A VAR Model for the Analysis of the Effects of Monetary Policy in the Euro Area

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This paper, by the estimation of a structural VAR model on aggregate data from 1980 to 2002, examines the macroeconomic effects of an unexpected change in monetary policy on the euro area. The results are in line with the economic theory and they are close to the one estimated by other authors. These results, considering the formation of the European Monetary Union, give rise to some doubts and require some considerations. Thus, this paper discusses the limits of both the econometric technique used, and the data compilation methodology usually applied in these works. [JEL Code: E52]

1. - Introduction

On the 1st of January in the year 1999, with the formation of the European Monetary Union (EMU), the formulation and implementation of monetary policy in Europe was shifted from the individual countries that adopted the euro to the Eurosystem.[1] As

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[1] The Eurosystem is composed of the European Central Bank and the national central banks of the euro-countries.

prescribed by the Maastricht treaty, the primary objective of monetary policy is to maintain price stability within the euro area. This objective was quantified as a yearly increase in the inflation rate of less than 2 percent. Furthermore, without undermining price stability, the European Central Bank (ECB) can support the broader economic policy of the Community, thus contributing to the achievement of a high level of employment, and to a sustainable, and non-inflationary growth.

The objective of this paper is to construct an econometric model that may evaluate the effects of monetary policy on the main macroeconomic variables, in particular on prices and output; i.e. a model that is able to describe and evaluate the degree of efficiency with which the ECB pursues its objectives.

There are major factors to consider when constructing an econometric model for the euro area. A major problem in studying monetary relationships in the euro area is the lack of data available following the introduction of the euro. It may be decided that before any substantial econometric work is undertaken, it is preferable to wait until sufficient data is available. Alternatively, the literature has suggested two different ways of overcoming this problem. The first involves constructing European time series by aggregating national data for the period before the introduction of the euro, while the second entails the estimation of a model for each individual country.

In this paper, I follow the first alternative, on the basis of the consideration that, after the introduction of the euro, the objective and instruments of monetary policy are defined by the ECB at the euro-zone level. However, it is necessary to point out that the application of this method produces some very serious problems. It is easy to understand that there is no method for data aggregation before 1999 that is universally accepted. The literature, in fact, has suggested several different possibilities and the estimation results have shown them to be significantly influenced by the choice of the aggregation method. Moreover, from an economic point of view, the aggregation has meaning only if we accept the assumption that before 1999 there already was a common monetary policy; i.e. that the monetary policy actions of the individual countries were effectively coordinated. This idea seems to be acceptable for the period just before 1999, but is more difficult to accept as we go back in time. The experience of the Union's member countries about monetary policy is, in fact, very diversified. In conclusion, any method for the analysis of the effects of monetary policy that is based on a structural time series model suffers from Lucas' critique (1976). In particular, the introduction of a single currency is such an important institutional change that it may profoundly alter the economic behaviour of the private sector.

How does monetary policy influence the economy? To answer this question it is necessary to keep in mind that monetary policy actions reflect only in part the policy makers' responses to non-monetary developments in the economy. A given policy action and the economic events that follow it reflect the effects of all the shocks impacting the economy. Afterwards, to understand the effects of monetary policy on macroeconomic variables, it is necessary to separate the effects that are derived from pursuing institutional objectives from those that are developed from other events. One possibility is to concentrate the analysis on the effects of change that cannot be explained from the variables in the model, and thus can be interpreted as exogenous changes in monetary policy. At this point it is clear how changes in monetary policy do not depend on changes in goal variables. The problem then is to ensure that the "exogenous shocks" on which we base the analysis are not specification errors (residuals) in the econometric model, but can be seen as shocks in the economic sense. That is, all kinds of systematic components need to be eliminated, beginning with all the correlation between errors in the model.

Our strategy will be to simulate an unsystematic monetary policy action (*monetary policy shock*) and verify its effects on the system. In order to prevent other economic shocks from interacting with our experiment, we have to filter them out. This condition is never fulfilled in concrete situations, so it is necessary to operate to reach it. A pioneering approach by Friedman and Schwartz (1963), the so called "narrative approach" suggests looking at data that purportedly signal exogenous monetary policy actions; for example, Romer and Romer (1989) suggest examining records of Federal Reserve's policy deliberations to identify times in which monetary policy shock should occur.

A more commonly followed alternative involves making enough identifying assumptions to estimate the parameters of the central bank's *feedback rule*; the assumptions include the functional form assumption, an assumption about which variables the central bank looks at when setting its operating instrument and an assumption about what the operating instrument is. In addition, assumptions must be made about the nature of the interaction of the policy shock with the variables in the *feedback rule*.

The literature has not yet converged on a particular set of assumptions for identifying the effects of an exogenous shock to monetary policy. Nevertheless, there is considerable agreement about the qualitative effects of these shocks. In particular, after a restrictive unsystematic monetary policy action, we expect that short-term interest rates will rise, while aggregate output, employment, profits and various monetary aggregates will fall, the aggregate prices level will decline very slowly, and wages will fall, albeit by a small amount.

The procedure that is suggested and that we adopt in our analysis consists in the use of structural vector autoregressive models (SVAR). The greatest advantage of using structural VAR models is that in order to obtain identification it is necessary to impose a very small number of assumptions, without having to resort to a complete model of the economy.

The research was conducted on quarterly aggregated euro area data from 1980 to 2002. The series was constructed by aggregating national data for the period 1980-1998, and, for the following period, using Eurostat data.

For the estimation of parameters in the central bank's *feedback rule*, we have used the set of assumptions that refer to the *recursiveness assumption*, proposed by Christiano, Eichenbaum and Evans (2000) and by Eichenbaum and Evans (1995). According to this hypothesis, the monetary policy shock is orthogonal to the variables in the monetary authorities' *feedback rule*, i.e. these variables at time *t* do not react to monetary policy shock realizations at time *t*.

The estimation of a structural VAR model has produced results in line with the economic theory: an increase of the nominal interest rate (roughly 30 basis points) tends to be followed by a real appreciation of the exchange rate and by a temporary fall of output between the second and the sixth quarters after the shock. Prices react sluggishly and start to move down significantly only several quarters after output (about 8 quarters). Even if the estimated response is qualitatively similar to that estimated for the US, the intensity is significantly less important, giving support to the idea that the European economy is characterized by less price flexibility than the US economy.

The comparison of our results with those obtained by other authors, i.e. Peersman and Smets (2003), has shown that the effects of monetary policy shocks are different from those expected, even though this difference is less significant. From an economic point of view, we can deduce that a restrictive monetary policy shock causes a minor fall in output, but this fall is followed by a smaller reaction in prices suggesting their sluggishness. It seems very difficult to support this interpretation. In fact, the implementation of a single currency in the euro area has pulled down the transaction costs due to the use of different currencies and has eliminated so called exchange rate risks; all these factors have certainly brought about greater competition between the Union's industries, and as a consequence should have increased price flexibility.

Moreover, the tests conducted concerning the stability of the model suggest the presence of a change in the relationship between variables (*structural break*) either at the beginning of 1999 to coincide with the implementation of monetary union, or at the beginning of 2001 in correspondence with Greece's entry in the union. Then we can conclude that the difference between our results and the ones obtained by Peersman and Smets, though not very significant, is due to a structural change in the model. In order to evaluate this hypothesis it should have been enough to estimate the model allowing a structural change and evaluating if a substantial improvement is obtained. Unfortunately, because we have too few observations, we can't follow this strategy.

The paper is structured as follows. In Section 2 we give a theoretical model that describes the euro area's economic structure and monetary policy transmission mechanism. Section 3.1 explains the econometric methodology that was used. In Section 3.2 we describe data and in Section 3.3 the model. In Section 3.4 we present the results that are discussed in Section 3.5. Section 4 concludes.

2. - A Benchmark Theoretical Model

The European Union treaty has assigned to the Eurosystem the primary objective of maintaining price stability, reflecting in this way a general agreement that price stability is the best contribution that monetary policy can give to economic growth, job creation and social cohesion.

From an operative point of view, the ECB pursues its goal of price stability controlling the monetary base. In the short run the actions of monetary base control are transmitted to the market mainly through the interest rate channel. Their effects spread until prices are determined and production changes.

In the ECB's *modus operandi*, the idea of money neutrality prevails. In other words, any changes in the supply of money will determine only changes in prices in the long run. Real output and unemployment, in the long run, are determined by real factors (*supply-side*). These are: technology, population growth, consumer preferences and the institutional structure of the economy (property rights, fiscal policy, welfare policy and the rules that determine the market's flexibility, the incentives to supply of labour and capital, and investment in human capital).

