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# The impact of external shocks on the eurozone: a structural VAR model

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Abstract: This paper studies the impact of the main external shocks which the eurozone and member states have undergone since the start of the 2000s. Such shocks have been monetary (drop in global interest rates), financial (two stock market crises) and real (rising oil prices and an accumulation of global current account imbalances). We have used a structural VAR (SVAR) methodology, on the basis of which we have defined four structural shocks: external, supply, demand and monetary. The estimates obtained using SVAR models enabled us to determine the impact of these shocks on the eurozone and its member countries. The study highlights the diversity of reactions inside the eurozone. The repercussions of the oil and monetary shocks were fairly similar in all eurozone countries – excepting the Netherlands and the United Kingdom – but financial crises and global imbalances have had very different effects. External shocks explain one-fifth of the growth differential and current account balance variance and about one-third of fluctuations in the real effective exchange rate in Europe. The impact of the oil crisis was particularly large, but it pushed the euro down. Global imbalances explain a large proportion of exchange rate fluctuations but drove the euro up. Furthermore the response functions to financial and monetary crises are similar, except for current account functions. A financial crisis seems to result in the withdrawal of larger volumes of assets than a monetary crisis. The study thus highlights the diversity of the reactions in the eurozone and shows that external shocks do more to explain variations in the real effective exchange rate than in the growth differential or current account, while underlining the particularly important part played by global imbalances in European exchange rate fluctuations.

Keywords: global imbalances, current account, eurozone, structural VAR model, contemporary and long-term restrictions, external shock, exogeneity hypothesis.

JEL classification: F32, F41, G15.

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## I. Introduction

The question of current account imbalances worldwide is one of the main concerns of international macroeconomics with particular attention focussing on the United States (Obstfeld and Rogoff, 2004). A large number of theoretical and empiric studies (Bachman, 1992; Lee and Chinn, 1998; Chinn and Prasad, 2003; Giuliadori, 2004; Chinn and Ito, 2007; Chinn and Jaewoo, 2009) have analysed the causes and consequences of these current account imbalances, as well as possible mechanisms for adjusting them. According to these studies current account imbalances originate in (i) too low a rate of saving, prompting countries to run up debt to fuel consumption without worrying about repayment<sup>2</sup> and (ii) economic policies, including on currency, deployed by certain emerging countries, primarily China (Obstfeld and Rogoff, 2009). Furthermore, as Chinn and Prasad (2003), or Gruber and Kamin (2007) have shown, current account imbalances also have “standard” origins: per capita income, budget balance, growth rate disparities, demographics, etc. Adjustment may take several forms. Firstly, *via* the exchange rate, even if there is no real international monetary system, which encourages uncooperative exchange rate strategies which enable certain emerging countries to undervalue their currency (Gruber and Kamin, 2007). Secondly, adjustment may come *via* economic policies designed to boost saving in industrial countries, in particular the US, and encourage consumption in emerging countries. In addition the financial crisis of 2008 also seems to have played a far from negligible role in the continued accumulation of current account imbalances in recent decades (Obstfeld and Rogoff, 2009). The question of current account imbalances in the eurozone has nevertheless attracted less attention, despite it being just as interesting for several reasons: (i) the US is not the only country to have accumulated a current account deficit; (ii) in the long term any current account deficit must be paid off, and (iii) the situation in the eurozone is not exactly the same in all countries. The diversity prevailing with the Economic and Monetary Union (EMU) has often been demonstrated (Giannone and Reichlin, 2005; Menguy, 2005; Jondeau and Sahuc, 2008), but until recently little interest has been shown in current account imbalances, now a central issue in particular with regard to the necessary adjustment mechanisms. At present it seems that the issue of current account imbalances in the EMU is attracting new interest, in particular with respect to the nominal exchange rate of the euro (Guyon, 2008). In the medium and long term it is usual to see current account imbalances in a diverse range of countries. Countries enjoying the highest rates of growth or a greater structural preference for

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<sup>2</sup> Debt being facilitated by surplus money supply due to a policy of very low interest rates (Lane, 2001; Bracke and Fidora, 2008).

present prosperity will experience medium-term current account deficits. Rather discussion focuses on the question of mechanisms for returning to what may be termed the right level of current account deficit. In the second quarter of 2009 the eurozone current account deficit stood at -1% of GDP but the situation inside the EMU is very diverse. In 2008 the eurozone current account deficit stood at -1.5% of GDP with the following dispersion: Germany (+6.6%), Netherlands (+4.8%), France (-2.3%), Italy (-3.4%), Spain (-9.5%), Portugal (-12.1%).

In the course of the past decade the global economy suffered some major shocks. To start with two real crises upset the external balance of the largest economies: higher oil prices disturbed the trade balance of oil importing and exporting countries; and the consequences of this accumulation of global imbalances reached beyond just the countries unable to balance their foreign trade<sup>3</sup>. In addition interest rates fell particularly low, notably in the US. On average American three-month rates were twice as low between 1998 and 2008 as between 1980 and 1997. They stayed below 2% for three years between 2002 and 2004. With the financial crisis they have been lower than 1% since December 2008. On top of these real and monetary difficulties, we must add the financial crises which have increased in intensity over the past decade. The US – followed by the rest of the world thanks to the knock-on effect and the high degree of financial integration at an international level (Borgy and Mignon, 2009) – suffered two financial crises in seven years with, in both cases, a 25% drop in the S&P 500 index in the space of one year.

