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The role of core inflation in monetary deliberations: an application to the Norwegian economy

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F. Felici

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“It is worthwhile to distinguish here between knowledge and human capital. Although the two terms are sometimes treated as synonyms, there is an important difference. Knowledge refers to society’s understanding about how the world works. Human capital refers to the resources expended transmitting this understanding to the labour force. Put crudely, knowledge is the quality of society’s textbooks; human capital is the amount of time that has been spent reading them………The best case for endogenous growth, therefore, relies on knowledge rather than human capital as the source of perpetual growth.”

N. Gregory Mankiw
da “The Growth of Nation” Harvard University

Il rispetto dei parametri comunitari, il contenimento della spesa pubblica e le riforme strutturali previste dall'Agenda di Lisbona rappresentano alcuni tra i principali obiettivi che l'Italia è chiamata ad attuare in questi anni. Il rilancio dell'economia italiana si basa sulla capacità di riformare il mercato del lavoro e di attuare politiche di recupero di efficienza e produttività.

In tal senso, Consip può rappresentare un importante strumento di supporto per la Pubblica Amministrazione, in particolare per il Ministero dell'Economia e delle Finanze che di questo processo di riforme è protagonista.

Questo perché Consip si pone come un'azienda che produce know how, riguardo i temi ad essa affidati dal Ministero dell'Economia e delle Finanze, avvalendosi di professionalità di notevole levatura, che garantiscono conoscenze di livello nella piena consapevolezza dell'importanza di una intensa e sistematica opera di formazione e confronto nazionale ed internazionale.

Un'azienda basata sulle competenze, infatti, non può che considerare strategico l'investimento nella crescita e sempre maggior specializzazione delle proprie risorse, e questa convinzione rappresenta l'architrave di tutte le politiche adottate per la crescita professionale ed il trasferimento delle conoscenze, che è per Consip un dovere sancito sin dal suo statuto. È appunto in questo ambito che si pone il Gruppo Modelli di Previsione di Consip, che può vantare una significativa esperienza economica ed econometrica pienamente riconosciuta. Un esempio è rappresentato proprio dalla collaborazione con il Centro Studi della Banca Centrale di Norvegia, oggetto del presente working-paper, affidata a Francesco Felici.

Si tratta di un progetto che ci ha particolarmente soddisfatto per la complessità dei temi affrontati con successo e per il grande interesse che l'istituzione norvegese ha mostrato per il lavoro svolto. Più in generale, poi, forme di collaborazione con istituzioni internazionali sono vissute con grande interesse perché ben rappresentano quello spirito d'apertura culturale e formativa che riteniamo auspicabile e anzi incoraggiamo, al fine di ampliare quelle competenze che vogliamo ci caratterizzino sempre per svolgere al meglio la nostra missione di supporto allo Stato.

Danilo Broggi

Amministratore Delegato Consip

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Abstract*

The success of monetary deliberations depends on whether the inflation measure captures long term movements or includes temporary shocks as well. In this context, core inflation is "that component of measured inflation that has no medium to long run impact on real output" (Quah and Vahey (1995)). After providing a theoretical foundation for this definition of core inflation, we apply the Quah and Vahey (1995) methodology to Norwegian data to estimate long term movements of inflation. This methodology imposes long run restrictions on a structural vector autoregression (sVAR) model with growth rate of output and inflation variables.

A second model distinguishes between domestic and imported inflation. A third model catches the international effects in competitiveness introducing the Imported Consumer Good Prices (PIPK) as an exogenous variable.
We conclude that in all models presented core inflation is a 'prime mover' of inflation

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1. Introduction

The concept of core inflation plays an important role in the monetary deliberations. Following Quah and Vahey (1995) we define core (or underlying) inflation as the component of inflation does not influence real output in the long run period and reflects the state of demand in the economy. This definition seems to remind Milton Friedman's thought that "inflation is always and everywhere a monetary phenomenon". For monetary purposes it is relevant to distinguish persistent long-term price movements (core inflation) from short-term shifts in prices (no core inflation). The persistent price movements are induced by monetary factors (demand side) and do not reflect the short-term shocks. Such an inflation measure must represent steady underlying economic fundamentals. Temporary shocks are driven by supply side factors and are outside the control of the central bank. So, the effectiveness of monetary policy, in terms of inflation control, depends on whether the inflation measure reflects long- term price movements or includes short-term structural shocks as well. On this point Bryan and Cecchetti (1994) argue: "During periods of poor weather, for example, food prices may rise to reject decreased supply, thereby producing transitory increases in the aggregate index. Because these changes do not constitute underlying monetary inflation, the monetary authorities should avoid basing their decisions on them". Thus, core inflation is "the component of price changes which is expected to persist over the medium-run horizon of several years". Quah and Vahey (1995) adopt a common view of core inflation that there's a well defined concept of monetary inflation that ought to be of concern to monetary policy makers. This kind of inflation cannot be captured by the development of a price index. In monetary practice, a consumer price index (CPI) is often used to measure inflation, since the value of money is in general associated with the purchasing power of money on the consumer level. This method of measuring inflation is flawed and raises serious problems for monetary policy. CPI index is not intended to measure price trend but the changes in the cost of living. So, it often delivers a distorted picture of underlying inflation making necessary a more appropriate target of monetary policy. To overcome the deficiencies of the CPI, the literature has proposed different measure of underlying inflation. To sum up, the methodology of measuring core inflation can be dived in three main approaches: one is based on statistical methods for finding a measure of core inflation from the data on price indices and inflation rates.

The most elementary of these approaches (and probably the most widely used) is to exclude some categories of consumer price index from the overall inflation rate. For instance, in the euro area a common measure of core inflation is the Harmonised Index of Consumer Prices (HICP) excluding some volatile categories of prices (the so called 'ex food and energy index'). Several attempts are made to improve this methodology (Blinder 1997; Dow 1994; Macklem 2001).

A second approach is the modelling one which focuses on the conceptual of defining core inflation. This approach was initially provided by Bryan and Cecchetti (1994) and implemented in Cecchetti (1996) and Bryan, Cecchetti and Wiggins (1997). It's applied to disaggregated CPI data using cross section and time series methodologies. In the literature of the modelling approach, four method of defining core inflation emerged (Roger, 1995, 1997): the percentile method, the exclusion method, the trimmed means method, and the standard deviation trimmed method.

The third approach is called the structural approach proposed in the paper of Quah and Vahey (1995). This approach is the only one based one economic theory, thereby diminishing the mismatch between the theoretical concept of inflation and the practical inflation measurement (see par. 2 for a closer examination).

Today, there's a wide part of economic literature concerning the issue of measuring core inflation. The need of finding a good measure of core inflation became more marked since the beginning of 1990s, when several countries adopted price stability as overriding aim of monetary policy.

In fact, during the 1990s, the central banks of many countries[1] adopted the inflation targeting regime (Bernake, B. and F. Mishkin 1997; Svensson, L.E.O. 1997; Haldane 1995; Neuman and Jurgen, 2002). This has produced further studies and contributed to the development of different methodology as well as measures of core inflation.

