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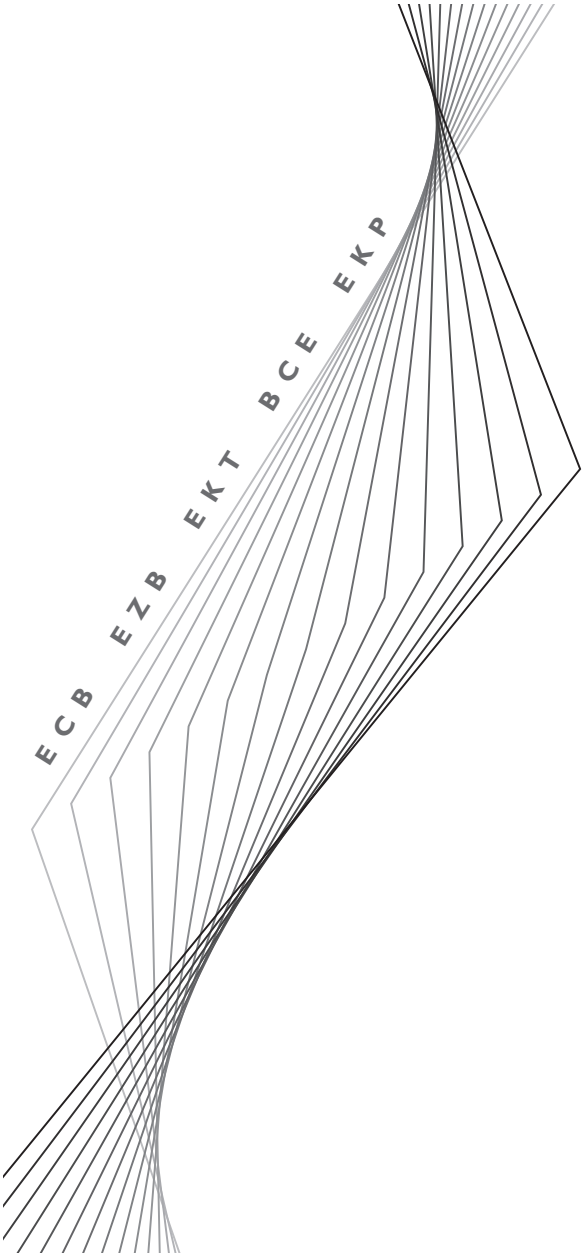

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Abstract

This paper puts forward a characterization of the structural features of the economic system relevant to the monetary-policy decisions of the European Central Bank. The econometric analysis adopts a parsimonious VAR representation of three key macroeconomic variables (interest rates, prices and GDP) aggregated across countries to obtain area-wide time series. The exogenous disturbances driving the multivariate system are identified imposing restrictions based on economic theory. The dynamic properties of the estimated models are analyzed and compared with the available evidence for the US. The robustness of this characterization is corroborated by the estimates from a different sample period and by the findings from an alternative model that singles out German monetary policy in view of its anchor role within the ERM.

1 Introduction

What are the effects on prices and output of a one-percentage-point change in the short-term interest rate? How long do these effects take to materialize fully? What is the shape of the response of these and other key macroeconomic variables to a monetary-policy shock? In short, what *does* monetary policy do? Without an answer to these questions — even an approximate one, offering ball-park figures when more precise and reliable estimates are not available — no fruitful debate can take place on what monetary policy *should* do — in general, and at certain critical junctures.

The long and rapid succession of attempts to address these difficult issues might not have mitigated the controversy on the appropriate characterization of the effects of monetary policy. However, it has produced a substantive body of information about the key macroeconomic relationships not only for the US — the economy that has been studied most — but also for several industrialized countries, including the European ones. In contrast, little is known about the features of the new, "composite" economic system brought about by the inception of Monetary Union despite the fact that Eurosystem[1] is already up and running.

This paper starts filling the gap by providing a first characterization of the structural properties of the euro area, considering it as a single, Union-wide, economic system, rather than the collection of the participating countries. The choice of the Union-wide approach is motivated by the belief that the knowledge of the way macroeconomic shocks impinge on the Union as a whole is, *unavoidably*, the starting point for any assessment of the appropriate monetary policy stance that the Eurosystem should adopt in the pursuit of its objectives.

The paper is organized as follows. Next Section discusses the methodological issues that arise in applying the VAR approach to a "synthetic" economic system consisting of macroeconomic variables aggregated across countries. Section 3 provides a framework for the interpretation of the empirical results, describing the two main empirical exercises presented in the model. Sections 4 and 5 respectively deal with the issues involved in the structural identification and the estimation of the VAR system. Section 6 presents the results of the benchmark model, providing a structured representation of the key features of the Union-wide economic system that are compared with the characteristics of the US and the major European countries. Section 7 assesses the robustness of the results from the benchmark model considering another specification of the VAR system that singles out Germany in view of its special role within the ERM. Section 8 concludes.

2 The union-wide approach

The estimation of identified-VAR systems to represent macroeconomic time series and characterize their key structural features is always confronted with difficult methodological issues, particularly as regards the choice of the identifying restrictions (see Leeper *et al*., 1996, for a review) and the treatment of cointegration (Sims *et al*., 1990). In addition to these standard issues, addressed later in the paper, the investigation of the properties of the Union-wide economic system on the basis of macroeconomic variables aggregated across countries faces a number of peculiar issues that have to be discussed before moving to the econometric analysis.

[1] *The Eurosystem includes the ECB and the 11 National central banks of the countries that have adopted the euro in 1999.*

The first issue stems from the differences in the economic structure, and hence in the transmission mechanism of monetary policy, across European countries. Such asymmetries are well-known to be sizable, regard both the extent and the timing of the propagation of macroeconomic shocks, including those originating from monetary policy actions (BIS, 1994, 1995), and are bound to play a major role in shaping the single monetary policy. As Dornbusch *et al*. (1997) forcefully argue, structural asymmetries imply that the cost of a disinflation episode could fall disproportionately on a few member countries posing a major challenge to the Eurosystem as public opinion may find it difficult to the accept the circumstance. Strains may surface within the decision-making body of the Eurosystem — the Governing Council, that consists of the governors of the central banks of the European countries participating in Monetary Union and the members of the Executive Board of the European Central Bank (ECB) — if the governors attach more importance to developments in their home country than to those in the Union as a whole. Moreover, as shown in Monticelli (1997), heterogeneity in economic structures has a bearing on monetary policy even if every member of the Governing Council entertains the same objectives are defined with reference to the Union as a whole, since it affects the transmission of shocks within and across countries, thereby influencing their impact on Union-wide macroeconomic variables.

The importance of structural asymmetries across countries participating in Monetary Union could be viewed as implying that econometric analyses using Union-wide macroeconomic data are inadequate on two scores. Doubts may be cast on the policy relevance of single, average macroeconomic relationships for the whole Union when differences across countries have so pervasive implications. Moreover, econometric estimates might be expected to be poor as a result of the bias following the imposition of invalid restrictions on the coefficients that is implicit in the process of data aggregation across countries and estimation of single supranational equations.

Skepticism on the usefulness of the Union-wide approach to address issues pertaining to the conduct of the single monetary policy is drastically attenuated when it is recalled that the choices of the Eurosystem will affect the liquidity conditions in all the countries participating in the Union with *no possibility for regional differentiation*. TARGET — the European payments system — brings about a unified European money market where intra-day arbitrage operations equalize the short-term interest rate in euro across the Union. Therefore, changes in the setting of instruments at the disposal of the Eurosystem will impart a single, Union-wide impulse triggering a response in Union-wide price and quantities. Even though the Union-wide impact is the result of differentiated national responses (that in turn might have an influence on the policy advocated by the various members of the decision-making bodies of the Eurosystem), the features of the Union-wide responses are an indispensable point of reference in the assessment of the single monetary policy.

As regards the econometric issue, the possible — and indeed likely — bias stemming from aggregation across countries of national behavioral equations characterized by different parameters, if not functional forms altogether, has to be weighed against the advantages of estimating aggregate, euro-wide equations. In addition to the heuristic expedience for the analysis of the developments of the Union as a whole, Union-wide relationships might provide an effective tool to address the specification bias that affects national specifications failing to account for the impact of foreign variables and correlation of shocks between countries as tightly integrated as European ones. The high level of collinearity often encountered between domestic and foreign variables as well as the difficulty in identifying the relevant foreign variables explain why the rapid progress in international integration has not been accompanied by the

diffusion of foreign variables as regressors in national macroeconomic relationships, notwithstanding the instability that has plagued several of the them in various countries.

The estimation of area-wide equations for groups of integrated countries cannot certainly be advocated as an infallible cure for the specification problems of national equations. However, as Pesaran *et al*. (1989) formally demonstrate, the estimation of aggregate equations is not necessarily an inferior choice from an econometric point of view because the bias associated with aggregation might be small and more than compensated by the effective remedy provided to the specification bias that affects several national equations as a result of the omission of relevant, "within-the-area" foreign variables. Moreover, very encouraging results have been obtained by several studies that have estimated area-wide equations for groups of European countries, particularly as regards the demand for money — a relationship that is most likely to be affected by "within-the-area" international spillovers (for a discussion of these findings see Monticelli and Papi, 1996; Browne *et al*., 1997).

Another issue relevant for the empirical inquiry of this paper is the extraordinary force of the Lucas critique in this particular instance. All econometric exercises are intrinsically liable to the possibility that their good in-sample performance is belied by a very poor post-sample performance because of changes in the underlying economic behavior, possibly as a result of new economic policies confronting the private sector. As the risk is in general ineluctable, awareness of it suggests great caution in extending econometric results to conditions where values of the variables or the parameters are, or can be expected to be, very different from the one observed in the sample.

