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ABSTRACT

Measuring Monetary Policy in Open Economies*

The empirical VAR literature on the monetary transmission mechanism in open economies has not yet provided a commonly accepted solution to the problem of simultaneity between interest rates and the exchange rate. In this paper we propose to solve the identification problem by using information extracted from financial markets independently from the VAR to measure monetary policy shocks. We also evaluate the relative importance of macroeconomic and monetary policy variables in explaining short-term fluctuations in the nominal exchange rate. Our main results are that the simultaneity between German policy rates and the US dollar/Deutsche mark exchange rate is not an empirically relevant problem and that monetary variables are dominated by macroeconomic factors in the explanation of exchange rate fluctuations.

JEL Classification: E44, E52, F41
Keywords: monetary policy, VAR models, exchange rates, implicit forward rate curve

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NON-TECHNICAL SUMMARY

The empirical vector autoregression (VAR) literature on the monetary transmission mechanism in closed economies has produced solutions to a number of empirical puzzles and has been successful in providing evidence with which theoretical models of the monetary transmission mechanism are now confronted. The empirical VAR literature on the monetary transmission mechanism in open economies has not enjoyed the same success and it is still marred with a number of empirical puzzles.

In closed-economy analyses, the ‘liquidity puzzle’ (the positive reaction of interest rates to an expansionary shock to monetary aggregates) and the ‘price puzzle’ (the positive reaction of the price level to a contractionary monetary policy shock) have been explained and solved by focusing on the market for banks reserves rather than on broader monetary aggregates to extract monetary policy shocks, and by the inclusion of the commodity price index as a leading indicator of inflation in the VAR specification

In the open-economy literature, the emergence of the ‘forward discount premium puzzle’ for the United States (i.e. following a restrictive monetary policy move in the United States, the dollar persistently appreciates and the response of the US interest rate is persistently higher than that of the foreign rate) and of the ‘exchange rate puzzle’ (i.e. a restrictive monetary policy shock in non-US countries causes a depreciation of the foreign currency *vis-à-vis* the US dollar) has not yet found a widely accepted explanation. As argued by McCallum, such puzzles could be explained by the incapability of VAR models to distinguish exogenous monetary policy shocks from the endogenous reaction of monetary authorities to exchange rate fluctuations in open economies. Indeed, the existence of a simultaneous feedback between interest rates and the exchange rate poses a formidable identification problem for structural VAR models.

In this paper we propose to solve the simultaneity between exchange rate and policy interest rates by using information extracted from financial markets independently from the VAR. We concentrate on the United States-German case to address the problem of identifying exogenous Bundesbank policy moves from the reaction of policy rates to fluctuations in the US Dollar/Deutsche mark exchange rate. Exploiting the fact that intervention on policy rates takes place on occasion of regular bi-weekly meetings of the Bundesbank Council, we estimate the term structure of spot rates and of instantaneous forward rates the day before regular meetings, obtaining a measure of expectations for Bundesbank interventions. With such direct measure of the shock we evaluate the importance of the simultaneity of exchange rates and policy rates and we reassess the puzzles observed in the literature. Lastly, we evaluate the relative importance of macroeconomic and monetary policy variables in explaining short-term fluctuations in the nominal exchange rates.

Our analysis shows that there is no within-month simultaneous feedback between policy rates and the exchange rate.

We also evaluate the relative importance of macroeconomic and monetary policy variables in explaining short-term fluctuations in the nominal exchange rates. The results from simultaneous feedbacks, impulse responses and variance decompositions reveal that monetary factors play a very limited direct role in explaining exchange rate fluctuations, which are largely determined by macroeconomic factors.

Introduction

The empirical VAR literature on the monetary transmission mechanism in close economies has solved a number of empirical puzzles and has been successful in providing evidence with which theoretical models of the monetary transmission mechanism are now confronted. However, when extended to open economies, this literature has not enjoyed the same success and is still marred with a number of empirical puzzles.

In close-economy analyses, the "liquidity puzzle" (the positive reaction of interest rates to an expansionary shock to monetary aggregates) and the "price puzzle" (the positive reaction of the price level to a contractionary monetary policy shock) have been explained and solved by focusing on the market for bank reserves rather than on broader monetary aggregates to extract monetary policy shocks, and by the inclusion of the commodity price index as a leading indicator of inflation in the VAR specification (Christiano, Eichenbaum and Evans (1998)).

In the open-economy literature, the emergence of the "forward discount premium puzzle" for the U.S. (i.e. following a restrictive monetary policy move in the U.S., the dollar persistently appreciates and the response of the U.S. interest rate is persistently higher than that of the foreign rate) and of the "exchange rate puzzle" (i.e. a restrictive monetary policy shock in non-U.S. countries causes a depreciation of the foreign currency vis-à-vis the US dollar) has not yet found a widely accepted explanation. As argued by McCallum (1994), such puzzles could be explained by the incapability of VAR models to distinguish exogenous monetary policy shocks from the endogenous reaction of monetary authorities to exchange rate fluctuations in open economies. Indeed, the existence of a simultaneous feedback between interest rates and the exchange rate poses a formidable identification problem for structural VAR models.

In this paper we propose to solve the simultaneity between exchange rate and policy interest rates by using information extracted from financial markets independently from the specification of the VAR system. After a review of the main issues and results from previous literature (Section 1), we concentrate on the U.S.-German case to address the problem of identifying exogenous Bundesbank policy moves from the reaction of German policy rates to fluctuations in the U.S. Dollar-Deutschemark exchange rate (Section 2). Exploiting the fact that intervention on policy rates takes place on occasion of regular bi-weekly meetings of the Bundesbank Council, we estimate the term structure of spot rates and of instantaneous forward rates the day before regular meetings, obtaining a measure of expected Bundesbank interventions; the unexpected part of interventions is taken as a direct measure of monetary policy shocks (Section 3). Using this measure in an open-economy VAR system, we evaluate the importance of the simultaneity of exchange rates and policy rates and we re-assess the puzzles observed in the literature. Lastly, we evaluate the relative importance of macroeconomic and monetary policy variables in explaining short-term fluctuations in the nominal exchange rates (Section 4). The main conclusions are finally summarized in Section 5.

1. Structural VAR models in close and open economies

VAR models of the monetary transmission mechanism are estimated within a research program aimed at using general equilibrium models for policy analysis. As described by Christiano, Eichenbaum and Evans (1998), empirical work should provide evidence on the stylized facts to be included in the theoretical model adopted for policy analysis and should allow to discriminate between competing general equilibrium monetary models.

The empirical success of VAR models is due to their capacity to identify monetary policy shocks and the ensuing responses of relevant macroeconomic variables in actual economies. Monetary policy shocks are not readily observable: given a statistical model for the vector of variables of interest, some structure has to be assumed for identification of the shocks. Such structure must be identified independently of specific predictions of alternative theoretical models: in fact, only in this case we can choose between alternative models on the basis of the empirical evidence (Uhlig (1997)).

Cumulative work on the analysis of the monetary transmission mechanism in the U.S. (the prototype of a close economy) led to the specification of a VAR system which has by now become the standard reference model (Strongin (1995), Bernanke and Mihov (1998), Gordon and Leeper (1994), Christiano, Eichenbaum and Evans (1997, 1998), Leeper, Sims and Zha (1996)). Such "benchmark" specification contains three macroeconomic non-policy variables (gross domestic product, the consumer price index and the commodity price level) and three policy variables (the federal funds rate, the quantity of total bank reserves and the amount of nonborrowed reserves). Given the estimation of the reduced form VAR for the six macro and monetary variables, a structural model is then identified by: (*i*) assuming orthogonality of the structural disturbances; (*ii*) imposing no simultaneous reaction of macroeconomic variables to monetary variables, while the simultaneous feedback in the other direction is allowed, and (*iii*) imposing restrictions on the monetary block of the model reflecting the operational procedures implemented by the monetary policy maker. All identifying restrictions satisfy the criterion of independence from specific theoretical models.

The estimation of benchmark VAR models has generated a number of "stylized facts" on the effect of a contractionary monetary policy shock: *(i)* the aggregate price level initially responds very little; *(ii)* interest rates initially rise, and *(iii)* aggregate output initially falls, following a j-shaped response, with a zero long-run effect of the monetary impulse. Such evidence leads to the dismissal of traditional real business cycle models, which are inconsistent with the liquidity effect of monetary policy on interest rates, and of the Lucas (1972) model of money, in which the effect of monetary policy on output depends on price misperceptions. The evidence seems to be more in line with alternative interpretations of the monetary transmission mechanism based on sticky prices models (Goodfriend and King (1997)), limited participation models (Christiano, Eichenbaum and Evans (1997)) or models with indeterminacy-sunspot equilibria (Farmer (1997)). Interestingly, such evidence seems to be robust to the choice of the sample and on the policy regime under which the model is estimated (Christiano, Eichenbaum and Evans (1998)).

