MONETARY POLICY TRANSMISSION IN THE EMS: A VAR APPROACH*

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WP-EC 97-11

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Editor: **Instituto Valenciano de Investigaciones Económicas, S.A.**
Primera Edición Octubre 1997.
ISBN: 84-482-1584-2
Depósito Legal: V-3846-1997
Impreso por Copisteria Sanchis, S.L.,
Quart, 121-bajo, 46008-Valencia.
Impreso en España.

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ABSTRACT

This paper analyzes monetary policy transmission in the European Monetary System using VAR techniques. After a discussion of several VAR identification procedures for the stance of monetary policy, this paper proposes an identification scheme that is essentially consistent with the basic facts and does not have significant puzzles. The strategy is based on extracting the stance of monetary policy from the German system and using that structural shock in the VAR systems of other countries of the EMS. The results show that the stronger the commitment with the EMS discipline, the stronger the effect of the German monetary policy on the monetary policy of other EMS countries and the weaker the effect on the exchange rates.

KEY WORDS: Monetary policy transmission, structural VAR.

RESUMEN

El documento analiza la transmisión de la política monetaria en el Sistema Monetario Europea usando técnicas de VAR (Vectores Autorregresivos). Tras discutir sobre varios procedimientos de VAR para la identificación de la situación de la política monetaria, se propone un esquema de identificación, el cual es esencialmente consitente con los hechos económicos. La estrategia está basada en extraer la situación de la política monetaria del sistema alemán y utilizar el "shock" estructural en los sistemas VAR de otros países del SME. Los resultados demuestran que a mayor compromiso con la disciplina del SME, más fuerte es el efecto de la política monetaria alemana en la política monetaria de otros países del SME y más débil el efecto sobre los tipos de cambio.

PALABRAS CLAVE: Transmisión de política monetaria, Vectores autorregresivos estructurales.

1 Introduction.

One of the main arguments that has justified the entrance of many countries in the EMS mechanism is the credibility transmission of inflation fighter from the Bundesbank to the central banks of the countries that take part in the system. What is the channel of transmission of such a credibility? The main channel is the transmission of monetary policy from Germany to the rest of the system together with a "quasi-fixed" exchange rate. One of the questions that this paper addresses is how German monetary policy affects monetary policy in other countries of the EMS. Theoretically, if exchange rates are fixed there is no possibility for autonomous monetary policy from the rest of the countries. However, the EMS is not a fixed exchange rates mechanism and therefore, there is scope for monetary independence in the context of its exchange rate bands (Svensson 1994). Another interesting question that we want to address is the extent of that "independence". How far away can monetary policy of a country in the EMS be from German monetary policy?

In order to address those questions we adopt as basic methodology the structural VAR approach. This is the natural choice given that most of the recent discussions on monetary policy identification and transmission are driven by that methodological approach. Section 2 supplies a discussion of the VAR and identification in general. Section 3 presents a summary of the main results of the application of VAR to the identification of monetary policy. Section 4 discusses some of the results for the case of interaction among different economies. Section 5 proposes an identification squeme for the transmission of monetary policy in the EMS with two applications: groups of countries in the system and Spain before and after the entrance in the EMS. Section 6 includes the main conclusions.

2 The identification of monetary policy.

2.1 The VAR methodology.

Do only innovations matter or anticipated monetary policy should be also considered? And if only innovations matter, How can we measure them? Most of the literature on the effects of monetary policy answers to these questions by using the VAR methodology [1]. This section covers some of the relevant issues when applying that methodology to the analysis of monetary policy effects [2].

Let y_t be a vector (n×1). The specification of y_t is a pth-order autoregressive process

$$\begin{aligned} y_t &= \alpha + \Phi_1 y_{t-1} + \Phi_2 y_{t-2} + \ldots + +\Phi_p y_{t-p} + \epsilon_t \\ \Phi(L) y_t &= \epsilon_t \end{aligned} \quad (1)$$

where the perturbation is iid. and has a distribution function $\epsilon_t \sim N(0, \Omega)$ and $\Phi(L) = A_0 - \sum_{k=1}^{\infty} A_k L^k$. Several questions arise when using the VAR methodology like the length of the lags (p), the type of deterministic components, the transformation of the data, the estimation procedure, etc. We are going to concentrate only on those issues that are significant for the application of this technique to the analysis of monetary policy. These issues are essentially related to the variables that should be included in the y_t vector, the proper identification of monetary policy and the orthogonalization procedure needed to separate exogenous economic policy shocks from endogenous effects.

Users of VAR models do not report regularly the coefficient estimates or standard deviations of unrestricted VAR models given that, in general, the degrees of freedom left are small and high collinearity give imprecise estimates

[1]An alternative line of research has used the dynamic stochastic general equilibrium model (DSGE) to analyze the effects of monetary policy using simulation and estimation. For this approach see Kim (1996), Cho and Cooley (1995), Leeper and Sims (1994), Yun (1994) or Cooley and Hansen (1995).

[2]For a general vision of VAR see Watson (1995), Canova (1995) or Hamilton (1994).

of short run relationships. The tools more often used to present the results of this kind of models are the *impulse-response function* and the *variance decomposition*. However, these exercises are meaningless if the model is not identified, in the sense of having VAR innovations being orthogonal and having a clear economic interpretation. This process is similar to the recovery of structural parameters from a reduced form estimation. In the case of the VAR the reduced form expression is

$$y_t = \Phi_1 y_{t-1} + \Phi_2 y_{t-2} + \ldots + \Phi_p y_{t-p} + \epsilon_t \quad (2)$$

and the structural form would be

$$A_0 y_t = A_1 y_{t-1} + A_2 y_{t-2} + \ldots + A_p y_{t-p} + u_t \quad (3)$$

In general the identification problem appears because we need to recover the structural parameters, or innovations, from the reduced-form model.

- In the reduced form model the number of parameter to be estimated are $n^2 p + n(n+1)/2$ corresponding to the matrices $\Phi_1, \Phi_2, ..., \Phi_p, \Sigma_\epsilon$, where n is the number of elements in the y_t vector.
- In the structural model there are $n^2(p+1) + n(n+1)/2$ parameters corresponding to the matrices $A_0, A_1, ... A_p, \Sigma_u$.

There is an obvious relationship between the reduced form and the structural one. We could rewrite the structural form as

$$y_t = A_0^{-1} A_1 y_{t-1} + A_0^{-1} A_2 y_{t-2} + \ldots + A_0^{-1} A_p y_{t-p} + A_0^{-1} u_t \quad (4)$$

which implies that

$$\begin{aligned} \Phi_1 &= A_0^{-1} A_1 \\ \Phi_2 &= A_0^{-1} A_2 \\ \ldots &= \ldots \\ \Phi_p &= A_0^{-1} A_p \\ \Sigma_\epsilon &= A_0^{-1} \Sigma_u A_0^{-1\prime} \end{aligned} \quad (5)$$

Therefore, there are n^2 more parameters in the structural form than in the reduced form and it is necessary to impose the same number of constraints to achieve identification[3]. The usual practice makes the diagonal elements of A_0 equal to 1 which reduces the number of required constraints to $n^2 - n = n(n-1)$. Some other restrictions come from economic theory considerations or from informational assumptions.

The initial step for the identification of monetary policy in a VAR system is to decide between an structural or a semi-automatic approach.

The *semi-automatic approach* has the advantage of reducing the discretion of the researcher in the choice of the relevant variables [4]. The innovations in the system are usually transformed into contemporaneously uncorrelated shocks using the Cholesky decomposition. Let's decompose the variance-covariance matrix of the innovations ϵ, Ω. Given that Ω is a real symmetric positive definite matrix, there exist a unique lower triangular matrix A and a unique diagonal matrix Σ with positive elements in the main diagonal, such that

$$\Omega = A\Sigma A' = A\Sigma^{1/2}\Sigma^{1/2}A = PP' \tag{6}$$

where $P \equiv A\Sigma^{1/2}$ is a lower triangular matrix and A has 1's on the main diagonal. This expression is the *Cholesky decomposition* of matrix Ω. Given that we assumed that ϵ_t was uncorrelated with its own lagged values and lagged values of y_t we can construct a new innovation, u_t, that has the same properties.

$$u_t = P^{-1}\epsilon_t = \Sigma^{-1/2}A^{-1}\epsilon_t \tag{7}$$

The elements of this new vector, u_t, are uncorrelated with each other, which makes them usable for economic interpretation, given that

$$E(u_t u_t') = E(\Sigma^{-1/2}A^{-1}\epsilon_t\epsilon_t' A^{-1}\Sigma^{-1/2})$$

[3]Leeper, Sims and Zha (1996) consider that using the condition $\Sigma_\epsilon = I$ the identification of VARs reduces the "a priori" identification restrictions of standard simultaneous equations models and makes the behavior of these models less dependent on the assumptions about A_0.

