been taken to support the real business cycle model, 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 emphasise that the negative correlation between output growth and inflation stem mainly from the non-core component of inflation as core inflation is positively correlated (or at least much less negatively correlated) with output growth.

Table 5. Norway; Sample moments

	ΔCPI	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; ΔCPI	1.00	0.89	0.91	0.29
Cross-corr; ΔGDP				
1973-1994	-0.11	0.12	0.09	-0.69
1985-1994	-0.23	0.08	0.06	-0.69

Table 6. UK; Sample moments

	ΔRPI	Core	Core (incl. oil)	Non-Core
Std. Error	1.55	1.21	1.33	0.48
Mean	2.13	2.07	2.11	0.00
Cross-corr; ΔRPI	1.00	0.88	0.89	0.55
Cross-corr; ΔGDP				
1973-1994	-0.34	-0.11	-0.18	-0.32
1985-1994	-0.13	0.01	0.13	-0.37

These results emphasise 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 output and inflation. 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 (where the cyclical component of prices and output are positive correlated) and a real business cycle view of output fluctuations (where productivity (non-core) shocks induce a negative correlation between inflation and output growth).

In figure 3, core inflation and the one quarter change in the CPI (inflation rate) in Norway are plotted together, whereas figure 4, shows ‘core including oil price shocks’ together with the CPI inflation rate. In figure 5, core inflation is compared with a measure of the median inflation rate in Norway. The peaks and troughs of core (and ‘core including oil’) match well with the inflation rate, and core is a prime mover of the inflation rate. However, during many periods, CPI inflation misrepresents core inflation. During the 1970s and early 1980s, Norway pursued price and wage controls in many periods, especially in 1974Q1-Q3, 1975Q4, 1976Q3-4 and 1978Q3-1980Q2 (see e.g. Bowitz and Cappelen, 1996). During 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 but allow output to increase (permanently). However, in the periods immediately following the price and wage controls, inflation «overshoots» and is above core. 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 3 versus figure 4).