Various papers have examined the effects of monetary shocks in open economies, but this strand of literature has been distinctly less successful in providing accepted empirical evidence than the VAR approach in closed economies. The first results have been provided by Eichenbaum and Evans (1995). We represent their model as a special case of the following $A-B$ structure in Amisano and Giannini (1996):

$$\mathbf{A_0 y}_t = \sum_{i=1}^{k} \mathbf{A}_i \mathbf{y}_{t-i} + \mathbf{B}\boldsymbol{v}_t \tag{1.1}$$

where $\mathbf{y}_t = \left[\begin{array}{ccccccc} Y_t^{US} & P_t^{US} & NBRX_t^{US}(FF_t) & Y_t^{FOR} & P_t^{FOR} & R_t^{FOR} & e_t(q_t) \end{array} \right]'$. Y^{US} and P^{US} are logs of U.S. output and price level, $NBRX^{US}$ is the ratio of non-borrowed to total reserves (the appropriate variable from which monetary policy shocks can be derived under a regime of non-borrowed reserves targeting), FF is the Federal Funds rate (considered as an alternative to $NBRX^{US}$, being the informative variable for the extraction of monetary policy shocks under a regime of interest rate targeting). Y^{FOR}, P^{FOR} and R^{FOR} are respectively the logs of output, the price level, and the level of short-term interest rate in the foreign country; e is the nominal bilateral exchange rate, while q is the real bilateral exchange rate.

The matrix $\mathbf{B}$ is diagonal and $\mathbf{A}_0$ is lower-triangular. The empirical analysis is implemented by considering as a foreign country each of the G7 countries in turn on a sample of monthly data from 1974(1) to 1990(5). The following evidence emerges: (*i*) a restrictive U.S. monetary policy shock generates a significant and persistent appreciation of the U.S. dollar; (*ii*) a restrictive U.S. monetary policy shock generates a significant and persistently larger effect on the domestic interest rate with respect to the foreign rate; (*i*) and (*ii*) imply a sharp deviation from the uncovered interest parity condition in favour of U.S. dollar-denominated investments (the "forward-discount puzzle"); (*iii*) identified U.S. monetary policy shocks are not different from the shocks derived within closed-economy VARs (*iv*) the close-economy response of U.S. prices and output to monetary policy shocks is robust to the extension of the VAR to the open economy; (*v*) a restrictive foreign monetary policy shock generates an appreciation of the U.S. dollar (the "exchange-rate puzzle"); and (*vi*) the response of the real exchange rate to the U.S. and foreign monetary policy shocks does not differ significantly from the response of the nominal exchange rate. Such evidence is substantially confirmed by the work of Schlagenhauf and Wrase (1995), who consider a very similar specification for the G-5 countries over the sample 1972(2)-1990(2), using quarterly data.

Some considerations are in order to help the interpretation of the above results. First, the empirical models are estimated over samples including shifts in U.S. and foreign monetary policy regimes: therefore, parameter instability is a potential problem. Second, these extensions to the open economy feature the omission from the VAR of the commodity price index and of the monetary variables not relevant to the extraction of the policy shocks. While the simplification of the monetary block is sustainable in the light of the absence of contemporaneous feedback between the informative variables and the other monetary variables under the chosen identification scheme, the omission of the commodity price index is not justifiable as it leads to the same mis-specification as in the close economy model for U.S. monetary policy shocks. Moreover, such omission might well also bias the identification of the foreign monetary policy shocks if the commodity price index is regarded as a leading indicator of inflation by the foreign policymaker.

Third, while some rationale can be provided for a quasi-recursive scheme in close economies, a similar justification is much harder to accept in an open-economy framework. In fact, the recursive identification scheme with the exchange rate ordered last, implies that neither the U.S. nor the foreign monetary authority react contemporaneously to exchange rate fluctuations. This assumption seems to be sustainable for the U.S. (the Fed benign neglect for the dollar) but it is certainly heavily questionable when the foreign countries are considered, as they are much more open economies than the U.S.

Therefore, most of the recent empirical work is aimed at breaking such recursive structure in the identification scheme. Kim and Roubini (1997) introduce a structural identification by the explicit consideration of a money demand and supply functions. They specify a model for non-U.S. countries including seven variables: two non-domestic variables (the world index of oil price in dollars and the Federal Funds rate) and five domestic variables (the short-term policy rate, a monetary aggregate -M0 or M1-, the log of consumer price index, the log of industrial production, and the nominal exchange rate against the dollar). The identifying restrictions are as follows: the U.S. economy is taken as exogenous and the exchange rate does not enter in the Fed reaction function, U.S. output and prices are not included in the VAR, while a simultaneous feedback is allowed between money demand and supply, capturing the rule followed by the central bank. According to this rule, contemporaneous U.S. interest rate movements are relevant to the foreign central bank only if they affect the exchange rate. Only the exchange rate is allowed to contemporaneously react to news in all other variables. The coefficients measuring simultaneous effects are estimated rather imprecisely and the potential simultaneous feedback between foreign monetary policy and the exchange rate does not seem to be empirically relevant. However, all puzzles disappear and the empirical results for the impulse response functions are broadly in line with those from the U.S. close-economy model.

We note that also in this case the sample considered spans different regimes. Moreover this methodology brings back into the specification broad monetary aggregates. Interestingly, money is used to extract demand rather than supply shocks, but the specification of money demand implicit in the VAR might not be rich enough to capture the dynamics in the data. As pointed out by Faust and Whiteman (1997), single equation work by Hendry and colleagues on money demand has clearly shown the importance of including in the model the opportunity cost of holding money, which is often a spread between interest rates. Those spreads, capturing the opportunity cost of holding money, are never included in VAR models of the monetary transmission mechanism.

An identification similar to the one adopted by Kim and Roubini is the one proposed for the Canadian case by Cushman and Zha (1997), who aid the structural identification by introducing explicitly the trade sector into the model. An interesting alternative approach to the identification of the simultaneous feedback between non-U.S. interest rates and exchange rates is proposed by Smets (1996, 1997). Smets considers a structural model for non-U.S. countries including four variables:output growth, inflation, a short term interest rate and the exchange rate appreciation. No U.S. variable is introduced, and the commodity price index is also excluded. Both macroeconomic and monetary shocks are identified by imposing three type of restrictions. First, macro variables do no react contemporaneously to monetary variables. Second, macroeconomic supply shocks are distinguished from macroeconomic demand shocks by following Blanchard and Quah (1989) to assume that demand shocks do not affect output in the long-run. Third, monetary policy shocks are identified from exchange rate shocks by assuming that the Central Bank reacts proportionally to interest rate and exchange-rate developments, adopting a short-term monetary conditions index (MCI) strategy. The relative weights in the MCI can be estimated or imposed given the knowledge of the weights used in practice by several Central Banks. This approach encompasses the pure interest rate targeting and the pure exchange rate targeting as special cases. The proposed strategy is judged rather successful in the solution of the relevant puzzles. The main empirical problems with this procedure are the instability of the estimated weights in the MCI and the potentially disruptive implications of mis-specification for the identification of aggregate demand and supply shocks (see Faust and Leeper (1997) on this point).

To sum up, our analysis of VAR models of the monetary transmission mechanism points towards two possible explanations for the puzzles observed in open economies: *mis-specification*, via the omission of a commodity price index in the benchmark open-economy VAR, and problems of identification related to the *simultaneity* between interest rates and exchange rates in small, open economies. We include the commodity price index in our VAR and explicitly address the identification problem by using a non-VAR measure of monetary policy shocks to investigate the simultaneous feedback between exchange rates and policy rates. We address the identification issue using a VAR model linking the U.S. and the German economies. The choice of Germany is justified by the opportunity of identifying monetary policy shocks using direct information from financial markets, independently from the specification of the VAR model. This opportunity is provided by the operational procedures adopted by the Bundesbank in setting policy rates.

2. An open-economy VAR model for U.S. and Germany

We estimate first a benchmark open-economy VAR model for the U.S. and Germany. The model is estimated on monthly data over the sample 1983(1)- 1997(11). The VAR system includes six lags of the U.S. industrial production (Y^{US}), the commodity price index (Pcm), the U.S. consumer price index (P^{US}), the Federal Funds rate (FF), the German industrial production (Y^{GER}), consumer price index (P^{GER}) and call money rate (R^{GER}), and the U.S.-dollar/Deutschemark nominal exchange rate (unit of DM for one U.S. dollar, e). All variables are displayed in *Figure1*. Since preliminary statistical analysis of the VAR revealed the presence of some outliers, we have augmented the specification with three dummy variables: the first taking a value of 1 in June 1984 and zero elsewhere; the second taking a value of -1 in June 1988, 1 in July 1988 and zero elsewhere, and the third one taking a value of 1 in January 1993 and zero elsewhere. Such dummies have been kept throughout the following empirical analysis.

The choice of the sample period is motivated by two reasons: (i) having a single monetary policy regime for the U.S., featuring Fed funds targeting (Bagliano and Favero (1998), Bernanke and Mihov (1998)), (ii) estimating the model over a sample allowing alternative derivations of monetary policy shocks. In fact, our proposed methodology involves the estimation of term structures of German interest rates on occasion of Council meeting, and such data are available on Datastream from 1983 onwards. The results of the estimation of the structural parameters in the benchmark VAR model in open economies are reported in *Table 1*, while responses of all variables to U.S. and German monetary policy shocks are shown in *Figures 2* and *3.*

Our adopted standard recursive specification does not allow any simultaneous feedback between German policy rates and the exchange rate. In fact, being ordered last, the exchange rate reacts simultaneously to all the other variables in the VAR, but the German policy rate is not allowed to react simultaneously to the exchange rate. The analysis of the contemporaneous feedbacks provides evidence on the endogeneity of the U.S. monetary policy, which reacts significantly to internal conditions. In fact, the U.S. policy rate shows a significant simultaneous response to shocks to domestic inflation and output: an unexpected one per cent increase in inflation (output) induces an increase of 37 (8.6) basis points in the policy rate. The German monetary policy reacts to internal conditions only, with an unexpected increase in output inducing an increase of 2.6 basis points in the policy rate. The exchange rates shows a significant contemporaneous reaction to U.S. monetary policy (with a one-per-cent positive interest rate shock in the U.S. causing appreciation of the U.S. dollar vis-à-vis the DM of 2.3 per cent) and to macroeconomic conditions in U.S. and Germany (with a one-per-cent positive shock in U.S. output generating a 1.22 per cent impact appreciation of the dollar, and a one-per-cent positive shock in German inflation causing a 2.57 per cent appreciation of the dollar).