In the case at hand, however, the very event which provides the motivation for the empirical analysis — the inception of Monetary Union — will involve a modification of the monetary regime so radical, sizable and wide-ranging as to have very few, if any, comparable precedents in economic history. Moreover, the introduction of the euro is bound to have a quicker and deeper impact on the functioning of financial markets and the behavior of financial intermediaries — the two elements of the economic structure that contribute most to shaping the extent and timing of the transmission of impulses originating from monetary policy to price variables and economic activity. The only convincing rebuttal to this critique is that, however poor and unreliable, information obtained from Union-wide econometric analysis is still more informative than sheer guessing. And certainly more helpful than the alternative of waiting for the availability of sufficiently long, *actual* (as opposed to constructed from national variables) Union-wide time series before attempting any econometric exploration of what the *single* monetary policy does.

3 A reference model

Since the path-breaking contributions of Blanchard and Watson (1986), Bernanke (1986) and Blanchard and Quah (1989), several alternative identification schemes have been put forward to provide structure to the innovations of VAR systems and interpret them with reference to a theoretical framework. This avenue of research, however, has rekindled the discussion on the appropriate interpretation of the business cycle within the VAR approach, given that the number of restrictions that can be drawn from the consensus core of economic theory is generally insufficient to identify a system even of small dimensions. Notwithstanding the controversy, this line of research provides a very useful disciplinary device to the debate on empirical macroeconomics in that it requires the unambiguous specification of the hypotheses maintained to identify the different kinds of disturbance.

Since the present analysis aims at providing an assessment of the structural features of the Union-wide economic system following the VAR approach (the alternative of an area-wide disaggregated macroeconometric model is pursued, for example, by Fagan and Henry, 1996), a consensus framework for the identification of the structural shocks would have been preferable. Unfortunately, even with a small number of variables, this option was not available and the reference model is, necessarily, at least in part controversial. The choice has fallen on the standard version of the aggregate supply/aggregate demand (AS/AD) framework, that assumes the presence of price and wage rigidities in the short run, while positing the neutrality of money in the long run. Although still lacking widely-accepted underpinnings in utility- and profit-maximizing behavior, this framework remains a central point of reference for policy makers and market participants since it offers a familiar characterization of the macroeconomic issues as a result of its lasting primacy in textbooks.

The AS/AD approach also stands as a convenient tool to couch the competing views of the main schools in macroeconomic thought as they can be encompassed by different values of the key elasticities of the equations of the model. Moreover, from an empirical point of view, Galí (1992) has shown that the AS/AD framework can deliver an effective stylized characterization of the postwar business cycles in the US, while Gerlach and Smets (1995) have usefully adopted it to identify monetary and real shocks in the G-7 countries.

For these reasons, the empirical analysis of the Union-wide economic system is based on the following theoretical framework cast in terms of a two-country Mundell-Fleming-Dornbusch model:

[1a]	$m - p = ay - bi - v$	$m^* - p^* = ay^* - bi^* - v^*$	[LM]
[1b]	$y = \bar{y} - d(i - E\Delta p_{+1}) + h(s - p + p^*) + gy^* + u$		[IS]
	$y^* = \bar{y}^* - d(i^* - E\Delta p_{+1}^*) - h(s - p + p^*) + gy + u^*$		
[1c]	$\Delta p = \Delta p_{-1} + j(y - w)$	$\Delta p^* = \Delta p_{-1}^* + j(y^* - w^*)$	[Phillips curve]
[1d]	$i = i[\cdot] - v_{ms}$	$i^* = i^*[\cdot] - v_{ms}^*$	[Reaction function]
[1e]	$E\Delta s_{+1} = i - i^* - z$		[UIP]
[1f]	$p = p^* + s + m$		[Stochastic PPP]

The notation is standard, with m standing for the log of the nominal money stock; y for the log of real output; p for the log of its price; i for the nominal interest rate; s for the exchange rate and E for the expectations operator; a star denotes foreign variables and a stochastic disturbance is added to each equation.

From the Union-wide standpoint, the key hypothesis embodied in the model is that the two countries are identical, both in size and parameter values, thus assuming that the transmission and propagation mechanisms of a shock are the same in the two economies. The available cross-country evidence suggests that this assumption is not precisely correct for countries participating in EMU. However, the Union-wide approach adopted in the empirical analysis maintains that the hypothesis of identical economic structures can be regarded as a reasonable approximation, at least to characterize the key features of the Union-wide system.

Accepting the assumption of identical parameter values, equations [1b] and [1c], can be aggregated into:

[2a] $$y^A = \bar{y}^A - d\left(i^A - E\Delta p_{+1}{}^A\right) + g\, y^A + u^A$$

[2b] $$\Delta p^A = \Delta p_{-1}{}^A + j\left(y^A - w^A\right)$$

where aggregate variables, denoted by the superscript '*A*', are defined as geometric averages of national ones:

$$x^A = \frac{1}{2}x + \frac{1}{2}x^*, \ \forall x$$

The above equations provide the basis for the identification of Union-wide demand and supply shocks in the empirical exercise. If all the shocks are of a symmetric nature, this approach entails no loss of information. Conversely, when shocks are asymmetric, the approach does not allow the identification of country-specific effects. Even in this case, however, the dynamic characteristics of the Union-wide economy are identified correctly, conditionally on the assumption that the transmission mechanisms is equal across countries.

Aggregating equations [1a] and [1d], respectively, provides Union-wide relationships that complete the model describing both sides of the money market. In particular, the Union-wide monetary policy reaction function can be written as:

[2c] $$i^A = f[.] - (v_{ms} + v_{ms*})$$

This equation assumes that the interest rate is set by the central bank responding to the developments in Union-wide variables in the pursuit of Union-wide objectives. Although this characterization is the appropriate benchmark for the monetary regime prevailing in EMU, it may be regarded as inadequate with reference to the sample period of the empirical analysis. In particular, the objective of exchange rate stability within the ERM has played an important role in the determination of monetary policy, particularly at times of turbulence in foreign exchange market. The 1992-93 crisis is the obvious example that springs to mind.

In order to assess the robustness of the empirical results obtained from the model described by equations [2a-c], we therefore consider an alternative specification which relaxes the assumption of a common Union-wide monetary shock and allows for the influence of the exchange rate in the determination of monetary policy. In the wake of the vast literature (see, e.g., Giovannini and Giavazzi, 1989) that assigns Germany the role of anchor within the ERM, the alternative scheme of interest-rate determination considers that Germany (denoted by the country with starred variables) sets its monetary policy without considering exchange rate developments with the ERM. Conversely, the other ERM countries (aggregated into a single bloc to ensure the tractability of the model) set the interest rate on the basis of Germany's interest rate and exchange rate movements vis-à-vis the Deutsch mark.

[2c'] $$i = i[i^*, s] - v_{ms} \qquad\qquad i^* = i^*[.] - v_{ms}{}^*$$

For this extension to be feasible, however, we need to the minimum the empirical description of the AS/AD model. We thus abstract from the complication of distinguishing between demand and supply in the money market and only investigate the propagation of monetary shocks to prices and output. In order to interpret *monetary* shocks as *money supply* shocks, we need to

make the additional hypothesis that central banks use a short-term interest rate as the policy instrument and that they are able to control such rate precisely enough to render slippages negligible. This appears to be a realistic assumption for the countries included in the analysis.

To summarise, our main specification includes three variables: area-wide output, prices and interest rates. The alternative specification, allowing for the influence of the exchange rate for the determination of monetary policy, includes five variables: area-wide income and prices, German short-term interest rates, short-term interest rate differential between the remaining EMU countries and Germany, a weighted average of the exchange rate of the former countries' currencies vis-à-vis the Deutsch mark.

In both empirical specifications, we implicitly assume that all possible sorts of aggregate demand (or supply) shocks have similar effects on output, prices and interest rates. This appears to be a reasonable assumption to make, since a more detailed break down of aggregate demand (and supply) shocks would probably prove too ambitious at the aggregate Union-wide level.

4 The union-wide macroeconomic variables

This Section discusses a number of further issues that need to be addressed before estimation

4.1 Aggregation method

Since the exchange rate is not constant in the available sample, aggregation of national time series into area-wide data is not straightforward. Two general classes of methods are available: current exchange rates or fixed conversion rates. No broad consensus has yet been reached even on the choice between these two methodologies (see Monticelli and Papi, 1996 for a general discussion). As a reference, Figure 1 shows the rate of growth of the area-wide GDP obtained according to different aggregation methods.

On the one hand, current exchange rates permit an obvious interpretation from an economic standpoint as they are the market yardstick (and indeed the only one actually available to economic agents) to convert income and assets into effective spending power across borders. On the other hand, using market exchange rates to convert a given time series amounts to 'distorting' its dynamics: the rate of growth, the standard deviation and in general all the moments, are affected by movements in the exchange rate used for the conversion, thereby introducing a large number of spurious shocks in the series.

Resorting to fixed exchange rates avoids this distortion but amounts to proceed 'as if' the exchange rate between the European currencies did not vary — a tenet clearly at odds with experience. However, from the point of view of the characterization of the Union-wide economy, the investigation of the structural relationship between macroeconomic variables *for given exchange rate* has a special appeal in that it amounts to assuming that the exchange rate is not a relevant variable — a sensible assumption to underpin a benchmark for the developments of the variables once the monetary union is established.

Given that neither of the previous methods appears completely satisfactory, in our empirical work we use a (geometric) weighted average of national outputs, with weights given by relative output sizes in 1993 (at PPP exchange rates). Since weighted averaging is the only option available to aggregate price and interest rate series, this methodology has the advantage of being consistent across the variables used in our empirical analysis. Moreover, it is consistent with the

reference theoretical model, where aggregate data are also obtained through geometric averages.

4.2 Key features of Union-wide data

The nominal short-term interest rate, the real interest rate, the inflation rate and the rate of growth of GDP for the European economy are reported in Figure 2. Visual inspection is sufficient to point to the drastic fall of inflation during the eighties, concomitant with a high level of the real interest rate with respect to the rate of growth — a recurrent feature in the experience of disinflation.

Some of the variables display a possibly non-stationary behavior. The execution of unit-root tests requires a choice on whether a constant and a trend should be included in the relevant OLS regressions. The marked fall of both inflation and the short-term nominal interest rate during the sample period suggest the specification with a trend for all variables.