Figure 3. Norway; Core and measured CPI inflation

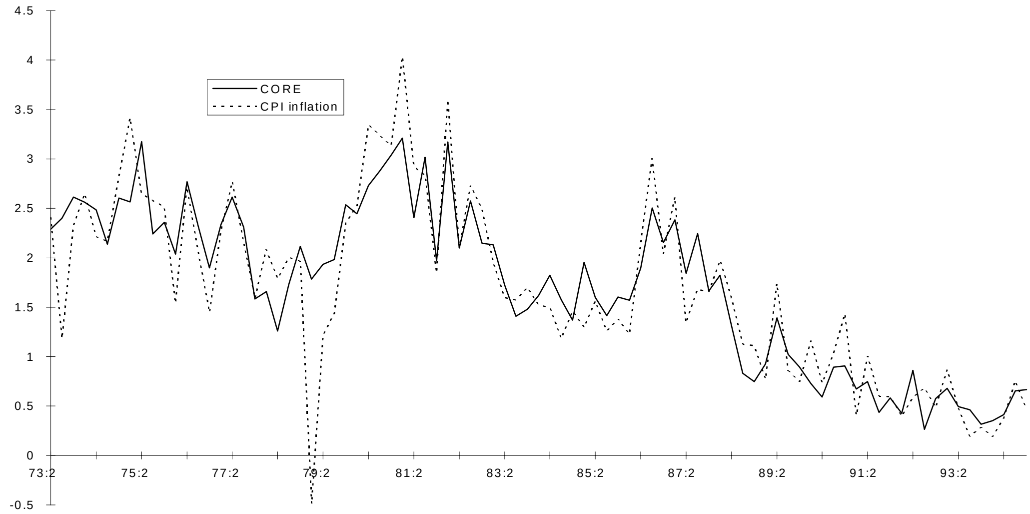


Figure 4. Norway; Core including oil and measured CPI inflation

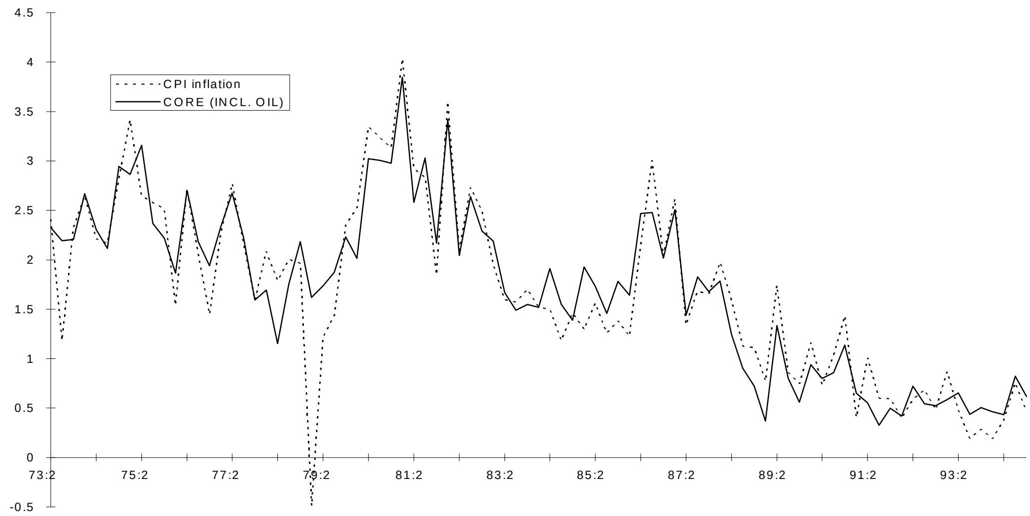
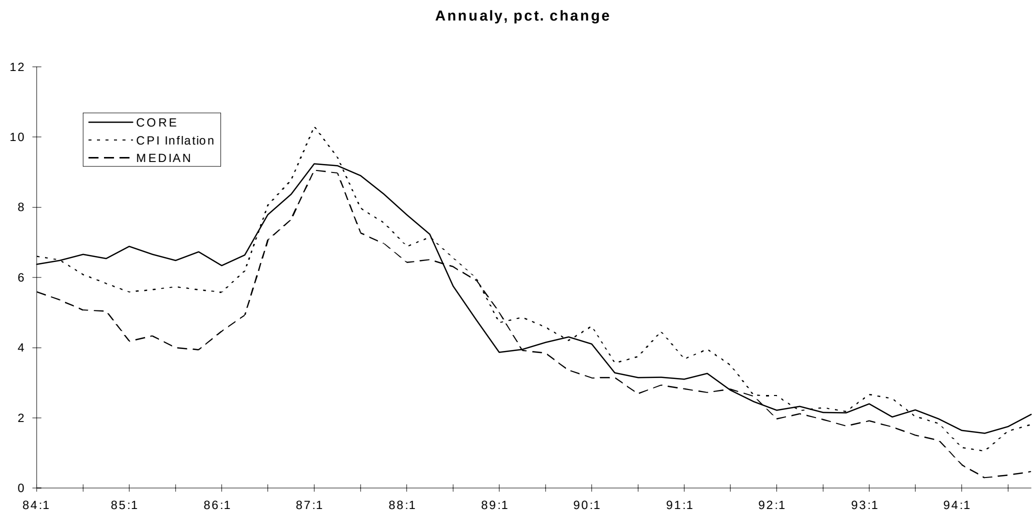


Figure 5. Norway; Core, median and measured CPI inflation; (1984-1994)



The Norwegian economy experiences a (demand led) recession from 1982-1983, and both core inflation and CPI inflation fall in the early 1980s (cf. figure 3). However, during the same period, the Norwegian currency is 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 inflation pressure in the economy than what the CPI captures[16]. From 1984/1985, a financial deregulation sets off a demand led boom, pushing core inflation and eventually (after almost a year), CPI inflation upwards. The fall in oil prices in 1986 reduces CPI inflation rate temporarily, but core inflation remains high until 1987 (cf. figure 3 versus figure 4). In the late 1980s, Norway experiences a severe recession, due to a series of negative permanent (supply) shocks (see e.g. Bjørnland, 1996a). During this period, CPI inflation overpredicts core inflation, as the negative non-core shocks increase inflation temporarily.