The analysis of the dynamic responses to monetary impulses in the U.S. and Germany confirms all main findings of the literature, namely:

- a significant U-shaped response of U.S. output to U.S. monetary policy;
- the absence of a price puzzle both for the U.S. and Germany, due to the inclusion of the commodity price index in the set of variables;
- an unexpected increase in the U.S. policy rates induces an temporary appreciation of the U.S. Dollar/D.Mark exchange rate. The maximum appreciation does not occur on impact, but after about fifteen months. This is due to a less than one-to-one response of German short-term rates. However, over a longer horizon the German rate reacts and we do not observe a forward discount bias;
- the effect of an unexpected increase in German policy rates is not symmetric to the U.S. case. In fact, the Federal Fund rate and the exchange rate do not respond significantly to German monetary policy.

This last set of responses would suffer most from potential simultaneity problem between German policy rates and the exchange rate. To address explicitly this issue we propose to solve the identification problem by using a non-VAR measure of German monetary policy shocks.

3. Measuring monetary policy shocks in Germany without a VAR.

In order to measure monetary policy shocks without imposing any linear, time-invariant, backward-looking structure to the data, we define a monetary policy shock as the unexpected change in the very short term interest rate occurring at "special" dates. These dates are the days of Bundesbank Council meetings, where most relevant decisions on monetary policy are taken (modifications in all reference rates –the marginal lending rate, the marginal deposit rate and the repo rate– have been regularly taken at Council meetings dates). The Bundesbank Council meets regularly every two weeks and the calendar of the meetings is information available to the public.

The unexpected change in the policy rates is derived following Svensson (1994), and Soderlind and Svensson (1997). We estimate a term structure of spot interest rates on the day before the Council meeting by fitting a smooth interpolant function through the observed rates. Given the availability of a smooth yield curve for spot rates, we can unequivocally determine the curve of istantaneous forward rates the day before the meeting. Interpreting the istantaneous forward rate as the overnight interest rate, the curve of instantaneous forward rates gives us the succession of expected overnight rates at all future dates. Therefore, we are able to compute the overnight interest rate expected for the day following the Council meeting. The difference between the overnight interest rate the day after the meeting and the expected overnight interest rate for the day following the meeting, conditional upon information available before the meeting, is our measure of monetary policy shocks.

The hypothesis involved in the estimation of the istantaneous forward rates, i.e. the pure expectational model of the term structure, implies that the market incorporates an expected monetary policy action in the yields with a maturity exceeding the day of the decision on the monetary policy action. In practice, for the short-end of the term structure, this means that whenever the Bundesbank Council is expected to change the stance of monetary policy on occasion of a given meeting, then a significative difference between the current overnight rate and forward rates with maturity higher than two days should emerge. We construct the series of overnight rates at any future day by estimating a yield curve for spot rates and by deriving the associated yield curve for instantaneous forward rates. Following Svensson's methodology, we use the continuous functional form proposed by Nelson and Siegel (1987), extended if appropriate, to fit the observed interest rates.

A standard practice in the application of this curve-fitting approach is to include the overnight rate in the information set, sometime constraining the fitted overnight rate to match the observed one in estimation. However, a monetary policy shock implies by definition a jump in, at least, the short end of the term structure. Forcing the smooth instantaneous forward rate curve to fit exactly the observed overnight rate would not allow to seize an eventual expected monetary policy action. For this reason, we exclude the overnight rate from the information used for estimation. Then, exploiting the continuity of the functional form, we reconstruct the very short end of the term structure allowing for a gap between the estimated overnight and the observed overnight. Such a gap represents the jump in the very short-end of the term structure associated with expectations of intervention by the Bundesbank.

An example can clarify matters. On occasion of the meeting held on the 2nd of December 1993, the Bundesbank reduced the repo rate by 25 basis points. In *Figure 4* we show Nelson-Siegel interpolants of the term structure of interest rates observed on the close of the markets before the meeting. Two yield curves for spot rates are displayed, the first one ($SPOTYO$) fitting the data including the overnight rate, while the second one excludes the overnight rate ($SPOTYW$). We also report the two instantaneous forward curves associated respectively to the spot curve estimated including ($IFOY$) and excluding the overnight rate (IFW). The figure clearly shows that the term structure reflected the expectation of a cut in the policy rate. Therefore, fitting the curve on data including the overnight rate, allowing no jump in the term structure from the date of the Council meeting afterwards, would have spuriously generated an interest rate shock.

3.1. Analyzing interesting episodes.

In this section we consider the performance of our methodology for estimating monetary policy shocks on specific occasions. We illustrate examples of monetary shocks generated by unanticipated *action* or by unanticipated *inaction* by the Bundesbank, and examples of markets' anticipation of Bundesbank behaviour when expectations on monetary policy turned out to be correct and no shocks were observed.

Consider July 1988, when the Bundesbank Council met twice, on the 14th and on the 28th. On the first occasion the Bundesbank didn't take any action, whereas at the second Council it was decided to raise the Lombard rate by 50 basis points. In the top panel of *Figure 5* we show the weekly and the overnight rates, alongwith the monetary policy action (PMA). Areas spanning three days centered around meetings are shaded. We note that no monetary policy action was expected during at first meeting, while some action was expected before the second one.

Six days before the meeting, the weekly rate contains the first six days of maturity which do not include the action and the seventh one which instead does include the action, so the weekly rate should start to "reflect" the monetary policy action six days before the meeting. Of course, the weight of the seventh day is only one-seventh and therefore the information doesn't appear clearly six days before, but as we approach the date of the Council the weight of the action becomes greater and the expectation discloses itself. It can be observed that the weekly rate starts reacting three days before the meeting. It is also possible than the market realizes that the Bundesbank will act only a few days before the Council (say less than six days before): in this case the weekly rate starts reacting later than six days before the Council. The weekly rate should be the best observed interest rate to identify expectations of monetary policy actions. In fact, Council meetings take place fortnightly and the 1-month rate observed immediately before any meeting reflects expectations on the outcome of the following two meetings.

The second episode we consider is the tightening of monetary policy occurred after German reunification in January-February 1991, with two meetings held, on the 17th of January and on the 2nd of February. As the middle panel of *Figure 5* clearly shows, the weekly rate increased sharply just before the first Council, revealing an expected increase in interest rates. The Bundesbank did not act on that meeting, the expected tightening occurring at the following Council meeting, when the discount rate and the Lombard rate were raised by 50 basis points. To summarize, on the 14th of January we observed a monetary policy shock arising from an anticipated action that did not in fact occur, meanwhile on the 2nd of February there was no shock as the policy move had been correctly anticipated.

The third episode we single out occurred in December 1991, when the Bundesbank tightened monetary policy, raising once again the discount rate and the Lombard rate by 50 basis points. The dates of the Bundesbank Councils are the 5th and the 19th of December. During the latter meeting the Bundesbank surprised the market, and we observe a shock arising from an unexpected policy action.

3.2. An assessment of our methodology.

The main strength of the above methodology is its flexibility and its capability to capture shocks independently from the specification of a linear autoregressive model. Other approaches to derive monetary shocks independently from a VAR have been followed by Skinner and Zettelmeyer (1996) and Rudebusch (1996). Skinner and Zettelmeyer construct a measure of unanticipated monetary policy actions by following a two-step methodology: first, using information from central bank reports and newspapers they compile a list of days on which monetary policy moves occurred; then, monetary policy shocks are identified as the changes in the three-month interest rate on those days. The main problem with this index is that it can only pin down shocks associated to monetary policy decisions reflected in some action on controlled variables, whereas shocks associated with *no* action (while some action was expected by the markets) are neglected. Rudebusch derives monetary policy shocks for the U.S. case from the 30-day Fed funds future contracts, which have been quoted on the Chicago Board of Trade since October 1988, and are bets on the average overnight Fed funds rate for the delivery month, corresponding to the variable included in the benchmark VAR. Shocks are constructed as the difference between the Federal funds rate at month t and the 30-day Federal funds future at month $t-1$. This procedure produces shocks which are comparable to the reduced form innovations from the VAR and not to the structural monetary policy shocks, because surprises relative to the information available at the end of month $t-1$ may reflect endogenous policy responses to news about the economy that become available in the course of month t. Moreover, such procedure cannot be extended to other, non U.S., countries.

We believe that our alternative methodology delivers monetary policy shocks which are not affected by the sample selection problem of Skinner and Zettelmeyer (1996) and which should be strongly related to exogenous monetary policy actions. In fact, all the information on the endogenous part of monetary policy should be incorporated in markets' assessment of the term structure immediately before the Bundesbank Council meetings.

The main limitation of our approach is caused by the volatility of very short-term rates not related to expectations on monetary policy. *Figure 6* shows daily observations on the overnight and the weekly rates for the estimation sample period used in the VAR. We immediately notice a number of blips in the series. Those blips could be very damaging to our methodology whenever they coincide with Bundesbank Council meetings. Most of those blips are generated by bank reserve management in a not perfectly liquid market, such as on the occasion of the last day of the average reserve maintenance period. We tried to make our inference robust to blips. In fact, we have estimated our curves starting from the 7-day rather than the overnight rate, and our methodology of estimation considers the information contained in the whole term structure. Moreover, we have run a further check and avoid to label as policy shocks all unexpected movements in policy rates which have disappeared within a week after a Council meeting. Such correction led us to single out two outliers in September 1988 and December 1991.