The results of unit-root tests are reported in Table 1. While GDP can more safely be considered I(1), the evidence for the nominal interest rate and, especially, prices is mixed. In the latter case, the evidence of non-stationarity seems stronger for the inflation rate than for the price level itself. However, the real interest rate also appears non-stationary, contradicting the priors from the standard theoretical models of economic growth. Although, as usual, the evidence is not clear-cut, the variables benchmark system $\{dy^A, i^A, dp^A\}$ are taken to be stationary.

5 Estimation

5.1 Specification

Although the results from standard information criteria obtained in preliminary investigations point to specifications with one or two lags for the VAR, the selected lag-length for the VAR is 5 both in order to completely eliminate autoregression from the residuals and to be consistent with the widely-accepted prior that monetary policy impulses take a relatively long time to produce effects, if any, on the real economy.

Although GDP and inflation series are seasonally adjusted, seasonal dummies have been added in the specification in order to take into account any possible remaining seasonal component.

5.2 Sample period, structural breaks and German reunification

Since consistent data are available only from 1976, the need for a sufficient number of lags led to use the full available sample for estimation: from 78q1 to 97q4. Although this period is not long in comparison with standard analyses on the US, it has nonetheless witnessed important changes for European economies, from the inception of the ERM to its crisis in 1992-93 and the final decision about EMU.

On the one hand, despite these changes, a fundamental continuity can be traced in behaviour and policies, especially for monetary policies that have been constantly concerned with the stability of intra-EU exchange rates, as revealed by the ERM precursor (the "Snake") before 1979 and by the behavior of the Italian interest short-term rates after the ERM crisis. Moreover, many empirical studies for Europe use a sample period starting in the late seventies (see, e.g., Gerlach and Smets; 1995, Andrés *et al.*; 1997, Bruneau and De Bandt, 1998). On the other hand, developments in the ERM clearly point to two major events that might be associated with

parameter instability: the first quarter in 1987, when the 'last' ERM realignments occurred, and the 1992-93 crisis.

Investigating the issue formally through Chow tests with reference to those dates fails to reject the null hypothesis of paramenter stability. However, the power of the tests may be weakend by the reliance on the assumption that the dates of the possible structural breaks are known (see Andrews, 1993, and Hansen, 1992), and by the fact that, for the 1987 test, the estimation period is shorter than the forecast period. For this reason, the analysis was complemented with a series of one-step ahead Chow tests, whose results, for the last part of the sample, are qualitatively different since they corroborate the hypothesis of possible breaks in the nineties for the interest rate and the inflation equations.

Since not enough data are available to split the sample in 1992 and carry out a separate estimation, the following route is taken. The model is first estimated over the whole sample, conditional on the hypothesis of no parameter change. The robustness of the results is then checked re-estimating the system over a sample that ends in 91q4. The conclusions that can be drawn from these estimates broadly match the findings of the longer sample, supporting the reliability of the characterization of the Union-wide economy discussed in the next Section. The main differentiating feature of impulse responses for the shorter sample is a much stronger impact of aggregate supply shocks on inflation and thus on interest rates (Figure 4).

Finally, it has to be stressed that the jump in German output due to the reunification has been smoothed out from GDP data in our main estimation exercise. This research strategy allows us to avoid the risk that our estimates be driven by a single predominant shock. We investigate the robustness of our findings to the "inclusion" of German reunification in the data in a separate regression. This exercise also provides us an indication of the goodness of fit of our identifying restrictions. Assuming that the German reunification epitomises a supply shock, our impulse responses to aggregate demand and money supply shocks should remain largely unchanged whether the reunification is or is not present in the data; only the impulse responses to supply shocks should vary. This is indeed shown to be the case in the comparison presented in figure 5.

5.3 Identification of a structural VAR

The model described in the previous Section provides the framework to identify the VAR system through a combination of short and long run restrictions, as in Galí (1992) and Gerlach and Smets (1995). The benchmark system includes three area-wide variables — the log-change in GDP (dy^A), the nominal 3-month interest rate (i^A) and the inflation rate (dp^A) — and three exogenous driving forces — u, w, and v_{MS}, the innovations in spending (IS), aggregate supply (Phillips curve) and the monetary shock that, as argued above, can be interpreted as a shock to interest rate setting, mainly of a policy nature.

Define the vector of variables included in the VAR system as x_t. If x_t is covariance stationary it will have a Wold moving average representation of the form

[3] $$x_t = A(L)\in_t$$

where L is a lag operator, $A(L)$ is a polynomial matrix in L and $\in_t$ is a vector of innovations in the elements of x_t.

Moreover, x_t also has a moving average representation of the form

[4] $x_t = B(L)e_t$

where e_t is a vector of serially uncorrelated structural residuals.

If the vector of innovations is a linear combination of the structural residuals, i.e. if $\in_t = Ce_t$, with C being a nxn matrix, then

$$x_t = A(L)Ce_t = C(L)e_t \text{, and thus } A(L)C = B(L)$$

These conditions permit to retrieve the structural representation [4] from the estimates of the reduced-form representation [3], provided that C is full rank. Zero restrictions on the elements of the C matrix are equivalent to imposing that the impact effect of a given shock on a certain variable is null, while long-run (neutrality or homogeneity) constrains are imposed setting to zero the appropriate elements of $C(1)$.

In line with the objective of a structured representation of the key features of the Union-wide economic system, the first set of restrictions adopted is the orthogonality condition among the structural shocks of the benchmark defined in the previous section. In addition, shocks to real aggregate demand and monetary shocks are assumed to have no effects on output in the long run, consistently with the widely-shared view that only technological shocks can have a lasting influence on economic growth. To achieve identification, reference is made to a customary and possibly uncontroversial "minimum delay restriction": monetary shocks are assumed not to have any contemporaneous effect on output, on the premise that at least three months are necessary for monetary shocks to impinge on economic activity.

The latter condition is often coupled with another one, prescribing the same minimum delay for the impact of monetary shocks on prices. We do not adopt this assumption in the identification of our main 3-variable model, because we want to allow for possibly "fast" reactions of prices to monetary shocks via an exchange rate channel. A given change in the average euro area interest rate could in fact be associated with different interest rate changes in different countries, thus triggering potential variations of the exchange rate which could be reflected into import/export prices. Moreover, the identifying assumption we adopt ensures full compatibility with the results obtained by Gerlach and Smets (1995), which are based exactly on the same structuralisation.

Recalling that the system variables are ordered as $x_t = [dy^A, i^A, dp^A]$, the identifying assumptions discussed above can be expressed in terms of zero restrictions on the coefficients of the C the $C(1)$ matrices of the VAR model, respectively as $c_{12}(1)=c_{13}(1)=c_{12}=0$. [2]

As a further robustness check, however, we also perform the structural analysis with a different identification scheme. As in the main scheme, we impose zero long run effects of aggregate demand shocks on output; we then identify monetary shocks by imposing the minimum delay restriction on both prices and output. In terms of the C matrix, this amounts to setting $c_{13}(1)=c_{12}=c_{32}=0$. The resulting impulse responses, that appear remarkably similar to those obtained under the main identification scheme, are included in Figure 3.

A final word of caution appears warranted concerning the identification of monetary policy shocks in the structural VAR literature. In the theoretical monetary economics literature, it is

[2] *The implementation of identifying restrictions follows the procedure by Amisano and Giannini (1998), while maximum likelihood estimation is performed using the RATS routine SVAR.SRC, by A. Lanzarotti and M. Seghellini.*

customary to identify monetary policy with the "rule" followed by a given central bank when reacting to macroeconomic shocks. Accordingly, the effects of monetary policy are interpreted as the changes, with respect to a hypothetical unchanged-policy scenario, caused in the behaviour of macroeconomic variables by the *reaction* of monetary policy to the occurrence of shocks. This interpretation of the effects of monetary policy requires that the researcher is capable to isolate the direct effects of a given macroeconomic shock from those induced by the monetary policy response to the same shock.

It is well known that VARs, because of their reduced form nature, are incapable of disentangling these two effects. In line with the rest of the structural VAR literature, therefore, what we label as monetary policy shocks are not the result of the implementation of the average rule followed by the central bank when reacting to macroeconomic developments. They are, instead, the unpredictable deviations of monetary policy from the average rule implicitly followed in the sample period (see also Section 6.3).[3]

5.4 Long run restrictions and confidence intervals

Long run restrictions have been criticized on the grounds that they only give reliable results under very restrictive conditions (Faust and Leeper, 1997). The main criticism is that the coefficients of the matrix $A(1)$ – on which the long run restrictions depend – are imprecisely estimated when only weak restrictions are imposed on the dynamics of the underlying VAR model. Although obviously momentous, this drawback has to be weighted against the fact that long run restrictions tend to have a sounder theoretical basis. For this reason, we believe that they remain particularly appealing. As discussed by Faust and Leeper, adopting them amounts to imposing that the model driving the data is a VAR with known maximum lag order.

A more general problem concerns confidence intervals. For structural VARs identified through short-run restrictions, Kilian (1998) shows that intervals based on asymptotic theory are strongly biased in small samples, especially when the variables included in the VAR display a high degree of persistence. Since our analysis is characterized by both a short sample and highly persistent variables, these findings are particularly relevant and led to resort to a small sample Bayesian Monte Carlo procedure[4] and, as suggested by Sims and Zha (1995), to present the results in terms of percentile intervals instead of intervals based on mean and standard errors. This modification is designed to avoid imposing symmetry on the small sample distribution of the responses.[5]

Faust and Leeper (1997) also argue that these procedures present additional problems when applied to structural VARs identified with long run restrictions. The imprecision in the estimates of the long run parameters implies that type II errors are more likely in constructing confidence intervals. This problem is clearly related to the general *critique* of long run restrictions. In order

3 The general suitability of structural VARs to accurately capture monetary shocks has been questioned by Rudebusch (1996). The main argument is that, in the USA, monetary shocks identified through structural VARs are little correlated with those that can be obtained comparing future and spot Federal Funds rates. The latter would provide a good benchmark for monetary surprises, because they are widely interpreted as such in financial markets and do not incorporate systematic forecast errors. Sims (1996) has questioned the view that forecast errors implicit in Federal Funds futures represent a correct measure of monetary policy innovations: the reason being that they necessarily confuse forecast errors for variables that influence policy with forecast errors for policy itself. Bagliano and Favero (1997) show that impulse response analyses obtained using the alternative definitions of monetary policy innovations do not substantially differ from each other.

