The transmission of monetary shocks
in the euro area:
a VAR analysis based on euro-wide data

JAN KAKES and SITIKANTHA PATTANAIK

1. Introduction

The launch of EMU in January 1999 marks the start of a monetary policy that explicitly focuses on the euro area. Consequently, the Eurosystem - comprising the European Central Bank (ECB) and the eleven national central banks (NCBs) of the participating countries - first and foremost looks at developments in euro-wide variables. Up to now, however, there have been only a few studies into monetary transmission which explicitly use euro-wide aggregated data. To some extent, this may be attributed to conceptual difficulties regarding both the construction of aggregate series and the interpretation of the analyses performed with these data. There are several ways to construct euro-wide time series, and each approach has its own

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1 See Van Bergeijk, Berndsen and Jansen (2000) for an extensive study of monetary policy in the euro area.

2 Exceptions are a VAR study by Monticelli and Tristani (1999) and money demand studies based on European aggregates (e.g. Kremers and Lane 1990, Monticelli and Strauß-Kahn 1992, Pase and Winder 1998, Vlaar and Schuberth 1998).
drawbacks. In addition, there exist substantial differences in monetary transmission across the member states, which are likely to be further influenced by the regime switch due to EMU. Indeed, the start of EMU can be considered a classic example where the Lucas critique applies, making any econometric analysis based on data prior to 1999 suspect. Nevertheless, some recent studies consider a number of EMU countries separately, primarily to analyse differences in monetary transmission. Also, a number of multi-country models have been used to make simulations for the euro area.

The aim of this paper is to analyse the responses of inflation and real activity to monetary shocks, using aggregated data for the euro area over the period 1980-98. Obviously, this implies that we ignore cross-national differences in monetary transmission and structural changes caused by the start of EMU. Our results should therefore be interpreted with caution. The fact that we use aggregated data does not mean that we think that cross-national differences are unimportant. Rather, our approach should be considered as complementary to studies that focus on individual European countries. The value-added of our approach is that it is consistent with the area-wide focus of the Eurosystem. In addition, even in the United States the transmission of monetary policy is different across states (Carlino and DeFina 1998), which suggests that the current differences in the euro area may to some extent persist. Hence, our results may give some indication of the effectiveness of monetary policy at the area-wide level after the start of EMU. Because this also offers a useful benchmark for a comparison with the United States, we repeat the analysis with US data in order to investigate to what extent the responses of both economies to a monetary shock are similar.

Our approach is in some respects similar to a recent study by Monticelli and Tristani (1999), who construct a structural VAR model using weighted averages of GDP, CPI and the short-term interest rate for the euro area. These authors identify aggregate demand shocks, aggregate supply shocks and monetary shocks by imposing a combination of long-term and short-term restrictions on the esti-

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mated VAR. There are two important differences between that study and our approach. First, we follow the more conventional VAR approach initiated by Sims (1980), in which disturbances are identified by imposing a causal ordering for the variables included in the VAR. The innovations of the interest rate equation that are obtained in this way are interpreted as unanticipated monetary policy shocks. A second difference is that we do not only look at the responses of inflation and real output, but also try to capture more of the transmission process in our analysis, by including the long-term interest rate, money aggregates, and the effective exchange rate for the euro area in our VAR.

The remainder of this paper is organized as follows. Section 2 presents the empirical results. First, we discuss the data and present the outcomes of stationarity tests. Subsequently, we show our results, which consist of innovation analyses with several VAR specifications for the euro area and the United States. In addition, we pay attention to the implications of our results for the Eurosystem’s monetary strategy. Section 3, finally, offers a summary and conclusions.

2. Empirical results

2.1. Data and pre-testing

We constructed euro-wide aggregated data as weighted averages of the time series of the individual member states over the period 1980Q1-1998Q4 (see Data Appendix). We include the following variables:

- as our monetary policy indicator, we use the short-term interest rate, following most of the recent literature.4

4 Following Bernanke and Blinder (1992), many VAR-based studies have established that using short-term interbank rates as monetary policy variables yields plausible results for both the United States and European economies. See, for example, Dale and Haldane (1995) for the United Kingdom, Escriba and Haldane (1994) for Spain, Guender and Moersch (1997) for Germany, Garretsen and Swank (1998) and Kakes (2000) for the Netherlands, and Barran et al. (1996) and De Bondt (2000) for several European countries.
- We include prices (CPI) and real activity (GDP), which are the main target variables of monetary policy.