More importantly, the policy of inflation targeting has stimulated heated debates on the efficiency of monetary policy to control price movements. From a theoretical point of view, inflation targeting works out the problems of time inconsistency connected with the government of money (Svensson, L.E.O., 1997;Walsh, C., 2003) and eliminates the typical trade-off between credibility (fixed rules) and flexibility (discretional policy) in the discussion about the best monetary policy (Kydland, Prescott, 1997; Barro, Gordon, 1983, Walsh, 1995).

[1] *Australia, New Zealand, Canada, Brazil Spain, Sweden and others adopted an inflation targeting regime over the last decade.*

In practice, the reference to price stability as the priority goal of monetary policy can be aimed in a different way. The price stability can be obtained in terms of a price index (HCPI) or through a rate of inflation cleared by short run shocks (core inflation). This second reference is applied in almost all countries adopted inflation targeting regime.
In this context plays a crucial role the economic view of central bank (Monetarist or Keynesian) and the impulse mechanisms of monetary policy.
The aim of this paper is to estimate core inflation for Norway by using Stuctural VARs approach. Our identification method is based on the work of Blanchard and Quah (1989), Quah and Vahey (1995) and Bjornland (2001).
The paper is constituted of five sections with the following structure.
The theoretical background of SVAR approach is provided in section 2.
In section 3 we explain Quah and Vahey methodology indicating how the Structural VAR approach works (par 3.1) and then specifying the long run restrictions we have need of (par 3.2).
In section 4 we present the empirical results of some applications to Norwegian economy. In a first model we identify core inflation (par 4.1); in a second model we distinguish the domestic and the imported inflation introducing the foreign inflation as new variable and explaining the role of oil price on monetary deliberations (par 4.2). In a third model we look for capturing the international effects in competitiveness introducing the Imported Consumer Good Prices (PIPK) as exogenous variable to capture the spillover effects of globalisation on Norwegian economy from emerging countries (par 4.3).
The final section (par 5) presents our conclusions.

2. Core inflation in the Structural VARs approach: a theoretical framework

As said, the Quah and Vahey methodology of measuring core inflation is based on an explicit long-run economic hypothesis. This long run identification scheme is implemented the first time in Shapiro and Watson (1998) and Blanchard and Quah (1989). To disentangle core inflation, Quah and Vahey (1995) assumed inflation is affected by two types of shocks, clearly identified by their effects on output and assumed to be uncorrelated with each other at all leads and lags.

The core inflation shock is output neutral (the long run impact is restricted to zero); the no core shock could influence output in the long run. Then, core inflation is the "underlying movement in measured inflation associated only with the first kind of disturbance". (Quah and Vahey (1995)).

The theoretical presumption for the Quah and Vahey approach is the economic concept of the vertical long run Phillips curve. This assumption is not without problems and generates some issues on its economic interpretation.

At the first, the acceptance of a vertical Phillips Curve in the long run involves that monetary policy is neutral in its effect on real economy. In this interpretation, the inflation is purely a monetary phenomenon. This proposition is not so obvious: it conduces to deprive the rule of monetary policy, relegating the monetary authority to a simple guardian of purchasing power without effects on real economy. This idea is in contrast with the factual analysis on New Keynesian Phillips curve and with the practical administration rules of monetary policy (e.g. Taylor rules).

At the second, the Quah and Vahey methodology doesn't state the speed of adjustment of the economy to core inflationary shocks. In particular, the SVAR approach doesn't restrict how quickly core inflationary shocks became output neutral, leaving indefinite the adjustment process of inflation toward long run (core) components. Such an adjustment may be explained with agents be subject to expectations errors (for information problems). In this sense the Quah and Vahey long period, provided by long run identification restrictions, is the time horizon of correction adjustment process for expectations. At the end of this time the economic system is in steady state and the (rational) expectations of agents are realized. This interpretation is in line with the theoretical predictions of an AD-AS model for supply and demand shocks.

For instance, suppose that the economic system (in the simplest framework) can be represented by the following equations (variables expressed in log):

$$\begin{aligned} y_t &= y_{t-1} + \Delta m - \pi_t + \varepsilon_t^D \ \text{AD} \\ y_t &= y^o + \lambda(\pi_t - \pi_t^e) + \varepsilon_t^S \ \text{AS} \end{aligned} \qquad (2.1)$$

where y_t and π_t are, respectively, the level of current output and the inflation rate; Δm synthesize the monetary tools; y^o is the steady state output level and π_t^e the forward looking expectation on inflation rate. In the short run period the difference between y_t and y^o is due to $(\pi_t - \pi_t^e)$ (the λ parameter express the speed of expectation adjustment). This term identifies the unexpected inflation costs.

In fact, once wage contracts have been fixed, increases in unexpected inflation π_t above π_t^e is benign for the real variables y_t (see AS schedule). Inflation is generated by supply and demand effects together (for a given Δm).

In the long run period, when the expectations are realized and ε_t^S disappears, $\pi_t = \pi_t^e$ and the system (2.1) can be rewritten as:

$$\begin{aligned} \pi_t &= \Delta m + \varepsilon_t^D \ \text{AD} \\ y_t &= y^o \qquad \text{AS} \end{aligned} \qquad (2.2)$$

In system (2.2) the supply schedule is vertical ($y_t = y^o$) and the only source of inflation are monetary shocks (demand side shocks) due to Δm. Implicitly, imposing long run restrictions to identify core inflation, the economic views of Quah and Vahey reflects the steady state status of the economy ((2.2) equations).

From an econometric point of view, this is equivalent to estimate system (2.1) and imposing $\lambda = 0$ as long run restriction.

3. Core inflation: Quah and Vahey's Methodology

In this section we explain the technique of measuring core inflation[2] using structural VAR approach implemented by Quah and Vahey (1995). Essentially, Quah and Vahey (1995) estimated a sVAR model in the growth rate of real output and inflation (CPI index). Their measure is based on long run restrictions on this bivariate VAR model. We suppose that there are only two types of exogenous shocks that are distinguished by their long run impact on the level of real output. We have a supply shock having permanent effects on output and aggregate prices, and the demand shock having non long run effects on output (but permanent effects on prices). The one type of shocks is allowed to influence the level of real output in the long run, the other type of shocks on the real output is posed to zero throught long run restrictions.
By this system Quah and Vahey (1995) define the former type of shock as no core inflationary and the latter core inflationary shocks.

3.1 The structural VAR approach

This section provides a formal representation of the structural VAR approach.
Taking first difference (to guarantee stationary) the structural VAR representation can be written as follow:

$$B(L)x_t = \varepsilon_t \tag{3.1}$$

where x_t is the vector of endogenous variables: (as usual, y_t indicates the log of output and π_t the log of price level):

$$x_t = \begin{pmatrix} \Delta y_t \\ \Delta \pi_t \end{pmatrix} \tag{3.2}$$

and ε_t is the vector of shocks:

$$\varepsilon_t = \begin{pmatrix} \varepsilon_t^D \\ \varepsilon_t^S \end{pmatrix} \tag{3.3}$$

where ε_t^D and ε_t^S are, respectively, core and no core shocks.