The 1988(9) outlier is the only one of a relevant magnitude. In *Figure 7* we show the behaviour of the 7-days and the 1-month rate in September 1988. Although no policy intervention was decided in this month, just before the meeting of mid-September we observe a hike in the 7-day rate. Such hike is not reflected in the term structure for longer maturities (the 1-month rate is shown for reference). Since this hike rise in interest rates is reversed within the week after the meeting, we do not consider this episode as signalling a monetary policy shock.

4. An evaluation of the simultaneous feedback between interest rates and the exchange rate

Having derived a direct measure of monetary policy shocks, we aggregate it to construct a monthly variable and include it as an exogenous variable in the benchmark VAR specification. Using this measure in combination with a Choleski ordering of the endogenous variables with the German policy rate coming last, we are able to identify the simultaneous feedback between German monetary policy and the exchange rate. We read the response of exchange rates to a monetary policy shock from the coefficient on our exogenous measure in the equation for the exchange rate, whereas the response of the interest rate to fluctuations in the exchange rate is made endogenous by the ordering chosen. Moreover, we can assess the relation between VAR-based monetary policy indicators and our direct measure of monetary policy shocks by analyzing the estimated coefficient on the exogenous variable in the equation for the German policy rate. Our estimated simultaneous feedback coefficients are reported in *Table 2.* The impulses responses to monetary shocks are shown in *Figure 8,* while *Figure 9* displays the response of the exchange rate to all variables in the VAR.

On the simultaneous relations, we do not observe a significant contemporaneous feedback between the German interest rate and the exchange rate in any direction. In our framework, this is a testable proposition rather than an assumed identified restriction. We note that our measure of monetary policy shocks enters significantly in the German policy rate equation and that the contemporaneous response of U.S. output to German monetary policy shocks is small but marginally significant.[1] Overall, the impulse responses are not different from those obtained by the benchmark specification. We can therefore conclude that the potential simultaneity between exchange rate and German policy rate is not empirically

[1] We report impulse responses based on restricting such coefficient to zero; relaxing this restriction does not affect the shape and magnitude of the impulse responses.

relevant and that explicitly addressing such simultaneity does not add much to the explanation of the puzzles provided by the inclusion of the commodity price index in the benchmark open-economy VAR.

4.1. The relative importance of macroeconomic and monetary factors in the determination of exchange rate fluctuations

We conclude our analysis of monetary policy in open economies by looking at the relative importance of macroeconomic and monetary factors in causing exchange rate fluctuations. We do so by looking at the contemporaneous determinants of exchange rate movements in the structural VAR, assessing the dynamic responses of the exchange rate to monetary and macro structural shocks and lastly analyzing the forecast error variance decomposition of the U.S. dollar/D-Mark exchange rate.

The evidence on the simultaneous relationship between the exchange rate and the other variables is robust to the alternative specifications considered in this paper. The exchange rate is significantly affected by contemporaneous fluctuations in the U.S. Fed funds rate, in U.S. output and in the German price level (increases in FF , Y^{US} and P^{GER} all generate a simultaneous appreciation of the dollar), whereas fluctuations in the other variables have no contemporaneous effect on the exchange rate. Within our framework, we are able to attribute to monetary policy actions the main source of fluctuations in the U.S. Fed funds rate, but we cannot identify the source of fluctuations in macroeconomic variables.

The impulse response analysis reported in *Figure 10* reveals that the effect of monetary policy on the exchange rate is very short-lived, while over the 50-month horizon macroeconomic factors play an important role, with some factors being significant in the first months following the shocks and other picking up significance later on.

To corroborate this evidence, we examine the forecast error variance decomposition of the exchange rate by considering the contribution of three type of shocks in explaining the variance of the forecasting error of the U.S. dollar/D.Mark exchange rate at different horizons: own shocks, monetary policy shocks (in both the U.S. and Germany) and macroeconomic shocks (to U.S. industrial production, U.S. prices, German industrial production, German prices and the commodity price index). The results are shown in *Figure 11*: the contribution of monetary factors is constantly negligible over the whole horizon, while the variance of innovations in macroeconomic factors has an increasing importance and explains up to half of the total variance of the 50-period ahead forecast error. Own shocks to the exchange rate are dominant over short horizons but their importance decreases as the role of macroeconomic factors increases.

5. Conclusions

In this paper we addressed the issue of the potential simultaneity between the exchange rate and policy interest rates in open-economy VAR models by using information on monetary policy actions extracted from financial markets. By considering the U.S.-German case we have derived a direct measure of German monetary policy shocks independently from the specification of the VAR, and we have then directly tested the existence of a simultaneous feedback between the German policy rate and the U.S. dollar/D.Mark exchange rate. Our analysis shows that there is no within-month simultaneous feedback between policy rates and the exchange rate.

We have also evaluated the relative importance of macroeconomic and monetary policy variables in explaining short-term fluctuations in the nominal exchange rate. The results from simultaneous feedbacks, impulse responses and variance decomposition analysis reveal that monetary factors play a very limited direct role in explaining exchange rate fluctuations, which are largely determined by macroeconomic factors.

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Table 1
The benchmark open-economy VAR

The estimated VAR model is:

$$\mathbf{A}\begin{pmatrix} Y_t^{US} \\ Pcm_t \\ P_t^{US} \\ FF_t \\ Y_t^{GER} \\ P_t^{GER} \\ R_t^{GER} \\ e_t \end{pmatrix} = \mathbf{B}^*(L)\begin{pmatrix} Y_{t-1}^{US} \\ Pcm_{t-1} \\ P_{t-1}^{US} \\ FF_{t-1} \\ Y_{t-1}^{GER} \\ P_{t-1}^{GER} \\ R_{t-1}^{GER} \\ e_{t-1} \end{pmatrix} + \mathbf{B}\begin{pmatrix} \nu_{1t}^{NP} \\ \nu_{2t}^{NP} \\ \nu_{3t}^{NP} \\ \nu_t^{FF} \\ \nu_{3t}^{NP} \\ \nu_{4t}^{NP} \\ \nu_t^{s} \\ \nu_t^{e} \end{pmatrix}$$

where $\mathbf{A}$ is a (eight-dimensional) lower-triangular matrix of coefficients. The sample period is 1983(1)-1997(11).

	Estimated elements of matrix $\mathbf{A}$:						
	a_{21}	a_{31}	a_{32}	a_{41}	a_{42}	a_{43}	a_{51}
coeff.	-0.537	-0.034	-0.008	**-8.629**	-1.279	**-37.288**	-0.290
(s.e.)	(0.2505)	(0.0261)	(0.0078)	**(3.2672)**	(0.9768)	**(9.4788)**	(0.2183)
	a_{52}	a_{53}	a_{54}	a_{61}	a_{62}	a_{63}	a_{64}
coeff.	**0.209**	-0.77	-0.002	-0.031	-0.014	-0.118	0.001
(s.e.)	**(0.0643)**	(0.6481)	(0.005)	(0.0351)	(0.0106)	(0.1042)	(0.0008)
	a_{65}	a_{71}	a_{72}	a_{73}	a_{74}	a_{75}	a_{76}
coeff.	0.008	2.773	0.604	7.726	-0.031	**-2.68**	8.112
(s.e.)	(0.0122)	(3.0447)	(0.9217)	(9.0431)	(0.0696)	**(1.0539)**	(6.572)
	a_{81}	a_{82}	a_{83}	a_{84}	a_{85}	a_{86}	a_{87}
coeff.	**-1.221**	0.153	0.328	**-0.023**	-0.037	**-2.57**	-0.009
(s.e.)	**(0.3677)**	(0.1112)	(1.0918)	**(0.0084)**	(0.1293)	**(0.7953)**	(0.0092)

	Estimated elements of matrix $\mathbf{B}$:							
	b_{11}	b_{22}	b_{33}	b_{44}	b_{55}	b_{66}	b_{77}	b_{88}
coeff.	0.004	0.014	0.001	0.178	0.012	0.002	0.162	0.019
(s.e.)	(0.0002)	(0.0007)	(0.0001)	(0.0096)	(0.002)	(0.0001)	(0.0087)	(0.0010)

Pcm is the log of commodity price index in US dollars; Y^{US} and Y^{GER} are logs of U.S. and German industrial production; P^{US} and P^{GER} are logs of U.S. and German consumer price indices; FF is the U.S. effective federal funds rate; R^{GER} is the German call money rate; e is the log of the U.S.$/DeutscheMark exchange rate (units of D.Mark for one U.S.$). All data are taken from Datastream.

Table 2
The VAR with an exogenous measure of German monetary policy shocks

The estimated VAR model is:

$$\mathbf{A}\begin{pmatrix} Y_t^{US} \\ Pcm_t \\ P_t^{US} \\ FF_t \\ Y_t^{GER} \\ P_t^{GER} \\ e_t \\ R_t^{GER} \end{pmatrix} = \mathbf{B}^*(L)\begin{pmatrix} Y_{t-1}^{US} \\ Pcm_{t-1} \\ P_{t-1}^{US} \\ FF_{t-1} \\ Y_{t-1}^{GER} \\ P_{t-1}^{GER} \\ e_{t-1} \\ R_{t-1}^{GER} \end{pmatrix} + \begin{pmatrix} g_1 \\ g_2 \\ g_3 \\ g_4 \\ g_5 \\ g_6 \\ g_7 \\ g_8 \end{pmatrix} Gercmrs_t + \mathbf{B}\begin{pmatrix} \nu_{1t}^{NP} \\ \nu_{2t}^{NP} \\ \nu_{3t}^{NP} \\ \nu_{4t}^{FF} \\ \nu_t^{NP} \\ \nu_t^{NP} \\ \nu_t^{e} \\ \nu_t^{S} \end{pmatrix}$$

where **A** is a (eight-dimensional) lower-triangular matrix of coefficients. The sample period is 1983(1)-1997(11).