Piecing together these considerations, we can represent the structure of the European economy with a standard version of the aggregate supply/aggregate demand (AS/AD) model, that assumes the presence of price and wage rigidities in the short run and perfect flexibility of these variables in the long run.

The structure of the economy can be summarised by the means of three equilibrium conditions: one for the goods market, one for the asset market and one describing the adjustment of prices over time, including a long-run neutrality restriction.

(1) $$m - p = \alpha y - \beta i - v_{md}$$ [LM]

(2) $$y = v_s - \delta\,(i - E\Delta p_{+1}) + \gamma y + v_{is}$$ [IS]

(3) $$\Delta p = \Delta p_{-1} + \phi\,(y - v_s)$$ [Phillips curve]

(4) $$\Delta m = v_{ms}$$ [Money supply process]

where variables are expressed in logarithms and the notation is standard with m being the (nominal) money stock, y the real output, p the prices level and i the nominal interest rate. v_s, v_{ms}, and v_{is} are random variables that describe supply, money supply, money demand and spending (IS) shocks.[2] Δ and E are the usual first difference and expectational operators.[3]

The dynamic response of the different variables to a shock will depend on the properties of those processes and on transmission mechanisms. Some of the predictions about the reactions of the system to different shocks are the following: shocks hitting the aggregate demand (v_{md}, v_{is} e v_{ms}) have short-run effects on output and other real variables as a result of slow adjustment of nominal variables; monetary shocks are transmitted to the real sector through changes in the interest rate; finally, real output and prices move in the same direction in response to an aggregate demand shock, but in opposite directions in response to an aggregate supply shock.

In order to close the model it is necessary to formalize a re-

[2] The steady state of that model is characterized by $y = v_s$, so v_s, can be interpreted as a process that describe the "natural" output.

[3] From an empirical point of view, GALI J. (1992) has shown that such a kind of model can characterize postwar business cycles in the US, while GERLACH S. - SMETS F. (1995) have adopted this scheme to identify monetary and real shocks in the G-7 countries.

action function for the monetary authority (*feedback rule*); that is a function that relates the central bank's actions to the state of the economy. Let s be a general monetary policy instrument, then that function can be written as:

$$s_t = f[.] + v_{mps}$$

where $f[.]$ is a function of goal variables and v_{mps} is a random variable that measures variations in the instruments, due to exogenous shocks that can't be associated with the object in $f[.]$. From an economic point of view, v_{mps} can represent different phenomena, such as the pursuit of different objectives from the ones in $f[.]$, which, for the ECB, is inflation. Another possibility, Ball (1995), is that v_{mps} represents shocks to expectations of private agents about central bank policy that can be self-fulfilling and lead to exogenous variations in monetary policy. An additional possibility, suggested by Bernanke and Mihov (1998), focuses on the measurement error in the preliminary data available to the central bank at the time it makes its decision.

Our goal is to try to quantify and describe the dynamics of the effects of the monetary shock v_{mps} on the macroeconomic variables.

3. - An econometric analysis on the sample 1980-2002

3.1 *The VAR models*

In this paper we analyse the effects of monetary policy using a structural VAR model. VAR models were first used by Sims (1980) and were developed, among others, by Bernanke (1986), Blanchard and Quah (1989) and Leeper, Sims and Zha (1996).

Lets suppose we have a set of n macroeconomics variables represented in a vector of stochastic process y_t, jointly covariance stationary, possessing a finite order (p) autoregressive representation.

$$y_t = A_1 y_{t-1} + A_2 y_{t-2} + \ldots + A_p y_{t-p} + \varepsilon_t$$

that can be written as:

$Y = \Pi X + \varepsilon_t$ where $\Pi = [A_1, A_2, ..., A_p]$ and where $X = [y_{t-1}', y_{t-2}', \dots, y_{t-p}']'$

here, p is a positive integer and ε_t has an independent multivariate normal distribution with zero mean, that is

$$\varepsilon_t \sim N(0, \Sigma) \qquad \det(\Sigma) \neq 0 \qquad E(\varepsilon_t \ \varepsilon_s' = [0] \ \forall s \neq t$$

If no restrictions are imposed on matrix Π, the ordinary least squares (OLS) parameter estimation asymptotically coincides with the maximum likelihood estimation and can be performed by the formulae $\hat{\Pi} = (X'X)^{-1}X'Y$.[4] Then, we can use fitted residuals $\hat{\varepsilon}$ for the estimation of matrix Σ with the formula

$$\hat{\Sigma} = T^{-1}\sum_{t=1}^{T}\hat{\varepsilon}_t\hat{\varepsilon}_t'$$

Lets suppose we know the A_i's, the ε_t's and Σ. It would still be impossible to calculate the dynamic response of variables y_t to the fundamental shocks that hit the economy. In fact, the error ε_t is the one-step-ahead forecast error. In general each element of ε_t is the effect of all fundamental shocks which can be deduced from the structure of the variance-covariance matrix Σ, which is not diagonal and thus it implies an interaction between the errors of the model. In order to interpret the errors as economic shocks, it is necessary to eliminate all systematic components, first of all the correlation between errors in the model; therefore, it is necessary to operate in order to obtain a variance-covariance matrix with a diagonal structure, i.e. $E(\varepsilon_t\varepsilon_t') = D$, where $D = diag$.

If we suppose that the residuals are a linear combination of the fundamental economic shocks, i.e. $\varepsilon_t = Ce_t$, with $E(e_t) = 0$ and $E(e_te_t') = I$, then we can write the model in his moving average representation as:

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[4] ZELLNER A. (1962) demonstrates that the OLS estimation of such a system is consistent and efficient if all the equations have the same set of explicative variables.

$$y_t = A\,(L)^{-1}Ce_t \qquad e_t \sim VWN\,(0, I_n)$$

Thus, the problem of the calculus of the dynamic response of variables to shocks can be solved with the estimation of the C matrix parameter. The equation, $\varepsilon_t = Ce_t$, involves the following relationship between the variance-covariance matrix of the reduced form and the structural shocks:

$$\Sigma = E\,(\varepsilon_t \varepsilon_t') = E\,(C\,e_t e_t'\,C') = C\,C'$$

If no restrictions are imposed, the system $\Sigma = C\,C'$ will have many solutions because it consists of n^2 unknowns from matrix C, and of $n\,(n + 1)/2$ equations, since Σ is an $n \times n$ symmetric matrix. In order to obtain the model identification, and thus a unique solution, it is necessary to impose and justify $n\,(n - 1)/2$ restrictions.

In the VAR literature one of the most widely used identification assumptions is the *recursive* system proposed by Sims (1980). The original proposal involves achieving orthogonal residuals via the triangular scheme imposed by matrix Σ's Choleski factor.

We can thus write the *moving average* representation as:

$$y_t = \Theta(L)Ce_t = \sum_{i=0}^{\infty} \Theta_i Ce_{t=i} = \sum_{i=0}^{\infty} \Phi_i e_{t-i}$$

with

$$\Phi_i = \Theta_i C \quad \text{and} \quad \Phi_0 = C \quad \text{Choleski factor of } \Sigma$$

Thus, because $\Phi_0 = \mathrm{C}$ is a lower triangular matrix, the shocks e_t have instantaneous effects on elements y_t according to the triangular scheme given by the Choleski factor.

3.2 *The Data*

The central problem of econometric analysis in the euro area is data availability. In fact, we have official area-wide data only since 1999, while, for the period before 1999, we have only national countries' time series. In order to perform econometric analysis it is necessary first to aggregate national data obtaining area-wide series, and then link this series to the ones provided by Eurostat. It is fair to say that there is no uncontroversial aggregation method for pre-1999 data. Moreover, we need to understand what the best procedure for linking pre-1999 to Eurostat data is.

The literature has proposed some aggregation methods. Thus, in Monticelli and Strauss-Kahn (1992) national data is first transformed in a single currency using current exchange rates vis-â-vis the ECU and then aggregated, while in Fase and Winder (1999) national data is transformed using fixed exchange rates. Fagan and Henry (1999), instead, propose to calculate area-wide data as a geometric weighted average of national data, without transforming data in a single currency. Thus, for any given variable x (expressed in logarithms) area-wide data is obtained as $X_z = \sum_z w_z X_z$,[5] according to a fixed weighted scheme w based on GDP at purchasing power parity (PPP).

The use of current exchange rates permits an obvious interpretation from an economic standpoint as, because they are market variables, they convert output and assets into effective spending power in nominal terms across borders. On the other hand, using current exchange rates involves *distorting* the dynamics of the series: growth rates, standard deviation and all moments in general are affected by movements in the exchange rates introducing a large number of spurious shocks in the series.

