# A SVAR MODEL FOR ESTIMATING CORE INFLATION IN THE EURO ZONE

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**Abstract**

A traditional role of central banks has been to protect the purchasing power of money by keeping a roof on inflation. Recently, several central banks have explicitly assumed an inflation control target. This is the case, among others, of the European Central Bank (ECB) whose monetary policy goal is to keep an annual inflation rate below 2% over a medium-term horizon (ECB 2001). In practice, inflation is often measured in terms of the Consumer Price Index (CPI). However, the headline inflation rate is not totally under the control of the ECB. In this paper core inflation is measured by means of the structural VAR approach, in particular it is based on long-run restrictions over crucial macroeconomic variables: inflation, money and output. Core inflation is estimated and compared with the standard measured inflation.

Un rol tradicional de los bancos centrales ha consistido en la protección de la capacidad de compra del dinero mediante la acotación o control de la inflación. Recientemente, varios bancos centrales has asumido explícitamente un objetivo de control inflacionario. Este es el caso, entre otros, de Banco Central Europeo (ECB) cuya política monetaria consiste en mantener un ratio de inflación por debajo del 2% en un horizonte temporal de medio plazo (ECB 2001). En la práctica, la inflación es frecuentemente medida en términos del Índice de Precios al Consumo (CPI). En cambio, la tasa de inflación general no está totalmente bajo el control del ECB. En esta comunicación, la inflación conocida como ‘core inflation’ es medida mediante la aproximación fundamentada en los vectores estructurales autorregresivos, en concreto esta comunicación se centra en las restricciones a largo plazo sobre variables económicas tales como la inflación, el dinero y el output. La inflación conocida como ‘core inflation’ es estimada y comparada con la medida estándar de inflación.

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## I INTRODUCTION

A traditional role of central banks has been to protect the purchasing power of money by keeping a roof on inflation. Recently, several central banks have explicitly assumed an inflation control target. This is the case, among others, of the European Central Bank (ECB) whose monetary policy goal is to keep an annual inflation rate below 2% over a medium-term horizon (ECB 2001). In practice, inflation is often measured in terms of the Consumer Price Index (CPI). However, the headline inflation rate is not totally under the control of the ECB. In fact, it is well known that policy changes affect underlying inflation pressures slowly over time. As well as , numerous economic transformations beyond the control of the monetary authorities may cause transitory (short-term) changes in the inflation rate. Therefore, it seems that an empirical measure of the underlying (medium-term or trend, also called core) inflation has significant implications in the monetary policy monitored by central banks.

A huge number of different measures of core inflation have been proposed to the end of assist monetary authorities to minimize misleading signals about current and future trends in inflation. Those measures are based on different technical approaches which can be divided in three main categories according with the information set they rely on: (1) Some measures address the problem of distortion in CPI inflation by reweighing the impact of the individual price data. Such reweighting process are based on the cross sectional distribution of individual price items, this is the case of the exclusion measures like the well known "ex food and energy" technique; the limited influence estimators proposed by Bryan and Cecchetti (1994), and Bryan, Cecchetti and WiggingsII (1997); and the variance weighted index suggested by Diewert (1995) and Dow (1994). Other measures, like the used by Stock and Watson (1991), combine cross sectional and time series dimension of individual price changes to identify core inflation. These authors understand core inflation as the common element of the individual price changes. (3) Finally, it can be distinguished among measures rooted on univariate and multivariate statistical techniques. Being the former those such as simple moving averages or more sophisticated methods, think of unobserved components models, based on  the Hodrick Prescott filter and the Kalman filter. And the latter, those measures that take into account additional information in terms of further economic variables. They basically entail the structural vector autorregresion (SVAR) approach suggested to this end by Quah and Vahey (1995) and the common trends approaches proposed by Blix (1997) and also recently by Bagliano et al. (2002). It is interesting to note that multivariate approaches comprise to modelling important (perhaps well established) interactions between economic variables considered in terms of (long run) restrictions.

In this paper core inflation is measured by means of the structural VAR approach, in particular it is based on long-run restrictions over crucial macroeconomic variables: inflation, money and output. This is developed by following the main lines introduced by Quah and Vahey (1995) for a better estimation of the core inflation. The reasons by which the paper considers the relations among these three variables are, in the one hand, the ‘two pillar’ monetary strategy of the ECB, for which conducting monetary policy entails the consideration of deviation of money growth form a reference value and future prices developments in the Euro area (ECB, 2000). And in the other hand, the fact that it would be more informative to allow for more macro-variables in the VAR system, than the two variables (output and inflation) considered in Quah and Vahey (1995) seminal paper. Some papers have used these three variables to evaluate different economic consequences for several countries of join the European Union, this is the case of Chamie( 1994).