- We include the long-term interest rate, money (M3) and the real effective exchange rate for the euro area, which may be important transmission variables. The choice of M3 is motivated by the fact that this variable has been assigned a privileged role in the Eurosystem's monetary policy decision making process.

- We add the oil price to our VAR as an exogenous variable, in order to take into account related supply shocks.5

All variables are included in logs, except interest rates. The choice of variables is limited by the fact that we use aggregated data. Other variables which might be useful to identify transmission channels, such as credit aggregates or various lending interest rates, are more difficult to aggregate due to cross-national differences regarding definitions and data availability.

We performed Augmented Dickey-Fuller tests to establish the order of integration of the time series. The results are presented in Table 1. It can be concluded that all variables are I(1), except CPI and the effective exchange rate which are I(2) and I(0), respectively. Regarding the implications of these tests for the model specification, there exist several approaches in the VAR-based literature. One possibility would be to estimate a VECM model, i.e. a model in first differences extended by cointegrating residuals. An alternative approach is to estimate a VAR in first differences or, if cointegration can be established, in levels. Of course, if there is no cointegration, both approaches are equivalent. In this paper we follow the second approach. Since cointegration can be established for all specifications considered, we perform our estimations in levels. Hence, we do not impose any constraints on the long-term structure that is captured by the model.

5 In the results we present below, the oil price is denominated in US dollars. We also investigated specifications with the oil price in euros, or with a commodity price index. This had hardly any impact on our results. We model the oil price as an exogenous variable because of a priori reasons, given the fact that changes in the oil price are to a large extent determined externally. Including the oil price as an endogenous variable has virtually no effect on our results, however.

6 Some authors (Sims 1980, Doan 1995; see also Enders 1995) recommend against differencing time series, even if these are nonstationary, in order not to throw away information concerning long-term relationships. In addition, our approach follows most of the VAR literature on monetary transmission in the United States (e.g. Bernanke and Blinder 1992; Bernanke and Gertler 1995), which increases the comparability of these studies with our results.

### Table 1

<table>
<thead>
<tr>
<th>Variable</th>
<th>Test statistics</th>
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<tbody>
<tr>
<td>CPI</td>
<td></td>
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<tr>
<td>D(CPI)</td>
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<tr>
<td>GDP</td>
<td></td>
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<tr>
<td>Exchange rate</td>
<td></td>
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<td>M3</td>
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<td>Long-term</td>
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<td>Short-term</td>
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The transmission of monetary shocks in the euro area: ...

In this way we avoid problems such as the exact determination of the cointegration rank, which is in general not straightforward.\(^7\)

### Table 1

<table>
<thead>
<tr>
<th>Variable</th>
<th>Levels</th>
<th>Lags</th>
<th>T/C</th>
<th>Differences</th>
<th>Lags</th>
<th>T/C</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPI</td>
<td>-3.32</td>
<td>1 T</td>
<td>C</td>
<td>-1.51</td>
<td>1</td>
<td>C</td>
<td>I(2)</td>
</tr>
<tr>
<td>D(CPI)</td>
<td>-1.51</td>
<td>1 C</td>
<td>C</td>
<td>-8.44**</td>
<td>1</td>
<td>C</td>
<td>I(1)</td>
</tr>
<tr>
<td>GDP</td>
<td>-2.47</td>
<td>3 T</td>
<td>C</td>
<td>-7.77**</td>
<td>0</td>
<td>C</td>
<td>I(0)</td>
</tr>
<tr>
<td>Exchange rate</td>
<td>-1.78***</td>
<td>4 C</td>
<td>C</td>
<td>-6.82***</td>
<td>0</td>
<td>T</td>
<td>I(1)</td>
</tr>
<tr>
<td>M3</td>
<td>-0.17</td>
<td>1 T</td>
<td>C</td>
<td>-4.97***</td>
<td>1</td>
<td>C</td>
<td>I(1)</td>
</tr>
<tr>
<td>Long-term interest</td>
<td>-2.94</td>
<td>3 T</td>
<td>C</td>
<td>-5.73***</td>
<td>1</td>
<td>C</td>
<td>I(1)</td>
</tr>
<tr>
<td>Short-term interest</td>
<td>-2.23</td>
<td>1 T</td>
<td>C</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Test statistics; ***, ** and *** denote rejection of nonstationarity at the 10%, 5% and 1% level, respectively, based on critical values by MacKinnon (1991); T indicates that both a trend and a constant are included in the tested equation, C indicates that only a constant is included.