In figure 5, we compare the annual rates of core inflation (and CPI inflation), with the annual median inflation rate in Norway from 1984 to 1994 (see Bråten and Olsen, 1997, for details on calculation). Clearly, the median inflation undervalues core inflation, except for a period in the late 1980s, when both CPI inflation and median inflation lie above core inflation. Hence, the median inflation rate seems not to be an accurate measure of the estimated core inflation rate. Especially, as the distribution of price changes has displayed 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.

[16] In a different study, Bowitz and Cappelen, (1997), also find that although the devaluation policies in the early/middle 1980s had some expansionary effects, eventually they manifested themselves into higher inflation.

Figure 6. UK; Core and measured RPI inflation

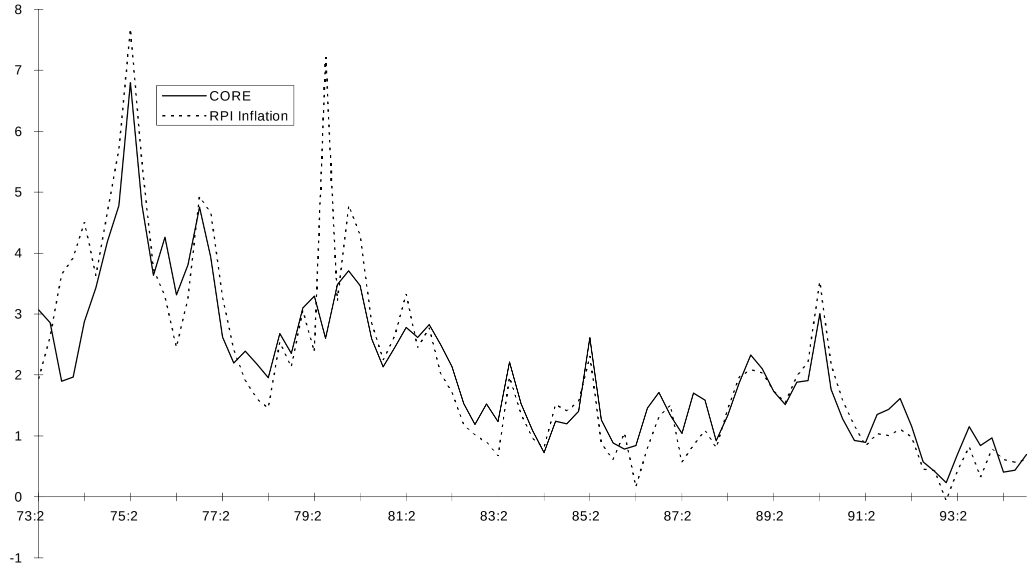
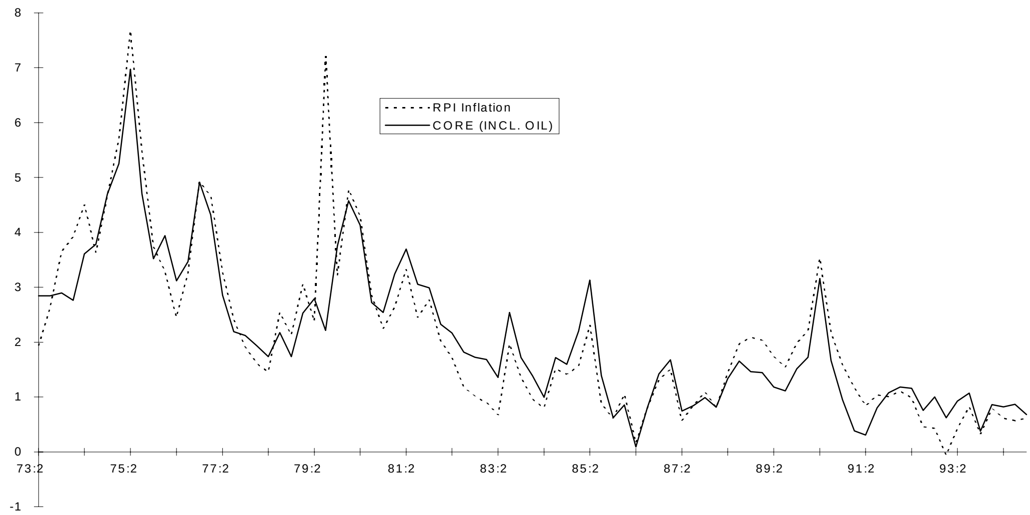