The rest of the paper is organised as follows. In section II, the SVAR technique and the identification process are explained. This methodology is applied to the Euro area for the 1981 to 2000 period and the main results and its interpretation are presented in section III.

## II METHODOLY

In order to identify all relevant sources of prices fluctuations, the decomposition method suggested by Quah and Vahey (1995)-based on Blanchard and Quah (1985)- is applied to a three variable VAR system. For the aggregate of 11 countries of the European Monetary Union, it is assumed that the difference of real GDP log ( $\Delta y$ ), the quarterly rate of consumer price inflation measured by Harmonized Index of Consumer Prices used by the ECB ( $\pi$ ) and the difference of M3 log ( $\Delta m$ ), follow a stationary stochastic process that responds to three types of orthogonal shocks: supply shocks ( $\varepsilon_s$ ), real demand shocks ( $\varepsilon_d$ ) and nominal shocks ( $\varepsilon_m$ ).

The structural VAR model can be expressed as follows:

$$B(L)X_t = \varepsilon_t \qquad E(\varepsilon_t \varepsilon'_t) = I \tag{1}$$

where $X_t = \left(\Delta y, \pi, \Delta m\right)'$ and $\varepsilon_t = \left(\varepsilon_{s_t}, \varepsilon_{d_t}, \varepsilon_{m_t}\right)'$. Without of loss of generality, the covariance matrix of structural shock $\varepsilon_t$ is normalized to *I*. Given that the stochastic process is covariance stationary, structural model (1) will have the next Wold representation:

$$X_t = D(L)\varepsilon_t \tag{2}$$

where $D(L) \equiv [D_{i,j}(L)]$ with $i, j = 1, 2, 3$ and $D(L) = B(L)^{-1}$.

To identify this structural model, the vector autoregressive reduced form of the model is estimated:

$$A(L)X_t = e_t \tag{3}$$

where $A(L) = A(0) + A(1)L + A(2)L^2 + ... + A(p)L^p$ and $L$ is the lag operator. Therefore $A(0) = I$. The covariance matrix of the residual ( $E(e_t e_t') \equiv \Omega$ ) is, in general, nondiagonal. Given that the stochastic process is stationary, the model may be written in its moving average form:

$$X_t = C(L)e_t \tag{4}$$

where $C(L) \equiv [C_{i,j}(L)]$ with $i, j = 1, 2, 3$ and $C(L) = A(L)^{-1}$ is an infinite-order lag polynomial. Reduced form model residuals are linear combinations of structural residuals:

$$e_t = D(0)\varepsilon_t \tag{5}$$

such that

$$\begin{aligned} E(e_t e_t) &= D(0)E(\varepsilon_t \varepsilon_t)D(0)' \\ \Omega &= D(0)D(0)' \end{aligned} \tag{6}$$

The problem remains of identifying the structural shocks ( $\varepsilon$ ) from the VAR reduced-form residuals ( $e$ ) and their variance. From (5), it is known that the solution depends on the identification of the matrix D(0), which entails $n^2$ elements (where $n$ is the number of dependent variables in the model; in this particular case 3). Since $\Omega$ is a symmetrical matrix, equation (6) gives $\left[(n^2 - n)/2\right] + n$ restrictions on the matrix D(0), therefore, $(n^2 - n)/2$ extra restrictions must be imposed to identify, which in this model means 3.

Combining equations (2), (4) and (5) we find:

$$D(L) = C(L)D(0) \tag{7}$$

Note that knowledge of D(0) is sufficient for the full identification of the structural system. Once D(0) is known, all structural coefficients of the lag polynomial D(L) and structural innovations are calculated from the estimated reduced form VAR using (5) and (7).