#### 2.2. Innovation analysis

We consider a six variable VAR specification including inflation (first difference of the price level), GDP, the real effective exchange rate, broad money (M3), the long-term interest rate and the short-term interest rate. We include four lags for each variable; imposing different lag lengths (ranging from 2 to 6) changes the outcomes only marginally and does not affect our conclusions. Hence, the effective sample is 1981Q1-1998Q4.

In order to perform innovation analysis, sufficient restrictions need to be imposed on the estimated VAR in order to ensure that the shocks driving the model are orthogonal. Following the initial solution by Sims (1980), the structure we impose in this paper is a causal ordering.\(^8\) Obviously, the ordering of the variables can be important for the simulation results, depending on the correlation between the

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\(^7\) The Johansen (trace) test suggests four or five cointegrating relationships, depending on the specification of the cointegration space. Impulse-responses that are carried out with these vector error-correction specifications do not deviate much from the simulations with our VAR model.

\(^8\) Approaches using other structures, more explicitly based on economic theory, are denoted as structural VARs. In addition, rather than using contemporaneous restrictions, it is possible to impose restrictions on the long-term dynamic properties of the VAR (see e.g. Blanchard and Quah 1989). Rather than following this approach, we choose to estimate a 'conventional' VAR, imposing as little \textit{a priori} structure as possible.
estimated residuals. However, Table 2 shows that relatively high correlations only exist between the short-term and long-term interest rates, between the short-term interest rate and inflation and between the long-term interest rate and GDP. Hence, the ordering of the variables – or any other contemporaneous structure – is not likely to have a large impact on the simulation results. 9

<table>
<thead>
<tr>
<th></th>
<th>Inflation</th>
<th>GDP</th>
<th>Exch. rate</th>
<th>M3</th>
<th>Long-term interest</th>
<th>Short-term interest</th>
</tr>
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<tbody>
<tr>
<td>Inflation</td>
<td>1.00</td>
<td></td>
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<tr>
<td>GDP</td>
<td>0.09</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exchange rate</td>
<td>-0.20</td>
<td>0.00</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M3</td>
<td>0.03</td>
<td>0.14</td>
<td>-0.11</td>
<td>-0.06</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>Long-term interest</td>
<td>0.13</td>
<td>0.23</td>
<td>0.12</td>
<td>-0.06</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>Short-term interest</td>
<td>0.27</td>
<td>0.07</td>
<td>0.10</td>
<td>0.19</td>
<td>0.58</td>
<td>1.00</td>
</tr>
</tbody>
</table>

We impose contemporaneous restrictions based on a causal ordering, using the order presented in Table 1, i.e. with the short-term interest rate ordered last. Hence, it is assumed that the monetary authorities are able to respond to shocks in the other variables within a quarter. This may seem unrealistic, as actual data on most variables is only available after more than a quarter, but is consistent with the fact that central banks in practice formulate their policy on the basis of several forward-looking indicators that are available earlier.

The first row of Figure 1 presents responses to an upward shock in the short-term interest rate, which can be interpreted as an unanticipated monetary contraction. Dashed lines indicate a 90% confidence interval, which is obtained through Monte Carlo integration. The size of the shock is one standard deviation of the innovation of the short-term interest rate equation, which is about 25 basis points. After the simulated shock, the interest rate gradually returns to a level not significantly different from the baseline level.

Regarding the responses of the two main target variables, it is striking that the impact on inflation is insignificant, whereas GDP shows a clear negative response. Presumably, nominal rigidities are important in Europe, limiting the short-term impact of monetary shocks on problems with exchange rate shocks. GDP is significant in ourVAR model, whereas the estimate of GDP is consistent with our empirical findings.

