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Spanish Monetary Policy: a Structural VAR Analysis†

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Abstract

Some past studies analyzed Spanish monetary policy with the standard VAR. Their problem is that this method obliges researchers to impose a certain extreme form of the short run policy rule on their models. Hence, it does not allow researchers to study the possibility of structural changes in this rule, either. This paper overcomes these problems by using the structural VAR. I find that the rule has always been that of partial accommodation. Prior to 1984, it was quite close to money targeting. After 1984, it became closer to the interest rate targeting, with more emphasis on the exchange rate.

1 Introduction

This paper studies monetary policy in Spain[1] in the post oil crisis period using a time series econometric method. I ask three important questions:

(1) What is the form of the short run policy rule of the Bank of Spain? What is the role of the exchange rate in that rule?

(2) Was there an important structural change in this rule?

(3) What are the effects of monetary policy shocks?

What distinguishes this paper from the past literature is that I actually estimate the form of the policy rule of the Bank of Spain, rather than imposing an arbitrary form from the beginning. For example, Escriva and Haldane (1994) estimate standard VAR models, assuming that shocks to monetary policy can be captured by innovations in the interest rate. As will be discussed shortly, this amounts to assuming that the Bank follows a strict interest rate targeting in the short run. Normally, justification for this kind of assumptions is taken from narrative analyses of monetary policy, and whether such an assumption is appropriate or not is not tested econometrically. However, there is no assurance that this kind of strong assumption is valid in reality. The use of the structural VAR allows researchers to overcome this problem.

The structural VAR has come to be used frequently in studies of monetary policy. Like the standard VAR method, it leaves medium to long run relationships between variables unrestricted. It simply estimates a set of dynamic equations where all the current endogenous variables are allowed to depend on all the lagged endogenous variables. The difference from the standard VAR lies in how it specifies the short run relationship between variables. The standard VAR method simply imposes a short run recursive structure in an a priori way. For example, researchers have to assume that shocks to the interest rate affects money supply but shocks to money supply does not affect the interest rate (or the other way round). This is inconvenient if a researcher does not want to impose such a structure from the beginning. The structural VAR method allows researchers to impose more general restrictions on contemporaneous relationships between the variables. Thus, for example, cases in which the interest rate and money supply are simultaneously determined can be studied, provided that the researcher imposes sufficient identification restrictions in other parts of the model.

[1] I do not wish to get into any debate on how to define this word. In this paper, "Spain" simply refers to the entire geographical area where peseta is used as the major medium of exchange.

Using this method, I will estimate a time series model of Spanish monetary policy which allows for the possibility that the short run policy rule is neither a strict interest rate targeting nor a strict money supply targeting. The former corresponds to the case where the "money supply curve" in the (R,M) plane is completely horizontal. This happens when the central bank accommodates fluctuating demand at a given interest rate. The latter corresponds to the case where the curve is vertical, or, when the central bank does not try to accommodate demand at all. Assuming that the "money demand curve" is downward sloping in the same plane, the standard VAR can deal with only those two extreme cases mentioned above. If the supply curve is horizontal, policy shocks can be identified as innovations in the interest rate. If the supply curve is vertical, policy shocks can be identified as innovations in money supply. But the reality may be in between the two cases, or, the supply curve may be upward sloping (mixed targeting or partial accommodation). In such a case, the interest rate and money become simultaneously determined, and both policy shocks and money demand shocks would affect both variables contemporaneously. The structural VAR permits researchers to allow for this possibility. Another reason for the use of this method is an open economy consideration. When dealing with a relatively small open economy such as Spain, it is often important to introduce the exchange rate into the model. This could complicate the identification scheme, as it is often necessary to model the interest rate and the exchange rate to be simultaneously determined. That is, on one hand, the central bank might be responding to innovations in the exchange rate contemporaneously. On the other hand, the exchange rate may be sensitive to changes in the interest rate. The standard VAR cannot deal with such a model. This makes the uses of the structural VAR even more essential.

The structural VAR offers another unique possibility. It is often argued that the Spanish monetary policy rule underwent an important structural change around 1984. See Ayuso and Escriva (1997) for a most recent review on the evolution of monetary policy in Spain. The argument is that, prior to 1984, the policy rule was essentially money targeting, with little emphasis on the exchange rate. On the other hand, it is argued that, after 1984, the policy rule was essentially the interest rate targeting, and that much more emphasis was placed on the exchange rate stability. The standard VAR, which obliges researchers to impose a certain extreme form of the policy rule, is not an ideal tool to study the validity of such a claim. Instead, I will estimate the **same** structural VAR model for both the sub-periods before and after a suspected break point (which itself will be determined statistically). The model is general enough to include the two cases mentioned above as special cases. That way, I will let the data tell if there was indeed an important structural break, and if there was, whether the policy rule changed in the way normally believed in the literature.

On the technical side, I incorporate the newly developed method of Sims and Zha (1995) for calculating error bands around estimated impulse response functions. Until recently, the correct method for such computation for overidentified structural VAR models was not known.

What I find are as follows. First, the Spanish monetary policy rule in the short run is characterized as mixed targeting. Hence, the standard VAR is an insufficient method to identify monetary policy shocks in Spain. Second, there was indeed an important structural change in Spanish monetary policy. The break point was most likely around 1984, as is commonly believed. Although the short run policy rule is essentially characterized as mixed targeting for both the pre-1984 and the post-1984 periods, before 1984, the rule was very close to money targeting, and the exchange rate did not play an important role in this rule. After 1984, the rule became much closer to the interest rate targeting, and the importance of the exchange rate increased. In these senses, the conventional wisdom in the literature is validated. Third, the identified policy shocks were unimportant sources of variation for the price level, output and the exchange rate before 1984, but their importance increased substantially after 1984.

The rest of the paper is organized as follows. Section 2 offers an overview of related literature. Section 3 discusses the empirical methodology. Section 4 explains data used in the analysis. In section 5, I describe the model. Section 6 discusses estimation results when I used the whole post oil crisis period as a single sample period. Section 7 analyzes the issue of the structural break, and Section 8 presents results for each sub-samples, namely before 1984 and after 1984. Section 9 concludes.

2 Overview

Problems with the traditional approach

In this section I quickly review the literature on identification of monetary policy shocks. A more exhaustive review can be found in Leeper, Sims and Zha (1996).

Recent efforts to identify monetary policy using time series data started with Sims (1972). After Sims (1980), it has become common to use the VAR. At an early stage of this literature, most studies identified innovations in money stock as monetary policy shocks. However, this approach was found to suffer from a problem now known as the "liquidity puzzle": innovations in money are often followed by a significant increase in the interest rate, while, theoretically speaking, a loosening of monetary policy is expected to decrease it. It has been suggested that this is because a large fraction of innovations in money stock in fact reflects shocks to money demand, rather than money supply shocks. This is true when the central bank tries to smooth the movement of the interest rate in the face of fluctuating money demand, by supplying money in an accommodating way. Because of this, some researchers proposed using innovations in the short term interest rate as an alternative indicator of policy (Leeper and Gordon (1991), for example). However, this identification scheme had its own shortcoming (Sims (1992)): it was found that a positive innovation in the interest rate, which supposedly indicates a tightening of monetary policy, was actually followed by an increase in the price level, not a decrease. This problem is called the "price puzzle".