[2] *We provide an exemplification of sVAR methodology using growth rate of real output and ionflation as example variables. In sub-section 4.2 we generalize the model introducing the imported inflation as endogeneous variable but the sVar metodology is the same.*

These structural shocks are orthogonal and white noise errors. They are normalized so their covariance matrix is:

$$E(\varepsilon_t, \varepsilon_t^T) = \begin{pmatrix} \mathrm{var}(\varepsilon_t^D) & \mathrm{cov}(\varepsilon_t^D; \varepsilon_t^S) \\ \mathrm{cov}(\varepsilon_t^D; \varepsilon_t^S) & \mathrm{var}(\varepsilon_t^S) \end{pmatrix} = \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix} = I \tag{3.4}$$

where I is the identity matrix.

The matrix *B(L)* provide us the coefficient of the covariance stationary process with L lags. We assume *B(L)* is a full rank matrix.

From the structural vector moving average (VMA) representation of x_t we can obtain:

$$\begin{aligned} \Delta y_t &= \sum_{k=0}^{\infty} c_{11,k} \varepsilon_{t-k}^D - \sum_{k=0}^{\infty} c_{12,k} \varepsilon_{t-k}^S \\ \Delta \pi_t &= \sum_{k=0}^{\infty} c_{21,k} \varepsilon_{t-k}^D - \sum_{k=0}^{\infty} c_{22,k} \varepsilon_{t-k}^S \end{aligned} \tag{3.5}$$

or

$$x_t = C(L)\varepsilon_t \tag{3.6}$$

where $C(L) = B(L)^{-1}$ is a polynomial in the lag operator.whose individual coefficients are denoted by $c_{ij,t}$.

We want to identify the coefficient matrices *C(L)* from the structural VMA representation and to estimate the structural shocks ε_t.

To find *C(L)* coefficient we must estimate the reduced form of the VAR system with the reduced-form innovations e_t:

$$x_t = Ax_{t-1} + e_t \tag{3.7}$$

If A is invertible, the reduced form Wold representation of x_t can be obtained:

$$\begin{pmatrix} \Delta y_t \\ \Delta \pi_t \end{pmatrix} = \begin{pmatrix} C_{11} & C_{12} \\ C_{21} & C_{22} \end{pmatrix} \tag{3.8}$$

or

$$x_t = D(L)e_t \tag{3.9}$$

where *D(L)* is a polynomial in the lag operator.

If $D(1)$ is the matrix of long run effect of reduced form shocks then, after some algebra, we have:

$$D(1) = (I - AL)^{-1} \tag{3.10}$$

Thereafter, we assume the reduced form innovations are linear combinations of the structural shocks:

$$\begin{pmatrix} \varepsilon_t^D \\ \varepsilon_t^S \end{pmatrix} = \begin{pmatrix} c_{11} & c_{12} \\ c_{21} & c_{22} \end{pmatrix} \tag{3.11}$$

or

$$e_t = C(0)\varepsilon_t \tag{3.12}$$

Given the relationship between the structural and reduced form shocks we must find the coefficient of $C(0)$. The estimation of $C(0)$ is obtained by some restrictions illustrated in the next section.

3.2 Restrictions and Identification of shocks

In our example the $C(0)$ matrix contains four elements (with three endogenous variables the E matrix contains nine elements). The problem is, as always happens in identifications issues, to be in a situation where we have more unknowns than equations. So, we have need some restrictions, one for each coefficient.

From the estimation of the reduced form VAR we can build the following matrix:

$$\Omega = C(0)C(0)^T \tag{3.13}$$

that represent the (known) variance-covariance matrix of the reduced form residuals. The first restriction come from the variance of the first VAR residuals:

$$Var(e^D) = c_{11}^2(0) + c_{12}^2(0) \tag{3.14}$$

Similarly we obtain the second restriction for the second residual:

$$Var(e^S) = c_{21}^2(0) + c_{22}^2(0) \tag{3.15}$$

The third restriction comes from the covariance of estimated residuals:

$$\mathrm{cov}(e^D, e^S) = c_{11}(0)c_{21}(0) + c_{12}(0)c_{22}(0) \tag{3.16}$$

The fourth restriction is backed by economic grounds. We must pose explicit long run restrictions on the behaviour of the system. To find it, we consider equation (3:5). Because $D(1)$ matrix represents the long run effect of the reduced form shocks, we can obtain the long run matrix of the structural shocks denoted by $C(1)$:

$$\begin{pmatrix} C_{11}(1) & C_{12}(1) \\ C_{21}(1) & C_{22}(1) \end{pmatrix} = \begin{pmatrix} D_{11}(1) & D_{12}(1) \\ D_{21}(1) & D_{22}(1) \end{pmatrix} \begin{pmatrix} c_{11}(0) & c_{12}(0) \\ c_{21}(0) & c_{22}(0) \end{pmatrix} \tag{3.17}$$

or

$$C(1) = D(1)C(0) \tag{3.18}$$

If $C(1)$ is lower triangular, we can derive the necessary restriction.
It comes from the restriction of one of the original shocks not having any long run impact on one of the VAR variables:
This restriction is:

$$C_{12}(1) = 0 \tag{3.19}$$

or

$$D_{11}(1)c_{12}(0) + D_{12}c_{22}(0) = 0 \tag{3.20}$$

From economic point of view, this restriction translates into aggregate demand shocks not having long term effect on product.
Now we are able to estimate $C(0)$ and together with $D(1)$ to estimate the structural shocks.

In fact, these restrictions make $C(1)$ lower triangular and we can use this property to recover $C(0)$.

Putting long period expression (3.7) and (3.13) together we have:

$$C(1)C(1)^T = D(1)\Omega D(1)^T \qquad (3.21)$$

Using the Choleski decomposition of (3.21), $C(0)$ can be identified by the following equation:

$$C(0) = D(1)^{-1} N \qquad (3.21)$$

where N is the lower triangular Choleski decomposition.

4. Models and empirical strategy

In this section we present three models applied to Norwegian data.
In the first model we work with two variables[3]: inflation rate is measured by quarterly changes in Consumer Price Index CPI and output by quarterly changes in real Gross Domestic Product GDP, to identify core and no core inflation.
A second model has three variables: quarterly changes in CPI, GDP and CPI_F (foreign inflation) to decompose core inflation in domestic and imported core inflation. The introduction of foreign inflation is significant for a small oil exporting country as Norway. As we will see, the importance of CPI_F is linked to the effects of globalisation, in wich Norway is largely involved, supplying oil and others commodities at high prices and increasingly importing low-cost consumer products. This phenomenon is speed up by the increasing demand of energy of emerging economies like China and India. In this perspective we have introduced a third model with four variables: quarterly changes in CPI, GDP, CPI_F and PIPK (International Price Impulses to Imported Consumer Good Prices).

The PIPK variable is included as exogenous variable to improve identification of Imported inflation and catch up the international effects in competitiveness and prices. However, in all three models we assume that core (domestic) inflation doesn't affect output in the long run. This hypothesis is achieved by long run restrictions on short run parameters. In the first model, we need one restriction to just identify the system; in the second model, we need three restrictions to just identify the system. Therefore, in models two and three we also assume that imported inflation (core imported) has no effect on output in the long run and that domestic core shocks cannot have long run effects on foreign price level (small economy hypothesis).