4 The adopted Monte Carlo procedure is provided with the RATS package. For a discussion on the correct way to calculate asymptotic confidence intervals in structural VAR with long run identifying restrictions see Vlaar (1998).

5 Kilian (1998) has proposed an alternative method (dubbed bootstrap-after-bootstrap), designed to correct the small sample bias of the estimated parameters of the VAR. Both its proponent and Sims and Zha (1995), however, present evidence showing that the bootstrap-after-bootstrap method performs very similarly to percentile-based Monte Carlo integration.

to deal with it, relatively wider probability bands (68%) are considered. The intervals reported in the figures are therefore based on empirical 16th and 84th percentiles taken from 1000 replications.

6 A structural characterization of the union-wide economic system

This Section discusses the results based on the longest available sample (78q1- 97q4) focusing on the impulse responses of the key macroeconomic variables to the structural shocks driving the AD/AS model. The exposition is organized considering the effects of each shock in turn and comparing the responses with those for the US, as characterized in Galí (1992), as well as with the ones for the four largest European countries — Germany, France and Italy — as obtained by Gerlach and Smets (1995, henceforth GS). The decomposition of forecast error variance is also presented.

6.1 Supply shocks

The first column of Figure 3 depicts the response of the Union-wide economic system to a negative, one-standard-deviation shock to aggregate supply. The initial fall of output by nearly 0.4 percentage points is followed by an uneven return to the baseline: the steady state output loss of about 0.6 percentage points is reached after approximately two years. The responses to a supply shock in Germany, France and Italy reported by GS reveal similar patterns, although with a larger steady-state effects. Comparison with the response to a supply shock of the US economy lends support to the 'Euro-sclerosis' view in that the US system reacts more promptly and vigorously — 0.7 percentage points in the first period, 1.1 in steady state with a peak around that value after one year, according to estimates of Galí (1992).

The lower impact effect on output in Europe is mirrored by a stronger effect on prices, consistently with the evidence by GS: prices rise by almost 0.2 percentage points, against a value of approximately 0.1 in the US. The subsequent behavior of inflation in Europe is however much more persistent: after 5 years, inflation does not return to the baseline in Europe, whereas one year is sufficient in the US.

Similar across the two sides of the Atlantic appears, instead, the minimal response of nominal interest rates, consistently with the view that monetary policy reacts to a real shock with an adjustment of money supply at unchanged nominal interest rates. This results is in contrast with the GS findings of a much stronger interest rate response, such as to outweigh the effects on inflation leading to a rise also in the real rate.

Regarding the decomposition of forecast error variance, another similar finding is that supply shocks account for most of output variability (Table 4). An interesting difference can however be detected from the pictures: in the US, the influence of supply shocks on output appears constant or increasing as the forecasting horizon lengthens; in Europe, other shocks start having a stronger, even if still minor, impact after approximately 6 quarters. Supply shocks have a negligible effect on the nominal interest rate, but a strikingly high one on inflation.

6.2 Real demand (IS) shocks

The second column of Figure 3 reports the response to an expansionary, one-standard-deviation impulse to aggregate demand. The shock increases GDP by 0.3 percentage points on impact and

up to a maximum of approximately 0.5 percentage points after 3 quarters, a smaller reaction than in the US, according to the findings in Galí.

A more interesting difference arises regarding the behavior of the other variables. The increase in inflation determines an interest rates hike in both the US and the Union as a whole; however, the increase is more marked in Europe, where it leads to a rise increase in real rates already after 3 quarters, than in the US, where real rates never become higher than in the baseline. The prompt reaction of European monetary policy appears to bring about a progressive reduction of the inflation rate, while this remains at a higher long-run level in the US.

Demand shocks are the main cause of inflation volatility, especially at the business cycle frequency.

6.3 Monetary shocks

The pattern of responses of the Union-wide economic system to monetary disturbances is to be assessed with particular caution since the change in policy regime brought about by the introduction of the single currency is likely to exert a more pronounced influence on this aspect of the economic system. Moreover, the introduction of the single currency will be such a momentous institutional event as to make untenable the following argument — often put forward, in the wake of Sims (1982), to support the validity of the VAR approach. When the monetary-policy rule is modified, agents may not distinguish the change from a random shock and, accordingly, maintain the same behaviour; eventually, the shift in policy regime would be noticed, affecting the private sector, but if the authorities return to the previous rule before such changes take place, the view that the variation in policy is random is justified from the perspective of market participants.

On the other hand, Monetary Union is such a radical development from an institutional point of view that economic agents may find it difficult to anticipate the behaviour of the new monetary authority with any reasonable degree of confidence. Therefore, rather than adapting to their initial perception of the new rule, for a time they may countinue to behave as they used to until they learn more about the money-supply rule. If this were the case, the characterization of response of the Union-wide economic system to a shock in the supply of money may be valid also for some time after the introduction of the single currency.

A one standard deviation monetary shock corresponds to a 10 basis points fall in the interest rate (third column of Figure 3). The size of the monetary shock appears small with respect to the existing evidence for both the US (approximately 50 basis point) and the main European countries (up to a whole percentage point in Italy). The shock is however well identified and persistent for 6 to 8 quarters, when it is eventually reversed to match the rise in the inflation rate.

The impulse responses to monetary shock are again consistent with the evidence available for the US. As in Galí (1992), the real interest rate initially falls together with the nominal rate; its effects on aggregate demand however take time to materialize. The response of output takes nearly 2 years to unfold, with a maximum increase of its level of 0.4 percent with respect to the baseline. In line with the 'Eurosclerosis' view, the effect on output is more persistent in the Union-wide economy, where the return to the baseline is not completed after 5 years. Inflation shows a small and short-lived rise on impact. Most of the effect of the monetary shock, however, occurs with much longer lags through the Phillips curve: the inflation rate increases up to 10 basis points after almost 3 years, remaining above the baseline after 5 years.

Monetary shocks account for most of the short-term variability of interest rates but they also have an increasingly important effect on output, and especially inflation, at longer horizons.

7 An alternative specification for monetary policy

The structural characterization presented in the previous section hinges on the specification of a single Union-wide, monetary policy rule. As discussed in Section 3, the appropriateness of this approach may be questioned with reference to the sample used in estimation — when the pursuit of exchange rate stability in the ERM framework at times required differentiated monetary policy responses with the Union. This section probes into the robustness of the empirical results obtained so far. It considers the alternative specification for monetary policy discussed in Section 3, where Germany is explicitly assigned the role of anchor country, setting the monetary stance for the whole area, while the other countries move their interest in the purpose of maintaining exchange rate stability.

7.1 Identification

The implementation of the alternative characterization for monetary policy requires the specification of a different VAR system that includes — in addition to the core Union-wide variables growth and inflation, dy^A, dp^A — the nominal 3-month interest rate in Germany, i^{DE}; the interest differential between periphery countries and Germany, $i-i^{DE}$; an exchange rate variable taken to be the log-change of the weighted average of the exchange rates of the periphery countries' currencies vis-à-vis the Deutsch Mark, ds. This specification implies that the system is driven by five exogenous forces: in addition to the disturbances to aggregate supply and real demand, there are monetary shocks in the anchor-country as well as in the other countries, and shocks to the exchange rate.

Identification of the larger system requires new restrictions. The customary hypothesis that only aggregate supply shocks can have a long-run effect on output leads to two additional restrictions in the novel specification, because also shocks to the exchange rate and to the monetary policy in the periphery countries need to be taken into account. As in the previous system, monetary policy shocks (this time from two possible sources) are assumed to have no contemporaneous effect on output, implying two short-run restrictions.

In addition, the following four "new" restrictions are imposed. First, monetary shocks in the anchor-country are assumed to have a delayed effect on prices, as well as on output — a commonly-adopted and relatively uncontroversial assumption. Secondly, monetary shocks in the periphery countries are taken not to have any impact on interest-rate setting on the part of the anchor-country, at least within a quarter, in line with the notion that German monetary policy had a larger scope of autonomy within the ERM. Thirdly, shocks to the exchange rate are assumed to have no impact effect on the interest rate of the anchor country, consistently with the view that the burden of adjustment to maintain stability falls with periphery countries. Finally, area-wide, symmetric shocks to the demand for goods are assumed to have no impact effect on the exchange rate.

In terms of the VAR specification model $\{dy^A, i^{DE}, dp^A, ds, i-i^{DE}\}$, these restrictions can be written as $c_{12}(1) = c_{13}(1) = c_{14}(1) = c_{15}(1) = c_{12} = c_{32} = c_{43} = c_{24} = c_{15} = c_{25} = 0$.

7.2 Empirical results

The results from the estimation of the five-variable VAR allowing for a different specification of monetary policy are presented in Figure 6 and Table 5. In general, and as expected given sample-size and lags-length, confidence bands become much wider. The model performs worse than the smaller one, apparently failing to provide an accurate description of the dynamics of all 5 variables in the available sample. Notably, the decomposition of forecast error variance is difficult to reconcile with theoretical priors, since it attributes most of the explanatory power of unexpected dynamics of all 5 variables to exchange rate and AS shocks.

In qualitative terms, however, the results are similar to those of the benchmark system discussed above, providing further support to the reliability of the characterization of the Union-wide economic system discussed in the preceding Section. It appears especially noticeable that the monetary shocks identified through the two systems appear consistent with each other. Figure 7 also provides a direct comparison of the monetary shock of the VAR–3 and the 'symmetric' monetary shock of the VAR–5. The shocks are highly correlated (0.73) and provide a very similar description of monetary policy actions in Europe in the EMS years.