	Estimated elements of matrix **A** :						
	a_{21}	a_{31}	a_{32}	a_{41}	a_{42}	a_{43}	a_{51}
coeff.	-0.48	-0.025	-0.007	**-8.997**	-1.307	**-37.802**	-0.333
(s.e.)	(0.258)	(0.0267)	(0.0078)	**(3.3517)**	(0.9779)	**(9.5310)**	(0.2238)
	a_{52}	a_{53}	a_{54}	a_{61}	a_{62}	a_{63}	a_{64}
coeff.	**0.205**	-0.833	-0.002	-0.036	-0.015	-0.126	0.001
(s.e.)	**(0.0643)**	(0.6512)	(0.005)	(0.0361)	(0.0106)	(0.1049)	(0.0008)
	a_{65}	a_{71}	a_{72}	a_{73}	a_{74}	a_{75}	a_{76}
coeff.	0.008	**-1.355**	0.148	0.15	**-0.022**	-0.045	**-2.439**
(s.e.)	(0.0122)	**(0.375)**	(0.1105)	(1.091)	**(0.0083)**	(0.1264)	**(0.7873)**
	a_{81}	a_{82}	a_{83}	a_{84}	a_{85}	a_{86}	a_{87}
coeff	1.49	0.432	4.872	-0.015	**-2.494**	9.767	-0.389
(s.e.)	(3.1892)	(0.9105)	(8.9464)	0.0698	**1.0369**	6.633	0.6234

	Estimated elements of vector **g** :							
	g_1	g_2	g_3	g_4	g_5	g_6	g_7	g_8
coeff.	-0.007	-0.010	-0.0013	-0.0892	-2.16E-05	0.0029	0.0084	0.2297
(s.e.)	(0.002)	(0.008)	(0.0008)	(0.1146)	(0.0011)	(0.0070)	(0.0127)	(0.0974)

	Estimated elements of matrix **B**:							
	b_{11}	b_{22}	b_{33}	b_{44}	b_{55}	b_{66}	b_{77}	b_{88}
coeff.	0.004	0.014	0.001	0.178	0.012	0.002	0.019	0.159
(s.e.)	(0.0002)	(0.0007)	(0.0001)	(0.0096)	(0.0006)	(0.0001)	(0.0010)	(0.0085)

Table 3

The simultaneous effect of macroeconomic and monetary shocks on the exchange rate

Simultaneous feedback from variables in the VAR and the exchange rate (e)								
		Y^{US}	Pcm	P^{US}	FF	Y^{GER}	P^{GER}	R^{GER}
Model 1	coeff	**-1.22**	0.15	0.33	**-0.023**	-0.037	**-2.57**	-0.009
	(s.e.)	(0.37)	(0.11)	(1.09)	(0.008)	(0.129)	(0.79)	(0.009)
Model 2	coeff	**-1.36**	0.15	0.15	**-0.022**	-0.045	**-2.44**	0.008
	(s.e.)	(0.37)	(0.11)	(1.09)	(0.0083)	(0.126)	(0.79)	(0.01)

Reported coefficient for Model 1 are the estimated parameters of the appropriate row of the $\mathbf{A_0}$ matrix in the following representation of the VAR :

$$\mathbf{A_0 y}_t = \sum_{i=1}^{k} \mathbf{A}_i \mathbf{y}_{t-i} + \mathbf{B}\, \boldsymbol{v}_t$$

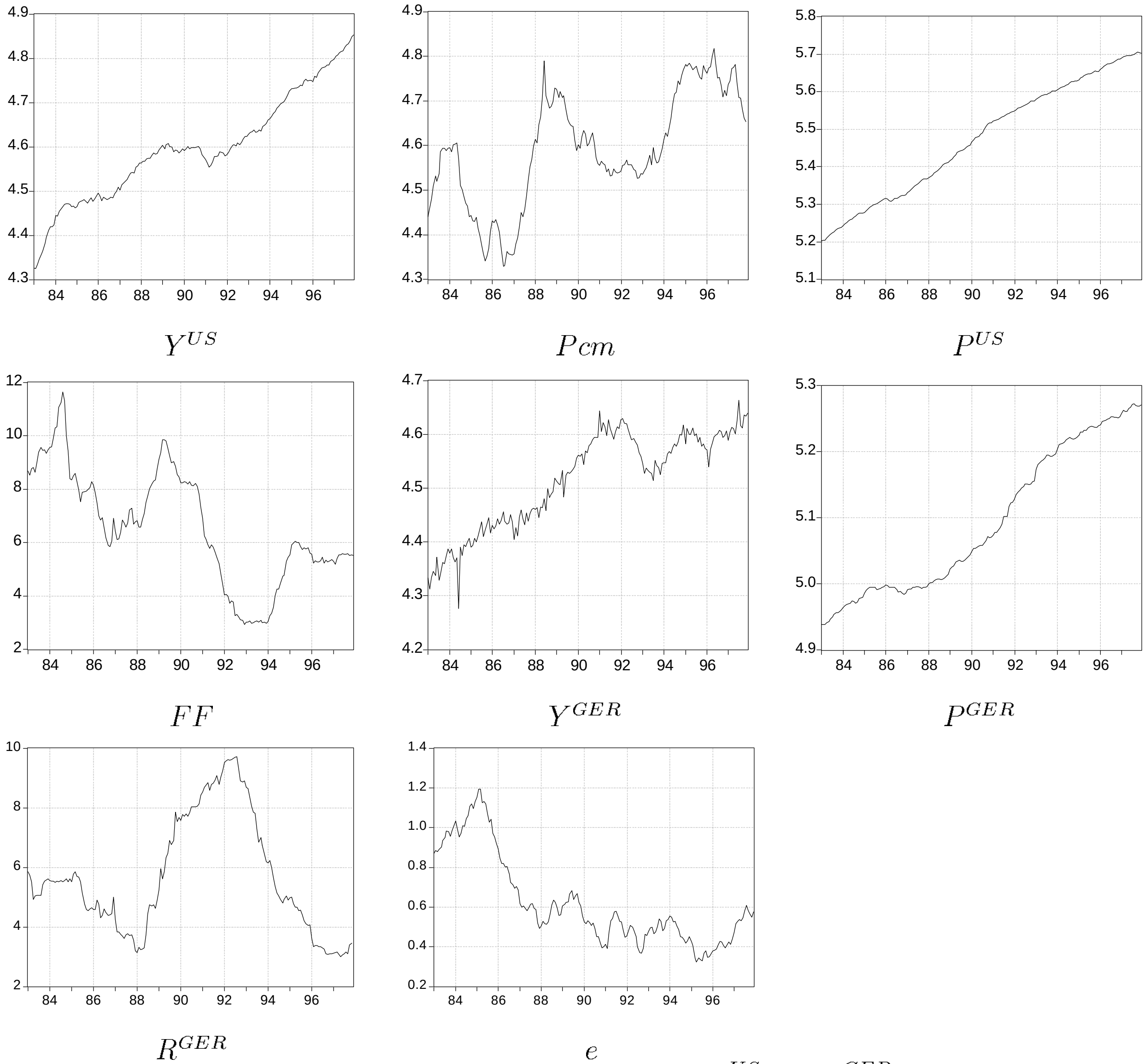
where $\mathbf{y} = \left[Y^{US},\ Pcm,\ P^{US},\ FF,\ Y^{GER},\ P^{GER},\ R^{GER},\ e\right]'$

Reported coefficient for MODEL 2 are the estimated parameters of the appropriate row of the $\mathbf{A_0}$ matrix and of the element g_7 of the $\mathbf{g}$ vector in the following representation of the VAR :

$$\mathbf{A_0 y}_t = \sum_{i=1}^{k} \mathbf{A}_i \mathbf{y}_{t-i} + \mathbf{g}\, Gercmrs + \mathbf{B}\, \boldsymbol{v}_t$$

where $\mathbf{y} = \left[Y^{US}, Pcm, P^{US}, FF, Y^{GER}, P^{GER}, e, R^{GER}\right]'$. A negative coefficient sign denotes appreciation of the U.S. dollar.

Figure 1
The variables used in the empirical analysis



Pcm is the log of commodity price index in U.S. dollars; Y^{US} and Y^{GER} are logs of U.S. and German industrial production; P^{US} and P^{GER} are logs of U.S. and German consumer price indices; FF is the U.S. effective federal funds rate; R^{GER} is the German call money rate; e is the log of the U.S.\$/D.Mark exchange rate (units of D.M. for one U.S.\$).