The substantial negative impact on inflation is a result of the common money demand shock. However, this finding is not robust, as exchange rate shocks are not significant in our model. The significant negative response of GDP is consistent with our empirical findings.

9 As a 'rule of thumb', 0.2 is often used as a critical value for the absolute value of the correlation between the estimated residuals. If the correlations are greater than this threshold, the structure (i.e. the ordering) that is imposed may be expected to have a substantial impact on the impulse-responses (see e.g. Enders 1995).
The transmission of monetary shocks in the euro area: ... shocks on prices. It should also be noted that many VAR studies have problems generating plausible responses of prices following a monetary shock (known as the 'price puzzle'). The negative response of GDP starts almost immediately after the shock and is statistically significant in the second, third and fourth quarter. In their structural VAR of the euro area, Monticelli and Tristani (1999) also find that real activity shows a negative response to a monetary contraction, whereas the response of inflation is insignificant (although their point estimate of the inflation response is slightly negative), which is in line with our results.

The responses of the three intermediate variables are not very substantial and, what is more, insignificant over most of the simulation period. The long-term interest rate initially increases, but does not show a clear response in either direction over time. The effective exchange rate does not show a significant response at all, which implies that the exchange rate channel is not important. Finally, M3 in the first instance increases after the monetary tightening. It is quite common to find a positive short-term interest rate elasticity of broad money demand (see e.g. Fase and Winder 1998), as broad aggregates include interest bearing elements with a short maturity, which become more attractive following the positive interest rate shock. Nevertheless, this 'perverse' short-term response should be taken into account if monetary policy is formulated on the basis of M3 growth. About a year after the initial increase, the point estimate starts declining, but this response does not become statistically significant. We repeated the analysis with a VAR in which we replaced M3 by the narrow aggregate M1, which includes fewer interest-bearing elements, making a positive relationship between money and interest rates unlikely. This time, money shows an immediate negative response while the responses of the other variables remain largely the same as in the specification with M3.

Next, we look at the response of the system to shocks in other variables, notably the long-term interest rate and the effective exchange rate. The results are reported in the second and third row of Figure 1. Both the long-term interest rate and the effective exchange rate show a gradual return to their baseline levels after a shock to these variables.

Positive shocks to the long-term interest rate are quickly translated into downward changes in M3, which is a plausible portfolio
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In our analysis, Hence, the period prior inflation is significant different than an it appreciate; want trans the second same as fo

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10 Simul changes in the Bank 1999). 
11 American dollar.
balance effect. In addition, the effective exchange rate appreciates significantly. As one would expect, a long-term interest rate shock reduces real activity. This response becomes significant after a year, which is much slower than the GDP response to a short-term interest rate shock, while the magnitude is more or less equal. The immediate positive impact on inflation, finally, does not have a straightforward interpretation. Possibly, a higher long-term interest rate reflects increased inflation expectations.

The positive effective exchange rate shock, finally, reflects a real appreciation of the euro. The most striking responses following this shock are the immediate decline in inflation and M3 and, after two quarters, the fall in real activity. Apparently, the economy is sensitive to (unanticipated) movements in the effective exchange rate. However, given our observation that the effective exchange rate is hardly affected by a shock to the short-term interest rate, this variable would not seem to be important for the transmission of monetary policy. Thus, while our analysis questions the effectiveness of an exchange rate policy for the Eurosystem, it underscores the importance of the effective exchange rate as an information variable. Replacing the real effective exchange rate by the nominal effective exchange rate or the euro-US dollar exchange rate does lead to some minor changes in the responses but does not affect the thrust of our conclusions.

In order to investigate the robustness of our results, we repeated the analysis for the sample 1981Q1-1992Q4 and for 1987Q1-1998Q4. Hence, we skip most of the period after German reunification and the period prior to 1987, which was characterized by a substantial higher inflation level. In the first case (1981Q1-1992Q4), we observe a significant decline in inflation following a monetary contraction, rather than an insignificant response. Further, the effective exchange rate appreciates, which suggests that the exchange rate channel was a relevant transmission mechanism in the earlier part of our sample. For the second sample (1987Q1-1998Q4), the results are essentially the same as for the entire sample. In addition, we checked the robustness

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10 Simulations with the multi-country model EUROMON also show that changes in the euro exchange rate have a substantial impact (see De Nederlandsche Bank 1999).