Money Supply Targeting vs. the Interest Rate Targeting vs. Mixed Targeting

In an effort to overcome these problems, recent studies have made important progresses in many directions. In particular, some economists have noted that it is probably too extreme to assume that monetary policy shocks can be identified as innovations in any single variable. As was argued in the introduction, policy shocks can be identified as innovations in money supply or the interest rate only when the central bank follows a strict money targeting or a strict interest rate targeting. If not, both variables become simultaneously determined and the standard VAR, which assumes a contemporaneous recursive structure, becomes unusable for policy analysis. For that reason, some papers employ the structural VAR, and allow for the possibility of mixed targeting or partial accommodation. Refer to Sims (1986) and Gordon and Leeper (1994). I will follow this line of literature and estimate a model general enough to allow for a mixed targeting rule[2].

The Exchange Rate Puzzle

Researchers who have worked with models that include the exchange rate have frequently encountered an additional difficulty, which is called "exchange rate puzzle". It means that an identified tight money shock is often found to be followed by a depreciation of the local currency instead of an appreciation. For example, Grilli and Roubini (1994) find that a positive innovation in the interest rate leads to a depreciation of the local currency in many industrialized countries (other than US) on their exchange rates[3]. A shortcoming of their analysis is that they use the standard VAR and do not consider simultaneity between the interest rate and the exchange rate.

[2] An alternative approach to resolve the problems, which is proposed by Eichenbaum (1992), is to identify policy shocks as innovations in non borrowed reserves. Strongin (1995) propose using a part of their innovations that is orthogonal to innovations in total reserves. Bernanke and Mihov (1995) test validity of competing approaches.

[3] Curiously, this puzzle does not exist for the US. Eichenbaum and Evans (1995) study effects of the US monetary policy shocks on the exchange rate between the US dollars and currencies of various industrialized countries. They find no exchange rate puzzle: the US dollars appreciate in response to a tight money shock in the US, as is normally expected.

Kim and Roubini (1996) try to resolve this puzzle by estimating a structural VAR model where the interest rate and the exchange rate are simultaneously determined. Their model yield a better result in the sense that their identified contractionary monetary shock is followed, at least initially, by an appreciation of the exchange rate.

Eichenbaum and Evans (1995) find another problem, called the "forward discount bias 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 expected to be depreciating over time. In other words, at the impact, 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 find that it is not the case in their estimation results. The US dollars keep appreciating for a few moths in response to their identified tight money shocks, instead of peaking at the impact.

In evaluating the results of estimation, I will pay a particular attention to the impulse response of the exchange rate to an identified policy shock, and will examine if it suffers from the two puzzles mentioned above. It will be an important criterion to decide if policy shocks are truly identified.

3 Statistical methodology

The structural VAR was developed by Sims (1986), Bernanke (1986) and Blanchard and Watson (1986)[4]. As was already argued, this method imposes identification restrictions on short-run relationships, without making strong assumptions on medium to long-run relationships. In this section, I will briefly discuss the methodology. Define a VAR model in a vector of variables $y(t)$ $(N \times 1)$ as

$$y(t) = B(L) \cdot y(t) + u(t), \tag{1}$$

where $B(L)$ is a polynomial in the lag operator L, and $u(t)$ is the residual vector. The components of $u(t)$ $(N \times 1)$ are not generally orthogonal to each other, and it is usually hard to interpret those residuals in economic terms. Hence the usual practice is to decompose those residuals into mutually orthogonal shocks with economic interpretations, such as "monetary policy shocks". Let $\epsilon(t)$ be a $(N \times 1)$ vector of such structural shocks, and assume that

$$\Gamma_0 \cdot u(t) = \epsilon(t). \tag{2}$$

[4]A related approach is the VAR with restrictions on long-run relationships. Refer to Blanchard and Quah (1989) and Shapiro and Watson (1988). Gali (1992) combine both short run and long run restrictions.

or,

$$u(t) = (I - \Gamma_0) \cdot u(t) + \epsilon(t) \tag{3}$$

From equation (2),

$$\Sigma = \Gamma_0^{-1} \cdot \Sigma_\epsilon \cdot \Gamma_0^{-1'}, \tag{4}$$

where Σ is the variance-covariance matrix for the vector $u(t)$. In the standard (unrestricted) VAR model, the $(N \times N)$ matrix Γ_0 and the variance-covariance matrix of $\epsilon(t)$ (denoted Σ_ϵ) are identified by assuming that Γ_0 is a triangular matrix (which amounts to assuming a contemporaneous recursive relationship) with its diagonal terms normalized to one, and that Σ_ϵ is a diagonal matrix. Under those assumptions, equation (4) can be solved for Γ_0 and Σ_ϵ by applying the Cholesky decomposition.

The structural VAR allows more general forms of restrictions to be imposed on the matrices Γ_0 and Σ_ϵ. Identification is accomplished through maximizing a log likelihood function of the form

$$F = \frac{T}{2} \cdot \ln(\det(\Gamma_0^{-1} \cdot \Sigma_\epsilon \cdot \Gamma_0^{-1'})) - \frac{T}{2} \cdot trace(\Gamma_0' \cdot \Sigma_\epsilon^{-1} \cdot \Gamma_0' \cdot \Sigma), \tag{5}$$

with respect to the free parameters in Γ_0 and Σ_ϵ (T is the number of observations). Thus, this method requires identification restrictions only on short-run relationships, leaving the reduced form VAR in equation (1), and thus medium to long-run relationships between the variables, unrestricted.

The correct way to compute error bands for an overidentified VAR model is given in Sims and Zha (1995). Define a matrix A_0 as

$$A_0 \equiv \Sigma_\epsilon^{-1/2} \cdot \Gamma_0 \tag{6}$$

Hence, from equation (5), the log likelihood function is rewritten as

$$F = T \cdot \ln(\det(A_0)) - \frac{T}{2} \cdot \text{trace}(A_0 \cdot \Sigma \cdot A_0'). \tag{7}$$

Take a second-order Taylor expansion around the peak of the above log likelihood function with respect to the free elements of A_0, and the normal distribution from which Monte Carlo samples are generated is obtained. The draws are weighted by the ratio between the F in equation (7), the true distribution, and the approximated distribution from which the draws are made.

4 Data

Throughout the paper monthly data is used because the identification restrictions in this analysis are most valid in the very short-run. Detailed descriptions of the data series are given in Appendix A. Variables used in the estimation are:

EXDD: US Dollar-DM Exchange Rate

P: Consumer Price Index,

Y: Industrial Production (SA),

R: Daily Interbank Money Market Rate,

M: Money Stock (M3, SA), and

EX: DM-peseta Exchange Rate.

In the above, "SA" means seasonally adjusted. Except for R, all the series are expressed in natural logarithms. R, which was originally in a percentage form, is divided by 100. EXDD is defined in such a way that an increase in this variable means a depreciation of the DM against the Dollars. Likewise, an increase in EX means a depreciation of the peseta against the DM. As the money stock variable I choose M3 because the Bank of Spain is known to target broader monetary aggregates rather than narrower ones[5], and also because it is the only monetary aggregate for which the deseasonalized data is available for a long enough period.