A one-standard-deviation positive shock to aggregate supply determines an impact increase of output of roughly the same magnitude observed in the benchmark model. The responses of the German interest rate and the inflation rate are also consistent with the previous results, although the variance associated with the estimates is slightly larger. Turning to the effects within the ERM, the supply shock determines a temporary appreciation of the Deutsch mark *vis-à-vis* the other currencies, accompanied by an immediate increase in the interest differential.

The effect of a shock to the IS schedule are virtually identical to the ones of the benchmark system in terms of both magnitude and time profile as well as of precision of the estimates. The behavior of output, inflation and the German interest rate after a monetary shock in Germany are analogous to the previous results, although less precisely identified. The fall in the German rate is not entirely matched by an equal reduction in the other countries, so that the interest differential increases temporarily bringing about a temporary depreciation of the Deutsch mark.

A one-standard-deviation shock to the exchange rate causes an impact appreciation of the Deutsch mark of approximately half a percentage point, a third of which is immediately passed through to the Union-wide price index. A prompt increase in the interest differential helps the return of the exchange rate to the baseline and the reduction of inflation, while German rates remain virtually unchanged.

An autonomous negative monetary shock in periphery countries shows as an increase of the interest differential by less than 5 basis points, revealing the tight cohesion of monetary policies in the ERM. Such a small increase has negligible effects on all the other variables, with the exception of the exchange rate with the Deutsch mark depreciating on impact by almost 0.8 percentage points.

8 Conclusions

This paper has attempted a characterization of the EMU-wide economic system relevant to the monetary policy decisions of the European Central Bank on the basis of a VAR model identified with restrictions drawn from economic theory. Any method to gauge the effects of the single monetary policy on the basis of past data and behaviour is beset with methodological difficulties,

particularly in view of the fact that the introduction of the single currency is such a momentous institutional change that it is likely to alter private sector economic behaviour deeply and pervasively. On the other hand, the assessment of the effects of the single monetary policy — an unavoidable prerequisite to define the appropriate interest rate level for the euro area — cannot wait the availability of sufficiently long euro-wide macroeconomic time series.

The key features of the euro-wide economic system can be summarized with reference to the response of inflation and interest rates to a one-standard-deviation shock to output aggregate supply, aggregate demand for goods and the money market. In line with widely-held priors from economic theory, a negative supply shock presses growth, rises inflation and triggers only a minimal reaction of short-term real interest rates. Although such responses are qualitatively the same as those found in the United States (e.g. by Gali, 1992), the magnitude is definitely smaller, lending support to the 'Eurosclerosis' view of an inferior flexibility of the European economies. This assessment is confirmed by the finding that a positive real demand shock increases output and inflation in the euro-area by less than it does in the US. Finally, the response of output and inflation to monetary shocks is, respectively, less and more persistent than in the US.

Such key features are confirmed by the additional econometric exercises carries out to test their robustness: the estimation of the model over a shorter period (up to the inception of the 1992-93 ERM crises) to consider possible parameter instability and the investigation of a different specification that defines two distinct monetary rules within the Union so as to take into account the anchor role played by Germany within the ERM — an issue that will become irrelevant in EMU but may be regarded as crucial in modeling monetary policy within the ERM framework.

The reasonable results obtained, both in qualitative and quantitative terms, and in their robustness to the alternative specification of the model support the authors' hope that this work can provide a useful starting point for the research aiming at answering the question 'What does the single monetary policy do?'

References

Amisano, Gianni and Carlo Giannini (1998) *Topics in Structural VAR Econometrics*. Berlin/Heidelberg: Springer-Verlag, 2nd Edition.

Andrés, Javier, Ricardo Mestre and Javier Vallés (1997) Monetary Policy and Exchange Rate Dynamics in the Spanish Economy. Banco de España, Servicio de Estudios, Documento de Trabajo No. 9727.

Andrews, Donald W. K (1993) Tests for Parameter Instability and Structural Change with Unknown Change Point. *Econometrica* 61, 821-56.

Bagliano, Fabio C. and Carlo A. Favero (1997) Measuring monetary policy with VAR models: an evaluation. CEPR Discussion Paper No. 1743.

Bank for International Settlements (1994) National Differences in Interest Rate Transmission. Basle: BIS.

Bank for International Settlements (1995) Financial Structure and the Monetary Policy Transmission Mechanism. Basle: BIS.

Bernanke, Ben S. (1986) Alternative Explanations of the Money-Income Correlation. *Carnegie-Rochester Conference Series on Public Policy* 25, 49-100.

Bernanke, Ben S. and Alan S. Blinder (1992) The Federal Funds Rate and the Channels of Monetary Transmission. *American Economic Review* 82, 901-21.

Bernanke, Ben S. and Ilian Mihov (1995) Measuring Monetary Policy. NBER, Working Paper No. 5154.

Blanchard, Olivier J. and Danny Quah (1989) The Dynamics Effects of Aggregate Demand and Supply Disturbances. *American Economic Review* 79, 655-73.

Blanchard, Olivier J. and Mark W. Watson (1986) Are Business Cycles All Alike?. In R. J. Gordon (ed.), *The American Business Cycle: Continuity and Change,* 123-53. Chicago, Chicago University Press.

Browne, Frank X., Gabriel Fagan and Jérôme Henry (1997) Money Demand in EU Countries: A Survey. European Monetary Institute Staff Papers No. 7.

Bruneau, Catherine and Olivier De Bandt (1998) La Modélisation VAR Structurel: Application à la Politique Monétaire en France. Banque de France, Notes d'Études et de Recherche No. 52.

Christiano, Lawrence J., Martin Eichenbaum and Charles L. Evans (1996) The Effects of Monetary Policy Shocks. Evidence from the Flow of Funds. *Review of Economics and Statistics* 78, 16-34.

Cochrane, John H. (1998) What do the VARs mean? Measuring the output effects of monetary policy. *Journal of Monetary Economics* 41, 277-300.

Cushman, David O. and Tao Zha (1997) Identifying monetary policy in a small open economy under flexible exchange rates. *Journal of Monetary Economics* 39, 433-48.

Dornbusch, Rudi, Carlo Favero and Francesco Giavazzi (1998) Challenges for the ECB. *Economic Policy* 13, 15-64.

Faust, Jon and Eric M. Leeper (1997) When do long-run identifying restrictions give reliable results?. *Journal of Business and Economic Statistics* 15, 345-53.

Fagan, Gabriel and Jérôme Henry (1996) A Small Scale Econometric Model of the Monetary Policy Transmission Mechanism in EU Countries. European Monetary Institute.

Gali, Jordi (1994) How Well Does the IS-LM Model fit Postwar US Data. *Quarterly Journal of Economics* 107, 709-38.

Gerlach, Stefan and Frank Smets (1995) The Monetary Transmission Mechanism: Evidence from the G-7 Countries. BIS, Working paper No. 26.

Giavazzi, Francesco and Marco Pagano (1988) The Advantage of Tying One's Hand: EMS Discipline and Central Bank Credibility. *European Economic Review* 32, 1055-75.

Gordon, David B. and Eric M. Leeper (1994) The Search Dynamic Impact of Monetary Policy. An Exercise in Tentative Identification. *Journal of Political Economy* 102, 1228-47.

Gros, Daniel and N. Thygesen (1992) *European Monetary Integration*. London: Longman.

Hansen, Bruce E. (1992) Testing for Parameter Instability in Linear Models. *Journal of Policy Modeling* 14, 513-33.

Kilian, Lutz (1998) Small-sample confidence intervals for impulse response functions. *Review of Economics and Statistics* 80, 218-30.

Kilian, Lutz and Pao-Li Chang (1998) How reliable are VAR estimates of responses to monetary policy shocks?. University of Michigan, June.

Kim, Soyoung and Nouriel Roubini (1997) Liquidity and Exchange Rates in the G-7 Countries: Evidence from Identified VARs. New York University, April.

Leeper, Eric M. and David B. Gordon (1991) In Search of the Liquidity Effect. *Journal of Monetary Economics* 29, 341-69.

Leeper, Eric M., Christopher A. Sims and Tao Zha (1996) What Does Monetary Policy Do?. *Brookings Papers on Economic Activity* 2, 1-63.

Monticelli, Carlo (1998) Structural Asymmetries and Euro-Wide Monetary Policy. A Theoretical Analysis. Paper presented at the Conference *Monetary Policy of the ESCB: Strategic and Implementation Issues*. Milan, July.

Monticelli, Carlo and Luca Papi (1996) *European Integration, Monetary Coordination and the Demand for Money*. Oxford: Oxford University Press.

Pesaran, M. H., R. G. Pierse and M. S. Kumar (1989) Econometric analysis of aggregation in the context of linear prediction models. *Econometrica* 57, 861-88.

Poole, William (1970) Optimal Choice of Monetary Instruments in a Simple Stochastic Macro Model. *Quarterly Journal of Economics* 84, 197-216.

Rudebusch, Glenn D. (1996) Do Measures of Monetary Policy in a VAR make sense. Banca d'Italia, Temi di Discussione del Servizio Studi.

Sims, Christopher A. (1980a) Comparison of Interwar and Postwar Business Cycles. Monetarism Reconsidered. *American Economic Review* 70, 250-7.

Sims, Christopher A. (1980b) Macroeconomics and Reality. *Econometrica* 48, 1-48.

Sims, Christopher A. (1982) Policy Analysis with Econometric Models. *Brookings Papers on Economic Activity* 22, 107-64.

Sims, Christopher A. (1992) Interpreting the Macroeconomics Time Series Facts: The Effects of Monetary Policy. *European Economic Review* 36, 975-1011.

Sims, Christopher A. (1996) Comment on Glenn Rudebusch's "Do Measures of Monetary Policy in a VAR make sense". Yale University, July.

Sims, Christopher A., James H. Stock and Mark W. Watson (1990) Inference in Linear Time Series Models with Some Unit Roots. *Econometrica* 58, 113-144.