11 A shorter sample of 1981Q1-1989Q4, including only observations prior to German unification, is impossible in our setting due to insufficient degrees of freedom.
of our results to alternative causal orderings. As we noted, Table 2 shows that the correlation is highest between innovations in the short-term interest rate and those in the long-term rate and inflation. Other orderings (e.g. putting the short-term interest rate first and inflation last), have only a limited impact on most of the results and do not materially change our conclusions.

2.3. Implications for the Eurosystem’s monetary strategy

The Eurosystem’s monetary policy strategy consists of three key elements (see European Central Bank, January 1999; Berk, Houben and Kakes 2000). First of all, the overriding objective of price stability has been precisely defined. Second, money has been assigned an important role, known as the ‘first pillar’ of the monetary strategy. This does not mean that money growth is used as a single target, but indicates that the deviation of M3 growth from its reference value is considered a privileged indicator for future inflation. Third, the strategic framework explicitly incorporates a broad-based assessment of prospective inflationary pressures, known as the ‘second pillar’ of the Eurosystem’s strategy. This framework includes several indicators such as model forecasts, the yield curve, confidence indicators, the output gap and the exchange rate.

The ‘perverse’ short-term response of M3 to a monetary contraction should be taken into account when interpreting money growth in the first pillar. It underscores the importance to focus on the medium-term relationship of this variable with monetary policy. However, it should also be taken into account that we only consider VAR-based short-term interest rate shocks, which are to be interpreted as unanticipated monetary policy.

The responses of inflation, GDP and M3 to an exchange rate shock imply that the Eurosystem cannot treat this variable with benign neglect. However, given our earlier observation that this variable is not significantly affected by short-term interest shocks, it cannot be concluded that there is scope for exchange rate targeting or for an exchange rate policy. Rather, our results indicate that this variable should be assigned an important role within the second pillar of the Eurosystem’s strategy.

2.4. A conclusion

In Figure 1, over the sample period we estimated for inflation, so there exist nisms in different countries. The first contraction shock it is, the response. This may be an of the oil price (1992), did plausible p. Blinder (1991) significant initial position was also for the increase in the European exchange rate. The relative exchange rate increase in the more important.

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13 There e to dani (1996) situ tion may be higher prices omy goes into, may raise thei.

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2.4. A comparison with the United States

In Figure 2 we present impulse-response analyses based on US data over the same sample.\textsuperscript{12} The United States are an interesting benchmark for the euro area: both are large and relatively closed economies, so one might expect similar outcomes. In addition, insofar as there exist substantial differences between the transmission mechanisms in both areas, it is interesting to see whether these are translated in differences regarding the eventual effects of monetary policy.\textsuperscript{13}

The first row of Figure 2 presents the responses to a monetary contraction, simulated as an unanticipated short-term interest rate shock. It is striking that inflation shows an immediate positive response. This 'price puzzle' shows up in many VAR-based studies, and may be an indication that an important variable is omitted. Inclusion of the oil price or a commodity price index, as recommended by Sims (1992), did not resolve the puzzle.\textsuperscript{14} The other responses show a more plausible pattern, consistent with previous studies (e.g. Bernanke and Blinder 1992, Bernanke and Gertler 1995). Real activity falls after a significant lag, which is somewhat longer than in the euro area; the initial positive response of this variable following a monetary shock was also found in other studies (e.g. Bernanke and Gertler 1995). Like in Europe, M3 initially shows a positive response, while the effective exchange rate does not show any significant response at all. The increase in the long-term interest rate, however, is more pronounced than in the euro area, which suggests that the interest rate channel is more important in the United States.

Responses to shocks in the long-term interest rate and the effective exchange rate are reported in the second and third row of Figure 2. In general, the impulse-responses show a similar pattern to that of

\textsuperscript{12} Like in the case of European variables, it can be established that these variables are I(1) and cointegrated.

\textsuperscript{13} For instance, European economies are often considered as 'bank-oriented' systems, whereas the United States is more 'market-oriented.'