The sample period is between January, 1976 and May, 1995. The choice of the starting period is dictated by data availability: the data on the seasonally adjusted M3 was available only from January 1975. As the maximum number of lags taken in this paper is 12 (see below), the sample period has to be started from 12 months after that.

Most of the variables I include are conventional ones, but the inclusion of EXDD requires some more explanation. There are two essential reasons. First, as will be shown later, it is highly negatively correlated with EX. This is presumably because a negative shock to the market value of the DM tends to increase EXDD (the dollar appreciates against the DM) and to reduce EX (the peseta appreciates against the DM) at the same time. Second, EXDD can reasonably be considered as independent from Spanish monetary policy, at least in the short run: movements in EXDD are likely to be dominated by what goes on in the US and Germany, and the Spanish economy is small enough that what goes on there is not likely to have an immediate effect on EXDD. Hence, a part of innovations

[5] According to Ayuso and Escriva (1997), the Bank of Spain targeted M3 until 1984, and then switched to ALP (a notion similar to M4).

in EX that is correlated with those in EXDD can be reasonably considered as independent from Spanish policy. Thus, by introducing EXDD and putting it at the top of the causal relationship in the model, the danger of mistakenly attributing a part of movements in EX that is exogenous to Spain to shocks to Spanish policy is reduced. In other words, the danger of overestimating the effects of Spanish policy on EX is reduced.

5 Modelling Spanish Monetary Policy

I estimate a VAR model with six endogenous variables, ordered as EXDD-P-Y-R-M-EX. Here, I explain its short run structure briefly. Table 1 represents this model, in the form of equation (3) in section 3. In this table, subscript "DD" stands for "EXDD". Also, "u's" are residuals from the first stage OLS estimation and "e's" are structural shocks. The large matrix on the right hand side corresponds to the matrix $I - \Gamma_0$. All the "a's" inside the matrix are free parameters. Note that I am normalizing the diagonal terms in the matrix Γ_0 in equation (2) to be one. As a consequence, all the diagonal terms inside the matrix on the right hand side of Table 1 are equal to zero. I also assume that the variance-covariance matrix for the structural shocks, Σ_ϵ, is a diagonal matrix.

Table 1: Short Run Structure of the Model

$$\begin{pmatrix} u_{DD} \\ u_P \\ u_Y \\ u_R \\ u_M \\ u_{EX} \end{pmatrix} = \begin{pmatrix} 0 & 0 & 0 & 0 & 0 & 0 \\ a_{2DD} & 0 & 0 & 0 & 0 & 0 \\ a_{3DD} & a_{3P} & 0 & 0 & 0 & 0 \\ a_{4DD} & 0 & 0 & 0 & a_{4M} & a_{4EX} \\ 0 & a_{5P} & a_{5Y} & a_{5R} & 0 & 0 \\ a_{6DD} & a_{6P} & a_{6Y} & a_{6R} & a_{6M} & 0 \end{pmatrix} \cdot \begin{pmatrix} u_{DD} \\ u_P \\ u_Y \\ u_R \\ u_M \\ u_{EX} \end{pmatrix} + \begin{pmatrix} e_{DD} \\ e_P \\ e_Y \\ e_{CB} \\ e_{MD} \\ e_{EXM} \end{pmatrix}$$

Note, first, that I am putting EXDD at the top of the causal ordering, and am assuming that it is predetermined for the rest of the model in the short run. As was already discussed, it seems reasonable to assume that the Spanish economy is small enough so that what happens there does not affect EXDD in the short run. Second, I divide the rest of the model into two blocks, the (P,Y) block and the (R,M,EX) block. I assume that the domestic economy has a short-run block recursive structure: the variables in the first block do not respond contemporaneously to innovations in the variables in the second block. This reflects the assumption that P and Y respond only slowly to changes in R and EX, because of decision lags. Similar assumptions are often made in the literature (Gordon and Leeper (1994), etc.). As a consequence, the whole matrix for the contemporaneous relationship between innovations, $I - \Gamma_0$ in equation (3), becomes block-triangular: there is no feedback from the lower part of u, or the (R,M,EX) part, to its upper part, or the (EXDD,P,Y) part. Because I am not so much interested in modeling the structure of the (EXDD,P,Y) part of the model in this paper, I simply impose a lower triangular structure on this part of the matrix $I - \Gamma_0$. This specification does not affect the estimated coefficients for the (R,M,EX) part of the model nor the responses of EXDD, P and Y to shocks to the (R,M,EX) part.

The lower half of the model consists of three equations: the central bank (**CB**), the money demand (**MD**), and the exchange market (**EXM**) equations, ordered in this way. The (CB) equation describes the behavior of the central bank. It is distinguished from the other two by exclusion of P and Y from the equation. This reflects the assumption that the central bank receives information on these variables with lags. Similar assumptions have been utilized frequently in the literature since Sims (1986) and have turned out to be quite useful. The (MD) or the money demand equation takes the standard form: demand for money depends on the price level, output, and the interest rate. Hence, EXDD and EX are excluded from this equation. The (EXM) or the exchange market equation is the equation that describes how the exchange rate is determined in the market. I assume that the market uses all the information to determine the exchange rate, so all the variables are included in this equation. All in all, the model is overidentified by one extra restriction.

Standard theories predict that the "money demand curve" is downward sloping, or a_{5R} is negative. On the other hand, the "money supply curve" is expected to be upward sloping (or horizontal or vertical), or, that $a_{4M} \geq 0$. Also, it is expected that $a_{4EX} \geq 0$, or, that when the Bank of Spain observes a depreciation of the peseta (an increase in EX), it tries to raise the interest rate. Unfortunately, when I estimated the model without any additional restrictions, resulting estimates often did not satisfy the latter two conditions, $a_{4M} \geq 0$ and $a_{4EX} \geq 0$. For example, sometimes estimates suggested that the Bank of Spain lowers (as opposed to raises) the interest rate when it observes a depreciation of the peseta. Hence, I decided to impose those two inequality constraints when estimating the above model. When at least one of the constraints turned out to be binding, I reestimated the model by restricting the corresponding coefficient(s) to be equal to zero.

6 Results from the whole sample

First Stage Estimation

I estimated the VAR model with six endogenous variables mentioned above. The sample period was January 1976 — May 1995. I also included the seasonal dummies. Throughout the analysis, I follow the recent convention in the literature and use levels, rather than first differences, for all the series. As Bernanke and Mihov (1996) argued, a levels specification yields consistent estimates whether cointegration exists or not, but a difference specification is inconsistent if some variables are cointegrated. Concerning the lag structure, the Likelihood Ratio Test of Sims (1980) suggested the use of the lag length of 2. To take out effects of seasonality in some of the variables which may not be fully taken out by the seasonal dummies[6], I add the 12th lag and use the structure (1, 2, 12). Similar but more complex lag structures are used in Bernanke and Mihov (1996), Clarida and Gertler (1996), and Shioji (1997).

The correlation matrix for the residuals from the first stage of the estimation is shown in Table 2. The diagonal terms are their standard deviations. "**" means that the correlation is significantly different from zero at the 5% level, "*" means that it is significant at the 10% level, and "+" means that it is significant at the 15% level. Note the strong negative correlation between EXDD and EX.