4.1 Finding core inflation: a first model for Norway

Quarterly changes in CPI and GDP of Norway from 1990q1 to 2006q2 are used to calculate a sVAR measure of core inflation. Really, this is a short sample by imposing long run restrictions but the results from the model are satisfactory.

[3] *All variables in this article are expressed in quarterly change in the log of original variables. Then, CPI is the quarterly change in the log of inflation*

At the beginning data are cleaned for seasonality and for outliers (we made auxiliary regressions with constant and dummies) and then we have performed some diagnostic tests (unit root test, lag length, residual normality, autocorrelation, cointegration, invertibility) before estimating a Structural Vector Autoregression (SVAR) with constant and trend (see Appendix A).

In fact, unit root tests confirms that for GDP and CPI can we reject the hypothesis of a unit root in favour of the stationary alternative (c.f. table A.1).

In a second time, we determine the lag order of the model performing several selection criteria as Akaike information criterion (AIC) and sequential modified LR test statistic (LR). All tests indicate to estimate the sVAR model with four lags, a constant and seasonal dummies. Using four lags we could reject the hypothesis of autocorrelation and heteroskedasticity.

At the end, in the sVAR model specified above, we test cointegration relation between CPI and GDP (by Johansen cointegration test). By testing for cointegration we confirm that none of the variables in the sVAR model are cointegrated (see table A.3). Therefore, as explained above, we can identify the sVAR by long run restrictions imposed on C*(L)* matrix.

Figure 1: CPI and GDP rate (quarters)

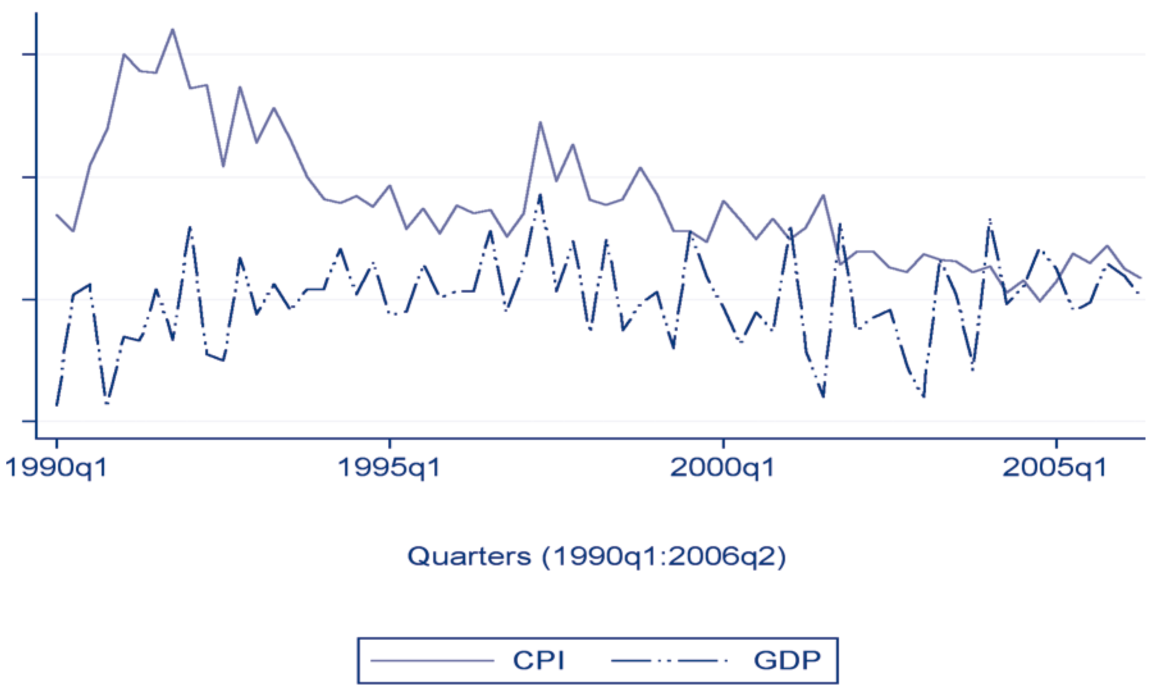


Figure 1 shows the developments of CPI and GDP in Norway from 1990q1 to 2006q2 (cleaned for seasonality and for outliers). It stresses the difficult to identify the short run non monetary factors influencing inflation. In fact, we note irregular fluctuations of CPI and GDP in the same direction in almost all years (incidentally, this is a graphical evidence of a negatively sloped Phillips curve). In this context inflation can be generated by two sources: the demand side boosts and the productivity shocks. The first source produces inflation without GDP movements (we aim it imposing long run restrictions); the second source is linked to output movements (supply side shocks). So, the policy maker might be misled by two effects conducting a wrong monetary policy.

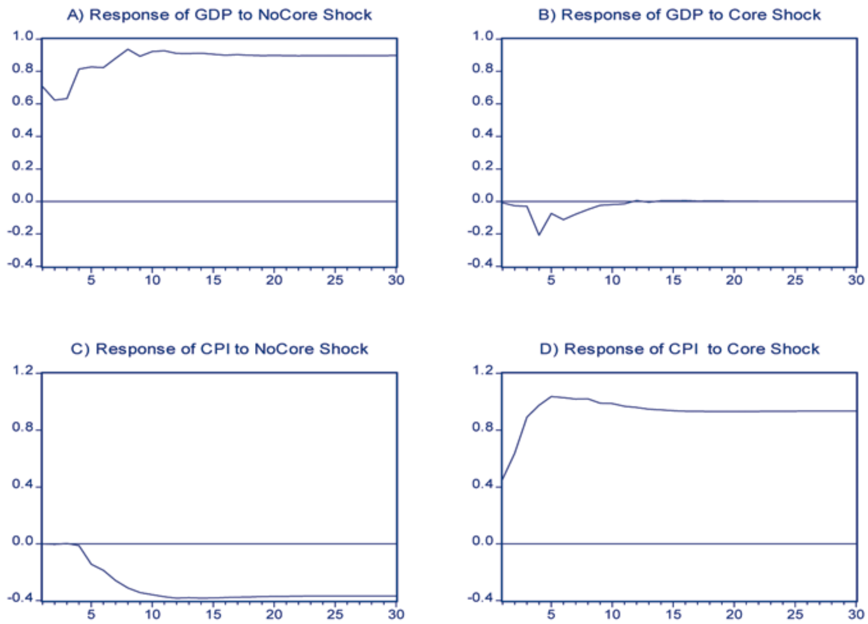
For example, if a negative (but temporary) shock impacts the productivity producing an increase of inflation, the central bank might be inducted to restrict its monetary policy so worsening the economic depression. It can reverberate the policy effects through the economy for a long period letting out a worse inflation signal for agent's expectations. To avoid it, a measure that can identify core inflation would allow for more effective administration in the economy as a whole since temporary shocks on prices ought not to activate a reaction by central bank.

From the graph we note that at the beginning of 1990s Norway got through a crisis generated by negative supply shocks (e.g. Bjornland, 1996). From 1995s to 2000s active policies carries out Norway from the depression (with high inflation). From the end of 2002s Central Norway Bank has raised interest rates several times, allowing an high growth of GDP with a moderate inflation rate until 2006s.