[4]Canova (1995).

$$= \Sigma^{-1/2}A^{-1}\Omega A^{-1}\Sigma^{-1/2} = I \tag{8}$$

is a diagonal matrix. It is well known that the order of the variables in the y_t vector is critical because the results tend to change when the order is altered. The ordering is based usually in assumptions about what information is known when a particular decision about monetary policy is taken.

The *structural approach* uses economic and informational restrictions to identify meaningful economic shocks. These restrictions can adopt one or several of the following skemes:

- Zero restrictions on the coefficients for the predetermined variables. This procedure is not used regularly for identification of VAR systems.
- Restrictions on Σ_u. The simplest restriction would be to assume that Σ_u is diagonal, which would imply that the shocks have an immediate economic interpretation.
- Restrictions on the matrix of contemporaneous coefficients, A_0. In general those restrictions make A_0 lower triangular producing a Wold causal chain (see Sims (1980)). However, this does not have to be the case (See, for instance, Blanchard and Watson (1986), Bernanke (1986), King and Watson (1993)) and constraints on A_0 can be 0 or nonzero equality restrictions without delivering a lower triangular matrix.
- The constraints for identification can be also placed on the long-run relationship, $A(1)$, which is to say in the sum of impulse responses[5] This works like a long run Wold causal ordering.

Usually, a combination of these restrictions is used to identify structural VAR systems being the most common the joint constraint over the matrix of contemporaneous coefficients and a diagonal variance-covariance matrix for the structural innovations.

[5]See Blanchard and Quah (1989) or King, Plosser, Stock and Watson (1991).

2.2 The identification of monetary policy.

One of the most interesting issues in monetary economics is the finding of one or several indicators of the stance of monetary policy. The traditional view is based on using monetary aggregates as the proper indicators. Given that only the innovations could be interpreted as policy shocks[6] the VAR methodology has been used extensively to obtain the innovations that should receive the name of monetary policy[7]. The use of innovations in a broad monetary aggregate to capture monetary policy shocks generates the so called liquidity puzzle. In the standard macroeconomic model an increase in money supply will lead to a reduction in the interest rate in the short run, if prices and output are sticky. However, positive innovations in the monetary aggregate equation have a positive effect on interest rates[8]. Besides, it is well known that when the VAR specifications contains a broad monetary aggregate and the interest rate money supply fails to Granger-cause output and its explanatory power over the variance of output is largely reduced. The main theoretical reason that explains these effect is the endogeneity of broad-money measures (Christiano and Eichenbaum (1992)): the Federal Reserve supplies reserves in order to accommodate demand innovations which implies that innovations in monetary aggregates are essentially demand impulses.

To avoid this identification problem some researchers have proposed the innovations on a narrow aggregate, the nonborrowed reserves, as the right measure of monetary policy. Christiano and Eichenbaum (1992) and Christiano and Eichenbaum (1995) argue that innovations in nonborrowed reserves should be considered as exogenous policy. Strogin (1995) have recently suggested that the use of the raw volume of nonborrowed reserves is not enough to identify monetary policy disturbances. He argues that, even though it is true that the nonborrowed reserves are more directly controllable by the central than borrowed reserves, what matters is the reserves mix. Therefore, Strogin (1995) uses innovations on the mix of borrowed and nonborrowed reserves to identify monetary policy innovations that are not the result of the

[6]Cochrane (1995) challenges this view of considering only the unexpected component of the money supply as active monetary policy.

[7]Cochrane (1995) and Rudenbush (1996) present some recent criticims to the use of VARs to identify monetary policy.

[8]A recent example of this effect can be found in Leeper, Sims and Zha (1996).

accommodation of the Federal Reseve to demand innovations. Gordon and Leeper (1994) estimate a demand and supply system for reserves and M2. Monetary policy innovations are identified as shifts of the reserves supply curve outward when the demand curve is unchanged.

Finally Bernanke and Blinder (1992) show that the Federal funds rate is superior to monetary aggregates as a forecaster of the economy and argue that movements in the Federal funds rate are true policy changes. From a theoretical viewpoint this is true when the supply curve for reserves is perfectly elastic, which implies that innovations in the short term interest rate can be identified as the stance of monetary policy. The empirical implementation of this idea generates what is called the price puzzle: a positive innovation in the Federal funds is associated with an increase in the price level[9] which is at odds with the conventional theory. Two solutions have been proposed to solve this puzzle. Sims (1992) argues that the Fed may use an indicator of inflation in its reaction function[10] and propose the use of commodity prices[11]. Other researchers propose the use of an structural or semi-structural approach instead of the semi-automatic approach. This literature is revised in the next section.

Bernanke and Mihov (1995), following closely Bernanke and Blinder (1992), consider most of the above mentioned approaches as particular cases of the system

$$
\begin{aligned}
Y_t &= \sum_{i=0}^{k} B_i Y_{t-1} + \sum_{i=0}^{k} C_i P_{t-1} + A^y v_t^y \\
P_t &= \sum_{i=0}^{k} D_i Y_{t-1} + \sum_{i=0}^{k} G_i P_{t-1} + A^p v_t^p \qquad (9)
\end{aligned}
$$

where Y is the vector of nonpolicy variables, P is the policy variables and the second equation can be interpreted as the policy reaction function. The

[9]Gordon and Leeper (1992), Eichenbaum (1992), Sims (1992) and Leeper, Sims and Zha (1996). Christiano (1992) and Christiano, Eichanbaum and Evans (1996) find the same price puzzle using the nonborrowed reserves as the monetary policy indicator.

[10]In terms of the informational explanation of the ordering of the VAR the equation for the monetary indicator should include an indicator of inflation.

[11]Christiano, Eichenbaum and Evans (1996) use the same argument and indicator.

structural error terms, v^y and v^p, are supposed to be uncorrelated. An additional condition to obtain identification is the assumption that the macro variables are not affected by the policy shocks in the same period, or $C_0 = 0$. Transforming the system it is possible to derive a relationship between the structural error terms and the reduced form errors that allows the imposition of alternative identification assumptions on the demand and supply of reserves and other monetary aggregates[12]

3 Identification of monetary policy in open economies.

There has been a lot of recent attention on the issues of the effects of monetary policy on exchange rates and the analysis of monetary policy on Germany. One of our objectives is to put together these two issues in the analysis of the transmission of monetary policy in the EMS.

The analysis of the effects of monetary policy on exchange rates delivers frequently what is called the exchange rate puzzle: a positive innovation in the interest rate is associated with the depreciation of a currency instead of the appreciation[13].

Curiously, this puzzle does not exist for the US. Eichenbaum and Evans (1995) reports the effects of the US monetary policy shocks on the dollar exchange rate with respect to currencies of other industrialized countries. They use the semi-automatic VAR approach which puts the US monetary policy tools before the exchange rate in the recursive ordering. They find that there is no exchange rate puzzle for the US: the US dollarss appreciate in response to a tight money shock in the US, as is normally expected. This contrast between the US and those for other countries is suggestive. A possible interpretation is that the exchange rate puzzle occurs when the

[12]Leeper, Sims and Zha (1996) argue that the economic interpretation in Bernanke and Mihov (1995) involves constrains not imposed by the other researchers mentioned in this section.

[13]Grilli and Roubini (1994) study the effects of monetary policy of several industrialized countries (other than US) on their exchange rates and report this kind of puzzle.

monetary authority responds endogenously to innovations in the exchange rate within one period. For example, if the central bank tightens its monetary policy stance as soon as it sees a depreciation of its currency, and if the econometricians put the monetary policy tools before the exchange rate in the recursive ordering, to the eyes of those econometricians it would look as if the tight monetary policy caused the depreciation. This puzzle does not occur in the case of the US, presumable because the Fed is insensitive to the exchange rate movements at least in the short run, and therefore it acts as a "leader" in its relationship with the central banks of other countries. This interpretation was put forth by Grilli and Roubini (1994).

If the above interpretation is correct, we may be able to resolve the exchange rate puzzle by explicitly modelling a possible simultaneous determination of the monetary policy tools and the exchange rate. This line of research was followed by Kim and Roubini (1996), who proposed an structural VAR approach to identify monetary policy shocks where, at least initially, the effect of a contractionary monetary policy is an appreciation of the exchange rate. Cushman and Zha (1995) highlight the role of exchange rates as a transmission mechanism.

Another important finding from the paper by Eichenbaum and Evans was the presence of the "forward premium puzzle". A positive shock to the US interest rate typically means a widening of the interest rate differential between the US and other countries. The formula of the uncovered interest rate parity suggests that, when the US interest rate is higher than a foreign interest rate, the US dollars should be depreciating over time. In other words, the initial impact of an increase in the US interest rate should cause an appreciation of the US dollars, but then the US dollars should start depreciating immediately. Eichenbaum and Evans found that it was not the case in their estimation results. The US dollars keep appreciating for a few moths in response their identified tight money shocks, instead of peaking at the time of the shock.

On the other hand some recent papers have used the VAR methodology to analyze German monetary policy. Clarida and Gertler (1996) show how German monetary policy, despite the public focus on monetary targeting, has involved the management of short term interest rates. Bernanke and Mihov

(1996), using the methodology proposed in Bernanke and Mihov (1995), find the same result and emphasize that even though the Lombard rate has been in the past a good indicator for monetary policy the use of the call rate cannot be rejected statistically as an indicator.