Sims, Christopher A. and Tao Zha (1995) Error bands for impulse responses. Federal Reserve Bank of Atlanta, Working Paper No. 95-6.

Strongin, S. (1995) The Identification of Monetary Policy Disturbances. Explaining the Liquidity Puzzle. *Journal of Monetary Economics* 35, 463-97.

Vlaar, Peter J. G. (1998) On the asymptotic distribution of impulse response functions with long run restrictions. De Netherlandsche Bank, Research Memorandum No. 539/9809.

Winder, C. C. A. (1997) On the construction of European area-wide aggregates: a review of the issues and empirical evidence. De Netherlandsche Bank, Research Memorandum No. 499/9714.

Appendix — Data description

In our analysis we consider real GDP, consumer price indices and the 3-month interbank interest rate. The frequency of observation is quarterly and the series are seasonal adjusted.

Because of data constraints, the EMU is actually constructed as an aggregate of 7 countries: the 11 participating minus Finland, Ireland, Luxemburg and Portugal.

The aggregate series are constructed as geometric weighted averages. Thus, for any given series x (expressed in logarithms) available for the 7 countries considered, area-wide data are obtained as[6]

$$x^A = \sum_{i=1}^{7} w_i x_i \ .$$

National data were all obtained from the BIS databank, with the exception of the Italian interbank rates (source: Banca d'Italia).

The following weights were used: Austria, 3.2%; Belgium, 4.1%; France, 22.8%; Germany, 31.7%; Italy, 21.5%; Netherlands, 5.7%; Spain, 11.0%.

6 *For the interest rates,* $x \equiv \ln(1+i)$.

TABLE 1

Unit-root tests*

	ADF1	PP1	ADF2	PP2
y^A	–2.38601	–1.70716	–16.02132	–5.89689
dy^A	–3.17916	–8.16763 ‡	–40.28626 ‡	–86.69089 ‡
i^A	–3.64881 †	–2.27166	–26.32399 †	–8.14250
di^A	–3.65106 †	–5.21884 ‡	–68.83962 ‡	–39.94791 ‡
p^A	–4.63539 ‡	–2.47015	–6.39216	–2.35774
dp^A	–1.75574	–3.24578	–7.59428	–17.38294
$i^A – dp^A$	–1.59983	–3.04858	–6.31941	–17.80246

TABLE 2

Correlation of VAR residuals

(three-variable system)

dy^A	1.0000		
i^A	0.1708	1.0000	
dp^A	–0.0002	0.4351	1.0000

* *A time trend and 4 lags are included in the OLS regressions for all variables. Sample period: 1978:1-1997:4. Critical values are: 5%=–3.466, 1%=–4.076 for the* $\hat{t}$ *statistic and 5%=–20.5, 1%=–26.9 for the* $T(1-\hat{r}_T)$ *statistic. Keys: ‡, significant at the 1% confidence level; †, significant at the 5% level.*

TABLE 3

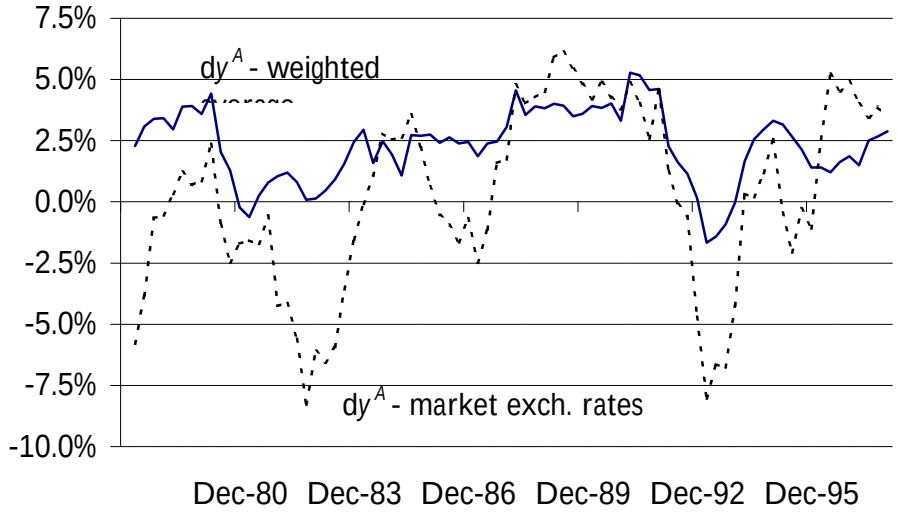
Correlation of VAR residuals

(five-variable system)

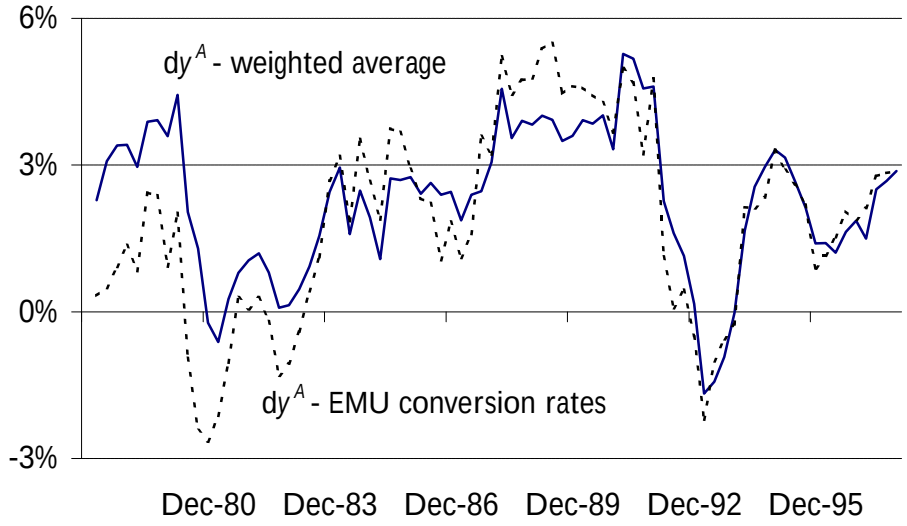
dy^A	1.0000				
i^{DE}	0.1206	1.0000			
dp^A	–0.0314	0.3926	1.0000		
ds	–0.0205	–0.1889	0.0015	1.0000	
$i-i^{DE}$	0.0525	–0.5227	–0.0653	0.4314	1.0000

FIGURE 1

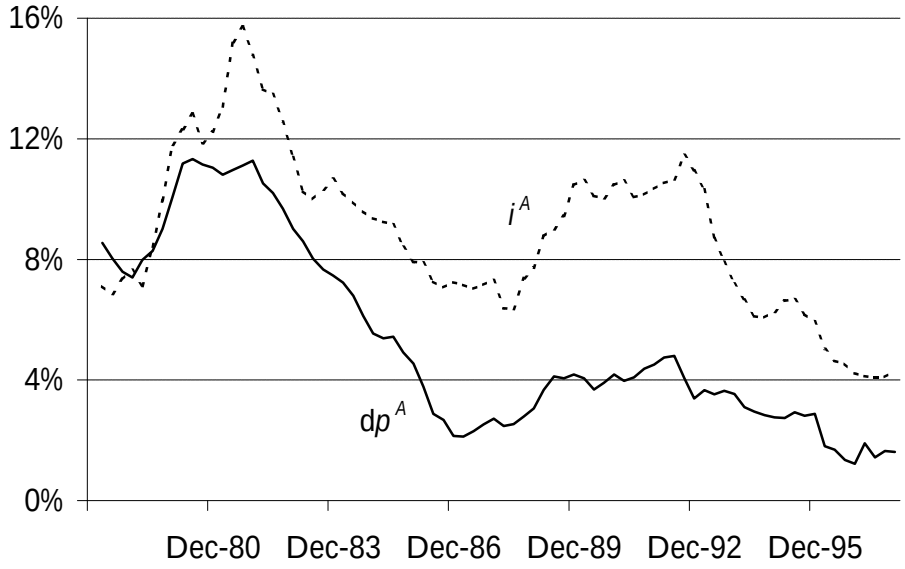
Aggregation methods:
4-quarter GDP growth



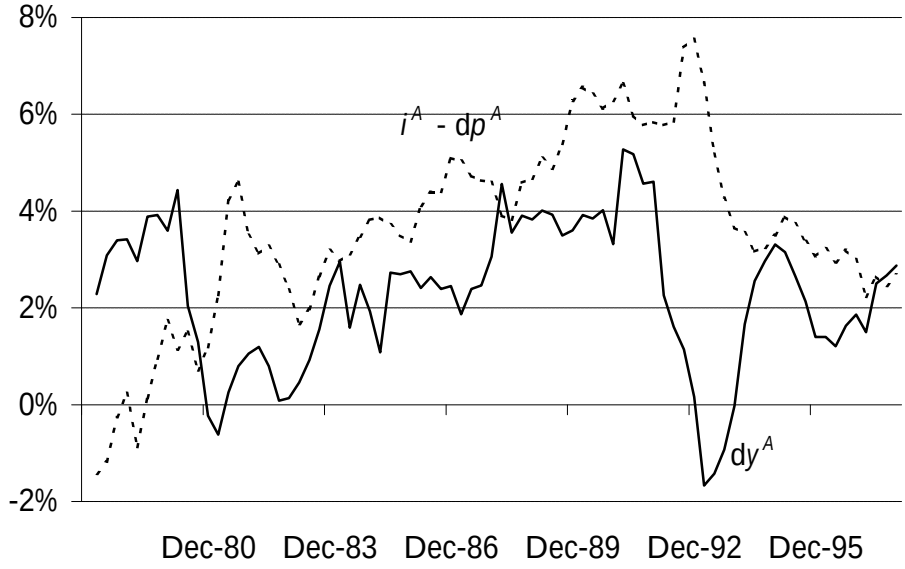
Aggregation methods:
4-quarter GDP growth