4.1.1 Impulse response analysis

In Figure 2 (below) we show the accumulated responses of inflation and real output to each shock (impulse responses analysis).

Figure 2: Accumulated Response to Structural One S.D. innovations



The vertical axes refers to the log of the variable and reports the contribution of the structural supply and demand shocks, while the horizontal axis indicates the time horizon in quarters.

In Panel A and B we show the dynamic reactions of the level of real output to, respectively, a one-unit non core disturbance (e.g. productivity) and demand shock over a period of thirty simulation years.

In panel A we note that a positive non core disturbance (e.g. productivity) has a strong impact on output stabilising its effect after 10 quarters. Our dynamics match very well the predictions of AS-AD model in the long run (see (2.2) equation). When the shock come from supply side the GDP is permanently affected.

But output is also impacted by core shocks. In panel B a positive core disturbance has a low impact on output (it goes to zero after 12 quarters) because the long run restrictions, confirming the output (long run) neutrality assumption. Together the two effects provide some evidence of a negatively sloped short-run Phillips curve.

In panel C and D we show the impulse response functions of the CPI depicting the different impact of supply and demand shocks.

The impulse response functions of CPI depict the different impact of supply and demand shocks on prices. While a negative supply shock induces a permanent reduces the CPI, a positive demand shock induces a permanent increase of the CPI. In line with the stationary property of Norwegian inflation we have assumed, both shocks affect inflation only temporarily. A CPI non core shock reduces mildly inflation at the beginning; then, after 12 quarters, it stabilises its effect (Panel C). In the opposite side the accumulated response of CPI to core shock has a permanent effect on inflation. The impulse response takes 12 quarters to settle down to its long run level.

4.1.2 Variance decomposition

The variance decomposition[4] for output and inflation over sixty quarters are reported in table 1 below.

In line with expectations it should be noticed that after 10 periods we have a 9% increase of variance in CPI for output equation. This looks strange because we have imposed no effects on output from core shocks. The reason might be that after 10 periods all the variance in forecasts comes from output and a weighted decomposition could improve this result. This result of the variance decomposition of the CPI are consistent with the concept of core inflation being demand driven. A demand driven measure captures the price trend, if the demand factors account for the predominant part of the variation in the price index in the medium to long-run. This result is not due to any kind of imposed restriction.

Table 1: Variance Decomposition of CPI and GDP

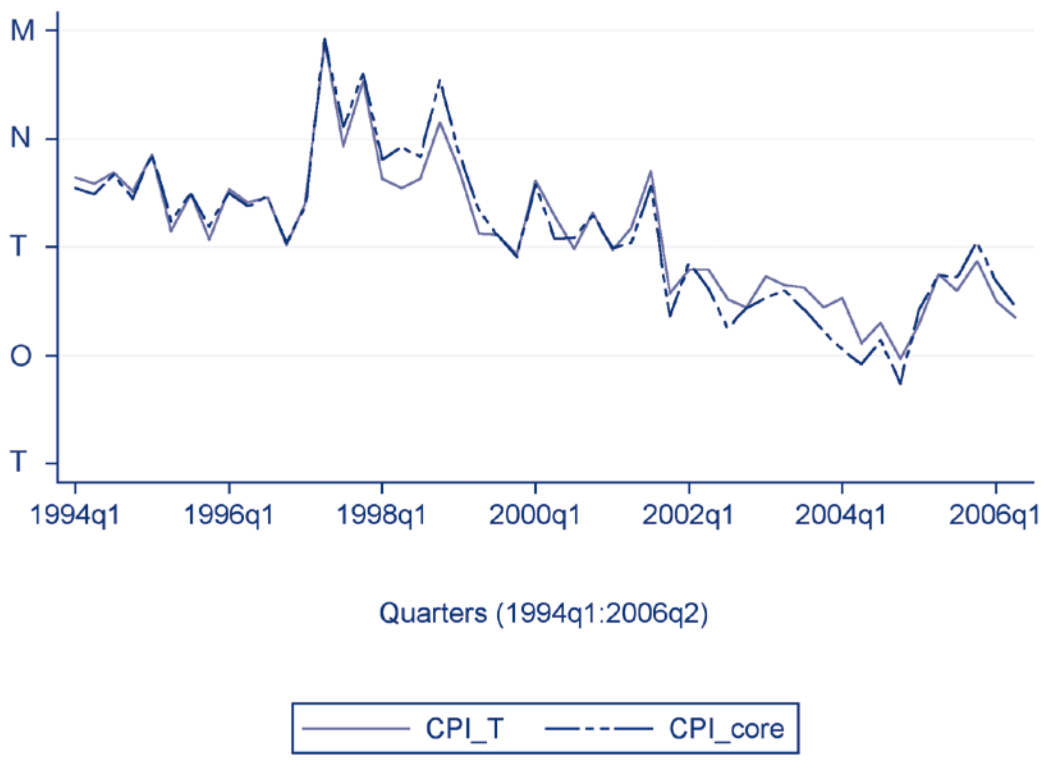
	Inflation	
Quarters	Core Shock	No Core Shock
1	0.00	0.07
2	0.00	0.14
3	0.02	99.98
4	0.09	99.91
10	8.27	91.73
60	8.35	91.65

[4] *the variance decomposition explains the contribution of same structural shocks to the variance of the n-step forecast errors of the variables.*

	GDP	
Quarters	Core Shock	No Core Shock
1	0.01	99.99
2	0.08	99.92
3	0.08	99.92
4	5.61	94.39
10	8.97	91.03
60	9.07	90.93

In order to check if the mesaured CPI match well the estimated core inflation, we report below a graph with CPI and estimated core inflation in quarterly changes.

Figure 3: CPI measured vs. Estimated Core Inflation (Quarterly Change)



From figure 3 we can note that core component of inflation appears to perform well in its role of first component of inflation. In particular, peaks and troughs of core match well with the headline. In this sense constitutes its “prime mover of movements”.
In general inflation was stronger than the measured one, likely because positive non core shocks pushed the supply side of the economy raising inflation (e.g. productivity shocks). This seems evident from 1998 to 2000. From 2002 to 2005 the inflationary process was weaker than indicated by CPI, non core disturbances (loss of productivity, competitiveness) generating an opposite impact on GDP. In the first six-months of 2006 the situation is inverted: core inflation walks (no randomly) very near to CPI measured in such a natural way; positive non core shocks pushed the supply side of economy raising inflation (likely productivity shocks).