4 Cross Country Analysis of Policy Transmission

4.1 Framework

In this section, we analyze transmission of German monetary policy shocks to other European countries by means of a cross country analysis. Degrees of commitment to the exchange rate system varied substantially across countries. For example, France, Belgium and the Netherlands can be considered as core member countries, in that their degree of commitment to keep their exchange rates within the bands has been consistently high over the periods. Italy and Spain can be considered semi periphery countries. Italy underwent frequent devaluation of its currency and moved out of the system temporarily. Spain joined the system much later than most of the member countries. The UK can be considered a periphery country as its commitment to the exchange rate stabilization has been practically inexistent.

We will try to take advantage of this cross country variation to uncover effects of joining the system on the movement of the interest rate and the stability of the exchange rate for the member countries. For that purpose, we estimate the same VAR model for each country separately and compare the effects of the German policy indicator on the interest rate and the exchange rate of those member countries. Specifically, our VARs include 5 variables: an indicator of German monetary policy, the index of industrial production of the local country (Y), CPI of the local country (P), the short term interest rate of the local country (R), and the exchange rate against the DM (EX). The last variable measures the unit value of the DM measured in the local currency so an increase in this variable means a depreciation of the local currency. Detailed definitions and sources of the data can be found in Appendix B. The data is monthly. The sample period starts in January 1980 and ends in May 1995 for Spain, December 1994 for Italy, October 1995 for

Belgium and December 1995 for the rest. The selection of the end period was dictated by the data availability. The number of lags to include in the VAR system was set to one. We use the Cholesky decomposition to orthogonalize the shocks. The variables were ordered as: the German policy variable - Y-P-R-EX. That is, German monetary policy is supposed to be predetermined for the local economy in the short run: the German monetary authority does not respond contemporaneously neither to the local monetary policy (represented by R) nor to EX. The local monetary policy is also supposed not to respond to EX within a period.

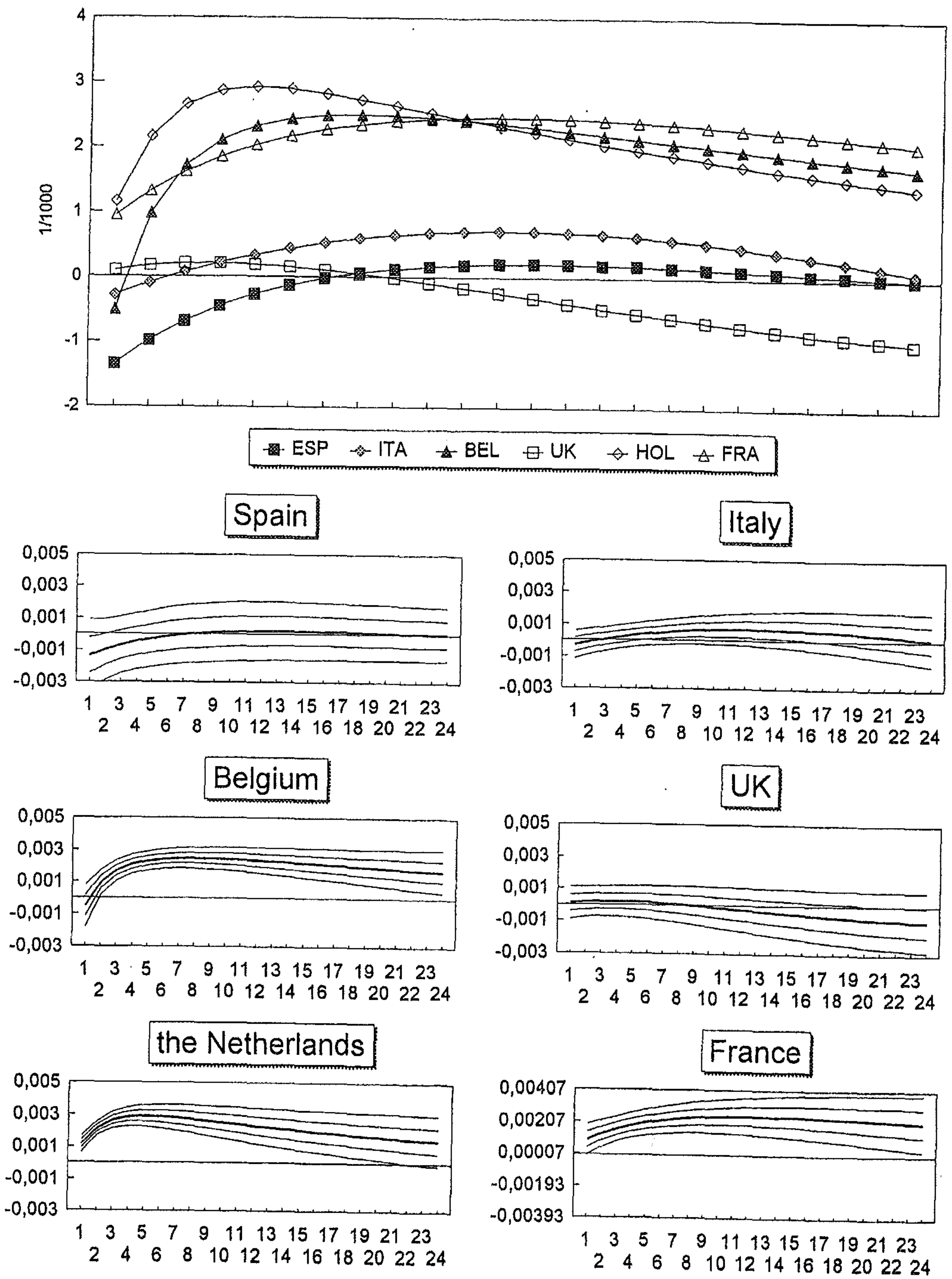
This two steps procedure implies that, for instance, German monetary policy does not react to changes in French monetary policy caused by changes in German policy. This is an strong assumption but is consistent with the comments in the beggining of the article. If Germany has to be the leader of a group of countries that get as the main advantage of the European Monetary System or, in the future, the Monetary Union, the transmission of credibility from the German central bank then German monetary authorities should only look to their internal conditions and the other countries should react to German monetary policy without the possibility of having any effect on it.

Leeper, Sims and Zha (1996) present a methodology that would allow the estimation of a VAR system with variables from Germany and other countries and endogeneity between German monetary policy and other countries' monetary policy. However, the size of the system would be very large. Besides, Leeper, Sims and Zha (1996) do not specify the operating procedure of the central bank. More important, as we pointed out before, the identification squeme followed in this paper is consisten with the theory of credibility transmission. This fact avoids the use of the nonrecursive identification pattern in the eighteen variable model proposed by the above mentioned paper.

4.2 Case 1: Estimation with the German interest rate

As an indicator of the German monetary policy stance, we first consider the German short term interest rate. Figure 1 shows responses of the local interest rates to one standard deviation shocks to the German interest rate. In the panel at the top, we show point estimates of the responses for the six countries together, for the sake of cross country comparison. In the lower

Figure 1: Responses of R to German Interest Rate Shock



six panels we show responses for each country separately, together with their error bands. In those diagrams, as well as in all the other diagrams of similar nature in this section, the lines in the middle are the point estimates, the two lines closer to the point estimates are the one standard error bands, and the two lines furthest outside are the two standard error bands. As Sims and Zha (1995) argued, in the VARs, standard errors around point estimates tend to be large as we do not impose strong a priori restrictions on the model, and therefore the use of the conventional two standard error bands seems to be too strict. For that reason, we shall use the one standard error bands as the main reference point.

Results in Figure 1 fit very well with our prior expectation. The interest rate of the core countries, that is, Belgium, the Netherlands and France, respond very strongly to the German monetary policy shock, presumably to keep the exchange rate against the DM within the permitted bands. The effects are significant for most of the periods after the shock. On the other hand, the responses are very small for the semi periphery countries. For Italy, the response turns significant only after 6 months and turns insignificant again in 11 months. For Spain, the response is never significantly positive and is even significantly negative initially. For the periphery country, UK, the response is never significantly positive, and it even turns significantly negative after 23 months.

Table 1 presents contribution of the German interest rate shock to the variance of R for each country. Consistently with the impulse responses in Figure 1, the contribution is larger for the core countries, Belgium, the Netherlands and France, and smaller for the others.