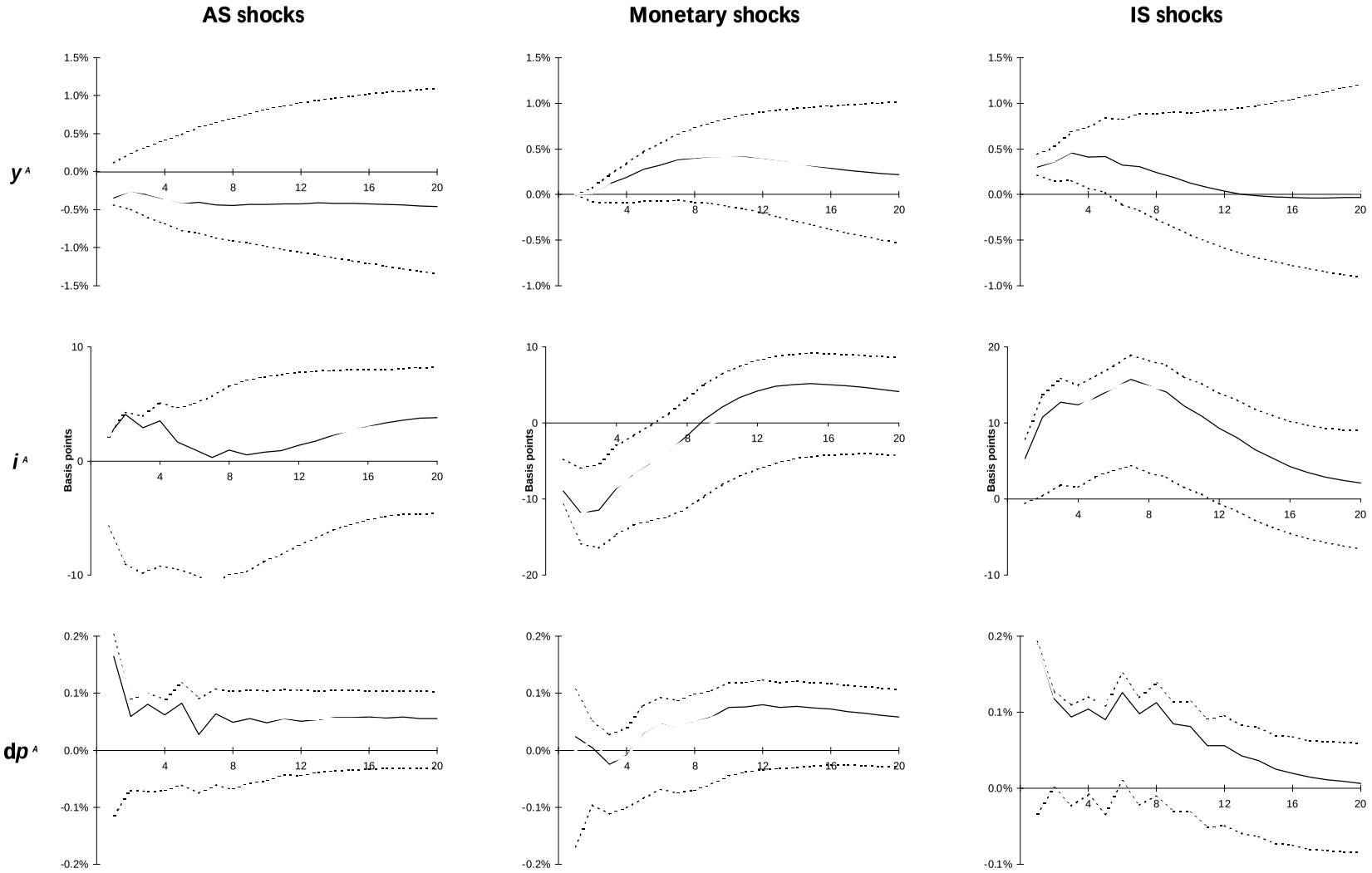
Euro area inflation and nominal interest rates



Euro area GDP-growht and real interest rate



Three-variable VAR
(78q1-97q4)
Impulse responses to

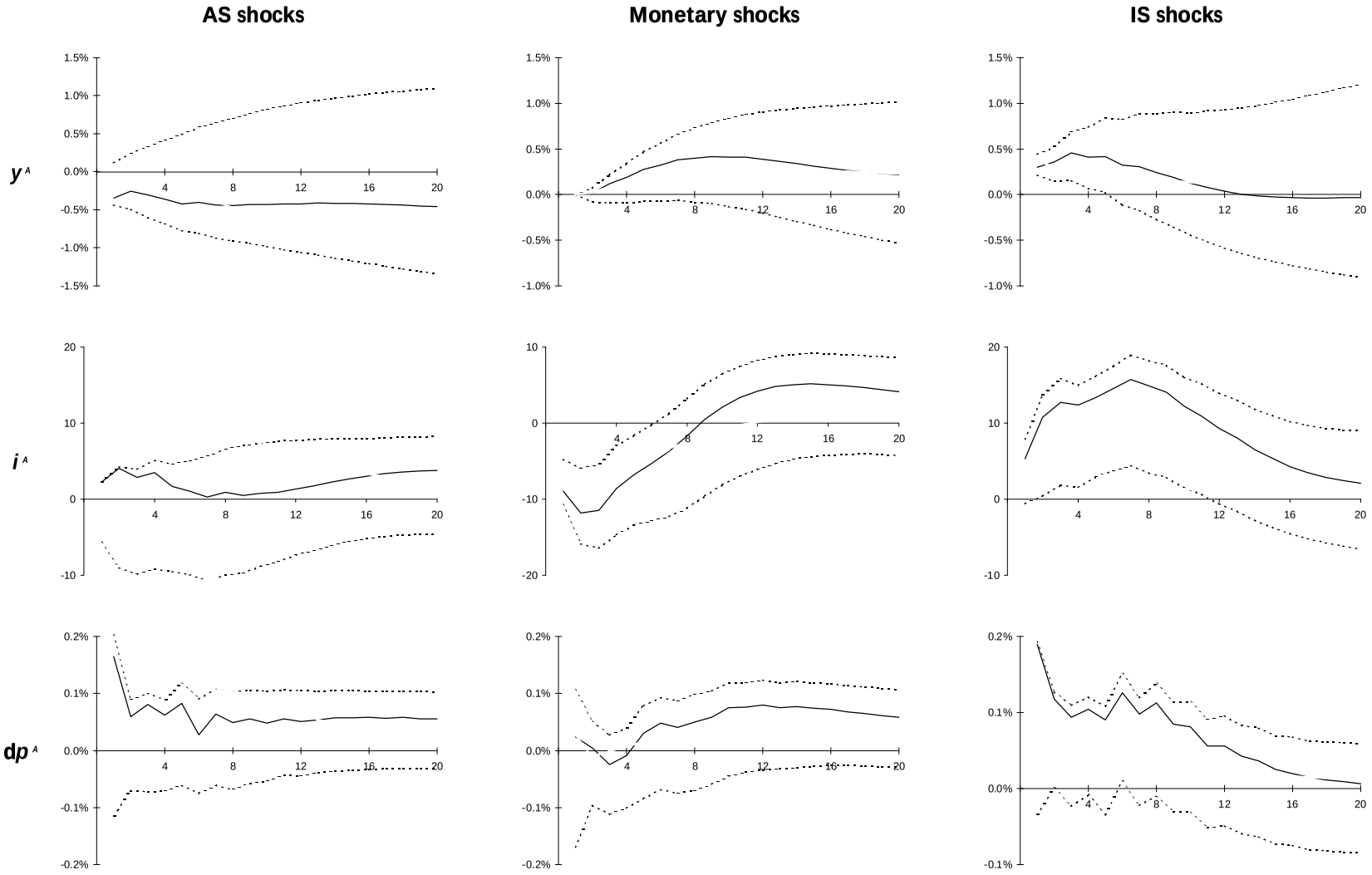


Keys: solid line: main identification scheme; grey line: alternative identification scheme; dashed lines: confidence bounds for the main identification scheme.

Three-variable VAR

Robustness across samples

Impulse responses to



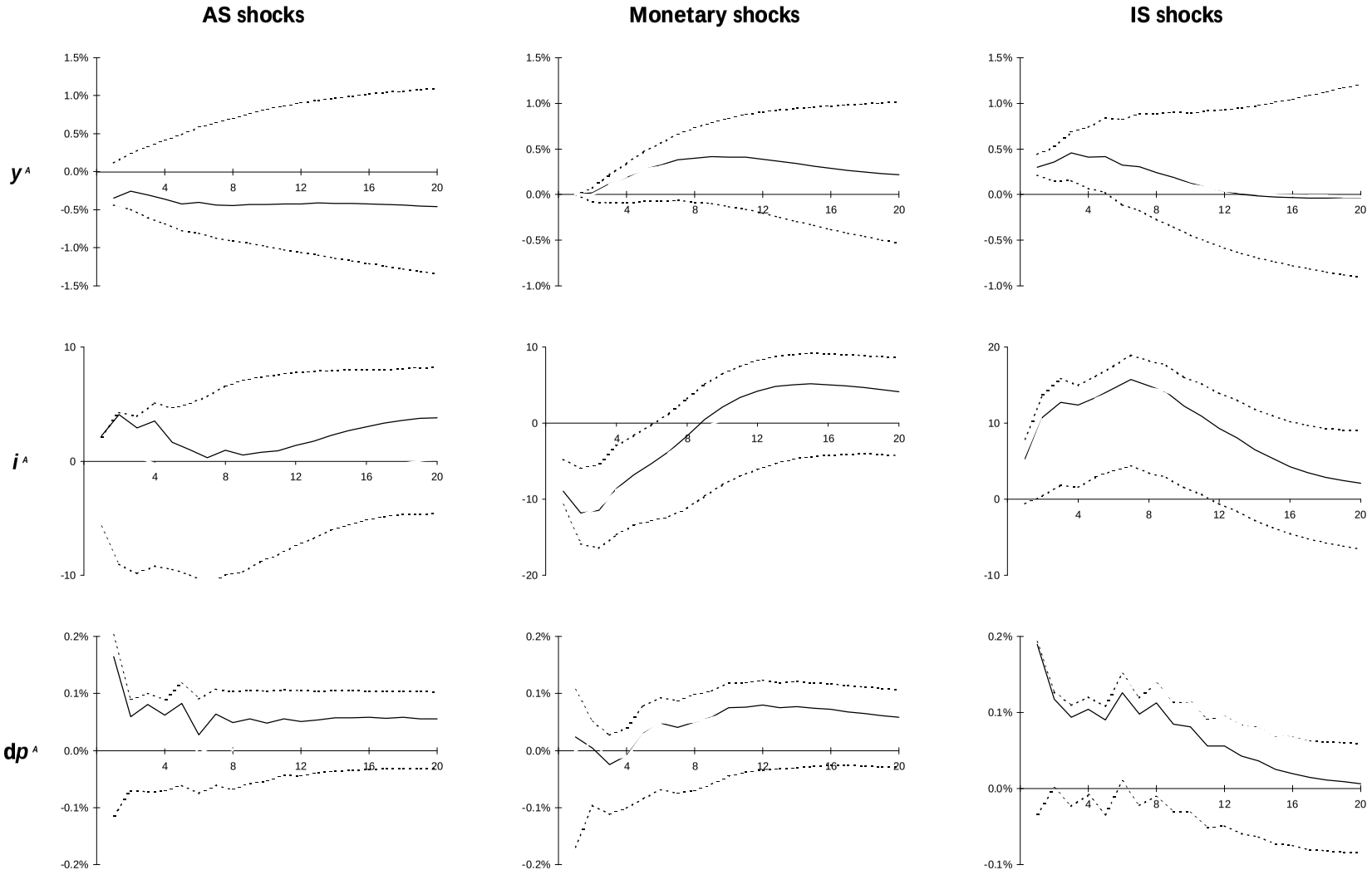
Keys: solid line: 78q1-97q4 sample; grey line: 78q1-91q4 sample; dashed lines: confidence bounds refer to the responses for the longer sample.