Following Quah and Vahey (1995), long-run economic restrictions are applied to identification. From (7), it is obtained a relation between the matrix of long-term effects of structural shocks *D*(1) and the equivalent matrix of reduced-form shocks *C*(1) which is obtained from the reduced-form estimates. The three necessary restrictions can now be imposed on the matrix of long-term effects of supply, real demand and nominal shocks on the dependent variables. The restrictions are: Neither real nor nominal demand shocks have any permanent effect on output (only supply factors such as productivity and demographics influence in the long run output). Finally, it is assumed that nominal shocks have the same permanent effect on the level of money and prices, therefore real balances are money-neutral in the long run.

Given these restrictions, the matrix *D*(1) takes the following form:

$$D(1) = \begin{pmatrix} D_{11} & 0 & 0 \\ D_{21} & D_{22} & D_{23} \\ D_{31} & D_{32} & D_{33} \end{pmatrix} \tag{8}$$

Only the first two restrictions has been implemented according to prespecified ordering of variables given in the vector $X_t = (\Delta y, \pi, \Delta m)'$. The third restriction implies that $D_{23} = D_{33}$. It results interesting to transform the long-term matrix into a triangular form, for that reason equation (8) is premultiplied by matrix F:

$$F \equiv \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & -1 \\ 0 & 0 & 1 \end{pmatrix}$$

The result is the lower matrix *T*

$$T = FD(1) \tag{9}$$

From (7) and (6), the next relation holds

$$C(1)\Omega C(1)' = D(1)D(1)' \tag{10}$$

Given equation (9), the following relation may be obtained:

$$FC(1)\Omega C(1)'F' = TT' \tag{11}$$

Since *T* is a triangular matrix, to solve for the element of *T*, the Choleski decomposition is applied to the left hand side of (11) that contains known elements. The matrix of long-term effects is calculated by $D(1) = F^{-1}T$, and *D*(0) is solved:

$$D(0) = C(1)^{-1}D(1) \tag{12}$$

Having completely identified the structural model, the structural VAR measure of core inflation is derived from the vector moving average representation of measured inflation rate:

$$\pi_t = \sum_{k=0}^{\infty} D_{21}(k)\varepsilon_{s_{t-k}} + \sum_{k=0}^{\infty} D_{22}(k)\varepsilon_{d_{t-k}} + \sum_{k=0}^{\infty} D_{23}(k)\varepsilon_{m_{t-k}} \tag{13}$$

According to core inflation definition proposed by Quah and Vahey, i.e., the component of measured inflation that has no long-term impact of the level of real output, core inflation is given by the sum of the two second terms on the right-hand side of equation (13). Note that core inflation' definition is implemented as two identifying conditions and the third one just incorporates the assumption that in the long-run real balances are money-neutral, which is consistent with the vertical long-run Phillips curve.

## III. RESULTS

First of all, it has to be noticed that for the pre-Euro (up to 1999) aggregate variables for the Euro area has been elaborated by a historical aggregation procedure[1]. This kind of artificial data has been utilised among others by Bagliano et al (2002), Gerlach and Svensson (2001), Galí et al. (2000).

A VAR system in the variables announced in Section II is estimated from 1981(1) to 2000(2)[2]. The choice of VAR(4) is consistent with LR test. Either considering seasonal dummies or not, final results were quiet similar. The standard ADF and Phillips-Perron unit root tests show that real output, measured inflation and monetary aggregate (M3) variables can be considered as $I(1)$ process. From results achieved with the Johansen cointegration test, it is concluded that the three series are not cointegrated. Diagnostic tests on each individual equation and on the system as a whole do not detect any sign of residual autocorrelation, heteroscedasticity and non-normality supporting the dynamic specification of the system.

The dynamic effects of the two innovations on measured inflation and output are reported in Figs. 1 and 2, respectively. The vertical axes denote the logs of both variables.

Fig.1 about here

Notice that in section II no identifying condition has been imposed regarding the impact of non-core inflationary shocks on the measured rate of inflation. According with the here used core inflation definition, a valid model must support that non-core shock are added noise to measured inflation, but not part of the underlying inflation process. This fact can be realised from bottom line of Fig. 1. The non-core shock has mildly effects on measured

[1] Aggregation procedures can be consulted on Beyer et al. (2000).

[2] Data are downloadable at http://www.uned.es/dpto-economia-aplicada-cuantitativa1/mariano.htm

inflation. However, a core inflation shock has a permanent effect, in fact the response takes quite long to be set to its long-run level.

Therefore it seems reasonable to think that in the long-run measured inflation is monitored by core inflation.