Figure 7. UK; Core including oil and measured RPI inflation



In figure 6, core inflation and the one quarter change in the RPI in the UK are plotted together, whereas figure 7 graphs core including oil in the UK together with the RPI. The peaks and troughs of the core (and core including oil) match well with the RPI inflation rate. Core is the prime mover of the inflation rate. The results seem also consistent with Quah and Vahey (1995), in that RPI inflation underpredicts core inflation during the early 1980s (as positive productivity shocks may have put downward pressure on inflation by increasing the output potential), and overpredicts core inflation in the late 1980s, (as negative productivity shocks may have pushed inflation above the core). However, consistent with the findings reported above, (that oil price shocks have pronounced effects on inflation), the extent to which core inflation in Quah and Vahey (1995) is above the RPI inflation rate in the early 1980s, may also reflect the high oil prices in this period, (features captured by 'core including oil' in figure 7). Also, the fall in core and RPI inflation in 1986 in Quah and Vahey (1995), coincides with the plummeting oil price, again captured by 'core including oil' in figure 7.

4.4. Domestic and imported core inflation in Norway

Using imported prices in the VAR model for Norway instead of oil prices, the three shocks identified; domestic core, imported core and non-core shocks, have the effects as expected[17]. Domestic and imported core inflation shocks increase inflation for prolonged periods. However, it takes some time before the imported price changes 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 pct. and 15 pct. of inflation movements respectively. Both domestic core and imported core increase output temporarily, accounting each for 6-7 pct. of the output movements the first year. The effects of both shocks thereafter die out. Non-core shocks behave as above.

Table 7. Norway: Variance Decomposition of inflation and GDP
Imported prices in the VAR model

	Inflation			GDP		
Quarters	Domestic Core	Imported Core	Non-Core	Domestic Core	Imported Core	Non-Core
1	74.7	0.1	25.2	5.4	6.0	88.7
2	76.3	1.5	22.2	6.9	4.8	88.2
4	78.4	2.9	18.7	5.4	5.4	89.2
8	70.2	14.1	15.8	3.2	3.6	93.2
16	67.4	17.6	15.1	1.9	2.4	95.7
32	67.4	17.6	15.1	1.0	2.0	97.0

In figure 8, we have graphed 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) and CPI inflation. Clearly, during the first two oil price shocks (1973/1974) and (1979/1980), total core is above doemstic 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

[17] To be consistent with the model using real oil prices, four lags and the impulse dummy in 1979Q1 are used. Using this specification, the model satisfies tests of autocorrelation, heteroscedasticity and non-normality. In addition, standard tests confirm that international CPI can be treated as I(1), and the model is not cointegrating. All test results can be obtained from the author on request.

international prices fell at a much higher rate than in Norway. From 1987, total core inflation lies below CPI inflation (as core inflation in figure 5), suggesting again that negative non-core (productivity) shocks reduce output permanently, thereby pushing CPI upwards vis-à-vis (total) core inflation.

Finally, in figure 9, 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 4) and the one quarter change in the CPI (inflation) rate in Norway. Clearly, ‘core including oil’ and total core behave very similarly, indicating how oil price shocks are imported into the total core inflation rates.