\textsuperscript{14} There exist several economic explanations for the price puzzle. Dale and Haldane (1995) suggest that the positive response of inflation after a monetary contraction may be explained by increasing variable costs which initially translate into higher prices due to cost mark-up pricing. Stiglitz (1992) argues that when the economy goes into a downturn (for instance due to a monetary contraction), some firms may raise their prices to increase their cash flows in order to avoid immediate problems (e.g. bankruptcy), transferring the costs of this behaviour (losing customers) to the future.
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3. Summary

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the euro area. Long-term interest rate innovations immediately have a positive, albeit very brief, impact on the short-term interest rate and inflation. However, the other variables are hardly affected significantly. Finally, unanticipated innovations in the effective exchange rate have a negative impact on real activity and M3. In contrast with the euro area, however, inflation initially shows a positive response and becomes slightly negative only after two quarters.

3. Summary and conclusions

In this paper, we have analysed the impact of monetary shocks on the euro area economy, using aggregated data over the sample 1981Q1-1998Q4. Obviously, our results should be interpreted with caution on account of the regime shift due to EMU. An important conclusion is that a monetary contraction, represented by a shock to the short-term interest rate, has a negative impact on real activity and hardly influences inflation, while M3 shows initially a positive response. In addition, changes in the effective exchange rate and the long-term interest rate have a substantial impact on real activity, while a real appreciation is also quickly translated into inflation. However, as the long-term interest rate and the effective exchange rate hardly respond to shocks in the short-term interest rate, these variables have only a limited importance in the transmission of monetary policy. Nevertheless, our results imply that the effective exchange rate is an important information variable. Finally, we make a comparison with a VAR estimated with US data. Interestingly, the impact of monetary shocks on real activity is similar in both economies.

Our results have important implications for the Eurosystem’s monetary strategy. First, the ‘perverse’ short-term response of M3 should be taken into account when interpreting the reference value for money growth. Second, the limited response of the exchange rate to interest rate shocks advises against pursuing an exchange rate policy. At the same time, however, the fact that exchange rate shocks have a significant impact on inflation, GDP and M3 indicates that this variable should be given a prominent place within the second pillar of the monetary strategy.
DATA APPENDIX

Some variables are taken from the data sources in aggregate form, others are aggregated by ourselves. For the latter, we applied fixed weights based on purchasing power parities using 1994 as the base-year. The weights that are obtained in this way for GDP are also used to construct area-wide averages for most of the other variables. Obviously, alternative methods are possible, for instance by using current weights for each quarter instead of a fixed base year, or by using exchange rates instead of purchasing power parities. We consider our approach as the most appropriate, for several reasons (see also Winder 1997). If the weights would be allowed to vary over the sample, these changes would have both a price and a volume component, making the developments in real variables hard to interpret. In addition, the use of current exchange rates would imply that the choice of a particular common currency would have an impact on the resulting aggregates. We used the following data for the euro area:

- Monetary aggregates (M3, M1) for the euro area have been constructed by the ECB and published in the ECB’s *Monthly Bulletin* of February 1999.
- The real effective exchange rate we used is the ‘synthetic’ euro area exchange rate constructed by the BIS, which is also published in the ECB’s *Monthly Bulletin*. An increase in this variable reflects an appreciation of the euro. In alternative specifications we also used the nominal effective exchange rate (same source) and the US dollar exchange rate (the ECU-USD rate which is published in the IMF’s *International Financial Statistics*).
- Gross domestic product has been constructed by ourselves. The weights we used, based on 1994, are as follows (in percentages): Austria 3.05, Belgium 3.94, Germany 30.62, Spain 10.17, Finland 1.52, France 21.35, Ireland 1.02, Italy 20.33, Luxembourg 0.25, Netherlands 5.46 and Portugal 2.29.
- The consumer price index has been constructed by ourselves, using GDP weights. An alternative would be to use weights based on private consumption, but these are practically the same as GDP weights (see Albers, Bijsterbosch and Vrieselaar 2000).
- Short-term (three-month) and long-term interest rates (government bond yields) have been constructed by ourselves, using GDP weights.

Data for the US are all taken from the IFS database. Monetary aggregates, CPI and GDP have been seasonally adjusted.
REFERENCES