FIGURE 5

Three-variable VAR

Treatment of German reunification

Impulse responses to



Keys: solid line: smoothing out the effect of German reunification on German GDP; grey line: no-smoothing of German GDP; dashed lines: confidence bounds for the main identification scheme.

FIGURE 6

Five-variable VAR

(78q1-97q4)

Impulse responses to

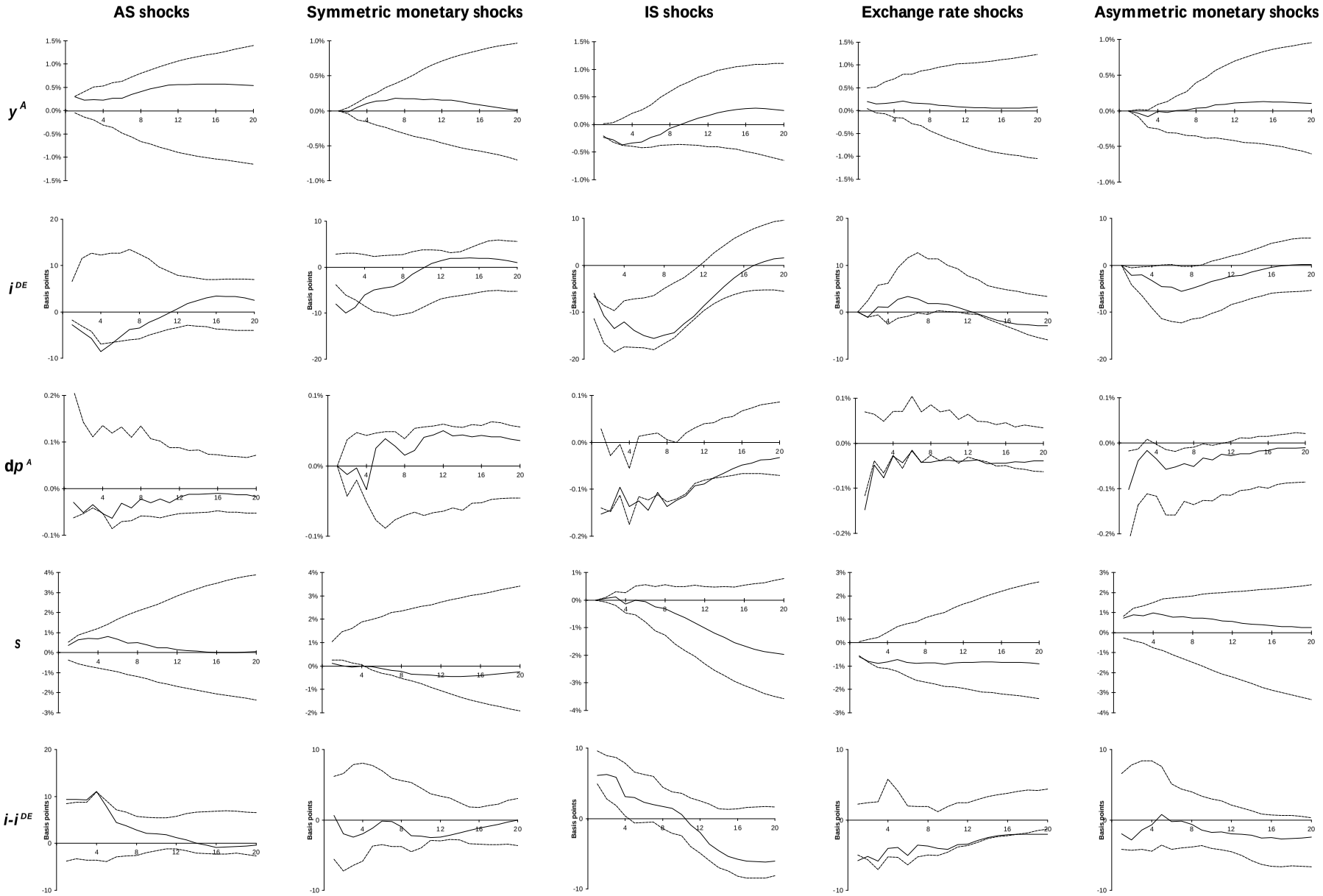
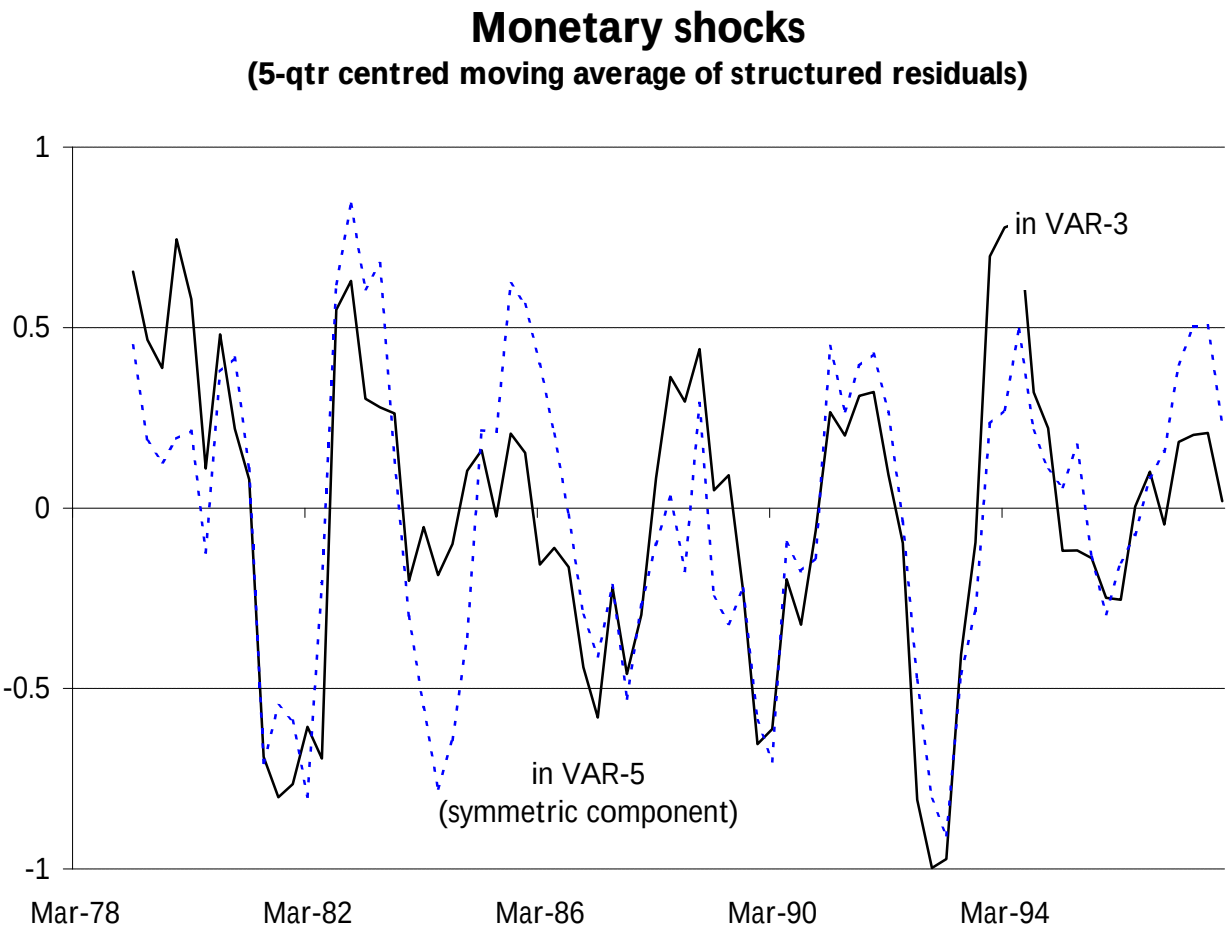


FIGURE 7


Monetary shocks
(5-qtr centred moving average of structured residuals)
1
0.5
0
-0.5
-1
Mar-78
Mar-82
Mar-86
Mar-90
Mar-94
in VAR-3
in VAR-5
(symmetric component)

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