Figure 8. Norway; Total Core, domestic core and measured CPI inflation

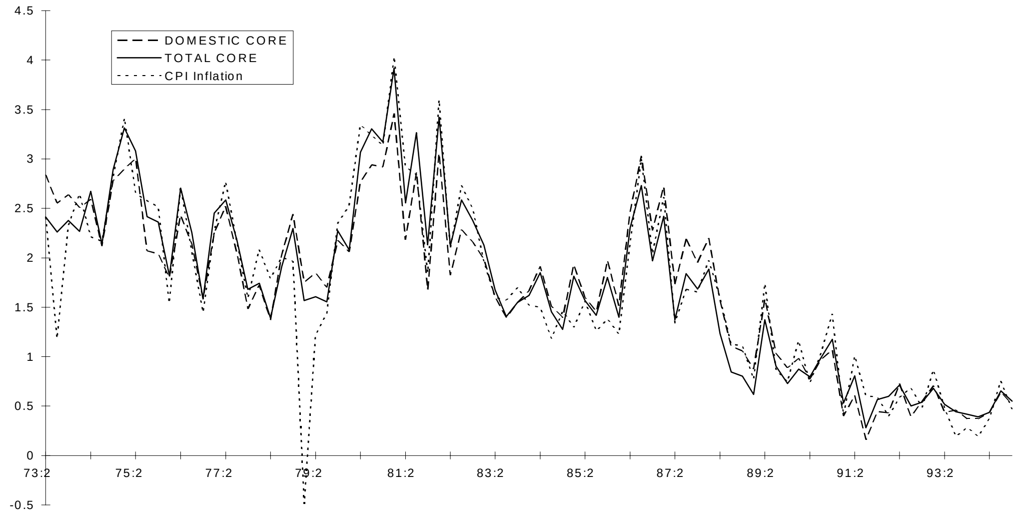
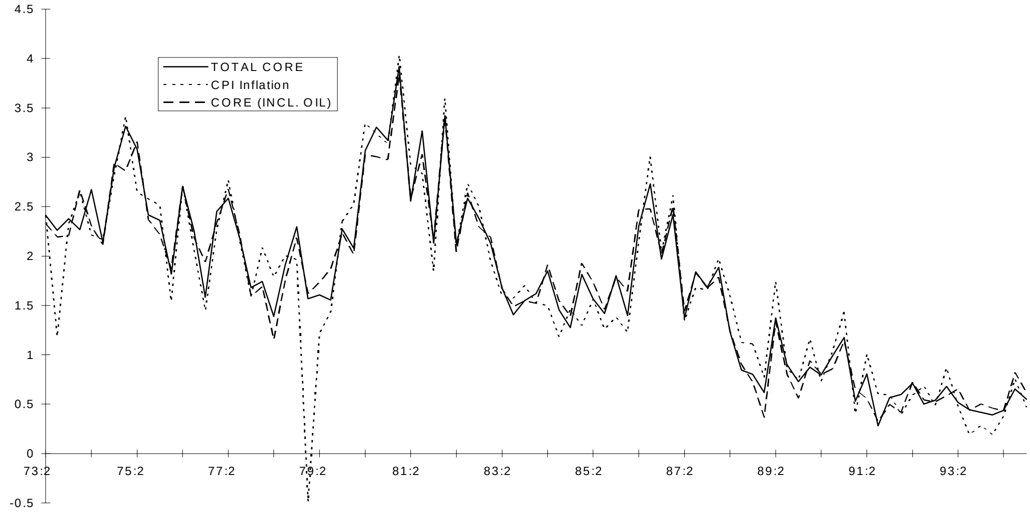


Figure 9. Norway; Total Core, core including oil, and measured CPI inflation



5. Conclusions and summary

If the Central Bank was to use an inflation target, it would need to have a precise measure of inflation that reflects the overall inflation 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 temporarily. Many Central Banks therefore calculate the so called underlying (or core) 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 is difficult to identify a measure of underlying inflation that serves both policy purposes and is accountable at the same time.

Here we have instead calculated core inflation using an econometric model. By using an econometric model rather than more subjective methods, we avoid the problem of having to determine subjectively which shocks to adjust for. In addition, we have a precise definition of underlying inflation we can judge the results from.

By imposing long run restrictions on a structural VAR model containing the growth rate of output, inflation and oil prices, three types of shocks are identified; core, non-core and oil price shocks. Core inflation is then identified as that component in inflation (or prices) that has no long run effects on output. No restrictions are placed on the response of output and inflation to the two other shocks. The analysis is applied to Norway and the UK, both oil producing OECD countries. A model that distinguishes between domestic and imported inflation, is also specified for Norway.