4.2 The role of imported core inflation: a second model

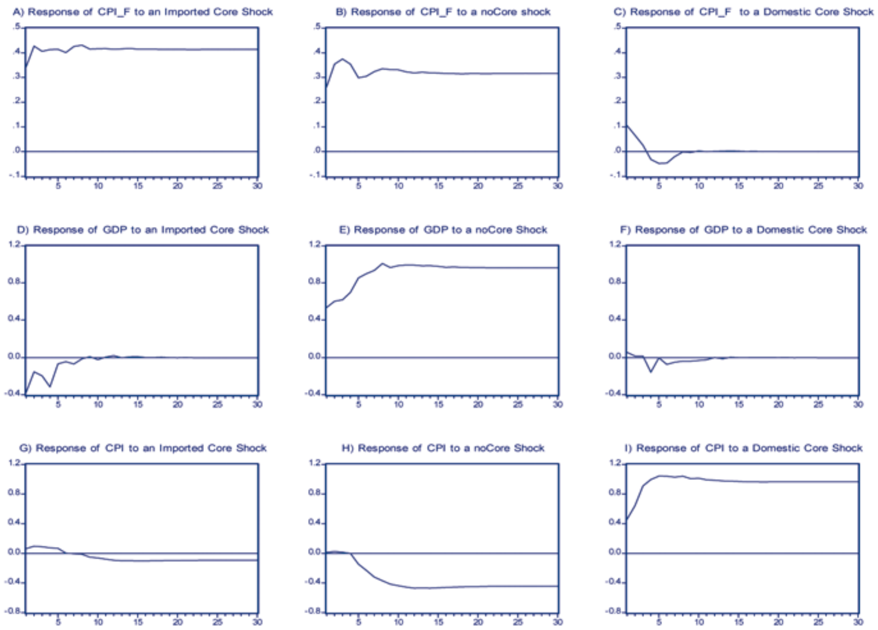
In the second model we work with three variables: CPI, GDP and CPI_F (foreign inflation) in quarterly changes to decompose core inflation in domestic (CPI) and imported inflation (CPI_F). In this model we adopt the same methodology described above; we generalize the first model inserting CPI_F as endogenous variable[5].
We have performed some diagnostic tests (unit root test, lag length, residual normality, autocorrelation, cointegration, invertibility) before estimating a Srtuctural Vector Autoregression (SVAR) with constant and trend (see Appendix B).
In fact, unit root tests confirms that for CPI_F can we reject the hypothesis of a unit root in favour of the stationary alternative (c.f. table B.1).
Then, we determine the lag order of the model performing the same selection criteria used for the first model: Akaike information criterion (AIC) and sequential modified LR test statistic (LR). While the LR test of parameter reduction reported four lags, the AIC indicated two lags (see Table B.2). We have decided to rely on LR criteria estimating the sVAR model with four lags, a constant and seasonal dummies.
At the end, in the sVAR model specified above, we test cointegration relation between CPI, CPI_F and GDP (by a Johansen cointegration test). None of the variables in the sVAR model are cointegrated (see table B.3).

[5] *In this case we need three long term restrictions to identify the model.*

4.2.1 Impulse response analysis

As above, we first report the results of impulse response analysis; then the variance decomposition.

Figure 4: Accumulated Response to Structural One S.D. Innovations



In figure 4 we can observe that a positive non core shocks have a strong effect on foreign prices in the long run. Domestic core shocks do not affect international prices in the long run (by restriction). In panel D we note that imported core shocks do not affect output in the long run; in panel F domestic core shocks do not affect output in the long run. As in the first model no core shocks have a low effect on the output in the long run; in addition imported core shocks have a low effect on domestic prices.

4.2.2 The variance decomposition

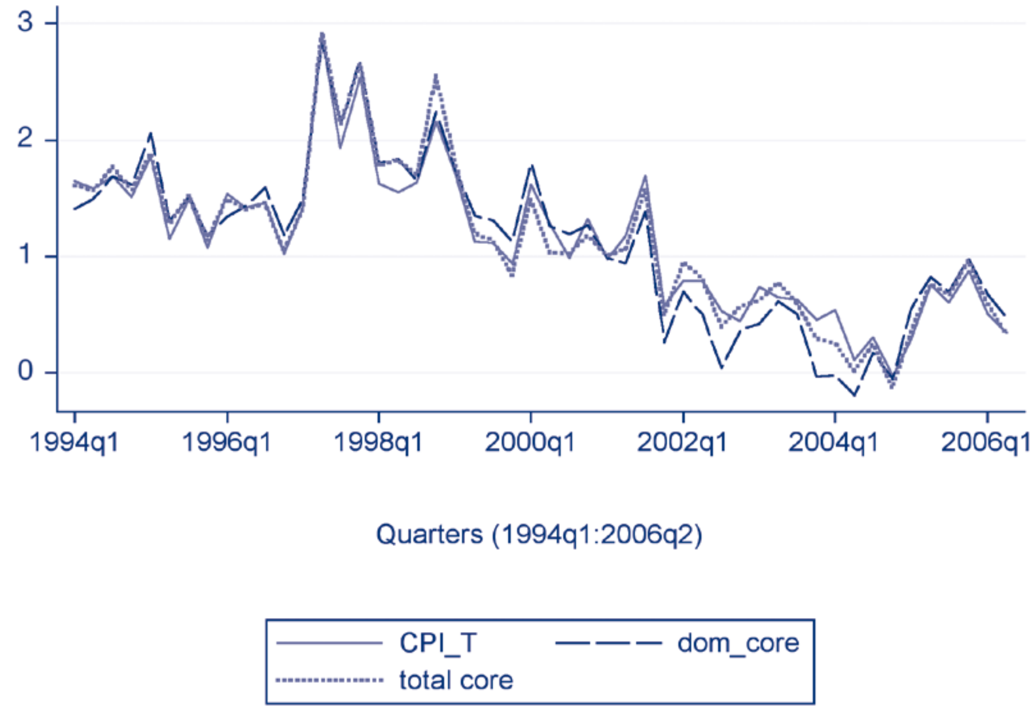
The variance decomposition of this model is rather in line with the expectations but again we observe a strange result.

Table 1: Variance Decomposition of CPI, CPI_F and GDP

	Inflation		
Quarters	Domestic Core	Imported Core	No Core Shock
1	98.02	1.91	0.07
2	97.82	2.04	0.14
3	98.26	1.60	0.14
4	98.16	1.63	0.21
10	85.98	2.91	11.12
60	85.72	3.03	11.25
	GDP		
Quarters	Domestic Core	Imported Core	No Core Shock
1	0.76	32.51	66.73
2	0.99	38.95	60.07
3	0.98	39.17	59.85
4	6.53	38.09	55.38
10	9.70	40.67	49.63
60	9.84	40.74	49.42

Imported shocks explain 40% of output variance after 12 periods against the long run restrictions (that do not have any effect in decomposition). The same results found for CPI in the first model. In this model we are able to disentangle the domestic core inflation by the imported core inflation. The domestic core inflation looks quite similar to the core inflation. To capture the differences we have to sum the other component of core inflation that is the imported core inflation. From 1999 to 2001 imported core shocks worked to reduce total core inflation. International prices fell at a much higher rate than in Norway. From 2002 to the end of 2004 total core was above domestic core, hence Norway imported inflation. Again in 2004 total core inflation lied below the CPI (as in the first model) suggesting that negative no core shocks reduced GDP. In the six-month of 2006 the situation was stable but international prices appeared to decrease at a higher rate than Norwegian prices.

Figure 5: Measured CPI vs. Total Core (Domestic Core Infaltion plus Imported Core Inflation)



4.2.3 The role of oil price on monetary deliberations: some insights and new challenges

Norges Bank has earned a high credibility with economic operators (foreign too) for its conduct of monetary policy. During the time the high credibility has aided to manage monetary policy generating an exemplary of inflation-targeting monetary direction. In recent years the imported low inflation has provided a new opportunity to consolidate the Bank's credibility, by keeping inflation impressively low without the need of any monetary intervention. Nonetheless, being Norway small oil exporting country, it's highly exposed to the volatility of oil price fluctuations coming from external channels. The new uncertainty about the functioning of the economy, becoming globalisation a more complex phenomenon, and the exogenous shocks affecting it, put Norges Bank in front of new challenges.