The use of fixed exchange rates avoids this distortion but amounts to proceeding "*as if*" the exchange rates between the European currencies did not vary, a hypothesis clearly contrasting with experience. However, it is true that analysing structural relationships between macroeconomic variables for given exchange rates amounts to assuming that the exchange rate is not a relevant variable, and this is true for the period post-1999, but it is absolutely false for the period pre-1999.

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[5] For the interest rate $x = \log(1 + i)$.

All these problem are solved using Fagan and Henry's method, that is the most widely used in recent econometric works: Monticelli and Tristani (1999) use a fixed weighted scheme given by relative output size in 1993 (at PPP exchange rates); whilst Coenen and Vega (2001), Coenen and Wieland (2000), Gerlach and Svensson (2003) and Peersman and Smets (2003) use data drawn from an "Area-wide model" (AWM) database by Fagan, Henry and Mestre (2001) which the weights used in aggregating individual country series are constant GDP at market prices (PPP) for 1995. Following the literature our choice is to use this last method and so draw data from the AWMI database.[6]

The problem of how to link pre-1999 to Eurostat data remains.

The criteria according to which the series are linked has been suggested by Fagan, Henry and Mestre and involves making a backdate operation of Eurostat series using the growth rates of the AWM series.

In conclusion, it is important to say that at the beginning the EMU was formed by eleven countries, but since the first of January, 2001, they have been joined by Greece. As a consequence, Eurostat time series are calculated for the area including eleven countries until December 2000, while since January 2001, the series are calculated including twelve countries; this fact gives rise to several pro blems for the series of GDP and M3, involving, in correspondence to the first quarter of 2001, some outliers. In order to avoid this problem, we chose to link pre-1999 data directly to the Eurostat time series that for the period January 1999-December 2000 include Greece.

3.3 *The Model*

The econometric analysis is conducted with a benchmark VAR model that has the following representation:

$$Y_t = A\,(L)\;Y_t + B\,(L)\;X_t + \varepsilon_t$$

[6] All the variables in the database are quarterly and seasonally adjusted.

$$A(L) = A_1 L + \ldots + A_p L^p$$

$$B(\mathrm{L}) = B_0 + B_1 L + \ldots + B_p L^p$$

where Y_t is a vector of endogenous variables and X_t is a vector of exogenous variables. The vector of exogenous variables contains a world commodity price index, US real GDP, and the short-term nominal interest rate:

$$X_t' = [cp_t \quad y_t^{US} \quad i_t^{US}]$$

We include these variables to control possible changes in world demand and inflation, thus helping to solve the so called *price-puzzle* (i.e. the empirical finding in VAR literature that prices rise following an interest rate tightening). By treating these variables as exogenous, we eliminate the possibility for foreign variables to be influenced by euro variables.

The vector of endogenous variables contains real GDP, consumer prices, short-term interest rate and the real effective exchange rate:[7]

$$Y_t' = [y_t \quad p_t \quad i_t \quad e_t]$$

Moreover, we present a different specification for the vector of endogenous variables with the inclusion of a broad monetary aggregate (M3) (henceforth model 2). This variable could help in the identification of the monetary shocks because historically, it played an important role in the monetary policy strategy of some of the EMU countries. Moreover, the ECB has assigned it a prominent role in the determination of its strategy:[8]

[7] Where the real effective exchange rate is expressed as foreign currency for euros, hence it follows that an increase in the exchange rate is equivalent to an appreciation of the euro.

[8] Specifically, the ECB looks to the deviation of M3 growth from a reference value which, under normal circumstances, is supposed to signal “risk to price stability”.

$$Y_t' = [y_t \quad p_t \quad m_t \quad i_t \quad e_t]$$

All variables are seasonally adjusted and log transformed, except the interest rate. We use the three month interest rate as the monetary policy rate. This choice is practically obliged as it is the only short term interest rate that is available for all countries over the whole sample period. It is believed not to be an excessively damaging choice because the main tools used for implementing the monetary policy consists of the interest rates at which liquidity is made available and of other measures that directly influence short-term interest rates. These tools were used by the national central banks and are now used by the ECB.

In both the first and second model, the VAR is estimated in levels using quarterly data over the sample 1980-2002.[9] In this paper we do not perform an explicit analysis of the long run behaviour of the economy.[10] By doing the analysis in levels, we allow for an implicit cointegration relationship in the data. However, in Appendix 2, we present both the results of a unit roots test and of cointegration tests. The unit root test demonstrates how all variables, except the interest rate, are $I(1)$. The cointegration tests (*trace test* and λ-*max test*), that are run on $I(1)$ variables, confirm that there are at least two cointegrating vectors.[11]

Regarding the estimation of VAR model with non stationary variables, some clarifications must be made. As we know, a time series is the realisation of a stochastic process, and without the hypothesis that the series is stationary, it is not possible to make an inference. Theoretically, if the variables are not stationary before making an inference, we should apply some transformations in order to obtain stationary variables. The presence of a cointe-

[9] The choice of the sample period can be justified by two considerations. First, approximately in 1980 start the EMS; second, some series are available only from this year.

[10] See COENEN G. - VEGA J. (2001) for an explicit analysis of long run behaviour of the euro area's economy.

[11] In the model used to compute the test statistic, the variables included are GDP, interest rate, consumer prices, and M3. Three lags are included for each variable. Furthermore, in the model are included a constant and a linear trend, while in the cointegration equation is included only a constant.

grating vector ensures us about the existence of a long run (stationary) relationship between variables. Hence the following idea: if the variables have some long run common behaviour, which kind of relationship do they have in the short run? This is the question we want to answer.

Technically, Sims, Stock and Watson (1990) show that in the presence of unit roots: *i)* the OLS estimate of parameters are consistent; *ii)* the coefficients in the original model with level variables are asymptotic normal if the model can be rewritten so that these coefficients are associated in the transformed model with stationary variables. Moreover, Sims, Stock and Watson (1990) show that the most traditional asymptotic tests are still valid if the VAR is estimated in levels.

About the non consideration of cointegration constraint, this choice can be justified with the following considerations. First, the analysis is generally focused on short-run constraints and the short-run dynamic response of the system; the exclusion of cointegration constraints only implies that the long-run response of some variables is not constrained and might follow a divergent path. However, the short run analysis is still valid. Second, Sims, Stock and Watson (1990) proved that standard asymptotic inference is not affected even when the variables included in the VAR in levels are cointegrated. Finally, although FIML estimates are no longer efficient if cointegration constraints are not included, they still remain consistent.

In the estimation of models, we have included a constant and a linear trend. Using standard likelihood tests and the usual lag length criteria, we have chosen the number of lags to include in the VAR, that turns out to be of order three.

In order to test the stability of the model we have run a Recursive Chow test starting in 1988:3 without any finding of instability at 5% confidence level.[12] Moreover, the possible instability was verified using a recursive residuals analysis, CUSUM test

[12] The Recursive Chow test verifies recursively whether the next observation is likely to be generated by the same model. A sequence of non-significant values of the test is a signal of a structural break point.

and CUSUM of square test. From this analysis we can detect a kind of instability in the model. About real variables there seems to be some evidence of a structural change after the beginning of the monetary union, in particular for prices. About interests rate, instead, the CUSUMSQ test shows a certain instability between 1992 and 1998, especially in the period of EMS's crisis when Italy and the UK left the treaty. We have closed the analysis performing a *test of predictive failure*. This test is presented in Appendix 3 for two possible break points, first in 2001, when Greece entered the monetary union, and the second in 1999 at the beginning of the single monetary policy. The results show that the only variable that has an unstable relationship is prices at both break points.

Even though there seems to be a certain instability in the model, we have chosen not to consider this instability and proceed with the analysis. This choice is mainly obliged as it is very difficult to estimate such a model including a relationship change. As we know, VAR models are over-parameterised; this fact, together with the scarce number of post-1999 observations complicates the use of *dummy* variables.

In order to estimate the structural form of the model, our choice is to follow the original proposal by Sims (1980), which is to use a Choleski decomposition of the variance covariance matrix with the variables ordered as presented.[13] The identification scheme that follows, refers to the so-called *recursiveness assumption*, by Christiano, Eichenbaum and Evans (2000) and by Eichenbaum and Evans (1995), which underlies the assumption that monetary policy shocks are orthogonal to the variables in the monetary authority's feedback rule, i.e. these variables do not react to monetary policy shock realization at time *t*. Using this scheme, we assume that the monetary policy shock, represented by an unexpected interest rate change in our model, has no contemporaneous impact on output, prices and money; furthermore, we assume that the monetary shock affects the exchange rate immedi-

[13] All the estimates, tests and graphs are obtained using RATS software, but the cointegrating tests are performed with E-Views.

ately, while exchange rate shocks does not have contemporaneous effects on the interest rate.[14]

Even though the identification scheme we have chosen does not perfectly correspond with the theoretical model previously used to describe the monetary policy transmission mechanism, the restrictions we have used impose some of the AS/AD model hypotheses. For example, the AS/AD model assumes the presence of price rigidities in the short run; this hypothesis correspond to the restriction that monetary policy shocks do not have contemporaneous effects on prices. In particular, what is really interesting is the formation of the monetary union, the adoption of the euro, and the effects caused by these phenomena. Moreover, the goal of this paper is not to evaluate how well the AS/AD model fits the euro area data, but it is to study the macroeconomic effects of monetary policy. Hence, we deduce that it be more important to put attention on the feedback rule's specification and on the hypothesis that is concerned with prices and GDP (the ECB goal variables), than to impose restrictions so that they perfectly reply the AS/AD model hypothesis. Anyway, the AS/AD model will be used to verify our results; that is, if our results differ from what are the economic theory predictions, we will reject the chosen identification scheme and the model in general.