The results show that core inflation is the prime mover of inflation, whereas non-core shocks are the main contributors towards output movements. Oil price shocks turn out to be important sources behind inflation movements for prolonged periods. However, whereas an oil price shock has a long run negative effect on output in the UK, the effect on output in Norway is weakly positive, emphasising the wealth effects of a higher oil price on a small oil exporting country.

The empirical results clearly demonstrate that CPI (RPI) inflation overvalues or undervalues core inflation in many periods in Norway and the UK. In both countries, adverse oil price shocks are important sources behind the ‘inflation differential’ in the late 1970s and early 1980s. Further, in both countries, positive non-core (productivity) shocks push inflation downwards relatively to core inflation in the first part of the 1980s, whereas negative productivity shocks are responsible for the overvaluation of inflation relative to core inflation in the late 1980s.

Finally, we find imported (core) inflation shocks to be important sources behind inflation movements in Norway, accounting for more than 15 pct. of the inflation variation after two years. Especially, during the two oil price shocks in the 1970s, Norway imported inflation, whereas from 1986-1990, imported inflation reduced total core inflation, first from the fall in oil prices, but thereafter as international prices fell at a much higher rate than in Norway.

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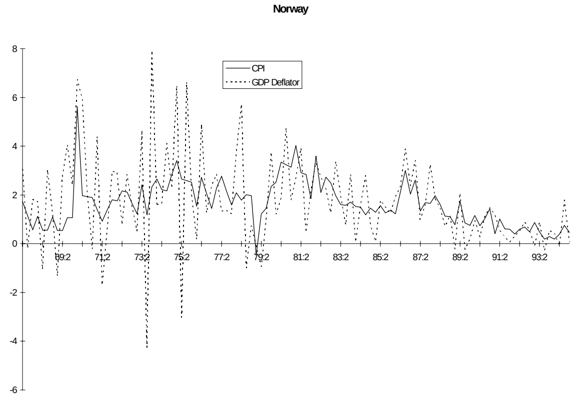
Appendix A

Figure A.1. Plot of some data series

A) Different measures of inflation



B) Growth in nominal oil prices

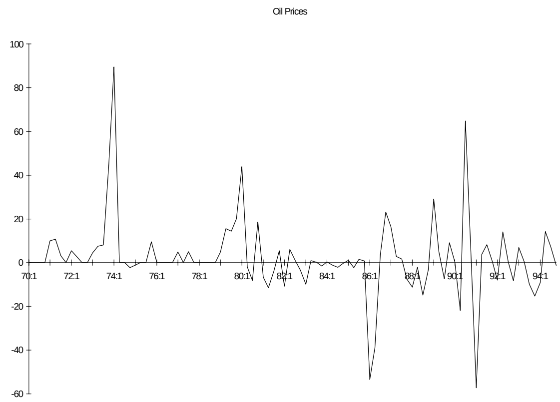


Table A.1. Augmented Dickey-Fuller unit-root tests[a]

	ADF(lags)[c]	Norway	ADF(lags)	UK
p	ADF(2)	1.01	ADF(2)	-0.81
y	ADF(2)	-1.78	ADF(6)	-2.86
o	ADF(4)	-1.46	ADF(4)	-1.83
π	ADF(1)	-4.60**	ADF(5)	-2.58
π^{b}	ADF(1)	-3.22*	ADF(1)	-2.50
Δy^{b}	ADF(6)	-3.47*	ADF(5)	-3.00*
Δo^{b}	ADF(3)	-5.71**	ADF(3)	-5.59**
$\Delta \pi^{b}$			ADF(6)	-3.73**

o; the log of real oil prices, *y*; the log of Gross Domestic Product, *p*; the log of the Consumer Prices Index (Norway), Retail Price Index (UK), $\pi = \Delta p$

[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 % level

* Rejection of the unit root hypothesis at the 5 % level

Table A.2. Norway: F-tests for model reductions[a]