Fig. 2 reveals that the EMU economy adjusts quickly to core inflationary shocks: the impulse response are quiet weak. However the speed of the adjustment can be interpreted in function of the degree of integration among analysed countries forming the EMU. A consistent integration should adjust faster than now. On the other hand, a non-core positive shock implies a stronger and permanent effect on the real economy.

Fig. 2 about here

The variance decomposition indicates the percentage contribution of the different structural shocks to the variance of the k-step ahead forecast errors of the variables. The variance decomposition of the inflation rate reported in Table 1 shows that the contribution of core shocks to movements in output is not very significant (non-core shocks are much more explicative). It also can be shown that core shocks explain a large part of the variation in measured inflation. Therefore the core measure entails elements that capture the price trend (i.e., the underlying inflation process), and in doing so, supports the requirements demanded by central banks for an indicative measure of inflation (as the indicated in the introduction section).

Table 1 about here

Figure 3. compares the estimated core inflation series with the measured consumer price inflation, both expressed as annual rates for the time period of 1990(1) to 2000(2).

It can be observed that (1) measured inflation and core inflation follow the same path; (2) peaks and troughs of the core match well with those corresponding measured inflation, and (3) the variability of core inflation estimation is smaller than that of measured inflation. Obviously, (1), (2) and (3) are interesting properties, since the prime objective of core inflation is to give a measure of the persistent component of inflation, as stated in the introduction section.

Figure 3 about here

In early 1990s, the inflation process was stronger than the indicated by the standard measure. However, from 1991(4) to 1994(2), the opposite occurs. In the first time span non-core shocks stimulated the supply side of the European economy. While in the second, non-core shocks seem to have had an adverse effect on the economy. It is remarkable the fact that during the construction of the EMU, countries have made large efforts to bring inflation down and meet Maastricht criteria, as it is shown in the period from 1992 to 1999. Within the former span time, it noticeable that from 1994 to 1997, both measured and core inflation are almost similar which emphasised the fact that non-core shocks did not affect the European economies (treated as a whole). Finally, the considerable increase in core inflation in the euro-area since 1999(2) can be explained because of the strong growth dynamic of this time period, along with the depreciation of the Euro and the increase of oil prices.

Needless to say, that other papers have tried to measured core inflation in the Euro area (see for instance, Bagliano et al. (2002)). Of course, the estimated core inflation depends on the model specification (delay time, variables included, etc...) and on the technique used for estimation. The three variables utilised in this paper (real output, CPI and the monetary aggregate M3) seems to be useful for the estimation of core inflation, in the sense that, within the commented methodology, makes understandable (from an economic point of view) the historical discrepancies between core and measured inflation of the last ten years of the Euro area.