3.4 *Results*

The results of the two models, with and without money, are shown in Graph 1. This graph gives the effects of a domestic, one-standard deviation, monetary policy shock on domestic GDP, domestic consumer prices, the exchange rate and the domestic short-term interest rate, together with a 90 percent confidence band.[15]

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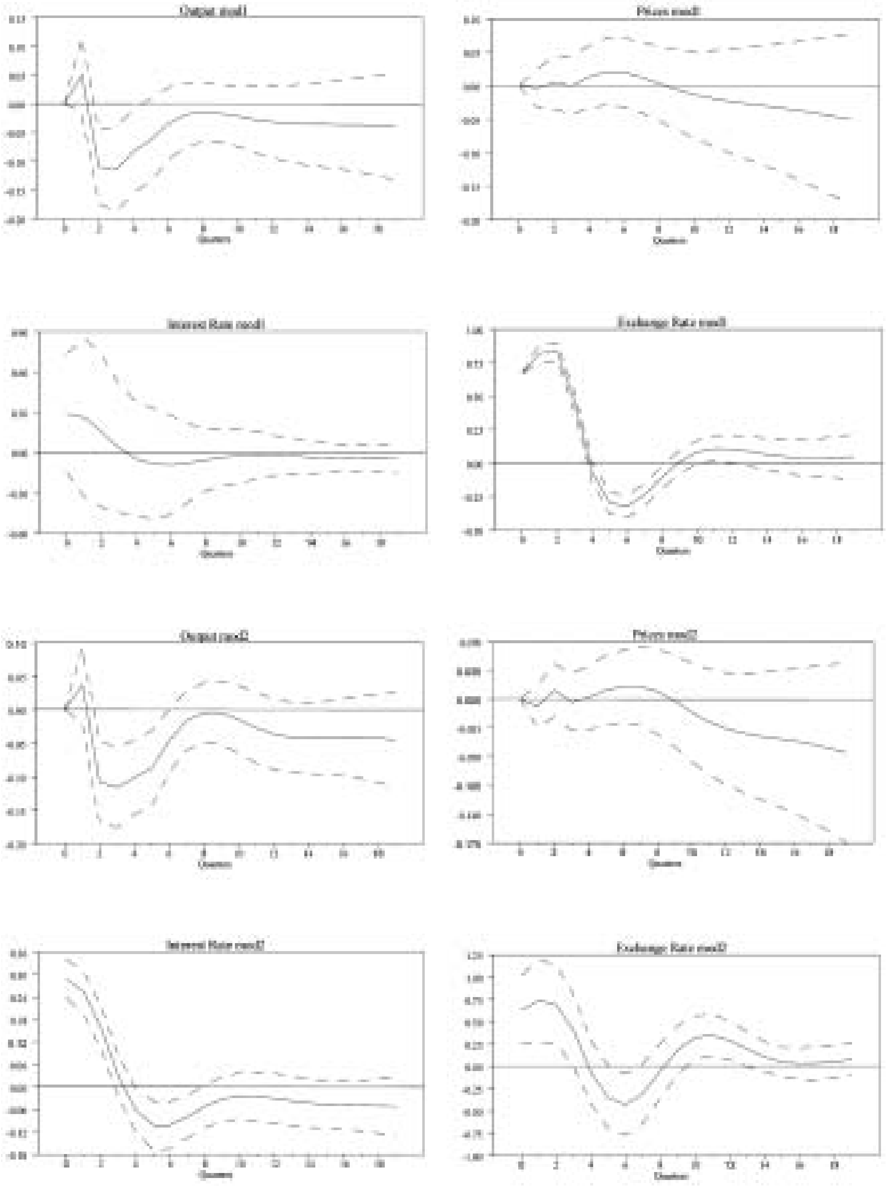
[14] This assumption is made for modelling the euro area as a closed economy.

[15] The confidence band is obtained through a standard bootstrapping procedure with 100 draws.

GRAPH 1

THE EFFECTS OF A MONETARY POLICY SHOCK
IN THE EURO AREA AND THE UNITED STATES
(1980-2002)



cont. GRAPH 1

THE EFFECTS OF A MONETARY POLICY SHOCK
IN THE EURO AREA AND THE UNITED STATES
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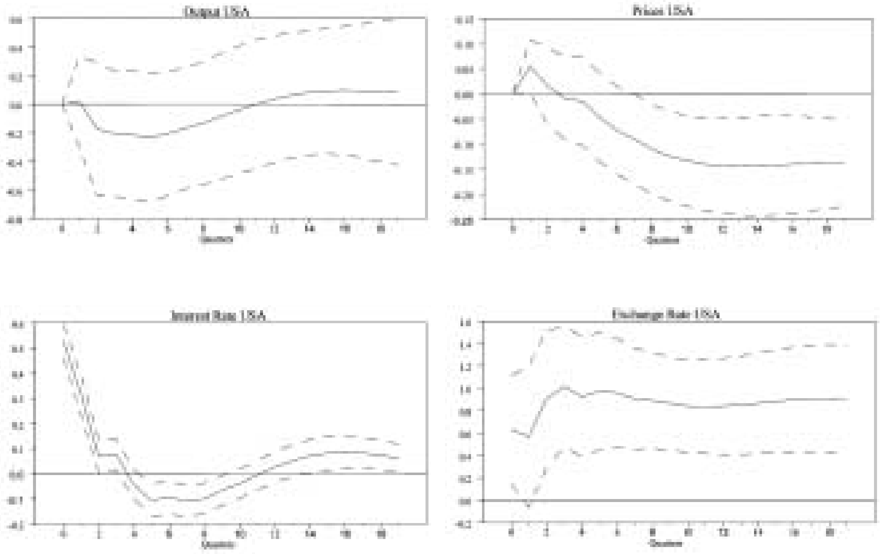

Shown on the above graphs are the results of a similar model for US data. The main difference with the model specification is for the exogenous variables. Following many other papers (e.g. Christiano, Eichenbaum e Evans, 2000), in order to avoid the *price-puzzle*, we introduce commodity prices in the vector of endogenous variable, $Y'_{US,\,t} = [cp_t \quad y_t^{US} \quad p_t^{US} \quad i_t^{US} \quad e_t^{US}]$. The sample period is the same and identification is again obtained using a standard Choleski decomposition with variables ordered as presented.

The results reported in the graph are broadly in line with economic theory. A monetary policy shock produces a temporary rise in the interest rate of about 30 basis points (bloch 2); the price's reaction is very sluggish, in fact only after about 8 quarters they begin a fall that tends to be persistent. GDP reacts after 2 quarters by decreasing and reaching its minimum after 4 quarters, after which it returns back to the baseline. The exchange rate tends to appreciate quickly as a consequence of the increase in the interest rate, reaching a peak after 2 quarters and then going back quickly to the pre-shock value.

A comparison of the first and second blochs of Graph 1 shows that overall the results obtained in the euro area models with and without money are very similar. The inclusion of M3 does lead to somewhat tighter estimates and, in particular, prices react quickly. Therefore, in the following analysis we will use model 2, i.e. those with money.

A comparison of the effects of a monetary shock in the euro area and in the United States points out the better flexibility of the US economy. We can infer that from the prices reaction, which is higher and faster in the US. In fact, in the US a monetary policy shock leads to an increase in the interest rate of 52 basis points; prices react quickly only after 2 quarters, while GDP reacts after 2 quarters with a fall that reaches a peak after 6 quarters.