Figure 2
Impulse responses to a US monetary policy shock
in the benchmark VAR

(dashed lines : 68% interval confidence band)

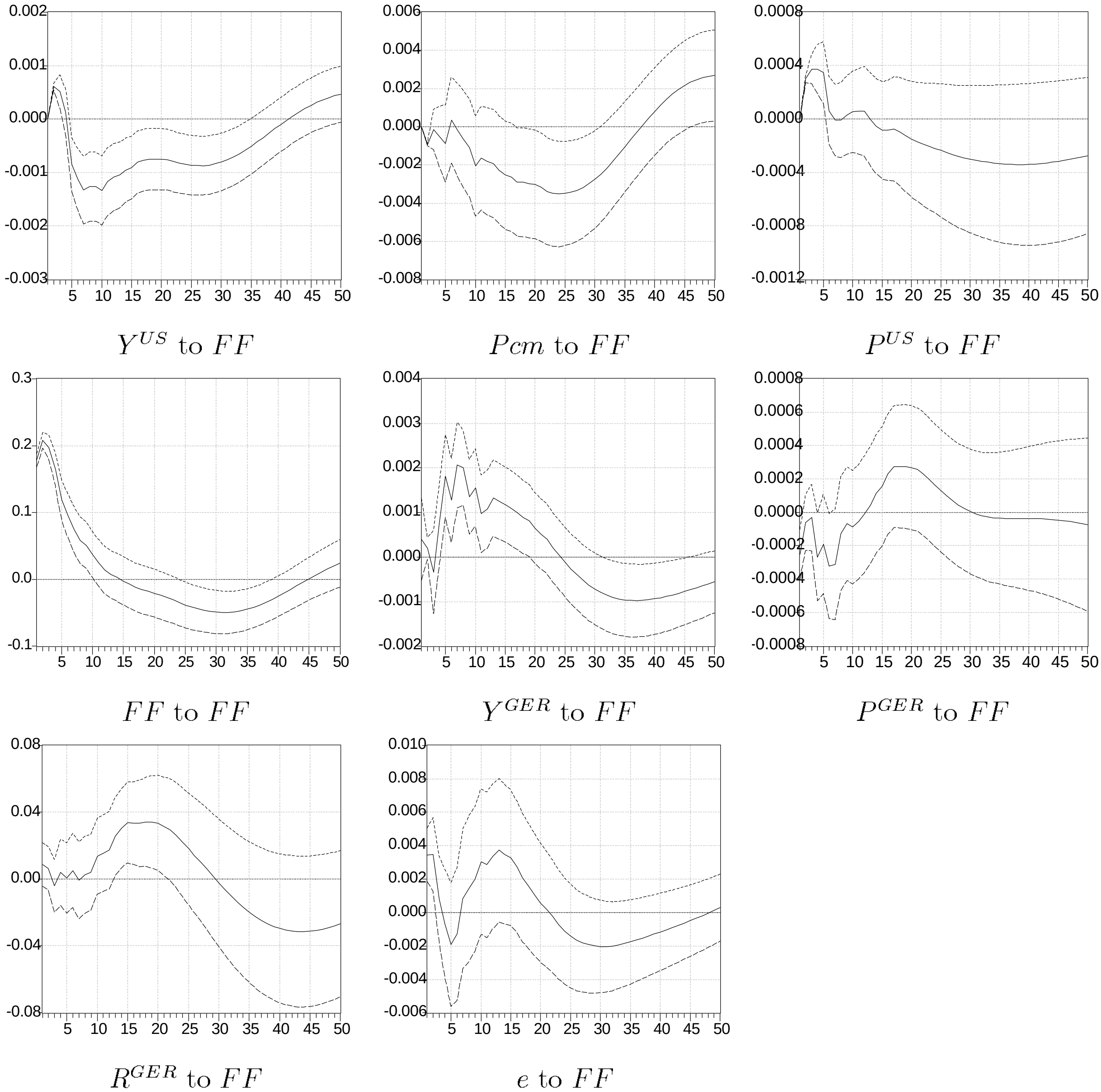


Figure 3
Impulse responses to a German monetary policy shock
in the benchmark VAR

(dashed lines : 68% interval confidence bands)

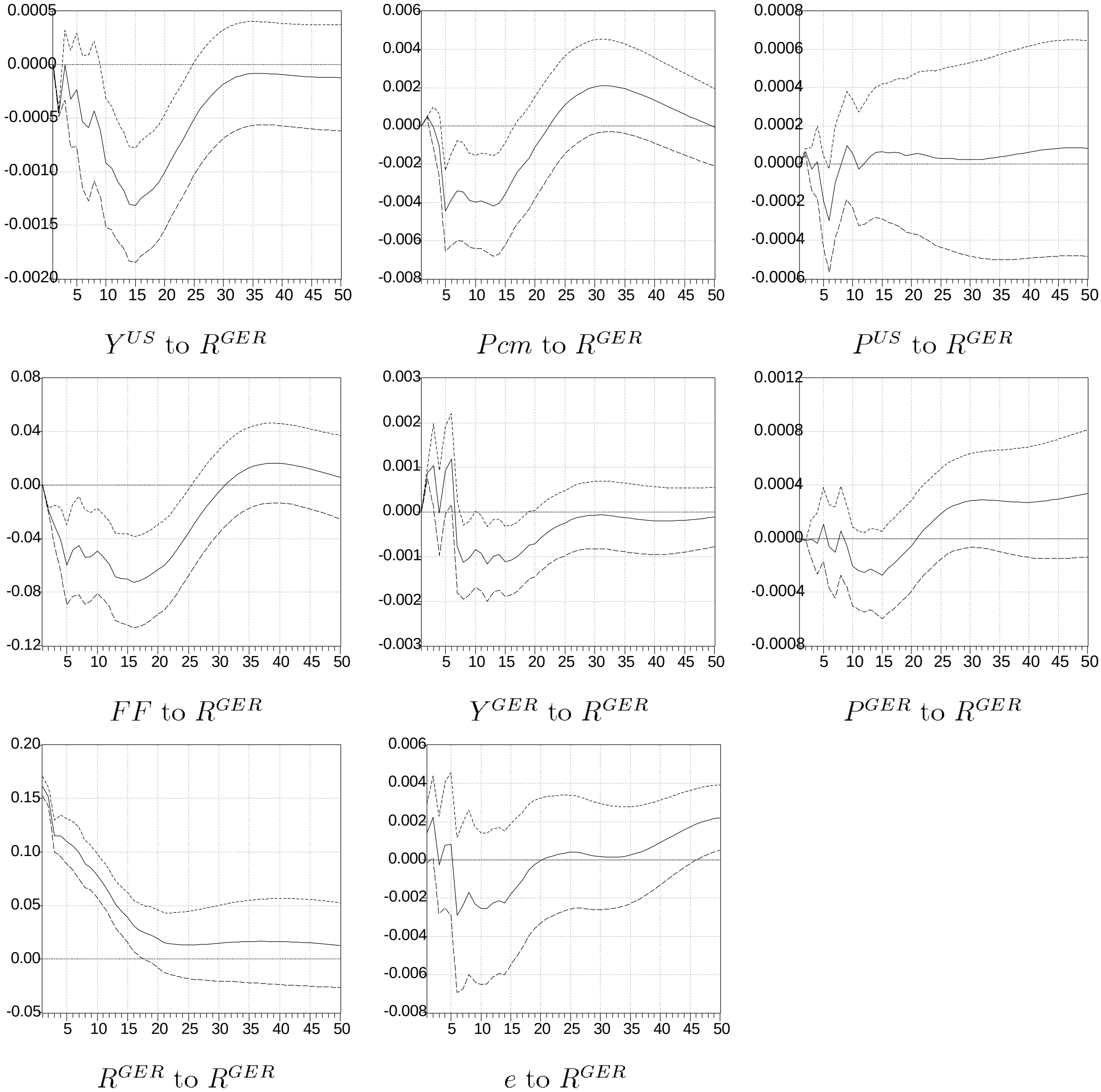
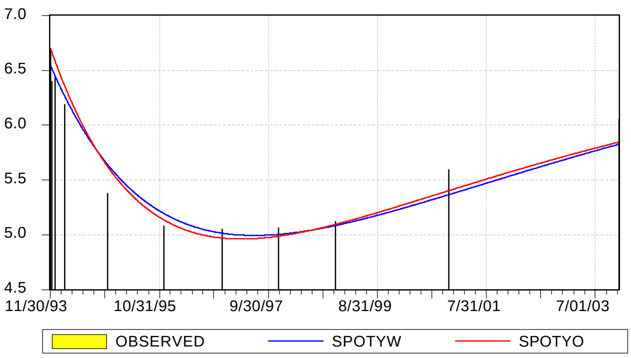
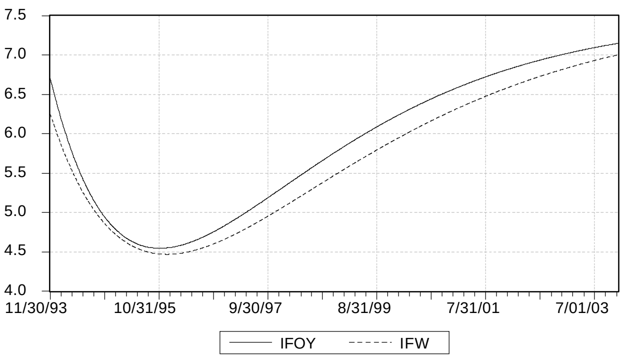


Figure 4



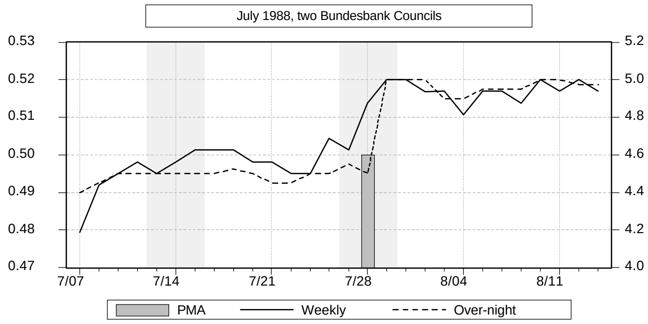
Estimated spot-rate curves on the 30/11/1993 with ($SPOTYO$) and without ($SPOTYW$) the overnight rate