Table 2: Standard Deviations and Correlations Across Residuals

	EXDD	P	Y	R	M	EX
EXDD	0.024	-0.012	-0.004	-0.043	0.066	-0.359**
P		0.005	0.049	-0.003	0.042	0.108*
Y			0.013	0.056	0.107*	-0.064
R				0.029	-0.023	-0.005
M					0.003	-0.141**
EX						0.018

Note: The diagonal terms are standard deviations.

Contemporaneous Relationship

The matrix of the contemporaneous relationship, $I - \Gamma_0$ in equation 3, was estimated using the procedure OPTMUM of GAUSS. I started the estimation using the BFGS algorithm. I switched to the Newton-Raphson algorithm as the procedure got close to convergence[7]. Table 3 presents the result. The standard errors around the point estimates are summarized in Appendix B. Superscripts

[6]As I discussed earlier, for Y and M, I use deseasonalized series. But I did not find deseasonalized series for P, and the original series contained some seasonality.

[7]A potential problem is that the log likelihood function may have multiple local maxima. If a researcher uses only one set of initial values for this iterative procedure, there is a fair chance that the resulting estimates do not represent the global maximum of the log likelihood function. This problem is present, for example, when one uses the pre packaged program in RATS, which always uses -0.1 as initial values for all the free parameters. My solution is to try many sets of initial values, picked by a random number generator. When multiple peaks are present, I pick the estimates that correspond to the highest value of the log likelihood.

"*" and "**" indicate that a point estimate is more than one and two standard error(s) away from zero, respectively. The standard errors were calculated from the inverse of the Hessian of the Log Likelihood, analytically derived. The tables also show standard deviations of the structural shocks (the vector ϵ_t in equation 3) at the end of each equation in parentheses.

As it turned out that the restriction $a_{4EX} \geq 0$ was always binding, I impose the additional restriction that this coefficient is zero. That is, EX does not enter the (CB) equation. This makes the model overidentified by two extra restrictions. The overidentification restriction was not rejected statistically. The p-value was 81.0%.

Table 3: Contemporaneous Relationship: *the whole sample*

(EXDD)	$u_{DD} = e_{DD}$ (0.024)
(P)	$u_P = -0.00 \cdot u_{DD} + e_P$ (0.005)
(Y)	$u_Y = -0.00 \cdot u_{DD} + 0.14 \cdot u_P + e_Y$ (0.013)
(CB)	$u_R = -0.10 \cdot u_{DD} + 7.57 \cdot u_M + e_{CB}$ (0.035)
(MD)	$u_M = 0.02 \cdot u_P + 0.03^{*} \cdot u_Y - 0.06 \cdot u_R + e_{MD}$ (0.003)
(EXM)	$u_{EX} = -0.26^{**} \cdot u_{DD} + 0.043^{*} \cdot u_P - 0.08 \cdot u_Y$ $-0.01 \cdot u_R - 0.82^{*} \cdot u_M + e_{EXM}$ (0.016)

Estimates are summarized in Table 3. The "whole sample" in the title means that the whole period of January 1976-May 1995 is being used. The estimates are consistent with theory in that the "money supply curve" is upward sloping (by restriction) and the "money demand curve" turns out to be downward sloping. The slope of the "supply curve" is fairly steep, though it is not as steep as the "demand curve".

Impulse Responses

Figure 1 shows estimated impulse responses to a shock to the central bank equation (e_{CB}), together with their one and two standard error bands based on 10,000 draws. Those are responses to a one standard deviation increase in e_{CB}. As this increases R initially, it should be considered as a tightening of policy stance. I follow Sims and Zha (1995) in using the one standard error bands as the main reference point. As they argued, since VAR models do not impose many arbitrary restrictions on parameters, they tend to have large standard errors, and therefore use of the conventional two standard errors as the main reference point seems too strict. Hence, in this paper, when I mention significance of responses, it is with respect to the one standard error bands.

Responses of M and R show patterns that are consistent with prior beliefs about monetary policy: R goes up significantly for a few months (**no liquidity puzzle**). The shock has a sustained negative effect on M. Response of P is also consistent with the standard belief in that it responds negatively to a tight money shock. That is, there is **no price puzzle** present in the estimate. Y responds significantly negatively as well, which is consistent with prior belief. The main problem is in the response of EX. The standard belief is that a tight money shock leads to an appreciation of the domestic currency. This view is supported by some theories such as that of Grilli and Roubini (1992). However, Figure 1 suggests that the identified tight money shock is followed by a depreciation of the peseta. In other words, the typical **exchange rate puzzle** problem is present in this estimation. This casts some doubt on if monetary policy shocks are correctly identified in this analysis.

Variance Decomposition

Table 4 shows results of variance decomposition. Table 4-1 shows contributions of all the shocks to variations in R, M, and EX, within one month (the impact effects). Under the additional restriction $a_{4EX} = 0$, the (R, M, EX) block becomes block recursive and the (EXM) shocks have no contemporaneous effects on R nor M. Note that shocks to both the (CB) equation and the (MD) equation are split between innovations in R and M. This suggests the importance of allowing for the simultaneous determination of R and M in the money market. In other words, the standard VAR, which imposes a short run recursive structure, is not an adequate method to analyze Spanish monetary policy. Table 4-2 shows contributions of policy shocks (e_{CB}) to forecast variance for the six variables at time horizons of the twelfth month and the twenty fourth month. It shows that the identified policy shocks are unimportant determinants of the variation in P, Y and EX.

Table 4-1: Variance Decomposition (*the whole sample*) for WITHIN ONE MONTH, in %

shock\Var.	R	M	EX
EXDD	0.4	0.2	12.7
P	0.0	0.1	1.1
Y	0.4	1.0	0.5
CB	69.7	31.9	0.3
MD	29.5	66.9	1.1
EXM	-	-	84.4

Table 4-2: Variance Decomposition (*the whole sample*):
Contribution of **Policy Shocks**, in %

	EXDD	P	Y	R	M	EX
12 months	2.8	2.7	2.7	47.6	36.7	1.6
24 months	2.9	3.2	3.8	46.5	34.9	5.5

7 Structural Change in Spanish Monetary Policy

There are at least three reasons to suspect that treating the whole post oil crisis years as a single sample period, as I did in the previous section, is not appropriate. It may be important to consider the possibility of structural change(s). One reason is that the estimates in the previous section suffered from the exchange rate puzzle problem, which may be due to the fact that I ignored the possibility of structural changes. Secondly, it is widely believed that Spanish monetary policy underwent an important structural change around 1984. For example, Bacchetta (1995) argue that, prior to 1984, the policy rule was close to monetary aggregate targeting, with little emphasis on the exchange rate. On the other hand, he argue, after 1984, the policy rule became much closer to the interest rate targeting and also that the Bank of Spain has come to pay much closer attention to the exchange rate. A similar argument is made by Ayuso and Escriva (1997) as well. If this is true, treating the whole period as a single sample period could be problematic. In fact, Escriva and Haldane (1994), in their time series analysis, start their sample period from 1984, considering a possible structural break prior to this period. Finally, the movement of the interest rate (R), plotted in Figure 2, seems to support the view that there was an important structural break around 1984. Prior to 1984, R was showing an extraordinary volatility. For example, it reached the lowest point of 1.909% in March 1978, and then shot up to the second highest point of 42.570% in August 1978, just five months later. After 1984, the movement has become much smoother, which suggests the possibility that the Bank of Spain started more vigorous interest rate smoothing operation.