Graph 2 shows the historical contribution of the monetary policy shocks to the short-term interest rate, whereas Table 1 provides the contribution of the monetary policy shocks to the variance of the forecast error of output, prices, the interest rate and the exchange rate at various horizons.[16] From Graph 2 we can see that the periods of expansive monetary policy can be situated during 1991, at the beginning of 1994 and after 1998. *Vice versa*, the

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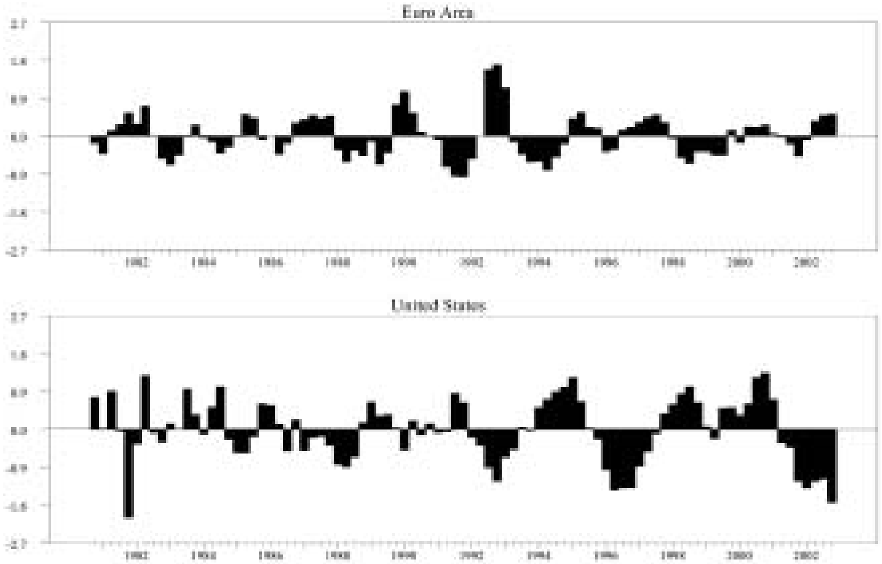
[16] The historical decomposition is based upon the following partition of the moving average

$$y_{T+j} = \sum_{s=0}^{j-1} \Psi_s e_{T+j-s}\ \beta + \left[X_{t+j}\beta + \sum_{s=j}^{\infty} \Psi_s e_{T+j-s} \right]$$

The first sum represents that part of y_{T+j} due to innovations in period $T+1$ to $T+j$. The second is the forecast of y_{T+j} based on information available at time T. If e has N components, the historical decomposition of y_{T+j} has $N+1$ parts:
– the Forecast of y_{T+j} based upon information at time T (the terms on the brackets).
– For each of the N components of e, the part of the first term that is due to the time path of that component.

GRAPH 2

CONTRIBUTION OF A MONETARY POLICY SHOCKS
TO THE SHORT-TERM INTEREST RATE



periods characterized by a tight monetary policy are at the beginning of 1990 (possibly in association with the reunification of Germany) and during the EMS crisis at the end of 1992 and the beginning of 1993.

The timing of these episodes is quite different from those in the US. In fact, the correlation coefficient between monetary shocks in the euro area and in the US is close to zero (–0.026).

Table 1 shows that the contribution of monetary shocks to output and the interest rate is rather limited. As the policy shock captures deviations from the "normal" monetary policy over the estimation period, this result was expected and is in line with the VAR literature. Besides, if we should obtain different results, these should be considered as a signal of some problem in the model.

TABLE 1

CONTRIBUTION OF MONETARY POLICY SHOCKS
TO THE FORECAST ERROR VARIANCE DECOMPOSITION
(in percent)

	Horizon				
	1 year	2 years	3 years	5 years	10 years
	Euro Area				
Output	11.7	15.4	12.0	8.6	4.5
Prices	0.2	0.1	0.9	2.4	2.5
Interest rate	58.5	43.6	36.0	24.0	9.6
Exchange rate	12.0	11.5	12.6	12.5	9.0
	United States				
Output	5.2	9.3	9.0	9.7	10.5
Prices	0.7	2.6	8.1	15.4	21.8
Interest rate	58.7	33.2	30.8	29.6	29.4
Exchange rate	8.5	13.1	15.3	18.6	21.8

3.5 *Some Observations*

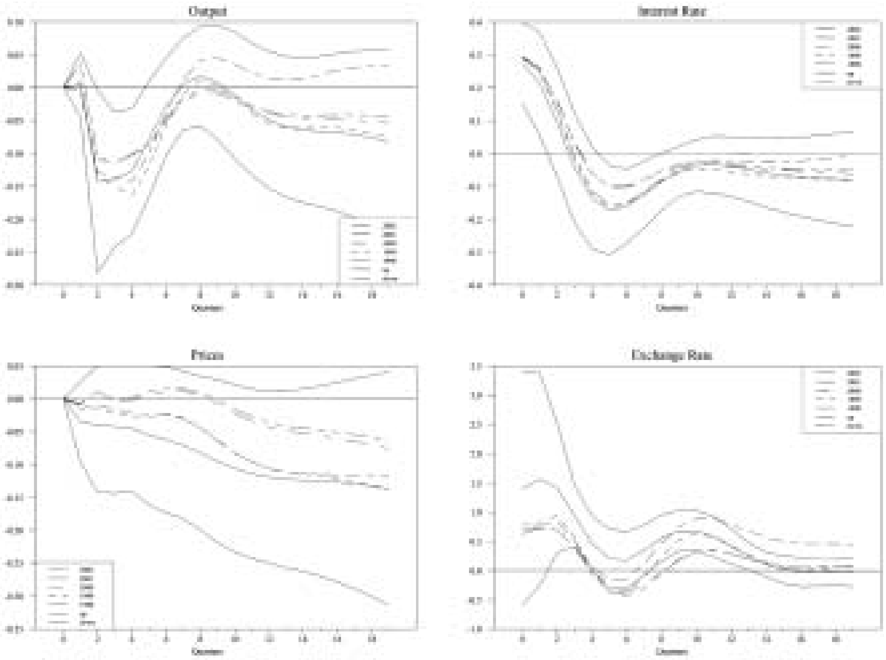
Having examined these results, we turn to their role in the literature. Graph 3 shows the impulse response functions that we have obtained estimating the model with different time horizons, choosing as the last observation the fourth quarter of 1998, 1999, 2000 and 2001, respectively. The so-called model 1998 is the reproduction of the results obtained by Peersman and Smets (2003).

It shows that the impulse response functions are sufficiently stable, in fact they are almost within the confidence interval estimated for model 1998. About the estimated prices' reaction, they are more reliable if compared with the ones obtained without regard to Greece's entry in the union (model EU11) (Graph 4).

Nevertheless it is necessary to note that the estimated prices' response is not what we expected, if we compare these reactions with the estimates by Peersman and Smets, although the difference is not very significant.

GRAPH 3

THE EFFECTS OF A MONETARY POLICY SHOCK
COMPARISON BETWEEN THE MODEL 1998-1999-2000-2001-2002*



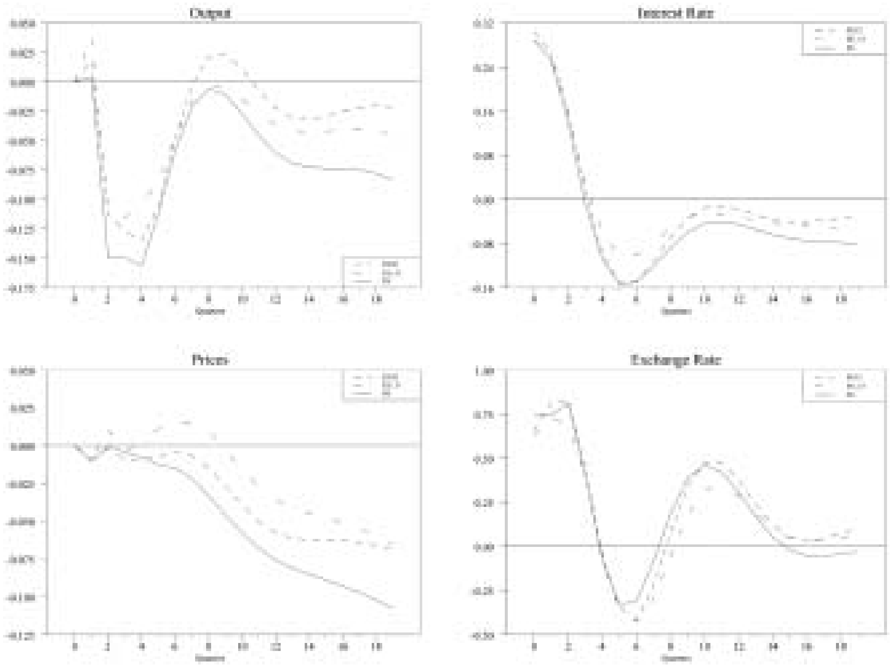
* The solid lines represent the results of 1998 model with the relative confidence interval.

Why did we obtain different results from Peersman and Smets by changing the sample period?