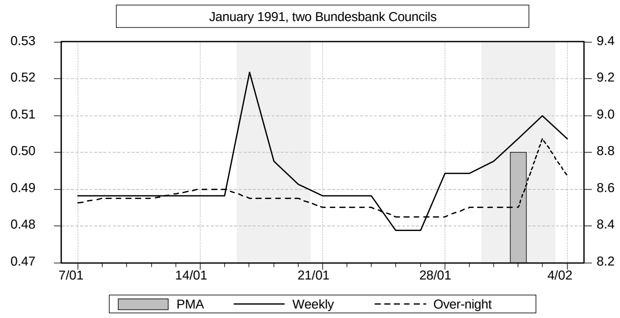
Estimated forward-rate curves on the 30/11/93 with ($IFOY$) and without (IFW) the overnight rate

Figure 5

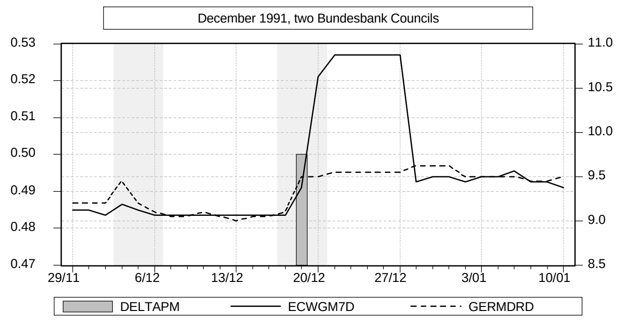
Monetary policy interventions and short-term interest rates in Germany



July 1988

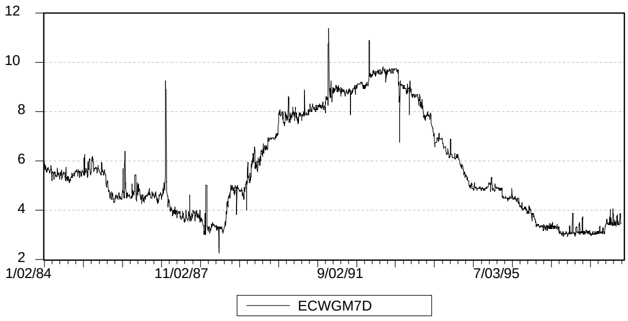


January-February 1991

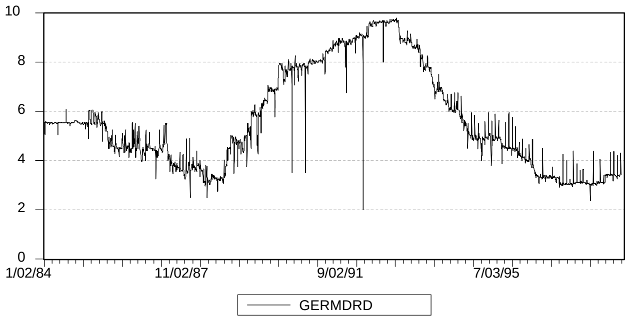


December 1991

Figure 6



The German 7-day rate



The German overnight rate

Figure 7
The German 7-days and one-month rate in September 1988

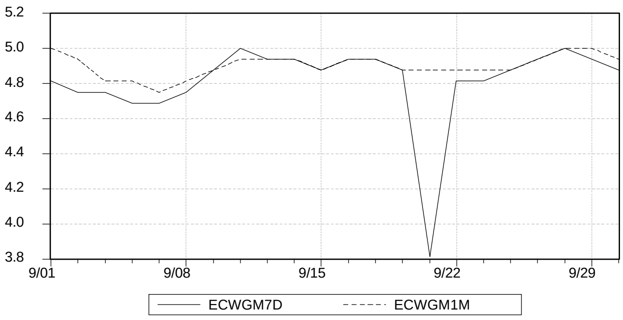


Figure 8

Impulse responses to a U.S. monetary policy shock in the VAR with an exogenous measure of German monetary policy shocks

(dashed lines : 68% interval confidence bands)

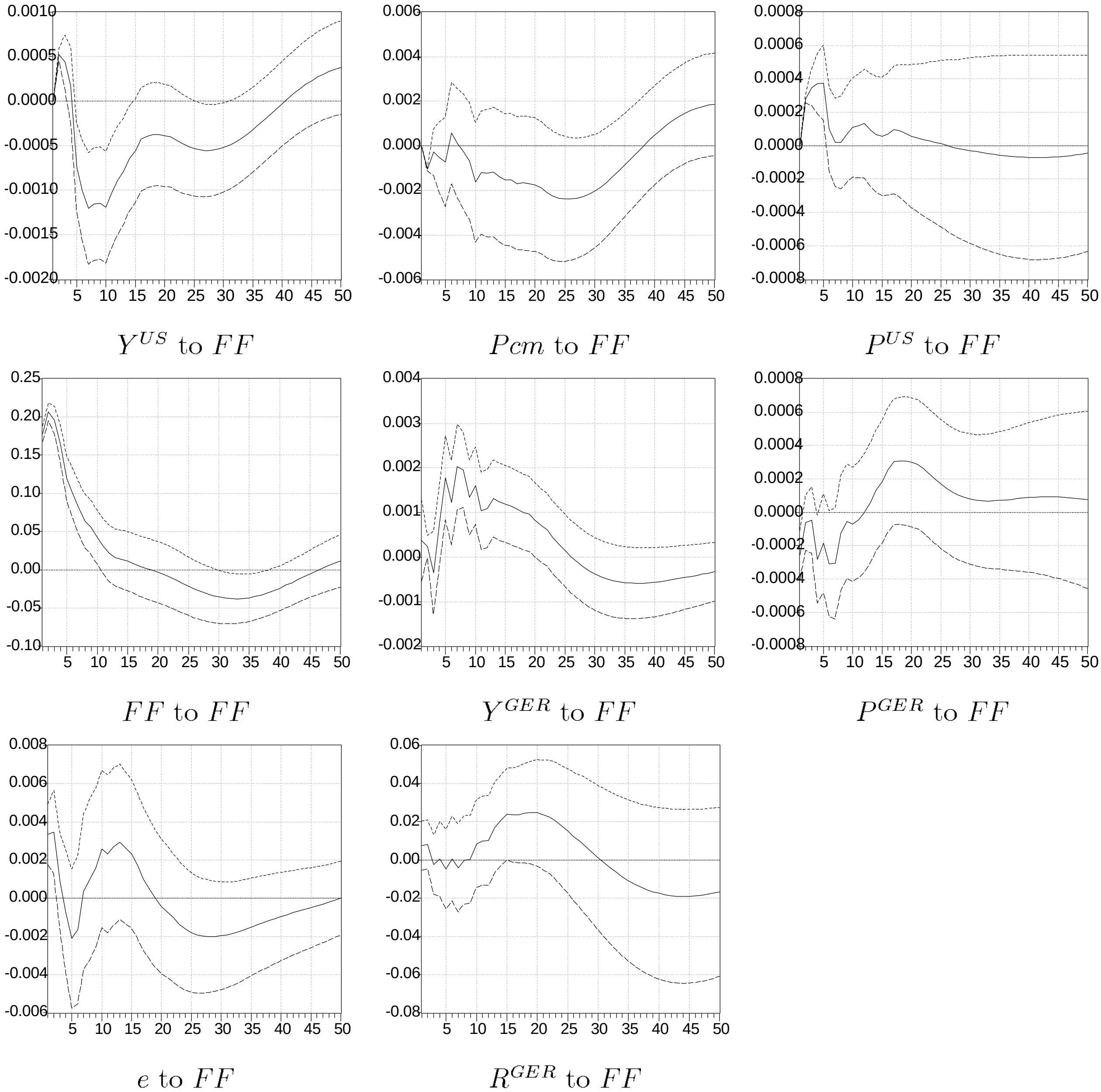


Figure 9

Impulse responses to a German monetary policy shock in the VAR with an exogenous measure of German monetary policy shocks

(dashed lines : 68% interval confidence bands)