Due to these considerations, I will split the sample and estimate the same model as in the previous section for each sub-sample. The size of the model (6 variables and 3 lags) and the relatively short sample (about 20 years in total) permits me to consider the possibility of presence of at most one structural break. Rather than assigning the break point to a certain month in an a priori way, I decided to determine it statistically[8], using the likelihood criterion. I cannot allow the break point to be too close to the beginning or the end of the whole sample, as that would leave too small a degree of freedom either for the first sub-period or the second sub-period. Hence, I tested placing the break point at

[8]I thank Xavier Sala-i-Martin for suggesting this approach.

months between 1981 and 1988. In all the cases, the null hypothesis that a break did not exist was rejected at any conventional significance level. I decided simply to pick a point which gave me the highest likelihood value. As a result, the first sub-period starts from January 1976 and ends in November 1984, and the second sub-period starts from December 1984 and ends in May 1995. This is consistent with the conventional view mentioned above that there was a structural break in monetary policy around 1984, which I find encouraging.

8 Results from the sub-samples

This section estimates the same model I estimated before for the first and the second sub-periods separately and compares the results.

Correlation across Residuals

The correlation matrices for the residuals from the first stage of the estimation for the first and the second sub-periods are shown in Tables 5-1 and 5-2, respectively. The diagonal terms are their standard deviations. "**" means that the correlation is significantly different from zero at the 5% level, "*" means that it is significant at the 10% level, and "+" means that it is significant at the 15% level. Interestingly, the correlation between EXDD and P, and that between EXDD and R, switch signs between the two sub-periods. The negative correlation between EX and EXDD weakens substantially in the second sub-period, which suggests that the peseta was co-moving much more tightly with the DM, in relation with the Dollars, in this period. A strong negative correlation between R and M, which is observed in the first sub- period, disappears in the second sub-period. This seems to indicate that the movement of the "money supply curve" was dominating that of the "money demand curve" in the first sub-period while that was not the case in the second sub-period.

Table 5-1: Standard Deviations and Correlations Across Residuals first half

	EXDD	P	Y	R	M	EX
EXDD	0.018	-0.119+	-0.035	-0.174**	0.070	-0.449**
P		0.006	0.064	0.055	0.141*	0.183**
Y			0.014	0.089	0.167**	-0.054
R				0.035	-0.165**	0.148*
M					0.002	-0.170**
EX						0.019

Note: The diagonal terms are standard deviations.

Table 5-2: Standard Deviations and Correlations Across Residuals second half

	EXDD	P	Y	R	M	EX
EXDD	0.022	0.099^{+}	-0.018	0.098^{+}	0.014	-0.155^{**}
P		0.003	0.090	-0.081	-0.030	-0.060
Y			0.010	0.037	0.129^{*}	-0.192^{**}
R				0.007	0.001	-0.076
M					0.003	-0.076
EX						0.011

Note: The diagonal terms are standard deviations.

Contemporaneous Relationship

Table 6-1 and 6-2 present estimated contemporaneous relationship between the variables for the first and the second sub-periods, respectively. The standard errors around the point estimates are summarized in Appendix B. Superscripts "*" and "**" indicate that a point estimate is more than one and two standard error(s) away from zero, respectively. The tables also show standard deviations of the structural shocks (the vector ϵ_t in equation 3) at the end of each equation in parentheses.

As it turned out that the restriction $a_{4EX} \geq 0$ was binding for the first sub-period, I restricted this coefficient to be zero and reestimated the model. That is, according to the estimates, the Bank of Spain was not paying attention to this variable in the short run during this period. For the second sub-period, neither of the two inequality constraints turned out to be binding. The overidentification restrictions were not rejected. The p-value was 96.1% for the first half and 31.2% for the second sub-period.

Table 6-1: Contemporaneous Relationship: *the first half*

(EXDD)	$u_{DD} = e_{DD}$ (0.018)
(P)	$u_P = -0.04^{*} \cdot u_{DD} + e_P$ (0.006)
(Y)	$u_Y = -0.02 \cdot u_{DD} + 0.15 \cdot u_P + e_Y$ (0.014)
(CB)	$u_R = -0.39^{*} \cdot u_{DD} + 7.80 \cdot u_M + e_{CB}$ (0.040)
(MD)	$u_M = 0.05^{*} \cdot u_P + 0.03^{*} \cdot u_Y - 0.03^{*} \cdot u_R + e_{MD}$ (0.002)
(EXM)	$u_{EX} = -0.44^{**} \cdot u_{DD} + 0.053^{*} \cdot u_P - 0.08 \cdot u_Y + 0.03 \cdot u_R - 1.58^{*} \cdot u_M + e_{EXM}$ (0.017)

Table 6-2: Contemporaneous Relationship: *the second half*

(EXDD)	$u_{DD} = e_{DD}$ (0.022)
(P)	$u_P = 0.01^* \cdot u_{DD} + e_P$ (0.003)
(Y)	$u_Y = -0.01 \cdot u_{DD} + 0.33^* \cdot u_P + e_Y$ (0.010)
(CB)	$u_R = 0.04 \cdot u_{DD} + 1.63 \cdot u_M + 0.18 \cdot u_{EX} + e_{CB}$ (0.008)
(MD)	$u_M = -0.08 \cdot u_P + 0.04^* \cdot u_Y - 0.21 \cdot u_R + e_{MD}$ (0.003)
(EXM)	$u_{EX} = -0.06^* \cdot u_{DD} - 0.20 \cdot u_P - 0.21^{**} \cdot u_Y - 0.39 \cdot u_R + 0.25 \cdot u_M + e_{EXM}$ (0.011)

The results from the (P) equation suggests that an increase in EXDD was a deflationary shock in the first sub-period but became an inflationary shock in the second sub-period. Corresponding to that, in the (CB) equation, it is suggested that the Bank of Spain responded to such a shock by lowering R in the first sub-period while the sign of the response was reversed in the second sub-period. The (CB) equation also suggests that the slope of the "money supply curve" decreased substantially in the second sub-period, from 7.80 to 1.63. This supports the conventional view mentioned earlier. Also, the coefficient on EX in the (CB) equation is zero in the first sub-period but is positive (though insignificant) in the second sub-period. This also supports the conventional view that the Bank of Spain has become much more conscious of the exchange rate movements in the second sub-period. Note also that there is a substantial reduction in the standard deviation of the policy shock between the two sub-periods, suggesting that the policy has become much less volatile in the second sub-period.

Impulse Responses

Figures 3 and 4 show estimated impulse responses to a shock to the central bank equation (e_{CB}), together with their one and two standard error bands based on 10,000 draws for the first and the second sub-periods, respectively. These are responses to a one standard deviation increase in e_{CB}.