Table 1: Contribution of the German interest rate shock to the variance of R (percentage)

	Spain	Italy	Belgium	UK	the Netherlands	France
1 month	0.81	0.29	0.35	0.02	9.82	2.19
6 months	0.60	0.40	15.95	0.10	45.57	12.66
24 months	0.55	1.86	45.10	1.41	47.90	40.43

Figure 2 shows responses of the exchange rate, EX, to a one standard deviation German interest rate shock. This time, the responses do not seem to make too much sense. As was discussed in the previous section, theory (Grilli and Roubini (1994), for example), predicts that a tight money shock in Germany should be followed by an immediate depreciation of the local currency against the DM (an increase in EX). In the figure, however, in five out of six cases the initial response is negative, not positive. For Spain, Italy and Belgium the effects are significant initially. For France the initial effect is negative but insignificant. In the case of Spain the perverse effect is particularly strong and significant. Only in the case of the Netherlands we find the expected positive (and significant) response. In other words, by using the German interest rate as an indicator of its policy we encounter the problem of the "*exchange rate puzzle*" (refer to Grilli and Roubini (1994)).

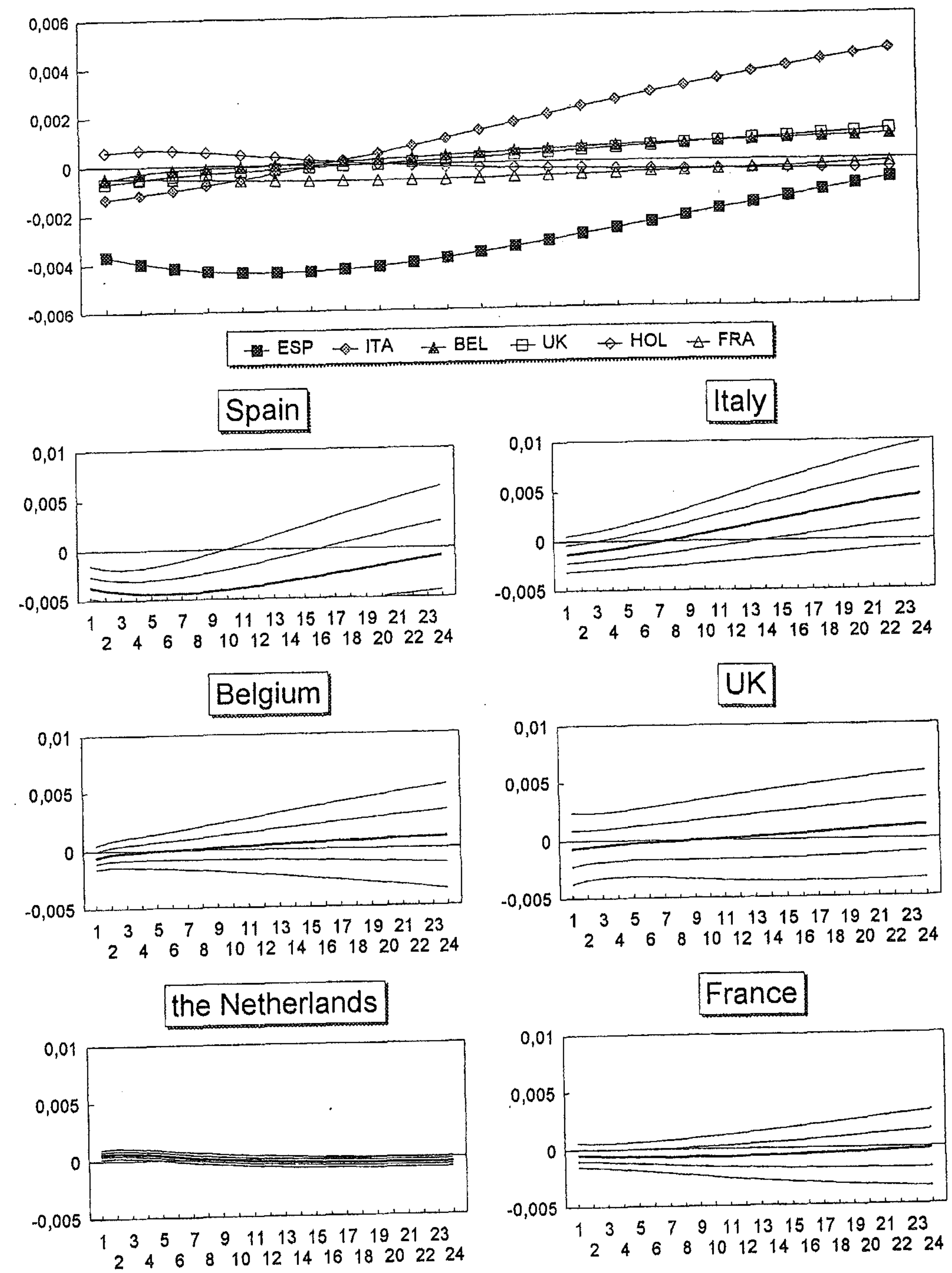
Table 2 shows contribution of the German interest rate shock to the variance of EX for each country. The effects are large for Spain (in the "wrong" direction) and for the Netherlands (in the "right" direction). For Italy the effect turns large (in the "right" direction) but only in the long run, contrary to theory.

Table 2: Contribution of the German interest rate shock to the variance of EX (percentage)

	Spain	Italy	Belgium	UK	the Netherlands	France
1 month	6.31	1.32	0.59	0.11	4.35	0.41
6 months	8.34	0.62	0.12	0.06	5.49	0.68
24 months	5.79	5.28	0.66	0.26	7.66	0.82

Figure 2 suggests that the short term interest rate may not be an appropriate indicator for the German monetary policy. A possible cause of the exchange rate puzzle that is frequently mentioned in the literature is endogenous response of the monetary authority to shocks to the exchange rate market. If the authority responds to those shocks within a period, the interest rate will reflect not only exogenous policy changes but also endogenous response to those shocks. In our case, if the German authority responds within a month to a shock that lowers the value of the DM by raising the interest rate, and if the econometric model fails to capture the information on this shock, to the eyes of the econometricians it would look as if the increase in the German interest rate caused the depreciation of the DM.

Figure 2: Responses of EX to German Interest Rate Shock



There are other reasons to believe that the German interest rate is a contaminated indicator of monetary policy. In Appendix A, we estimate a VAR model for Germany which includes seven variables used in the study of Kim and Roubini (1996) but using the Cholesky decomposition instead of their structural VAR model to orthogonalize the shocks. The seven variables are: oil prices, the US federal funds rate, CPI, the index of industrial production, the interest rate, money supply and the exchange rate between the US dollarss and the DM. It is shown that the use of the interest rate shock as an indicator of exogenous policy changes not only causes the exchange rate puzzle but also causes the "price puzzle": the German price level decreases instead of increases in response to an increase in the German interest rate.

In Appendix A, we propose to solve those problems by estimating a structural VAR model that is similar to that of Kim and Roubini (1996) which takes into account endogenous response of the German monetary authority to the exchange rate market shocks within one month. Responses to the monetary policy shocks thus estimated are all reasonable: the price level, output and money supply of Germany decrease in response to a tight money shock, while the German interest rate goes up and the DM appreciates. We consider this estimated policy shock as a more reliable indicator of autonomous changes in German monetary policy than the interest rate itself. In the next subsection we use this shock series instead of the German interest rate as an indicator of German monetary policy and redo the cross country analysis of the previous subsection.

4.3 Case 2: Estimation using the identified shocks

In this subsection we present results from VARs using the identified German monetary policy shocks from the structural VAR model in the Appendix as an indicator of autonomous changes in German monetary policy. An increase in this series means a tightening of the German monetary policy stance. The order of orthogonalization is again the German monetary policy shocks - Y-P-R-EX. This ordering amounts to assuming that the German monetary authority does not respond to innovations in R nor EX contemporaneously. That is, within Europe, Germany acts as a "leader" (using the terminology of Grilli and Roubini (1994)). On the other hand, the German monetary policy shock series was derived from a model in which the German monetary

authority was assumed to respond to innovations in the US Federal Funds Rate and the exchange rate between the US dollarss and the DM contemporaneously (refer to Appendix for details). Thus, in the relationship with the US, we are assuming that Germany acts as a "follower". We consider those assumptions as fairly realistic.

Of course, the German monetary policy shocks are drawn from the estimation of the structural VAR, and therefore are estimates that have standard errors around them. However, to facilitate the comparison between this Case 2 with Case 1, and to save the estimation time, we treat them as if they were precisely measured data. We intend to take into account the uncertainty around this estimated series in our future work.