First, Norges Bank must maintain high credibility to manage inflation stabilizing oil price expectations at that time. Some external shocks can undermine its reputation inducing Norges Bank to level off and to deflect from its monetary pronouncements. This risk is sensible and foreseeable because of the higher Chinese and Indian inflation once the productivity growth there expires. It will be critical to further build up credibility while global conditions are difficult: globalisation shocks can put in difficult position a solid economy posing challenges even to such a highly successful monetary policy.

Second, the Norwegian business cycle may be highly influenced by global macroeconomic shocks and cycles. In fact, cycles in real oil prices, real oil revenue cycles or oil investment are correlated to the global business cycle, strongly impacting on small oil-exporting economies (as Norway) in the short run (see Bjornland, H.C., (1998)). This result may be confirmed by past episodes of supply driven oil price increases (e.g, OPEC shocks), which depressed worldwide demand. In the current global cycle the demand side drives increases: oil price increases may sharpen economic fluctuations.

Third, from figure 5 we can note that the core inflation is below Norges Bank target (2.5%) from 1998s. Nonetheless, Norges Bank has raised the interest rate in some steps. This may reflect sign of (expected) tensions now emerging on some market (labour and energy), which could lead to higher inflation expectations if interest rate deliberations go toward the maintenance of interest rates below the natural level for too long. A tight monetary policy may become necessary if oil price (wage) growth seems to accelerate more than expected.

4.3 Estimating International effects in competitiveness: a third model

In this model we introduce the International Price impulses to Imported Consumer Good Prices (PIPK) as exogenous variables to improve the identification of Imported inflation. The main idea is to capture international effects in competitiveness and prices (for instance, China effect).

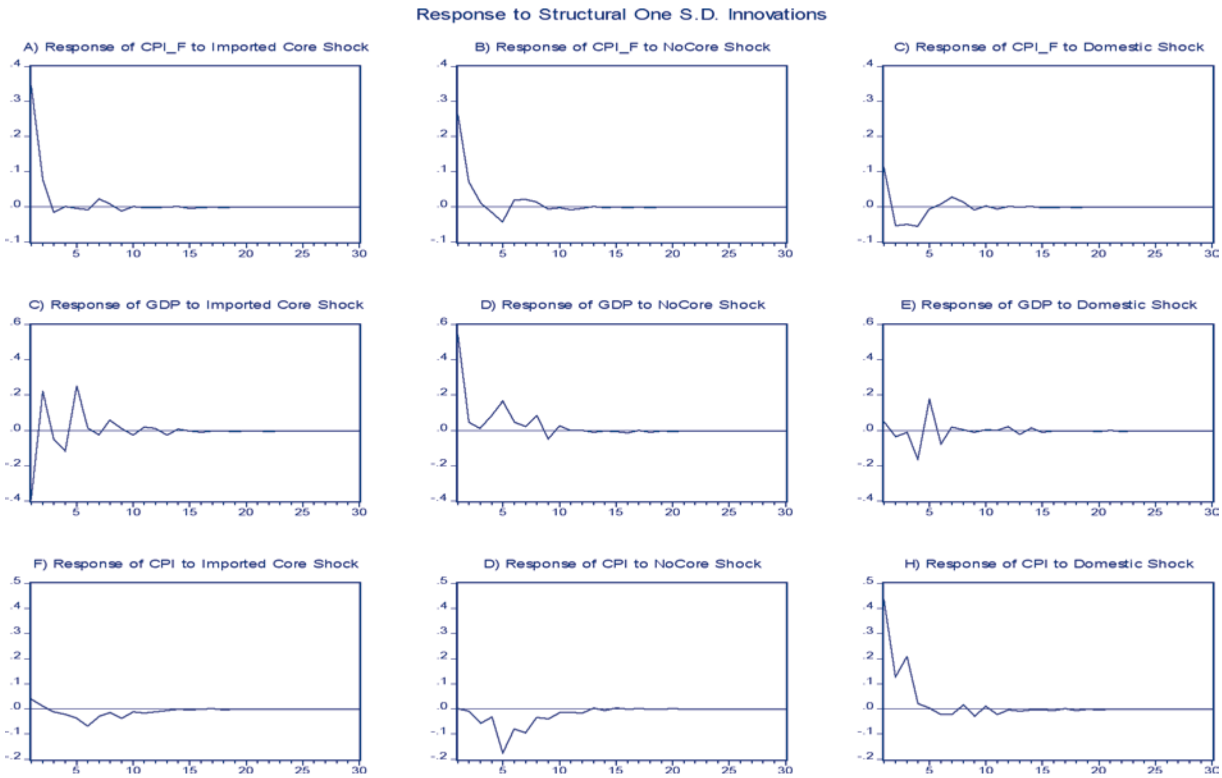
As above, we have performed some diagnostic tests (unit root test, lag length, residual normality, autocorrelation, cointegration, invertibility) before estimating a Structural Vector Autoregression (SVAR) with constant and trend (see Appendix C).

Unit root tests confirm that for PIPK can we reject the hypothesis of a unit root in favour of the stationary alternative (c.f. table B.1).

Then, in the sVAR model specified above, we test cointegration relation between CPI, CPI_F, PIPK and GDP (by Johansen cointegration test). None of the variables in the sVAR model are cointegrated (see table C.2).

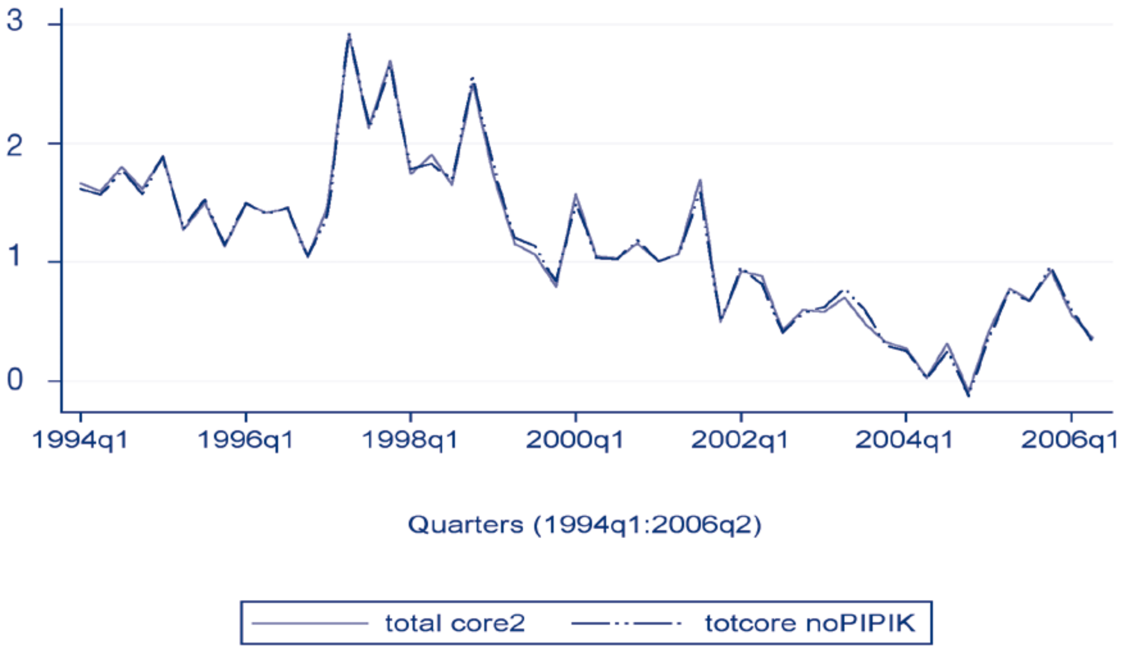
We obtain the same results of the second model, save for only a small increase in reaction of CPI to an imported core shock.