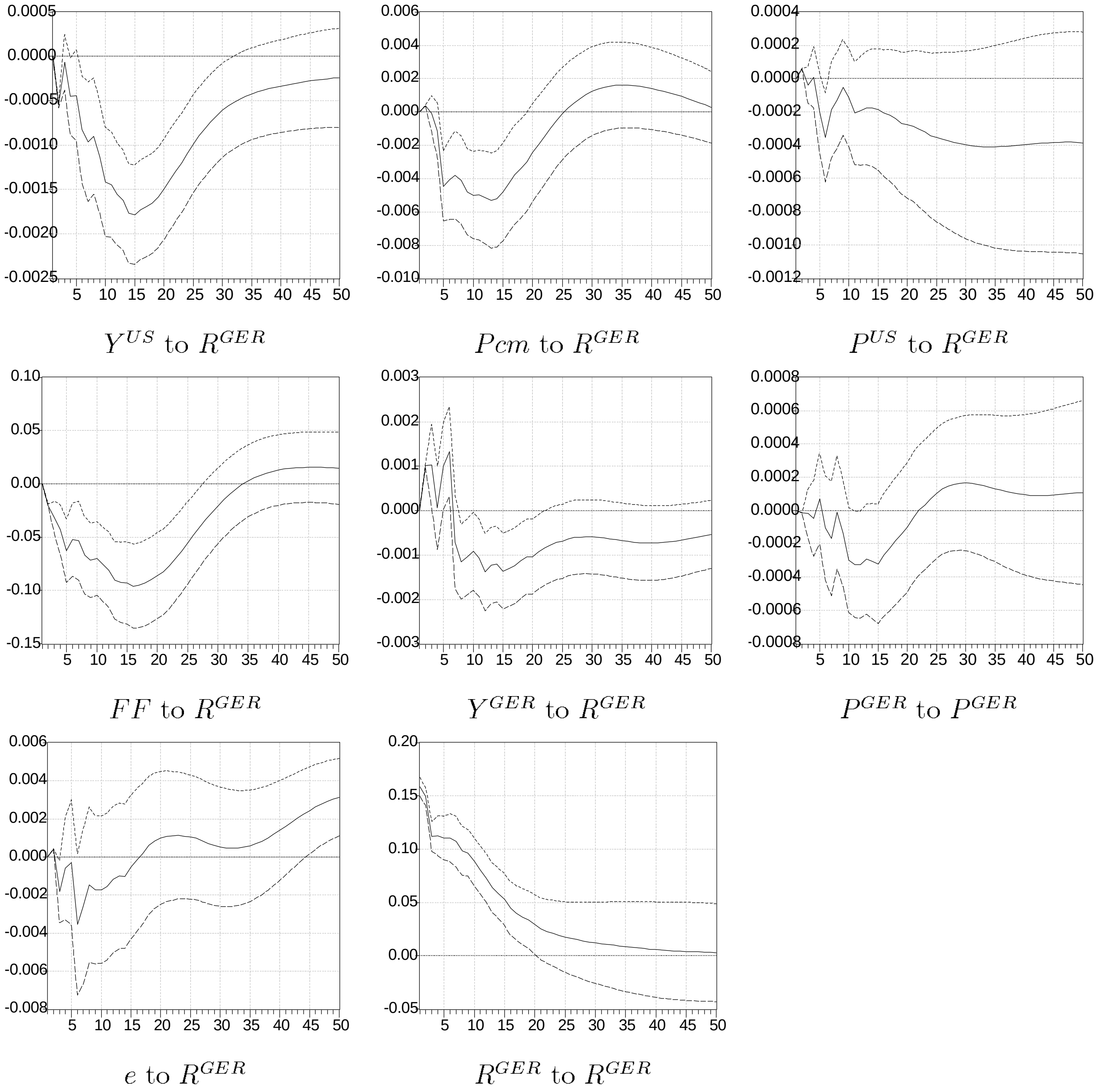
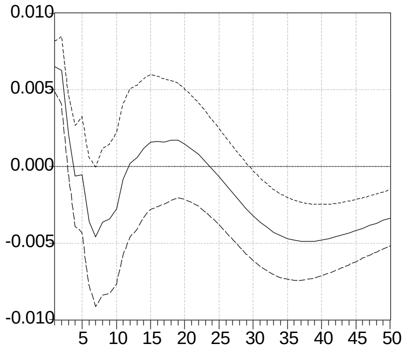
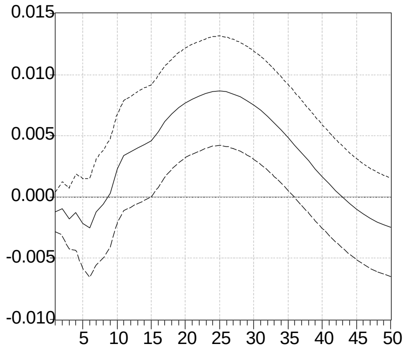


Figure 10
Responses of the U.S. $/D.Mark exchange rate to structural shocks in the VAR with an exogenous measure of German monetary policy

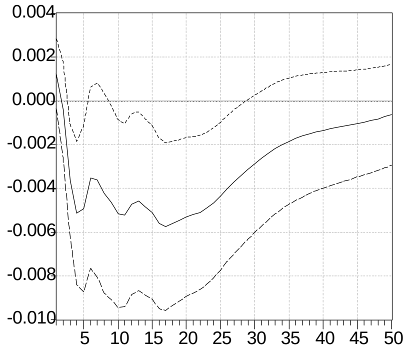
(dashed lines : 68% interval confidence bands)



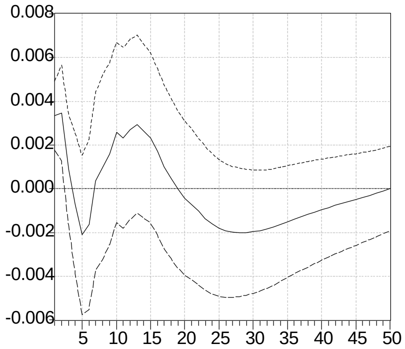
e to Y^{US}



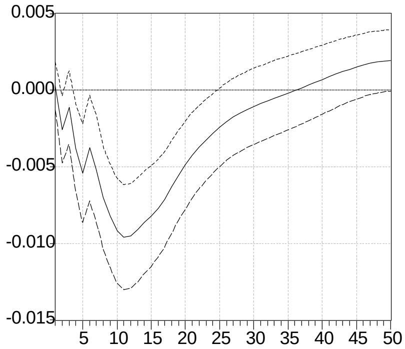
e to Pcm



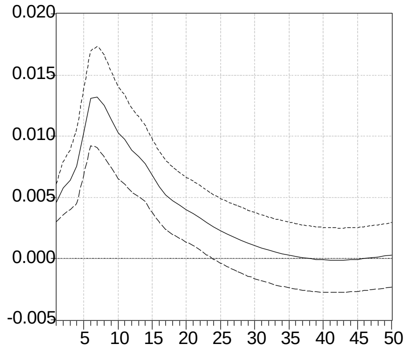
e to P^{US}



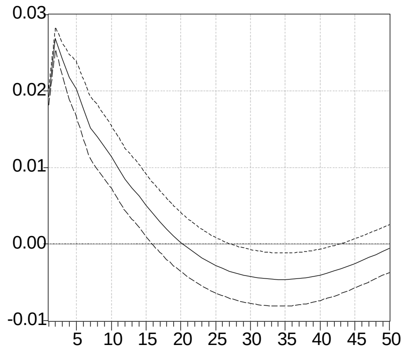
e to FF



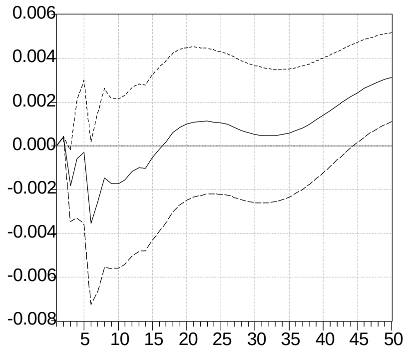
e to Y^{GER}



e to P^{GER}



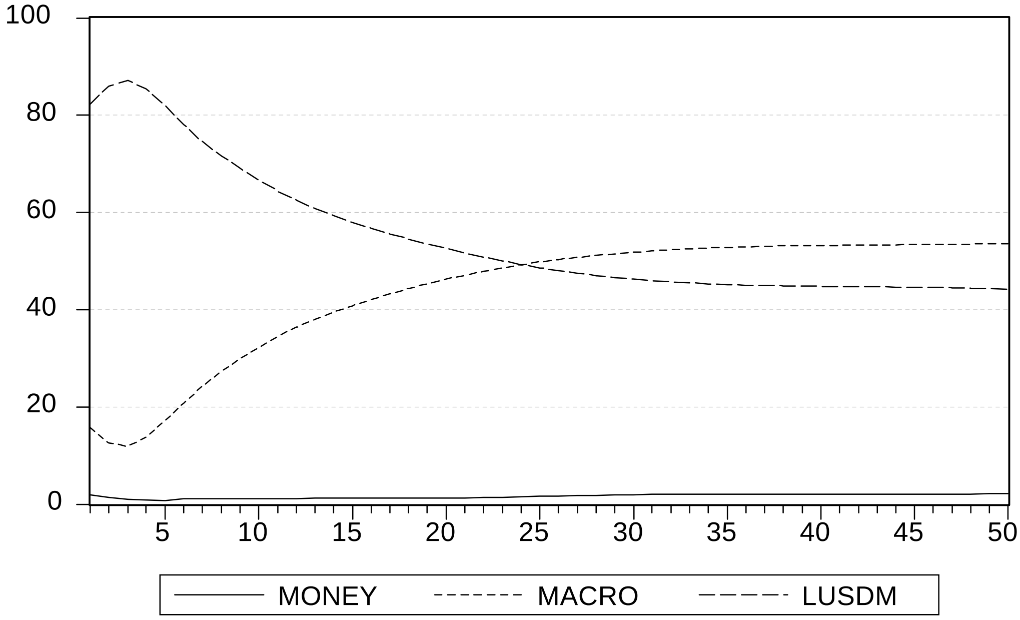
e to e



e to R^{GER}

Figure 11

Forecast Error Variance Decomposition of the (log of) U.S. Dollar/D.Mark exchange rate



MONEY is the component attributable to monetary shocks (US and Germany monetary policy shocks);

MACRO is the component attributable to macroeconomic shocks (US industrial production and CPI, German Industrial production and CPI);

LUSDM is the component attributable to own shocks, orthogonal to the MONEY and MACRO shocks.