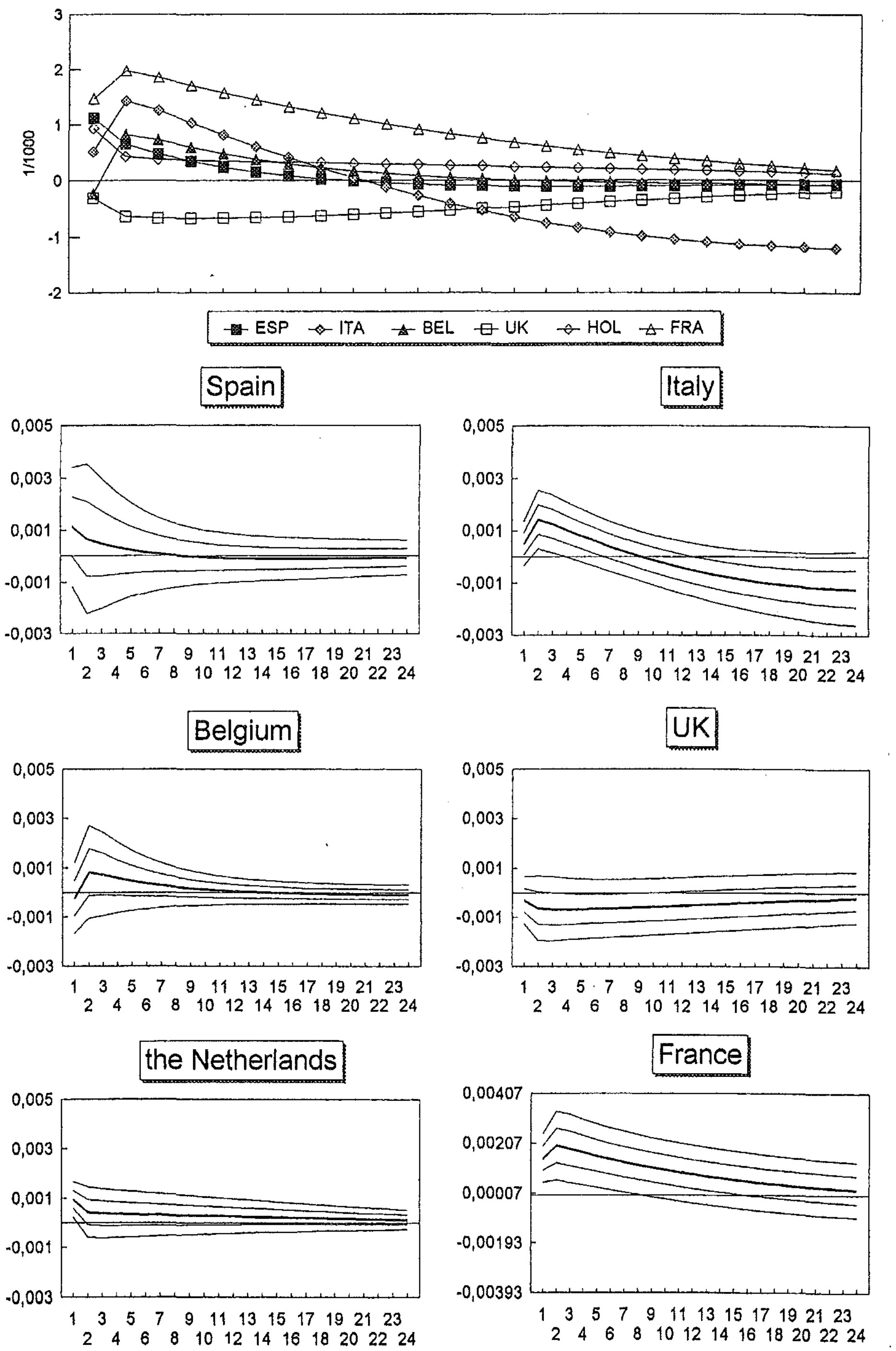
Figure 3 shows responses of the local interest rates to a one standard error German monetary policy shock. Note that the scales are the same as those in Figure 1. In most cases the responses change drastically from those in Figure 1. We could divide the six countries into three groups. The first group shows the expected positive responses of R to the German tight money shock, and includes Spain, Belgium, the Netherlands and France. The second category includes only Italy, which shows the expected positive response in the short run but an unexpected strong negative response in the long run. The third group consists of UK alone, which shows a "wrong", negative response.

It is worth noting that the first group of countries, which show the "correct" responses, includes all the "core" countries of the system, Belgium, the Netherlands and France. The response is particularly strong for France. The response of the Dutch R is significant for only one month. The responses of the Belgian and the Spanish R are never significant.

The response of the Italian R is somewhat puzzling. One possible explanation is that it reflects the behavioral pattern of the Italian monetary authority: in the face of a tight money shock in Germany the authority raises the interest rate at the beginning to keep the exchange rate within the permitted bands, but later reverses the course of action after facing protests and pressures from the public and politicians in response to deflationary effects of the initial policy change.

The fact that the response of the British R is negative itself is counterintuitive, but, on the other hand, the fact that its response is lower than those

Figure 3: Responses of R to Identified German Monetary Policy Shock



for other countries (except for Italy in the long run) makes sense. As UK was never committed to keeping the exchange rate within the bands, it did not find it necessary to respond to a tight money shock from Germany by tightening the monetary policy stance, unlike the other countries.

Table 3 presents contribution of the German monetary policy shock to the variance of R for each country. It is generally very small, less than two percent with the exception of France, Holland in the short run and Italy in the medium to long run.

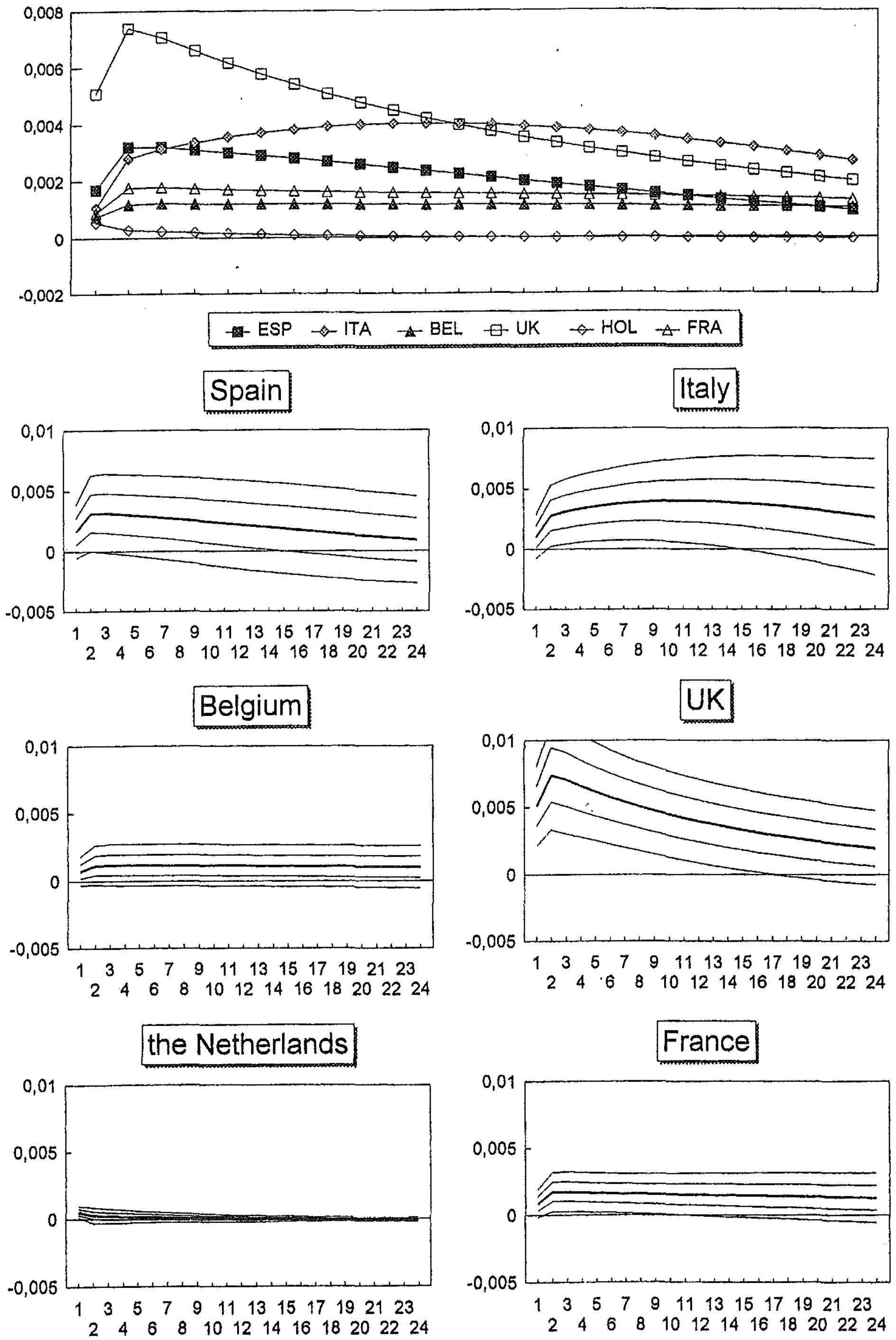
Table 3: Contribution of the Identified German policy shock to the variance of R (percentage)

	Spain	Italy	Belgium	UK	the Netherlands	France
1 month	0.56	0.92	0.06	0.23	3.45	4.90
6 months	0.34	4.64	0.72	1.13	1.38	8.44
24 months	0.31	5.07	0.70	1.26	1.20	7.94

Figure 4 presents responses of EX to a one standard deviation German monetary policy shock. Note that *the exchange rate puzzle has completely disappeared* by switching the indicator of German monetary policy. All the responses are either positive or practically zero for all the periods. This supports the superiority of the estimated shocks to the interest rate as an indicator of German monetary policy. Also, *the relative size of the responses across the countries fits our prior belief perfectly.* UK, which has had the least commitment to the EMS shows the largest response. Italy and Spain, which have been a bit more loyal to the system, show smaller (at least in the short run) but still large responses. The "core" countries of the system, Belgium, the Netherlands and France, are characterized by much smaller responses than the "periphery" and the "semi-periphery" countries. The response is particularly small for the Netherlands.