Figure 6: Impulse responses



In general the exogenous PIPK doesn't give a strong contribution to the model. The major effect is visible from 2002 to 2004 (high growth of Chinese economy); this could help us to understand which type of inflation was imported and the origin of negative no core shocks effecting the economy.

Figure 7: Total Core of Model 2 vs. Total Core Estimation of Model 3



5. Conclusion

In this paper the structural VAR methodology developed by Quah and Vahey (1995) is applied to decompose Norwegian inflation in non core (or temporarily) shocks and long term price shocks (core inflation). Temporary shocks are driven by supply side factors and are outside the control of central bank. The core component of inflation can be influenced by monetary authorities through demand-management policies (monetary growth). Using the concept of a vertical long-run Phillips curve, we impose some long-run restrictions obtaining that demand shocks have no long run effect on output. In this context the core inflation is the persistent (or underlying) component of measured inflation that has no medium to long run effect on output. Given that the central banks of several countries are focusing the monetary policy on price stability, we first discuss the notion of core inflation from a theoretical point of view, explaining because, in the practice, the concept of core inflation in the formulation of policy aimed at controlling inflation mostly (e.g, inflation targeting), plays a crucial role in monetary deliberations. Thereafter, we use Quah and Vahey (1995) methodology to identify core inflation using quarterly changes in CPI and GDP variables; in a second time we try to distinguish between domestic and imported inflation. Finally, in a third model, we introduce the Imported Consumer Good Prices (PIPK) as exogenous variable to capture the international effects in competitiveness. We show that the actual inflation remained around the core inflation during most of the period of estimation. Therefore we conclude that in our application on Norwegian economy core inflation is a 'prime mover movement' of inflation.

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6. Appendix A: First Model

Notes: All variables in this article are expressed in quarterly change in the log of original variables.

Table A1. Unit root tests

GDP	Confidence	t-Statistic	Prob.
Augmented Dickey-Fuller test		-9.3197	0.0000
Test critical values:	1% level	-4.1055	
	5% level	-3.4805	
	10% level	-3.1680	
CPI	**Confidence**	**t-Statistic**	**Prob.**
Augmented Dickey-Fuller test		-4.0186	0.0128
Test critical values:	1% level	-4.1079	
	5% level	-3.4816	
	10% level	-3.1687	

Table A.2. Lag order tests (first model)

Lags	LogL	LR	AIC
0	98.02	NA	3.95
1	97.82	20.37	3.73
2	98.26	3.91	3.79
3	98.16	7.83	3.77
4	85.98	10.64*	3.70*

** indicates lag order selected by the criterion; LR: sequential modified LR test statistic (each test at 5% level); AIC: Akaike information criterion*

Table A.3. Cointegration tests

Series: GDP CPI

Lags interval (in first differences): 1 to 4

Unrestricted Coint. Rank Test (Trace)

Hypothesized		Trace		
No. of CE(s)	Eigenvalue	Statistic	CriticalValue(5%)	Prob.
None	0.16	17.05	25.87	0.41
At most 1	0.10	6.11	12.52	0.45

Trace test indicates no cointegration at the 0.05 level.

Unrestricted Coint. Rank Test

Hypothesized		Max-Eigen		
No. of CE(s)	Eigenvalue	Statistic	CriticalValue (5%)	Prob.
None	0.16	10.94	19.39	0.52
At most 1	0.10	6.11	12.52	0.45

Max-eigenvalue test indicates no cointegration at the 0.05 level.

7. Appendix B: second model

Table B.1. Unit root test

CPI_F	Confidence	t-Statistic	Prob.
Augmented Dickey-Fuller test		-6.3259	0.0000
Test critical values:	1% level	-4.1055	
	5% level	-3.4805	
	10% level	-3.1680	

Table B.2. Lag order tests (second model)

Lags	LogL	LR	AIC
0	-151.01	NA	5.07
1	-132.27	34.45	4.75*
2	128.37	6.81	4.92
3	-122.91	8.98	5.03
4	-111.91	17.03*	4.96

** indicates lag order selected by the criterion; LR: sequential modified LR test statistic (each test at 5% level); AIC: Akaike information criterion*

Table B.3. Cointegration tests

Series: CPI_F GDP CPI				
Lags interval (in first differences): 1 to 4				
Unrestricted Coint. Rank Test (Trace)				
Hypothesized		Trace		
No. of CE(s)	Eigenvalue	Statistic	CriticalValue(5%)	Prob.
None	0.25	34.62	42.92	0.26
At most 1	0.17	17.16	25.87	0.40
At most 2	0.09	5.44	12.52	0.53
Trace test indicates no cointegration at the 0.05 level				
Unrestricted Coint. Rank Test				
Hypothesized		Max-Eigen		
No. of CE(s)	Eigenvalue	Statistic	CriticalValue(5%)	Prob.
None	0.25	17.47	25.82	0.42
At most 1	0.17	11.71	19.39	0.44
At most 2	0.09	5.44	12.52	0.53
Max-eigenvalue test indicates no cointegration at the 0.05 level				

8. Appendix A: Third Model

Table C.1: Unit root tests

PIPK	Confidence	t-Statistic	Prob.
Augmented Dickey-Fuller test		-5.7881	0.0000
Test critical values:	1% level	-4.1055	
	5% level	-3.4805	
	10% level	-3.1680	

Table C.2. Cointegration tests

Series: CPI_F GDP CPI				
Exogeneous series: Trend PIPK PIPK(-4)				
Lags interval (in first differences): 1 to 4				
Unrestricted Coint. Rank Test (Trace)				
Hypothesized		Trace		
No. of CE(s)	Eigenvalue	Statistic	CriticalValue(5%)	Prob.
None	0.27	34.86	42.92	0.12
At most 1	0.21	19.38	25.87	0.26
At most 2	0.08	5.06	12.52	0.59
Trace test indicates no cointegration at the 0.05 level.				
Unrestricted Coint. Rank Test				
Hypothesized		Max-Eigen		
No. of CE(s)	Eigenvalue	Statistic	CriticalValue(5%).	Prob
None	0.27	19.48	25.82	0.27
At most1	0.21	14.32	19.39	0.23
At most 2	0.08	5.06	12.52	0.59

Max-eigenvalue test indicates no cointegration at the 0.05 level

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