In both of the sub-periods responses of R and M have expected signs. The response of R initially takes a huge value in the first sub-period. The initial response is much smaller for the second sub-period. On the other hand, the response quickly converges to near zero in the first sub-period but for the second sub-period it goes back only gradually to zero. This is a further indication that the Bank of Spain was engaged in interest rate smoothing more vigorously in the second sub-period. For the first sub-period, responses of P, Y and EX are not consistent with the standard belief. Figure 3 shows that, in response to a tight money shock, P essentially stays unchanged, Y goes up rather than goes down (significantly for a few periods) and the exchange rate depreciates rather than appreciates (again, significantly for a few periods). This casts some doubt on if my model is correctly identifying policy shocks in this sub-period. It seems that policy shocks in this period cannot be adequately captured as a combination of innovations in R and M. This might be because, in this sub-period, the Bank of Spain was using non market measures such as moral suasion or credit control as policy tools, and the money market was not always at the intersection between the supply and the demand curves. On the other hand, for the second sub-period, responses of P, Y and EX are all consistent with the standard belief (Figure 4). In response to a tight money shock, P and Y decrease significantly for a number of periods, while the exchange rate appreciates in the short run (there is no exchange rate puzzle). The trough of the response of EX does not come at the impact, and, in that sense, the estimate is not completely free of the forward discount bias puzzle. But the trough still comes fairly quickly, within three months after the shock. I conclude that, for this sub-period, my identification scheme correctly identifies the policy shocks.

Variance Decomposition

Tables 7 and 8 show results of variance decomposition for the first sub-period and the second sub-period, respectively. Tables 7-1 and 8-1 show contributions of all the shocks to variations in R, M, and EX, within one month (the impact effects). Note that, for the first sub-period, under the additional restriction that $a_{4EX} = 0$, the (R, M, EX) block becomes block recursive and the (EXM) shocks have no contemporaneous effects on R nor M. Tables 7-2 and 8-2 show contributions of policy shocks (e_{CB}) to forecast variance for the six variables at time horizons of the twelfth month and the twenty fourth month.

Table 7-1: Variance Decomposition (*the first half*) for WITHIN ONE MONTH, in %

shock\Var.	R	M	EX
EXDD	3.0	0.5	20.1
P	0.3	1.9	1.8
Y	0.4	2.8	0.6
CB	85.1	24.0	1.4
MD	11.0	70.8	1.1
EXM	-	-	75.1

Table 7-2: Variance Decomposition (*the first half*):
Contribution of **Policy Shocks**, in %

	EXDD	P	Y	R	M	EX
12 months	1.3	0.1	2.0	57.9	31.6	4.1
24 months	8.7	0.1	5.1	39.0	38.3	6.2

Table 8-1: Variance Decomposition (*the second half*)
for WITHIN ONE MONTH, in %

shock\Var.	R	M	EX
EXDD	0.4	0.2	2.2
P	0.2	0.2	0.3
Y	0.1	2.0	3.5
CB	71.4	23.0	5.8
MD	24.2	73.3	0.5
EXM	3.8	1.2	87.6

Table 8-2: Variance Decomposition (*the second half*):
Contribution of **Policy Shocks**, in %

	EXDD	P	Y	R	M	EX
12 months	1.6	29.4	18.8	54.4	13.7	14.8
24 months	14.5	19.7	30.9	36.9	12.7	9.6

Tables 7-1 and 8-1 show that, in both of the sub-periods, both the (CB) shocks and the (MD) shocks are important sources of variation in both R and M, in the short run. This supports the validity of the partial accommodation view. The short run effect of the identified policy shocks on EX has increased in the second sub-period, though the contribution is still modest. The short run effect of EXDD on EX was substantial in the first sub-period but has become much smaller in the second sub period.

Table 7-2 shows that the contribution of the identified policy shocks on variations in P, Y and EX were quite small. On the other hand, in Table 8-2, it is shown that their relative contributions were substantially larger in the second sub-period, in particular on P and Y.

9 Conclusions

Important conclusions from this study are as follows. First, it is important to allow for the possibility of partial accommodation when trying to identify monetary policy shocks in Spain. In all the three samples I tried, both policy shocks and money demand shocks were important sources of variation for both R and M in the short run. Second, it is important to take into account the structural break. Statistical tests support the presence of the break, and, when I estimated the model separately for the two sub-samples, the estimates turned out to be substantially different between the two. The break point was likely to be around 1984, which is consistent with the conventional wisdom. Third, the estimates for the contemporaneous relationship suggest that there were important changes in the short run Spanish monetary policy rules between the two sub-periods. Although the policy rule was essentially that of mixed targeting in both periods, that of the first sub-period was very close to monetary aggregate targeting while in the second sub-period it has become much closer to the interest rate targeting. In the first sub-period, the exchange rate did not enter into the short run policy rule of the Bank of Spain, but its importance increased in the second sub-period. These findings are consistent with what has been believed widely but without any empirical support. Fourth, there is some indication that my identification scheme does not correctly identify policy shocks in the first sub-period. I tentatively attribute this deficiency to possible existence of non market measures used by the Bank of Spain, such as moral suasion and credit control. However, more studies are needed for this sub-period to make any definite conclusion. The fifth and final conclusion is that my identification scheme turns out to be quite successful for the second sub-period, after 1984. All the estimated responses to policy shocks are consistent with the standard belief. It was found that the identified policy shocks are important sources of variation for the price level, output, and the exchange rate for this sub-period.

Appendix

A Data Source

EXDD: Market Rate, Deutsche Mark, International Financial Statistics, IMF, code 134 RF.

P: Consumer Price Index (1990 = 100), International Financial Statistics, IMF, code 184 64.

Y: Indexes of Industrial Production (1990 average=100), Seasonally Adjusted, International Financial Statistics, IMF, code 184 66C.

R: Daily Interbank Money Market Rate, Monthly Bulletin of Statistics, Bank of Spain, code BE200401 and CU239819.

M: M3, seasonally adjusted, Monthly Bulletin of Statistics, Bank of Spain, code BE010607 and CU258339

A.1 Full Results: Contemporaneous Relationship

This section reports full results for the estimated contemporaneous relationship. In the table, "whole", "first", and "second" m an estimation results for the whole sample, the first sub-sample (until 1984) and the second sub-sample (after 1984), respectively.

	whole	first	second
a_{2DD}	-0.002 (0.013)	-0.037 (0.030)	0.012 (0.010)
a_{3DD}	-0.002 (0.036)	-0.021 (0.073)	-0.012 (0.037)
a_{3P}	0.139 (0.184)	0.147 (0.236)	0.333 (0.302)
a_{4DD}	-0.104 (0.109)	-0.386 (0.214)	0.041 (0.048)
a_{4M}	7.569 (7.997)	7.800 (8.067)	1.634 (2.519)
a_{4EX}	- -	- -	0.178 (0.572)
a_{5P}	0.018 (0.042)	0.049 (0.031)	-0.085 (0.098)
a_{5Y}	0.028 (0.017)	0.026 (0.013)	0.041 (0.026)
a_{5R}	-0.059 (0.059)	-0.027 (0.018)	-0.208 (0.284)
a_{6DD}	-0.257 (0.044)	-0.437 (0.091)	-0.063 (0.046)
a_{6P}	0.426 (0.230)	0.529 (0.291)	-0.199 (0.363)
a_{6Y}	-0.078 (0.082)	-0.082 (0.120)	-0.211 (0.096)
a_{6R}	-0.012 (0.037)	0.027 (0.048)	-0.395 (0.778)
a_{6M}	-0.819 (0.425)	-1.575 (0.951)	0.253 (1.817)

Standard errors are in parentheses.