From an economic point of view, looking at the Graph we can conclude that a restrictive monetary policy shock causes only a minor fall in output, but this fall is followed by a smaller reaction in prices suggesting their sluggishness. However, it seems very difficult to support this interpretation. Indeed what we expected was in the contrary; that is, more prices flexibility due to greater competition between the industries of the Union. Although the circulation of goods, labour, capital and services were already freed on January 1st, 1993, the implementation of a single currency in the euro area further pulled down the transaction costs due to the use of different currencies, and eliminated the exchange rate risk. Furthermore, the important interbank market was fully integrated since day one. In fact, with the creation of TARGET[17] there is no possibility for interest-rate arbitrage inside the Union.[18] All these factors certainly have driven toward greater integration among national markets, and consequently greater competition among the industries of the Union.

GRAPH 4

THE EFFECTS OF A MONETARY POLICY SHOCK
COMPARISON BETWEEN THE MODELS EU12, EU11
AND PEERSMAN&SMETS



[17] Trans-European Automated Real-Time Gross settlement Express Transfer.

[18] ANGELONI I. - EHRMANN M. (2003), starting with this observation, point out that "key bank decision variables, the prices on the products they offer, have started behaving in a different way exactly at the time and in the way one would expect" (p. 21). Even though the reason for this change is not perfectly clear, "banks could have behaved in such a way because of increased pressure from the euro-induced new competitive environment" (p. 21).

We must notice that the stability test suggests the presence of a change in the relationship between variables (*structural break*) around the beginning of 1999, i.e. at the time of the implementation of monetary union. We conclude that the difference between our results and those obtained by Peersman and Smets, although not very significant, is due to a structural change in the model. In order to evaluate this hypothesis it should have been sufficient to estimate the model allowing a structural change, and evaluate if substantial improvement is obtained. Unfortunately, because we have little data for the period post-1999, we can't follow this strategy.[19]

Moreover, the results for the so-called model 1999 and model 2000 are in the expected direction. However, when we include the year 2001 in the sample space, it is no longer clear if the structural change is at the beginning of 1999 or at the beginning of 2001 in correspondence with Greece's entry in the Union.

At this point, we may ask: what is the source of the model instability?

One hypothesis is that we have encountered the Lucas critique (1976), that is to impute structural change to the change in monetary policy regime due to the formation of the EMU. About that, Angeloni and Ehrmann (2003) discard this hypothesis and sustain that "EMU is a *process*, not a one-time event" (p. 6); therefore "the transition to a new currency and monetary policy was something economic agents had time to prepare for, and adjust for, over a number of years" (p. 6).

On the other hand, we can suppose that the passage from an adjustable to a fixed exchange rate regime has, in some way, influenced the estimation of the effects of monetary policy shocks on prices. For example, Italy resorted frequently to lira devaluations in which the initial positive effects on exports are slowly absorbed by rising prices. If Italy devalues the lira, the aggregate variables will show a rise in prices and a change in the real ef-

[19] Technically the estimation is possible, but because we have few degrees of freedom, it is not possible to calculate the standard error and then perform the usual hypothesis test. Moreover the estimate obtained would not be reliable.

fective exchange rate. The problem is that the changes that we see in prices and in the exchange rate are generally different. If in our model exchange rate variations can't fully explain the price changes, it is possible that we are over-estimating the effects of interest rate changes on prices i.e. the effects of monetary policy shocks. Since the formation of the EMU, devaluations are no longer possible. It is as if we had lost a source of price variations that implied an over-estimation of the effects of monetary policy shocks; hence we can infer that it is not prices which have become less flexible, but their flexibility was previously overestimated.

Moreover we have to consider that the period from about 1996 to current time is characterized by low inflation, low interest rates and relative stability, in complete contrast with the previous period characterized by high inflation and high interest rates. Yet, income's behaviour (growth rate) remains mainly unchanged during the sample space; what probably has changed is the income-prices/exchange rate relationship, not the prices-interest rate relationship. Such variation implies a change in the model parameter that, ultimately, will imply a different path of the *impulse response functions* (which themselves are a model parameter function).

In conclusion, we have to say that one of the main problems affecting our analysis refers to data homogeneity. The data before 1999 is calculated on 11 countries, while for the period post-1999 it is calculated on 12 countries.

Another problem concerns the data compilation methodology. The pre-1999 series are drawn from the AWM database where area-wide data are calculated as geometric weighted averages of national data according to a fixed weighted scheme based on constant GDP at market prices (PPP) for 1995. Post-1999 data is instead taken from Eurostat. The compilation methodologies are very much different:

1. GDP is expressed in euros and is calculated as the sum of national data. For the period 1999:Q1–2000:Q4 Greece's GDP was converted in to euros using the average exchange rate drachma/ECU of 1995.

2. The real effective exchange rate is calculated as a geometric weighted average of the bilateral exchange rates of the euro against the currencies of the partner countries, whilst in the AWM database it is computed as a weighted average of national real effective exchange rates.[20] For the period 1999:Q1 - 2000:Q4 the exchange rate is calculated with the inclusion of Greece using the drachma/euro exchange rate.

3. Eurostat published as a consumer prices index a weighted arithmetic average of national HICP[21] with country weights changing each year,[22] whilst in the AWM database it is computed as a weighted average of national *Consumer Prices Index* (CPI) according to a fixed weighted scheme.[23] Moreover, the HICP is calculated as a chain index and it is expressed mathematically as:

$$I_{Eur12}(Jan99) = \left(\sum_{c \in Country} \frac{I_c(Jan99)}{I_c(Dec98)} \cdot w_c(1999) \right) \cdot I_{Eur12}(Dec98)$$

where I_{Eur12} $(Jan99)$ is the all items index for Eur-12 in January 1999, I_c $(Jan99)$ is the all items index for one of the EMU countries in January 1999 and w_c (1999) is the country weight for 1999, whilst in the AWM database the index is computed as:

$$I_{Eur11}(Jan98) = \sum_{c \in Country} I_c(Jan98) \cdot w_c{}^{24}$$

In conclusion we have to say that the AWM database prices index is an average of 11 countries while the Eurostat data is computed for twelve countries.

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[20] Which themselves are a geometric weighted average of the bilateral exchange rates of the national currency against the currencies of the partner countries.

[21] *Harmonized Index of Consumer Prices.*

[22] The weights of each country is its share of private domestic consumption expenditure in the euro area.

[23] We have to keep in mind that the basket of goods used for the HICP is different from the one used for the CPI. The AWM prices index is calculated using CPI because the HICP time series starts only in 1995.

[24] Eurostat uses a chain index because the weights (both country weights and item weights) may change every year. A simple weighted average would produce a discontinuous index, while the chain index takes account of the changes in weights.

4. Interest rates and monetary aggregates are directly obtained on the area-wide market without applying any transformation.[25] In the period from January 1999 to December 2000 the interest rate is a weighted average of interbank rates (EURIBOR) and ATHIBOR where the weights are GDP. In the same period Greece's value in the various M3 components is integrated having been previously converted in to euros.

Given these clarifications concerning data, we cannot rule out that the structural change in the relationship between variables is due to the different methodology used for data compilation. If we want to go on using this methodology we can do nothing except wait until more data is available and then estimate the model including a structural change.

Otherwise it is possible to abandon the methodology that consists in joining two different databases. We have two possibilities in this respect: first, we can wait until Eurostat and the ECB construct a new series for pre-1999 data using a methodology "more compatible" with the post-1999 data, or second, we can change one of the two compilation methodologies thus obtaining more homogeneous observations.

This second possibility is the only one that we can follow immediately. Concerning this it is necessary to make a distinction between real variables (output and prices) and monetary variables (interest rate, exchange rate and monetary stock).

Regarding real variables, it is possible to change both methodologies. For example, we can substitute Eurostat data aggregating national data using the AWM database methodology. Alternatively, we can aggregate pre-1999 data discarding Fagan and Henry's (1999) methodology for an aggregation based on data previously transformed in a single currency using fixed or current exchange rates.

On the other hand, concerning monetary variables we can only modify pre-1999 data compilation techniques; in fact, since the im-

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[25] As we have previously indicated, since the implementation of the single currency, interest rates are directly determined because the market is perfectly integrated. The same is true for monetary aggregates, whose components are directly observed on the area-wide market.

plementation of the single currency these variables are directly observed on the euro area market, and, besides, the observation of these variables on a national scale does not make sense. The problem is that these changes are less intuitive than the ones proposed for the real variables. For example, interest rates have to be necessarily calculated as an average of national data because interest rates do not depend on exchange rates; at this point the problem is choosing the best weighting scheme. That is, to understand how to build weights, if it is better to use a fixed or a variable scheme, etc. Concerning money stock, we are not constrained to choose an aggregation using a weighted average. For example, we can construct area-wide data using a sum of national money stocks previously transformed in ECU (using fixed or current exchange rates). Regarding real effective exchange rate, we have to understand if it is better to construct an average of national rates or to try and create a measure directly for the ECU.