The relative size of the responses from Figure 4 is not exactly inversely related to the relative size of the responses from Figure 3. We do, however, find a pattern that the periphery country which is least committed to the exchange rate system shows the lowest response of R and the largest response of EX, and that the core countries exhibit a high sensitivity of R to German

Figure 4: Responses of EX to Identified German Monetary Policy Shock



monetary policy shocks and their EX responds relatively weakly. Italy, one of the semi periphery countries, is characterized by a perverse response of R and a strong (though weaker than UK) response of EX. A major exception to this pattern is Spain, whose R responds strongly (though insignificantly) to a German monetary policy shock (which is contrary to our prior expectation), and, despite that, its EX responds relatively strongly to the shock. This may be because Spain underwent a major structural change when it entered the EMS. If so, putting periods both before and after the entrance to the system together may lead to a misspecification and therefore wrong estimates.

Table 4 presents contribution of the German monetary policy shock to the variance of EX for each country. The only difference from the impulse response analysis is that the contribution to the Spanish EX turns out to be fairly small.

Table 4: Contribution of the Identified German policy shock to the variance of EX (percentage)

	Spain	Italy	Belgium	UK	the Netherlands	France
1 month	1.34	0.87	1.17	6.22	3.31	1.51
6 months	3.89	6.46	2.59	13.25	1.58	5.54
24 months	2.50	9.85	3.02	14.21	1.19	6.74

Therefore our results are broadly consistent with our prior belief. When the German monetary authority tightens its policy stance, the core countries of the system respond strongly by raising the interest rate. Because of that, those countries experience relatively small changes in the exchange rate, and thus are able to keep it within the permitted bands. More peripheral countries respond less strongly to the German monetary policy tightening. As a result, their exchange rates respond more strongly. In short, joining the EMS (and taking it seriously) contributes to stabilizing the exchange rate, while imposing more constraints on the conduct of monetary policy.

Our remaining problem is the "Spain puzzle". Estimated results using the whole sample from 1980 to 1995 are not necessarily consistent with our prior beliefs. This may be because Spain joined the EMS in the middle of the sample, July 1989, and thus there is an important structural break around that period. In the next section we pursue this possibility by splitting the sample into the pre-joining EMS period and the post-EMS joining period. In fact, this analysis offers another interesting opportunity to studying the consequences of the EMS. We could ask, for example: did the Spanish interest rate become more responsive to the German monetary policy shocks, as one would expect? Did the Spanish exchange rate against the DM become less responsive to the German monetary policy shocks?

In order to answer these questions, we redo the analysis we performed in the previous section for Spain, but splitting the sample in two periods: before July 1989 and after July 1989. We first used the German interest rate as an indicator of the German monetary policy stance, but the results suffered from the same kind of anomalies as we found in the previous section for Spain. Therefore, we report only the case where we used the identified German monetary policy shocks from the structural VAR as a policy indicator.

Once again, the number of lags is set to one, and the seasonal dummies are included. The pre-EMS period is from January 1980 to June 1989, and the EMS period is from July 1989 to October 1995. Figure 5 reports the responses to a one standard deviation shock to German monetary policy of R and EX. Note that the scales are the same as the previous graphs. Predictably, due to the short sample periods, the error bands around the point estimates are huge. Nevertheless, we learn the following. There is no evidence that responsiveness of R increased after Spain joined the system. If anything, the point estimates are higher at the impact in the pre-EMS period. However, the standard errors are so large that, the right conclusion one should draw is that we do not know precisely what happened to the responsiveness of R. On the other hand, the response of EX is significantly positive in the pre-EMS period but turn significant after joining the EMS. This is what one would expect: When Spain is outside the system, the Bank of Spain did not try to stabilize the exchange rate, so it fluctuates in response to German monetary policy shocks. But after joining the system the exchange rate becomes insensitive to German monetary policy shocks as the Bank of Spain tries to maintain the exchange rate. The reason that this effect does not show up in the responses of R may be because the Bank of Spain used tools other than the standard monetary policy to stabilize the exchange rate. One candidate of such a tool is the capital control, which was frequently imposed during this period. A

further study is needed to investigate this possibility.

Table 5 reports the results of variance decomposition. This confirms the impression from Figure 5. The only sizable effect exists for EX in the pre-EMS period. We found that the contribution peaks in the fifth month at 11.47%. After Spain joined the EMS, this contribution goes down to almost nothing. The result confirms the idea that joining the EMS tends to insulate the exchange rate from fluctuations in the German monetary policy stance.

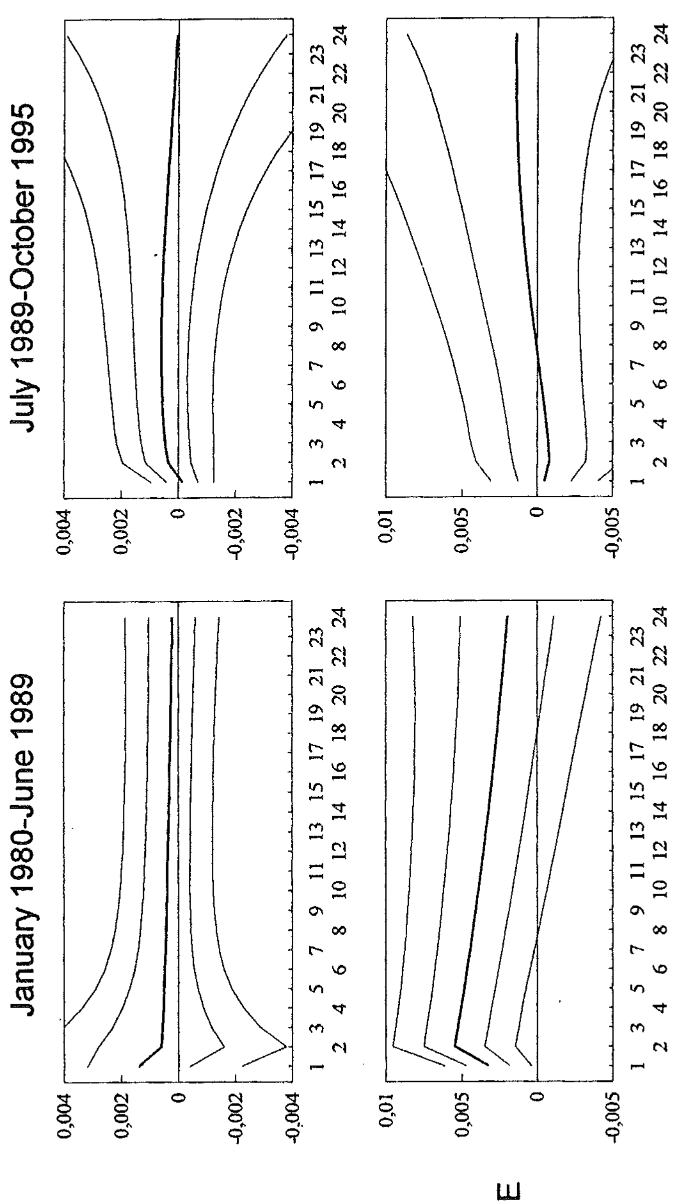
Table 5: Contribution of Identified German Monetary Policy Shocks. to R and EX: Spain (%)

	R, pre-EMS	R, EMS	EX, pre-EMS	EX, EMS
1 month	0.61	0.09	5.02	0.13
24 months	0.68	2.40	8.90	0.61

5 Conclusions

Our results are fairly consistent with the standard view on the European Monetary System. We have shown in the cross country analysis that joining the EMS and sticking to its rule means giving up at least some part of the independence of monetary policy, as the interest rate has to be responding to monetary policy shocks from Germany. On the other hand, those countries tend to achieve more exchange rate stability in that the exchange rate tends to be insulated from shocks to German monetary policy. In the cross-period analysis for Spain it was shown that, after joining the EMS, the Spanish exchange rate has become much less responsive to German monetary policy shocks while the interest rate is more responsive.

Figure 5: Responses to Identified German Monetary Policy Shock: Spain



A Identifying Monetary Policy Shocks in Germany

A.1 Introduction

This Appendix reports how we derived the German monetary policy shock series that was used in section 5 of the paper. Our approach is to use a structural VAR model which is very close to the one used in Kim and Roubini (1996). Here, we first present results from a standard VAR analysis to explain why it was necessary to use a more complicated structural VAR model. Then we present our results from the structural VAR. The variables included are almost exactly the same as those in Kim and Roubini:

OP: Oil Price Index

FFR: US Federal Funds Rate

P: Consumer Price Index

Y: Index of Industrial Production (SA)

R: Short Term Interest Rate

M: Money Supply (M3) (SA)

EXDD: Exchange Rate (the value of US$ in German DM: so an increase in this variable means a depreciation of the DM against the US$).