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## FIGURES AND TABLES

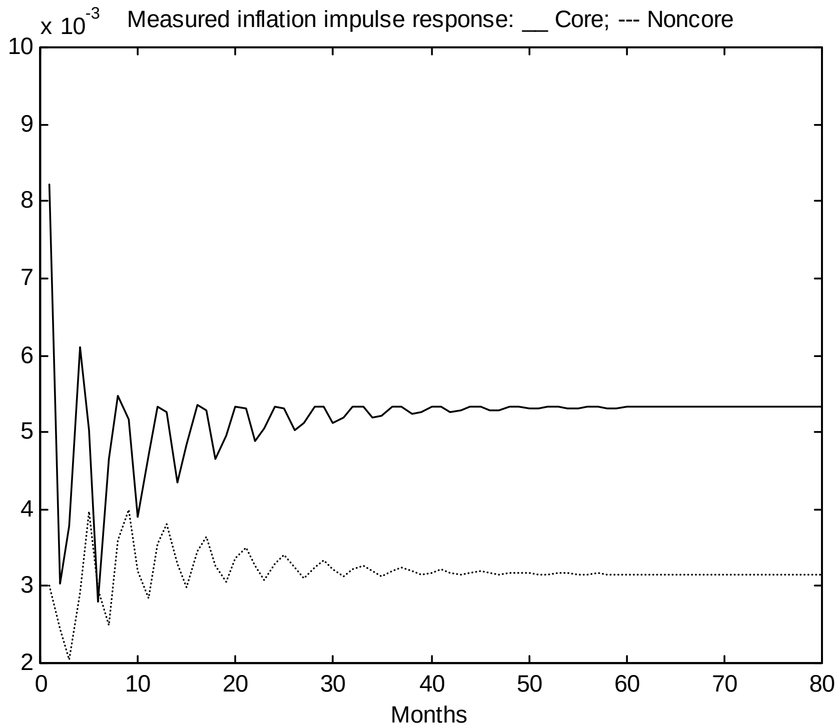


**Figure 1**

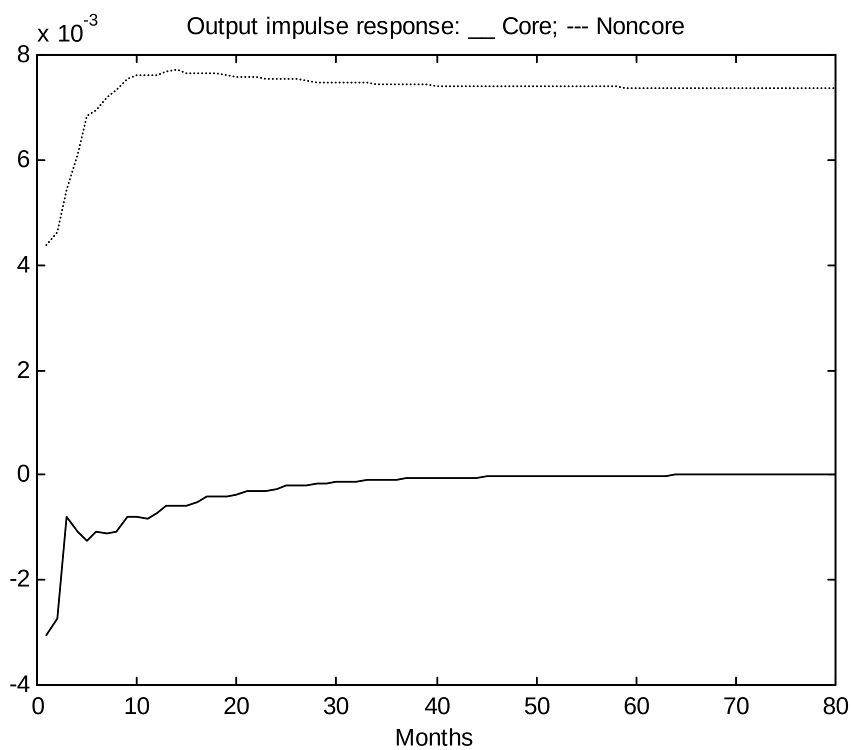


**Figure 2**

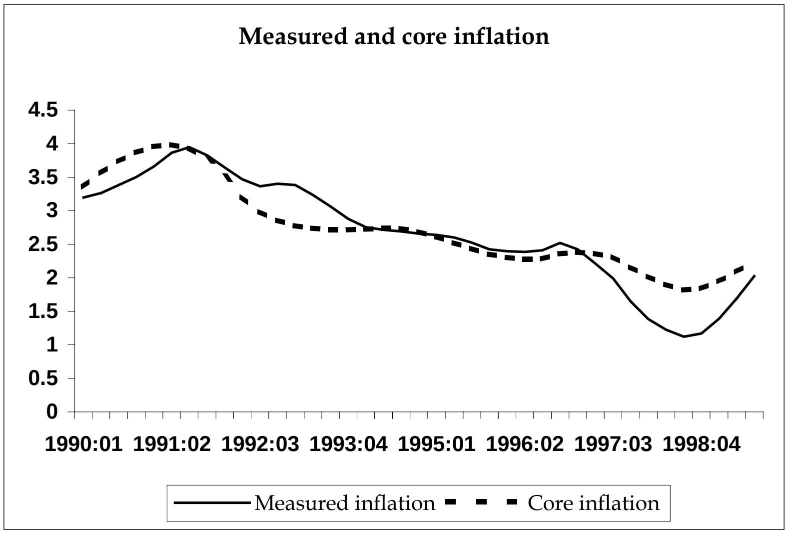


**Figure 3**

Variance Decomposition of Measured Inflation and Output
Percentage due to Core

| Horizon | Measured Inflation | Output |
|---|---|---|
| 1 | 86,7 | 18,6 |
| 4 | 83 | 12,9 |
| 12 | 75,9 | 8,5 |
| 8 | 72 | 6,4 |
| inf | 65 | 1 |