In conclusion, we cannot exclude that for each variable it is necessary to effect a specific change in the data compilation methodology; this should imply working with time series constructed using different rules. Therefore, we have to understand if and which problems imply doing analysis using variables aggregated with different methodologies.

As can be deduced by the number of proposal and by their diversity, a change in methodology would require knowledge which is not the aim of this paper.

4. - Conclusions

This paper, by the estimation of a structural VAR model on quarterly aggregate data from 1980 to 2002, examines the macroeconomic effects of an unexpected change in monetary policy on the euro area considered as a whole.

The results are in line with the economic theory: a monetary policy shock produces a temporary increase of the nominal interest rate that tends to be followed by a real appreciation of the exchange rate and by a temporary fall of output between the second and the sixth quarters after the shock. Prices react sluggishly and start to move down significantly only several quarters after output. Even though the estimated response is qualitatively similar to that estimated for the US, the intensity is significantly less important, giving support to the idea that the European economy is characterized by less price flexibility than the US economy.

Moreover, we have compared our results with those of other authors, specifically Peersman and Smets (2003). Our analysis is identical to the one conducted by Peersman and Smets (2003), but differs solely in sample size. In fact, Peersman and Smets (2003) analyze data up to 1998, that is, before the formation of the monetary union. Whereas, we extend the sample by including data up to 2002.

The goal of this comparison was to understand how the estimation of the monetary policy transmission mechanism would change once we include "real" euro area data in the analysis. The question we asked was the following: Are the possible differences in the estimation results caused by technical factors or by the effects of the shift to a common monetary policy?

The results of this comparison are different from those expected; in fact, a restrictive monetary policy shock causes a minor fall in output, but this fall is followed by a smaller reaction in prices suggesting their sluggishness. It seems very difficult to interpret these results. In fact, the implementation of a single currency in the euro area has pulled down the transaction costs due to the use of different currencies and has eliminated so called exchange rate risks; all these factors have certainly brought about greater competition between the Union's industries, and as a consequence should have increased price flexibility.

However, it is necessary to take into account that this analysis is unfortunately affected by many problems, first of all the data. In fact, the series was constructed by aggregating national data for the period 1980-1998, and, for the following period, using Eurostat data. It is fair to say that there is a big difference between these two datasets, but, at this time, this is probably the best way to conduct such a kind of analysis.

Moreover, the test conducted concerning the stability of the model suggests the presence of a change in the relationship between variables (*structural break*) either at the beginning of 1999 to coincide with the formation of the monetary union, or at the beginning of 2001 in correspondence with Greece's entry in the union. In order to overcome this problem it should have been enough to estimate the model allowing a structural change, but, because we have too few observations, we can't follow this strategy.

In conclusion, we think that the difference between our results and the one obtained by Peersman and Smets (2003) can be attributed more to technical factors than to changes in the monetary policy transmission mechanism. Hence, we conclude that in order to evaluate quantitatively, the effects of the shift to a common monetary policy and of the adoption of the euro, it is necessary to wait until more data will be available.

APPENDIX 1

Variable	Source	Code	Description	Sample
Output EU	AWM Database	yer	Euro-zone[1] GDP real	1980-1998
y	Eurostat - New Cronos Database	na-b1gm-kp95-sa-mio_eur	Euro-zone 12 GDP 1995 PRICES	1999-2002
Prices EU p	AWM Database ECB	hicp ICP.M.U2.S.000000.3.INX	Euro-zone HICP Euro-zone 12 HICP - Overall index	1980-1998 1999-2002
M3 EU m	AWM Database ECB	m3SA BSI.M.U2.Y.V.M30.X.1.U2.2300.Z01.E	Euro-zone M3 Euro-zone 12 Monetary aggregate M3	1980-1998 1999-2002
Interest rate EU i	AWM Database ECB	Stn RT.MM.EU12.3M.LAST	Euro-zone short-term interest rate Euro-zone 12 Reuters. Money market.Euro. Euribor 360.3 months.Last	1980-1998 1999-2002
Exchange rate EU	AWM Database	eer	Euro-zone real effective exchange rate	1980-1998
e	ECB	EXR.M.Z10.EUR.ERCO.A	Euro-zone 12 real effective exchange rate CPI deflated	1999-2002
Commodity prices cp	IFTS Database	00176AXDZF…	World export commodity price index	1980-2002
Output USA y^{US}	IFS Database	11199B.RZF…	US GDP 1996 prices	1980-2002
Prices USA p^{US}	IFS Database	11164…ZF…	US Consumer prices index	1980-2002
Interest rate USA i^{US}	IFS Database	11160B…ZF…	US Federal Founds Rate	1980-2002
Exchange rate USA e^{US}	IFS Database	111REUZF…	US Real Effective Exchange Rate based on RNULC	1980-2002

* EUROZONE = 11 countries
EUROZONE12 = 12 countries

APPENDIX 2

AUGMENTED DICKEY-FULLER T-TEST*

	Critical values			*t*-test
	1%	5%	10%	
Output	–4.04	–3.45	–3.15	–1.9791
Prices	–4.04	–3.45	–3.15	–2.9581
Money	–4.04	–3.45	–3.15	–2.5299
Short rate	–3.51	–2.89	–2.58	–1.1125
Exchange rate	–3.51	–2.89	–2.58	–3.0181

* The number of differences to include in the regression for computing the statistic has been selected using the BIC criterion. For output, prices and m3, in the regression has also been included a linear trend.

COINTEGRATION TEST

Trace test

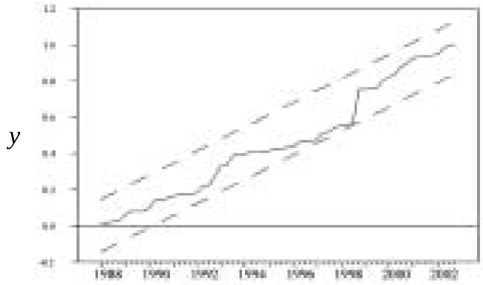
Hypothesized No. of CE(s)	Critical values		Statistic	Eigenvalue
	1%	5%		
None	54.46	47.21	71.86849	0.374254
At most 1	35.65	29.68	30.14427	0.176582
At most 2	20.04	15.41	12.85229	0.088532
At most 3	6.65	3.76	4.602131	0.050395

λ-max test

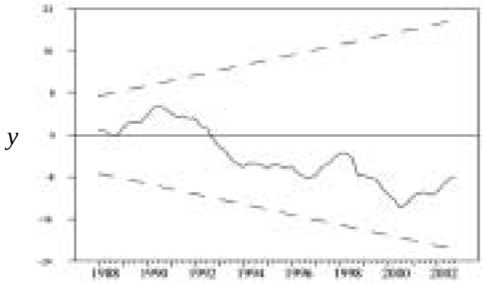
Hypothesized No. of CE(s)	Critical values		Statistic	Eigenvalue
	1%	5%		
None	32.24	27.07	41.72422	0.374254
At most 1	25.52	20.97	17.29198	0.176582
At most 2	18.63	14.07	8.250161	0.088532
At most 3	6.65	3.76	4.602131	0.050395