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Figure 1
Responses to
One Standard Deviation Policy Shocks
(whole sample)

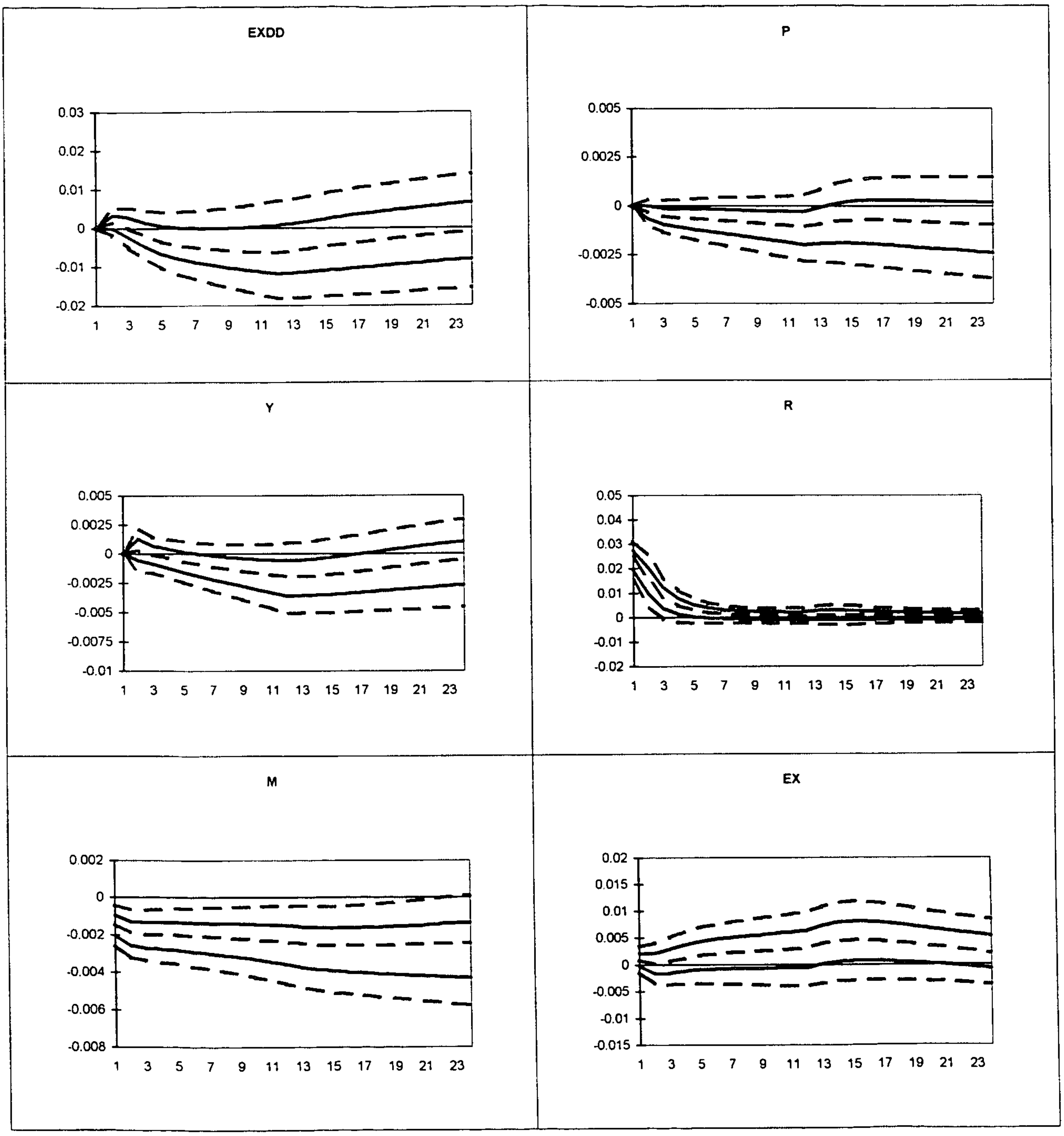


Figure 2
Daily Interest Rate in Spain (%)

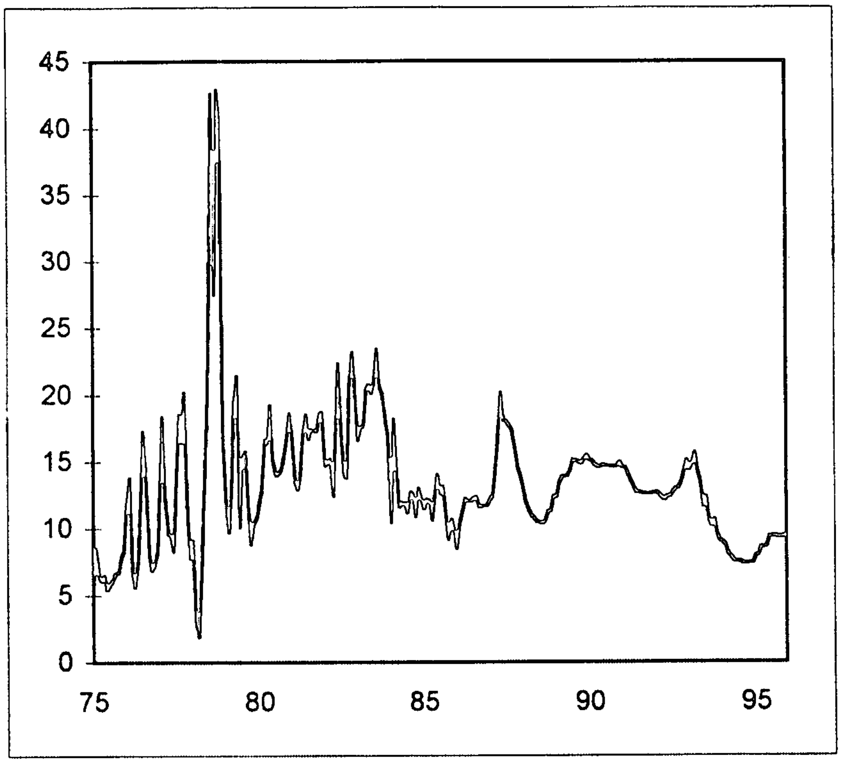


Figure 3
Responses to
One Standard Deviation Policy Shocks
(first half)