**Table 1**

## ONLY FOR REFEREES

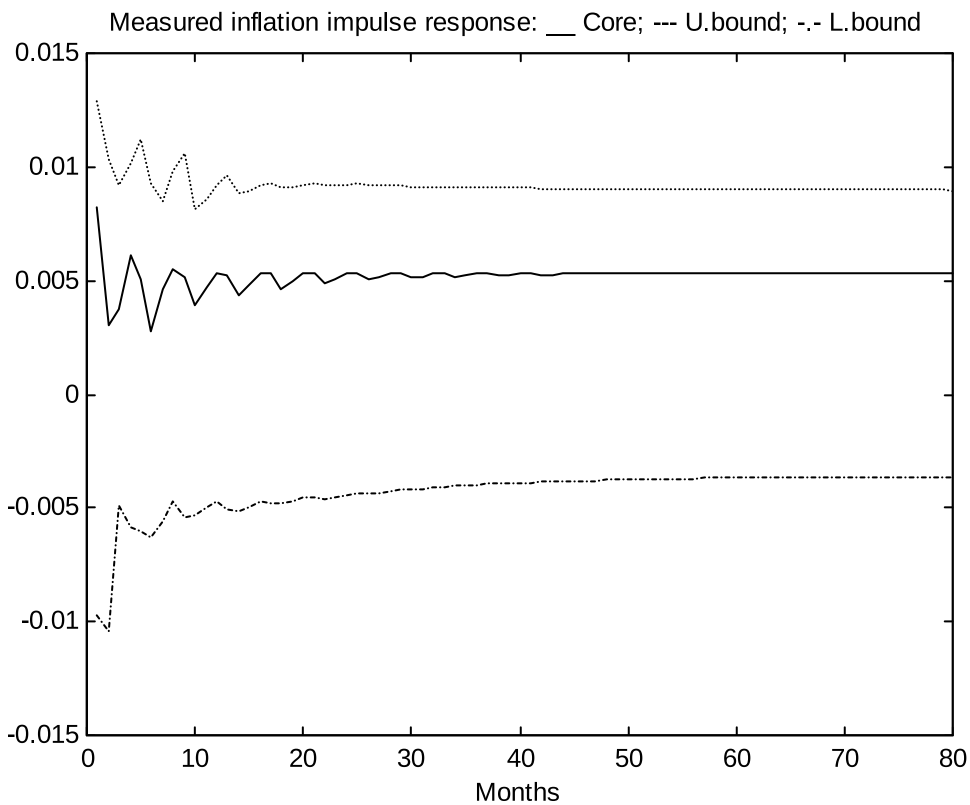


**Fig A 1**

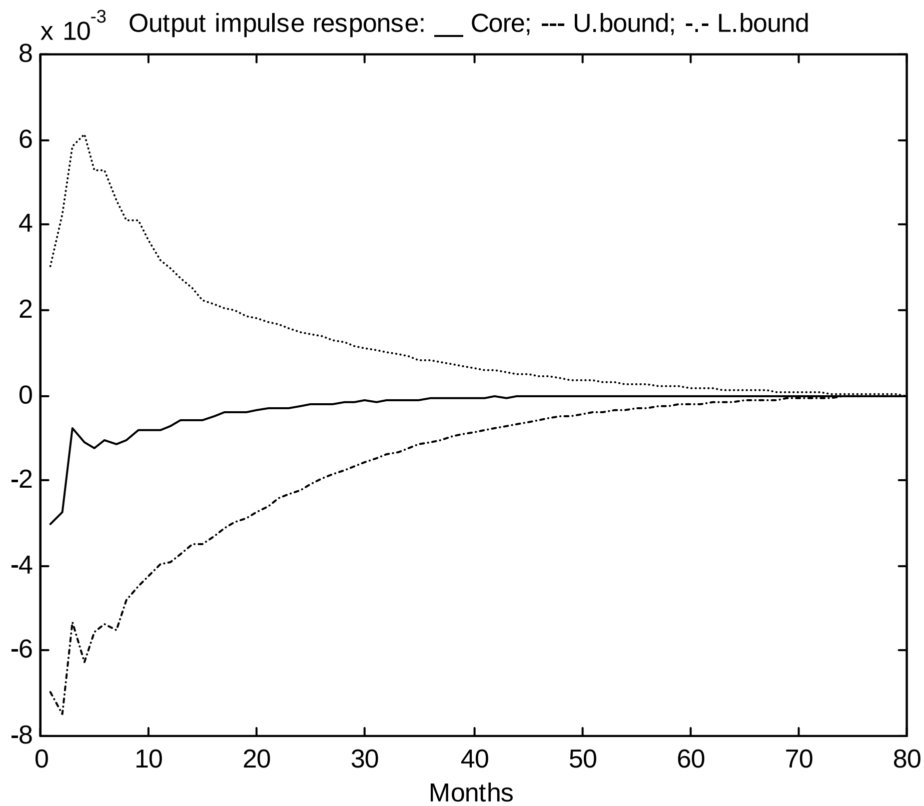
x 10-3 Output impulse response: __ Core; --- U.bound; -.- L.bound
8
6
4
2
0
-2
-4
-6
-8
0
10
20
30
40
50
60
70
80
Months