APPENDIX 3

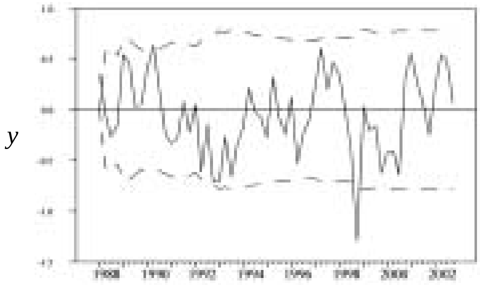
CUSUMSQ



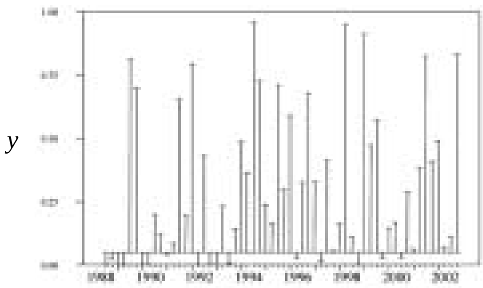
CUSUM

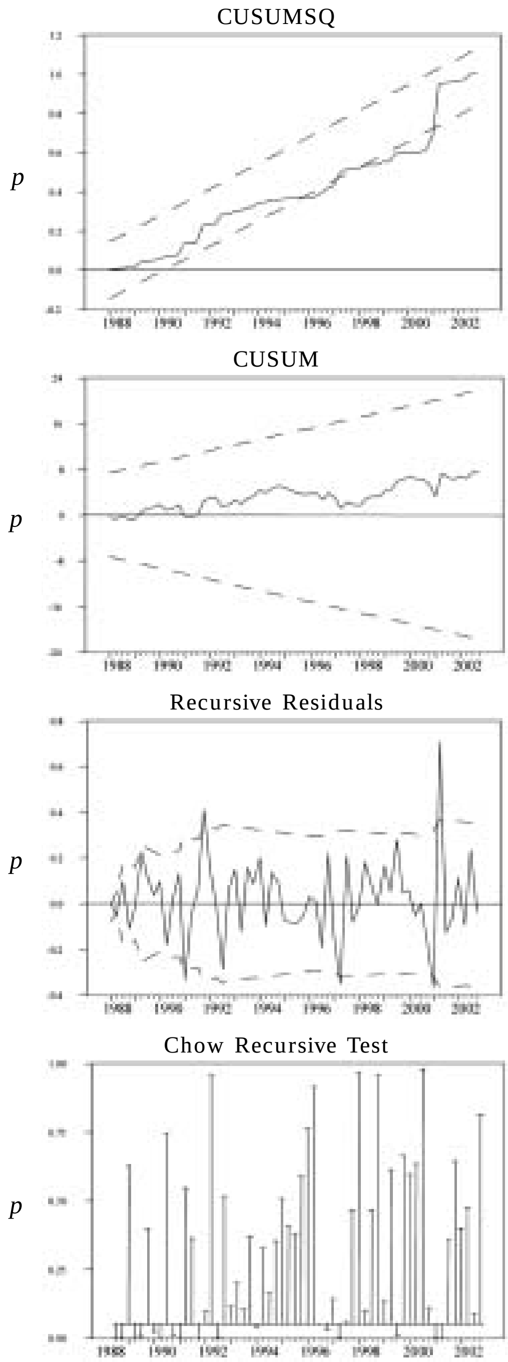


Recursive Residuals



Chow Recursive Test

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p
1988 1990 1992 1994 1996 1998 2000 2002
CUSUM
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1988 1990 1992 1994 1996 1998 2000 2002
Recursive Residuals
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Chow Recursive Test
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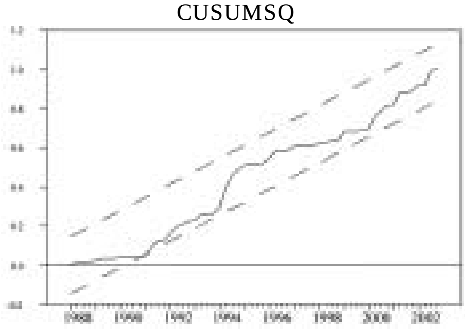
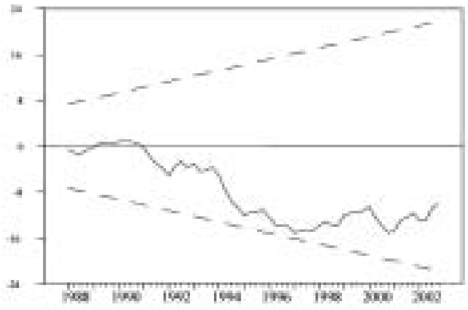
CUSUMSQ

m



CUSUM

m



Recursive Residuals

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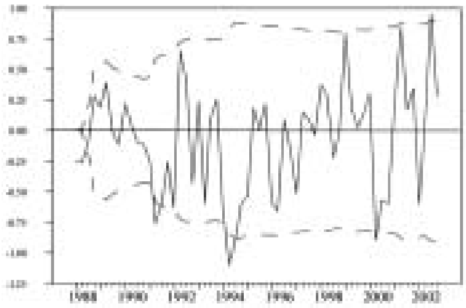

Chow Recursive Test

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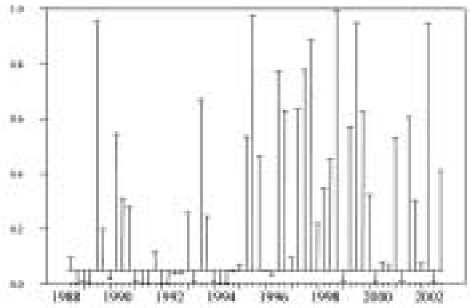
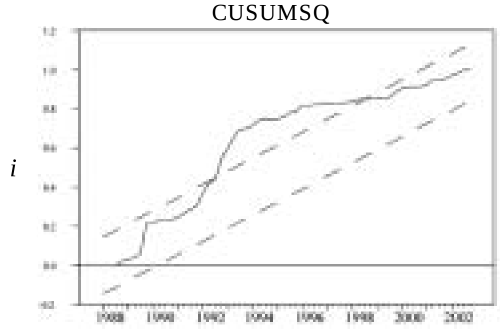
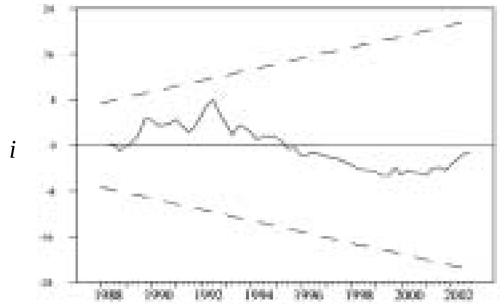


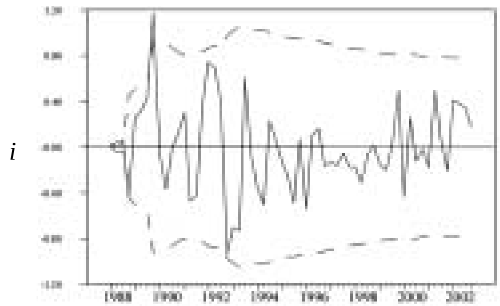
CUSUMSQ



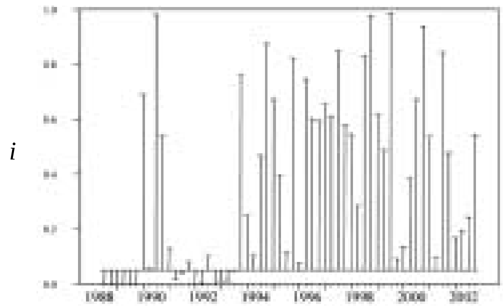
CUSUM

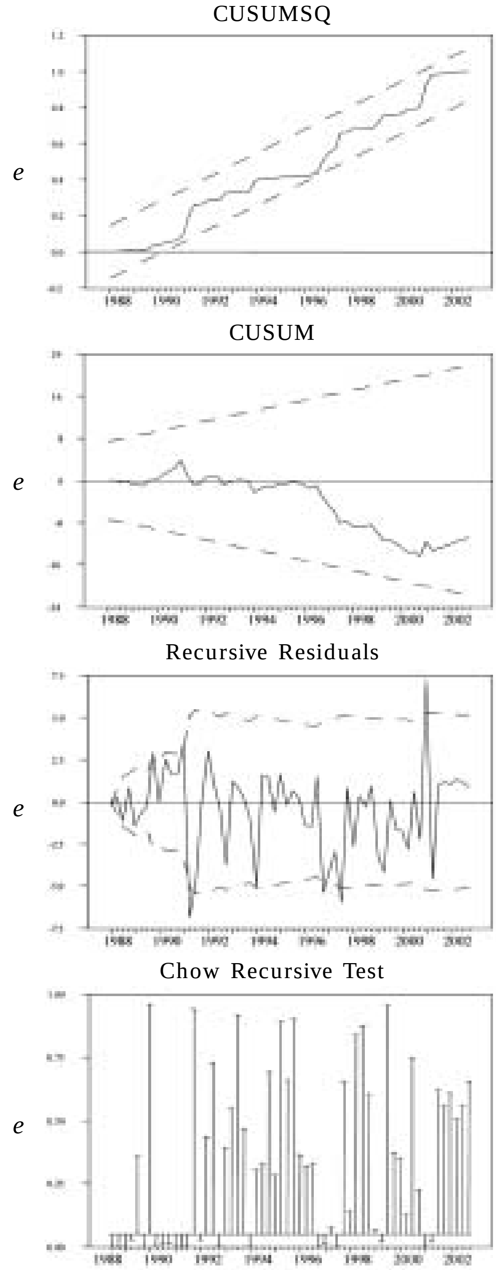


Recursive Residuals



Chow Recursive Test





For the CUSUMSQ test and for the CUSUM test, the dotted lines represents confidence interval at 5 % level.
For Recursive Residuals, dotted lines are defined as ± 2 standard errors.
For Chow recursive test dotted line is 5%.

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