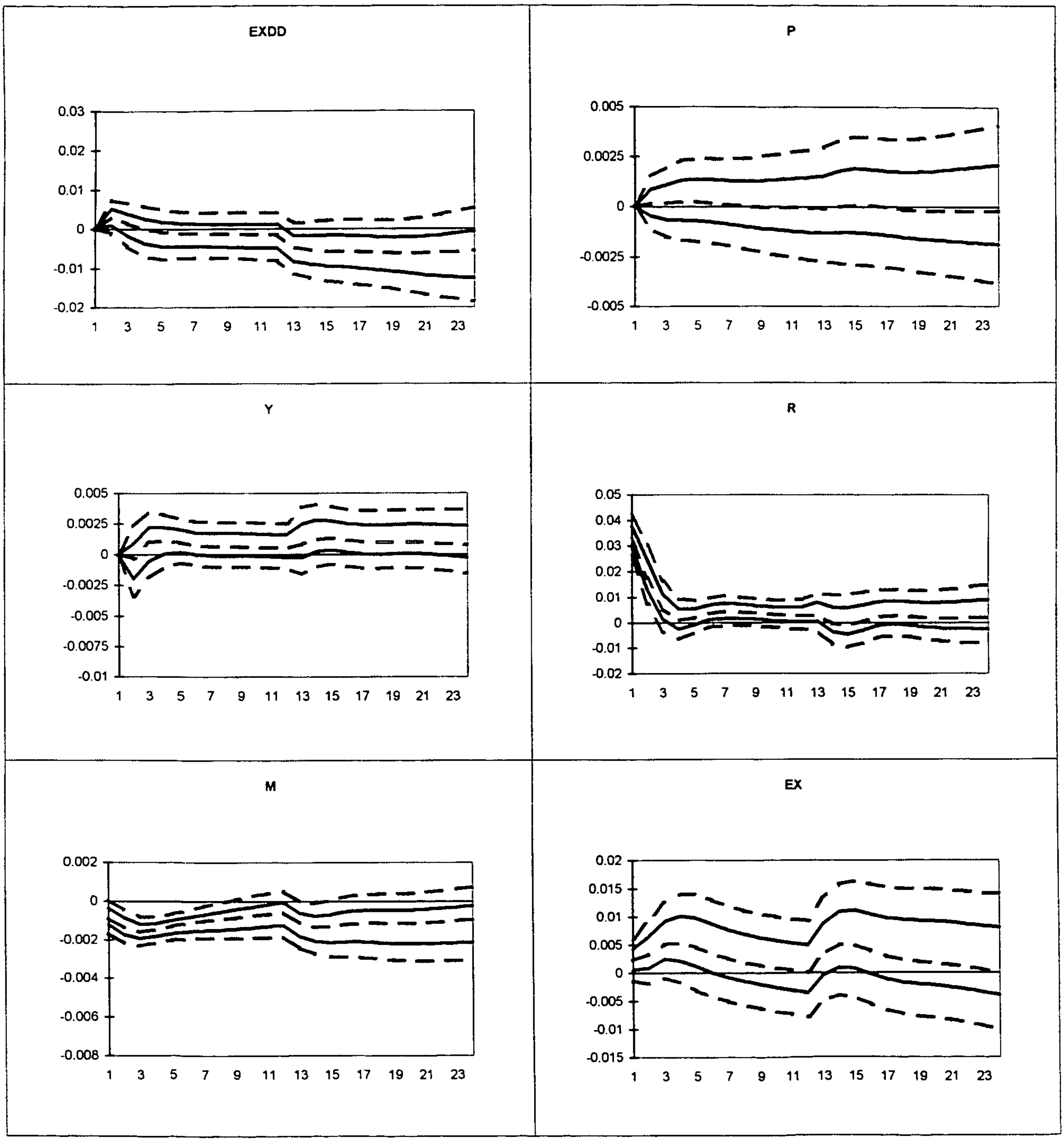
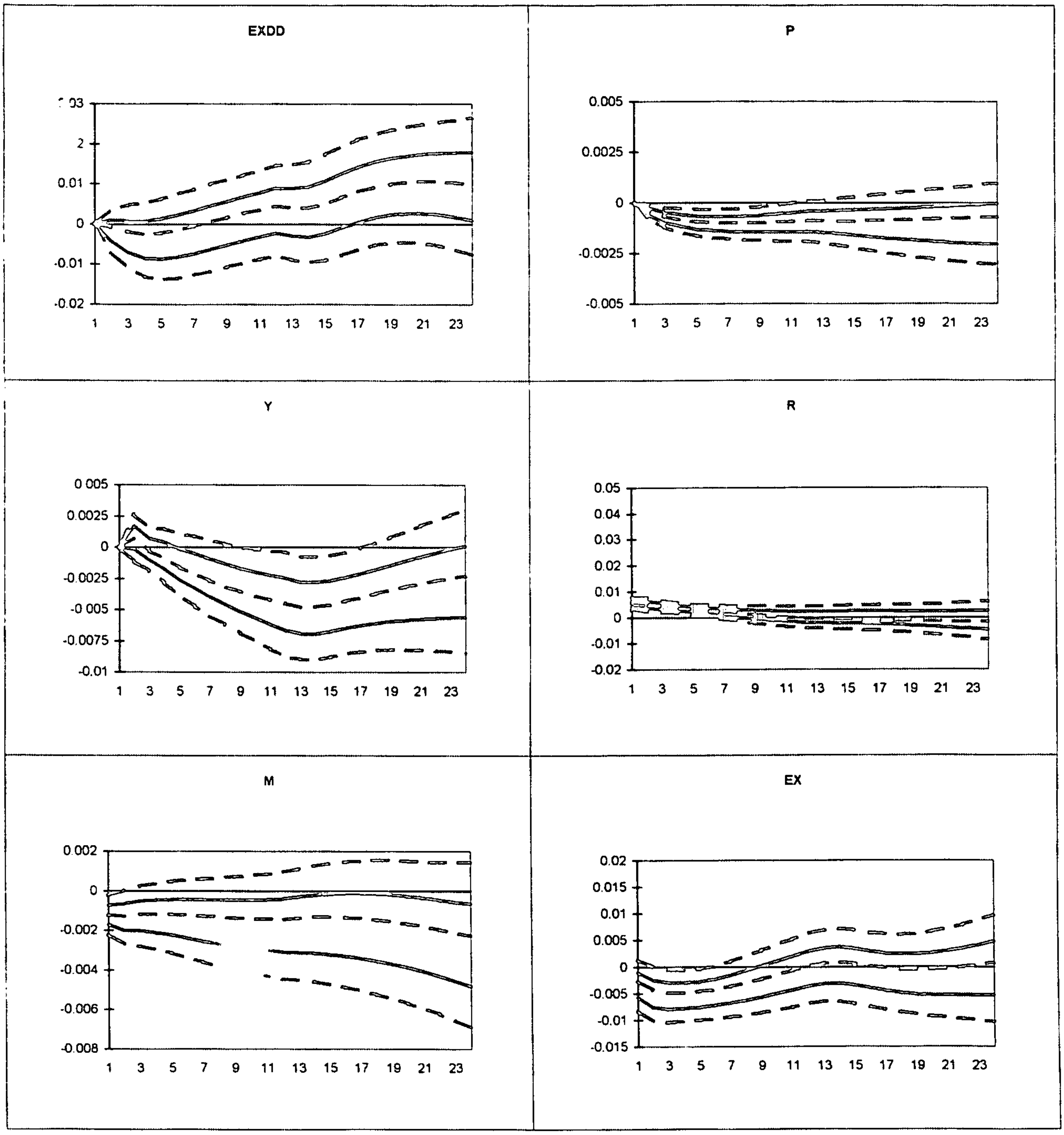


Figure 4
Responses to
One Standard Deviation Policy Shocks
(second half)



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