**Fig A 2**

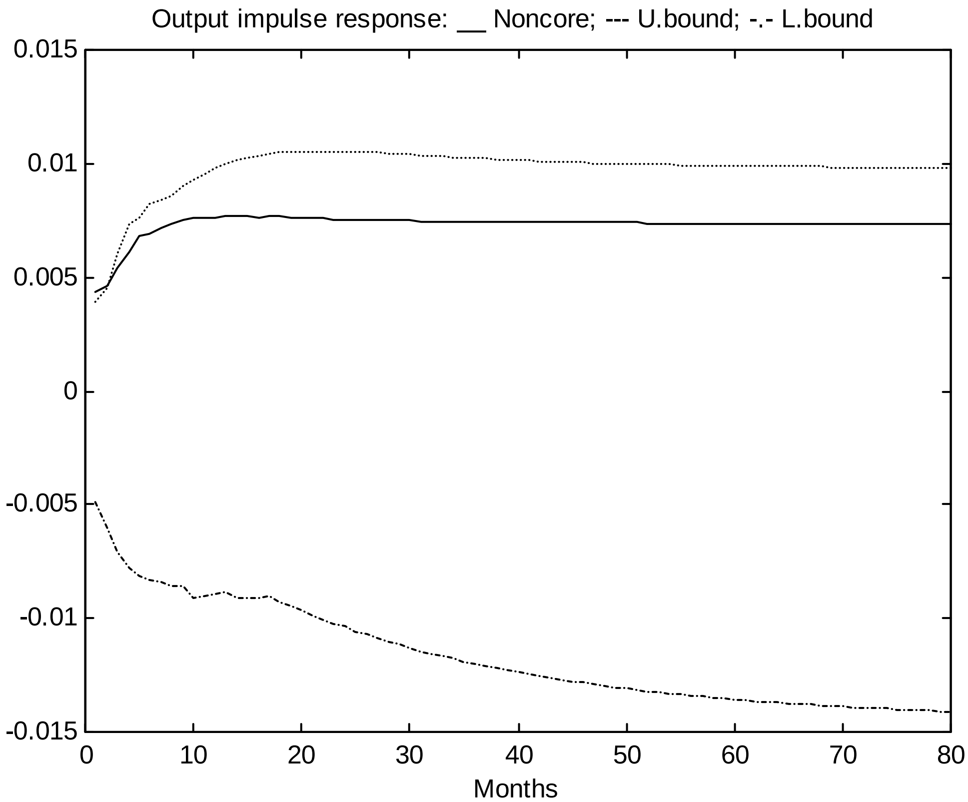


**Fig A 3**

Table A1
COINTEGRATION RESULTS

| Null | Altern | Eigen stat | 90% | 95% | 99% |
|---|---|---|---|---|---|
| r = 0 | r >= 1 | 27.830 | 21.873 | 24.252 | 29.263 |
| r <= 1 | r >= 2 | 15.599 | 15.001 | 17.148 | 21.747 |
| r <= 2 | r = 3 | 3.054 | 2.705 | 3.841 | 6.635 |

Table A2 : Diagnostic testes on the unrestricted VAR(4) system

| | Equation for: DY | DCPI | DM3 | Whole system |
|---|---|---|---|---|
| ARCH(5) | 6.40 | 5.8 | 10.12 | |
| BP-HETERO | 0.99 | 0.16 | 0.75 | 0.81 |
| NORM | 3.13 | 9.67 | 0.67 | 2.97 |
| AR(5) | 1.82 | 1.51 | 14.59 | 1.18 |