Lags	Sequential F-tests	p-value	Direct F-tests	p-value
6				
5	F(9, 165) = 0.78	0.635	F(9, 165) = 0.78	0.635
4	F(9, 172) = 1.64	0.107	F(18, 192) = 1.20	0.263
3	F(9, 180) = 1.30	0.241	F(27, 199) = 1.24	0.203
2	F(9, 187) = 0.79	0.626	F(36, 201) = 1.13	0.292
1	F(9, 194) = 3.90	0.000	F(45, 202) = 1.69	0.008

[1] Sequential F-test with corresponding p-value reports the sequential model reductions (6→5,...,2→1 lags), direct F-test with corresponding p-value reports the direct model reductions (6→5, ..., 6→1 lags). All test-statistics are calculated using PcFiml 8.0 (see Doornik and Hendry 1994).

Table A.3. UK: F-tests for model reductions[a]

Lags	Sequential F-tests	p-value	Direct F-tests	p-value
6				
5	F(9, 165) = 1.90	0.055	F(9, 165) = 1.90	0.055
4	F(9, 172) = 5.96	0.000	F(18, 192) = 3.99	0.000
3	F(9, 180) = 1.43	0.179	F(27, 199) = 3.24	0.000
2	F(9, 187) = 3.40	0.000	F(36, 201) = 3.49	0.000
1	F(9, 194) = 1.27	0.257	F(45, 202) = 3.14	0.000

[1] For a description of these tests, see table A.2.

Table A.4. Misspecification tests, Norway[a]

Test	Statistic	Δy	Δo	π
Q Test[b]	*Q(23)*	19.60	17.71	22.61
		(0.67)	(0.77)	(0.48)
AR 1-5[c]	$X^2(5)$	10.22	0.14	11.96
		(0.07)	(0.10)	(0.04)
ARCH 4[d]	$X^2(4)$	1.80	0.48	2.81
		(0.77)	(0.98)	(0.59)
Normality [e]	X^2 (2)	9.34	18.05	2.78
		(0.01)	(0.00)	(0.25)

For a definition of the symbols, see table A.1
[a] The number in brackets are the p-values of the test statistics. All statistics have been calculated using RATS, except for the normality test, which is calculated using PcFiml 8.0 (see Doornik and Hendry 1994).
[b] The Ljung-Box Q (1978) test against higher order serial correlation
[c] General LM test for serial correlation of order 5
[d] LM test for 4th order ARCH in the residuals proposed by Engle (1982)
[e] Test of normality due to Shenton and Bowman (1977), see Doornik and Hansen (1994) for a description.

Table A.5. Misspecification tests, United Kingdom[a]

Test	Statistic	Δy	Δo	π
Q Test[b]	*Q(23)*	24.41	22.35	29.71
		(0.33)	(0.50)	(0.16)
AR 1-5[c]	$X^2(5)$	6.36	3.46	9.43
		(0.27)	(0.63)	(0.09)
ARCH 4[d]	$X^2(4)$	1.03	0.90	4.99
		(0.91)	(0.92)	(0.29)
Normality	X^2 (2)	20.61	11.46	3.90
		(0.00)	(0.00)	(0.14)

For a definition of the symbols, see table A.1
[a] For a description of the tests, see table A.4.

Table A.6. Johansen cointegration tests[a]

Cointegrating vectors: Norway (y_t, o_t, p_t); UK (y_t, o_t, π_t)

H_0	H_1	Critical value 5 %	Critical value 5 %	Norway		UK	
		λ_{max}	λ_{trace}	λ_{max}	λ_{trace}	λ_{max}	λ_{trace}
r=0	r≥1	23.78	34.55	22.34	31.26	16.23	24.31
r≤1	r≥2	16.87	18.17	8.69	8.92	5.26	8.08
r≤2	r≥3	3.74	3.74	0.22	0.23	2.83	2.82

For a definition of the symbols, see table A.1.
[a] All test-statistics are calculated using PcFiml 8.0 (see Doornik and Hendry 1994).
Critical values are taken from Table 1 in Osterwald-Lenum (1992).

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