In this study we use M3 instead of M1 which was used by Kim and Roubini, as M3 is the variable which has been monitored carefully by the Bundesbank (Bernanke and Mihov (1996)). The sample period is July 1975-December 1995, and the data is monthly. We have found that the M3 series underwent two major definitional changes during this period. We included dummy variables corresponding to those periods to take out their effects. Those periods were: December 1985 and January 1991. As seasonality was present in some of the series, we included seasonal dummies in all the regressions. The interest rate variables are divided by 100. For the other series we use log levels. For OP, we divided its logarithmic value by 100. This is simply to make the convergence of the estimation procedure faster and does not have any effect (other than scaling) on our results. The number of lags was set to 6.

A.2 Evidence from a Standard VAR Analysis

We first estimated a standard VAR model which assumes a recursive ordering of OP-FFR-P-Y-R-M-EXDD. Figure A-1 presents impulse responses to one standard deviation shock to R, together with error bands (derived from the Bayesian Monte Carlo Integration with 1,000 draws) that correspond to one and two standard error bands, respectively. Two things are worth noting. First, in response to an increase in R, which presumably represents a tight money shock, the price level, P, increases, not decreases, as suggested by most standard theories (*the price puzzle*). Secondly, the exchange rate shows a positive response, that is, it depreciates, contrary to what is suggested by the theory of Grilli and Roubini (1994) etc (*the exchange rate puzzle*). In addition, Y initially increases (though the effect is significant for only one month) before it starts to decrease in the medium run, and M decreases significantly for only one month. Those observations, especially the first two, led us to conclude that the interest rate itself was a poor indicator of autonomous changes in monetary policy.

A.3 Structural VAR model

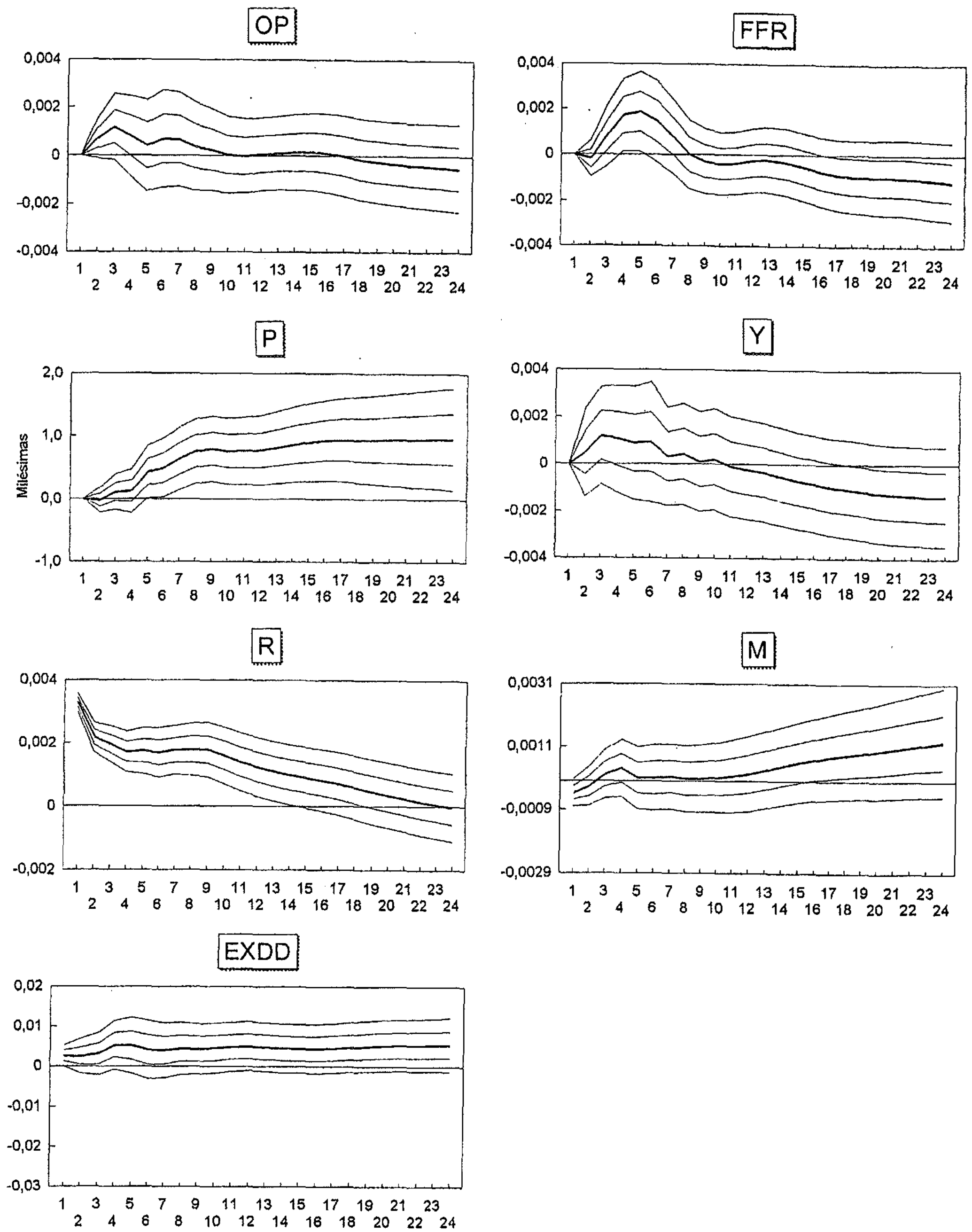
We estimate a structural VAR model close to that in Kim and Roubini. The short run restrictions are summarized in the following table. "*" means a free parameter. A blank means a zero restriction.

Table A-1: Short run restrictions
in the structural VAR model

Eq.\Var.	OP	FFR	P	Y	R	M	EXDD
OP	1						
FFR	*	1					
P	*		1				*
Y	*		*	1			*
MS	*	*			1	*	*
MD			*	*	*	1	
MKT	*	*	*	*	*	*	1

The model is overidentified (two extra restrictions). (MS) is the money supply equation. P and Y are excluded because the central bank obtains

Figure A-1: Reponses to German Interest Rate Shock (standard VAR)



information on those variables with lags. The central bank is assumed to respond to EXDD within a month. (MD) is the usual money demand function. (MKT) is the exchange market equation and it includes all the variables. As the exchange rate is a forward looking variable, it reflects all the information available to the market. A major difference between this model and that of Kim and Roubini is that both P and Y are assumed to depend on EXDD. In that sense, our model is slightly more general than that of Kim and Roubini.

A.4 Estimating the structural VAR model

We first estimated the model without any further restriction, but the results were anomalous in two ways. First, the estimated coefficient on EXDD in the (MS) equation meant that the Bundesbank lowers the interest rate when it observes a depreciation of the DM (an increase in EXDD). Secondly, the estimated coefficient on R in the (MKT) equation meant that the exchange rate depreciates when the interest rate increases. We normally expect the both of those relationships to be the other way round. To avoid this problem, we imposed two additional inequality constraints: R can respond only positively to EXDD in the (MS) equation, and EXDD can respond only negatively to R in the (MKT) equation. After imposing those two restrictions, the anomalies disappeared. The resulting estimates are the following.

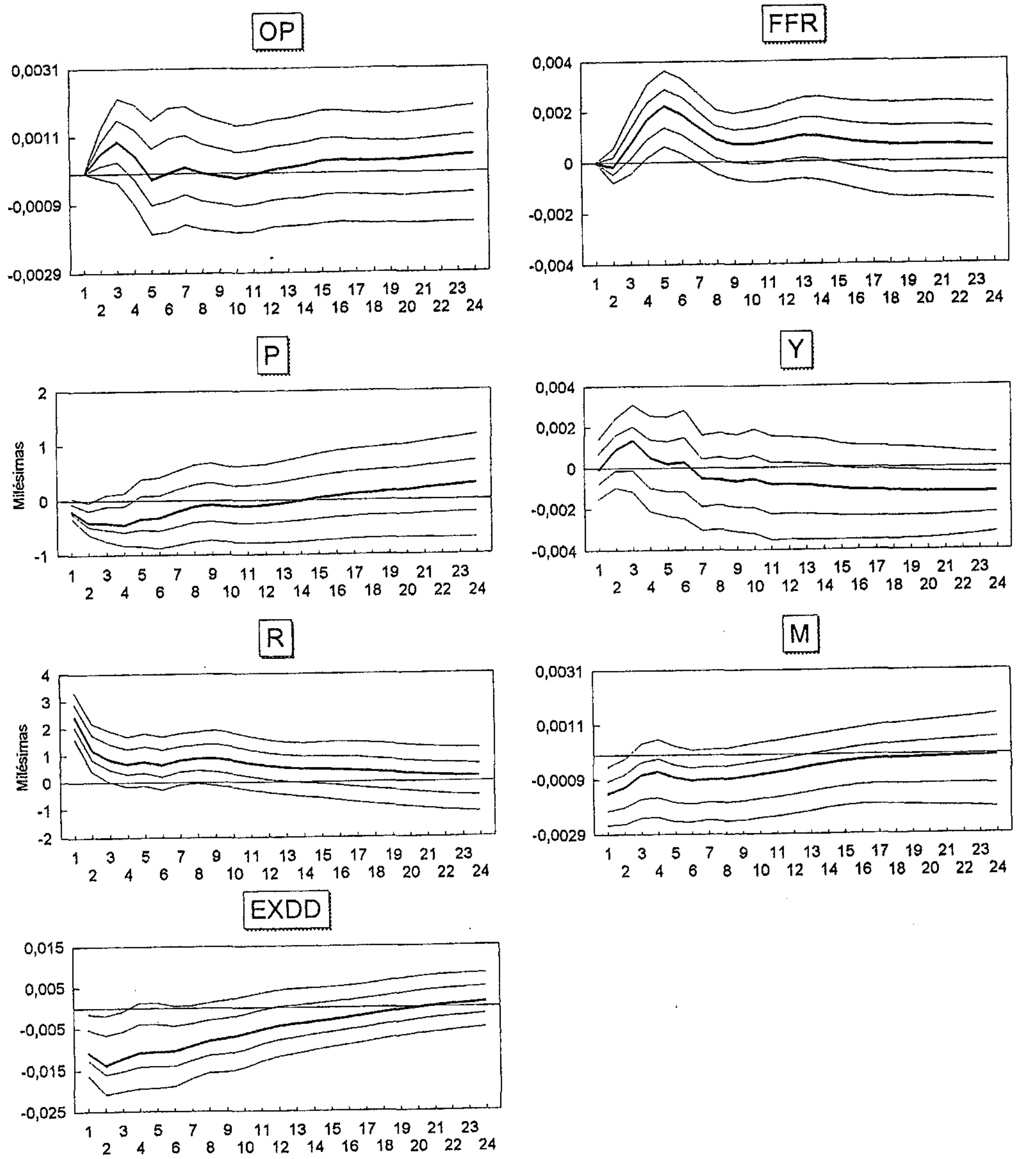
$$\begin{pmatrix} u_{OP} \\ u_{FFR} \\ u_P \\ u_Y \\ u_R \\ u_M \\ u_{EX} \end{pmatrix} = \begin{pmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0.06^{*} & 0 & 0 & 0 & 0 & 0 & 0 \\ 0.05^{**} & 0 & 0 & 0 & 0 & 0 & 0.02^{**} \\ 0.18^{*} & 0 & -0.50 & 0 & 0 & 0 & 0.02 \\ 0.04 & -0.1 & 0 & 0 & 0 & 0.35 & 0.12 \\ 0 & 0 & -0.12 & 0.03 & -0.58 & 0 & 0 \\ -0.11 & 1.15^{**} & -0.71 & 0.15 & -3.18 & 2.28 & 0 \end{pmatrix} \cdot \begin{pmatrix} u_{OP} \\ u_{FFR} \\ u_P \\ u_Y \\ u_R \\ u_M \\ u_{EX} \end{pmatrix} + \begin{pmatrix} e_{OP} & e_{FFR} & e_P & e_Y & e_{MS} & e_{MD} & e_{MKT} \end{pmatrix}'$$

"*" means that the point estimate is more than one standard error away from zero. "**" means that the point estimate is more than two standard errors away from zero. significantly different from zero at the 5% level.. The overidentifying restrictions were not rejected. The p-value was 98.4%. Unfortunately, most of the estimates have large standard errors around them. This is partly because the model is highly complicated in that five variables are simultaneously determined. In that sense, it is the price we pay for the generality of the model. Standard deviations for the structural shocks are: e_{OP}: 0.0062, e_{FFR}: 0.0061, e_P: 0.0014, e_Y: 0.0149, e_{MS}: 0.0042, e_{MD}: 0.0038, and e_{MKT}: 0.0261.

A.5 Impulse responses

Figure A-2 shows responses to one standard deviation shock to the (MS) equation (a contractionary monetary policy shock). Error bands are calculated following the method of Sims and Zha (1994) and are based on 10,000 draws (their method requires taking substantially more draws to get reliable outcomes than the method usable for the standard VAR). Note that *both the price puzzle and the exchange rate puzzle disappeared* from the estimates. Also, note that the trough of the response of EXDD comes very quickly. Although we had not had time to test it formally, this model does not seem to suffer from the "forward premium puzzle" of Eichenbaum and Evans (199?). Moreover, M responds much more strongly negatively in this figure than in the standard VAR case, and the effect lasts longer. For those reasons, we consider this estimated (MS) shock as a much more reliable indicator of autonomous changes in German monetary policy than the interest rate itself. A major remaining problem is that the response of Y is still positive in the short run.

Figure A-2: Reponses to German Monetary Policy Shock (structural VAR)



A.6 Variance decomposition

Table A-2 presents results of the decomposition of the within month forecast variance.

Table A-2: Variance decomposition:
for the within 1 month forecast variance (%)

Var.Shock	OP	FFR	P	Y	MS	MD	MKT
OP	100	0	0	0	0	0	0
FFR	0	100	0	0	0	0	0
P	3	1	90	0	2	0	4
Y	0	0	0	99	0	0	0
R	0	0	0	1	54	17	28
M	0	0	0	0	16	74	9
EXDD	0	8	0	1	24	1	66

Note that the MS shocks have large effects on all of R, M and EX even in the short run. On the other hand, innovations in R have a large component of shocks to the money demand and shocks to the exchange rate market. This justifies our speculation that the interest rate is a contaminated indicator of the German monetary policy stance.

Table A-3 presents results for the 24 months ahead forecast variance.

Table A-3: Variance decomposition:
for the 24 months ahead forecast variance (%)

Var.Shock	OP	FFR	P	Y	MS	MD	MKT
OP	74	9	10	4	1	0	3
FFR	14	49	13	6	4	1	11
P	40	14	11	1	1	13	21
Y	2	6	2	84	2	2	1
R	19	25	8	21	7	6	14
M	22	12	3	8	2	49	3
EXDD	10	5	6	9	12	3	56

The effects of the monetary policy shock are modest at best in the long run. Only its contribution to the variance of EXDD exceeds 10%. Most importantly, monetary policy is definitely an unimportant source of variation for P and Y.

B Data Source

Most of the data re from International Financial Statistics (IFS) of IMF. To calculate the exchange rate (the variable EX in the text) between Germany and other member countries, we divided the exchange rate of the latter against the US$ by that of Germany against the US$.

Germany:

Index of Industrial Production: IFS, 134 66C

CPI: IFS, 134, 64

the interest rate: IFS, 134 60B (call money rate)

the exchange rate (against US$): IFS, 134 RF

Money Supply: IFS, 134 38 NBC (M3, National Definition, seasonally adjusted)

Spain:

Index of Industrial Production: IFS, 184 66C

CPI: IFS, 184, 64

the interest rate: the day-to-day interbank money market rate, Monthly Bulletin of Statistics, Bank of Spain

the exchange rate (against US$): IFS, 184 RF

Italy:

Index of Industrial Production: IFS, 136 66C

CPI: IFS, 136, 64

the interest rate: IFS, 136 60B (call money rate)

the exchange rate (against US$): IFS, 136 RF

Belgium:

Index of Industrial Production: IFS, 132 66B

CPI: IFS, 132, 64

the interest rate: IFS, 132 60B (call money rate)

the exchange rate (against US$): IFS, 132 RF

UK:

Index of Industrial Production: IFS, 112 66C

CPI: IFS, 112, 64

the interest rate: Eurostat 269313042 (day-to-day money rate)

the exchange rate (against US$): IFS, 112 RF

the Netherlands:

Index of Industrial Production: IFS, 138 66C

CPI: IFS, 138, 64

the interest rate: IFS, 138 60B (call money rate)

the exchange rate (against US$): IFS, 138 RF

France:

Index of Industrial Production: IFS, 124 66C

CPI: IFS, 124, 64

the interest rate: Eurostat 149313042 (day-to-day money rate)

the exchange rate (against US$): IFS, 124 RF

Others (for Appendix A):

Oil Prices: IFS, 001 76AAZ (Spot US$ per Barrel, World)

Federal Funds Rate, US: IFS, 111 60B

Note on the money supply data for Germany: As discussed in Appendix A, there were two important definitional changes in the sample period, in December 1985 and January 1991. We take out their effects by using dummy variables. Also, the series shows a suspicious drop in January 1986 (the value was 919.10) and then goes back to a seemingly normal value. We studied similar series, such as broader M3 in IFS and M3 in the German data set, and never found a similar one time drop. For this reason we concluded that this drop was due to a typing error. Using the growth rate of broader M3 in IFS, we estimated the correct value of M3 for this month to be 949.69.

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