In theory the eurozone should be relatively insensitive to outside turbulence, for its size – about 15% of global GDP<sup>4</sup> – and growing integration supposedly limit the impact of foreign problems. But Europe is more open than other major economic zones – with an 18% rate of opening<sup>5</sup> compared with, respectively, 12% and 13% for the US and Japan – and most external shocks are transmitted to the system by the financial channel, as Ehrmann et alii (2005) have demonstrated. Some 26% of the variations in the price of European assets are linked to the behaviour of US financial markets, whereas the opposite effect is much smaller, at 8%. Moreover Borgy and Mignon (2009) have shown the existence of a relation of cause and effect between the US and the eurozone since the start of the 1980s, gathering momentum after the stock market crash of 1987.

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<sup>3</sup> Here we use the definition in flow of global imbalances according to which they are a real phenomenon linked to current account imbalances (Bracke et alii, 2008). Global imbalances also have a financial dimension in stock, in other words in terms of the net external position.

<sup>4</sup> The measurement used here concerns the GDP at PPP.

<sup>5</sup> The rate of opening is defined as the sum of exports and imports over GDP.

Despite these major external shocks the current account balance of the eurozone has stayed close to zero since 1998, oscillating between -1.3% and 1% of GDP. This seems to suggest that the eurozone was only slightly affected by outside events. However, this assumption could be mistaken for two reasons. Firstly the current account balance of the eurozone is an aggregate of the balances of member countries. An apparent equilibrium conceals large surpluses in Germany and the Netherlands, and substantial deficits in Portugal and Spain<sup>6</sup>. Furthermore the 30% rise in the euro's real exchange rate since 2000 could well be caused by shocks elsewhere in the world. For several years Europe alone has suffered the consequences of the exchange rate adjustments due to the imbalances in the current accounts of the US, Asian countries and OPEC, the latter having indexed their currencies on the dollar (Cartapanis, 2009). The loss of price competitiveness could well have been compensated by lower growth than elsewhere, enabling the eurozone's current account balance to stay close to zero, despite the increased value of its currency.

Only a few studies have looked at the impact of current account imbalances on and inside the eurozone, and in most cases the subject has been addressed using temporal series and structural VAR (SVAR), SVAR with exogeneity and VECM<sup>7</sup> processes. In general, issues related to current account imbalances, particularly in the US, have given rise to several SVAR-based studies of the link between the current account balance and the exchange rate, the latter being regarded as the only adjustment mechanism. However, apart from Blanchard (2007), Blanchard and Giavazzi (2002), Arghyrou and Chortareas (2008), only a few studies have taken an interest in the impact of external shocks on the current account balance of the eurozone, how they have propagated through the zone and the means of adjustment available to the zone and its member countries to bring their current account balances back to a "sustainable" level.

The present paper has two goals: (i) to determine to what extent the eurozone was affected by the various types of external shock in the global economy in recent years; and (ii) to measure the diversity of reactions to such shocks in the eurozone and in the UK.

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<sup>6</sup> For a more detailed presentation of the structure of the eurozone current account balance see, for example, Paul (2002).

<sup>7</sup> See, for example, Arghyrou and Chortareas (2008).

## II. Empirical specification

### 2. 1. SVAR model

We estimate a VAR in a reduced form:

$$A(L)X_t = u_t \quad (1)$$

With  $X_t = (\Delta ext, \Delta(y^d / y^*)_t, \Delta r_t, \Delta(ca / y)_t)'$ .  $ext$  is the logarithm of the external variable. This variable is modelled, successively by the price of Brent oil (in real terms), the S&P 500 US stock market index, the Federal Funds interest rate and the global current account imbalances<sup>8</sup>.

$y^d / y^*$  represents the relative GDP of the baseline country in relation to global GDP,  $y^d$  being the logarithm of that country's GDP and  $y^*$  global GDP.  $r$  is the logarithm of the domestic real effective exchange rate and  $ca / y$  the current account balance as a percentage of GDP, with  $\Delta$  indicating the prime variations of these variables and  $u_t$  acting as white noise, with an average of nil and variance of  $\sigma^2$ .

The infinite-order moving average (VMA) of the process is written:

$$X_t = B(L)u_t \quad (2)$$

The errors of the reduced form may be rewritten as a linear combination, such as:  $u_t = S\varepsilon_t$  with  $\varepsilon_t$  representing structural shocks. We thus consider a vector of normalized and orthogonal innovations  $\varepsilon_t = (\varepsilon_t^e, \varepsilon_t^{d,s}, \varepsilon_t^{d,d}, \varepsilon_t^{d,m})'$ , where  $\varepsilon_t^e$ ,  $\varepsilon_t^{d,s}$ ,  $\varepsilon_t^{d,d}$  and  $\varepsilon_t^{d,m}$  are, respectively, the external shocks affecting domestic supply, domestic demand and domestic money supply, satisfying:  $u_t = S\varepsilon_t$  and  $E(\varepsilon\varepsilon') = I$ . This implies that  $SS' = \Sigma$  and that thanks to an orthogonalization matrix  $S$  the VMA representation may be expressed in terms of independent, or structural, shocks:

$$X_t = C(L)\varepsilon_t \quad (3)$$

With

$$C(L) = B(L)S \quad (4)$$

Comparison of the number of parameters to be determined for identification of the structural form with the number of parameters actually estimated in the VAR model show that to identify the structural form we need to impose  $n(n-1)/2$  restrictions. We thus need to identify six constraints.

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<sup>8</sup> The latter is the sum of the current account imbalances outside the European Union as an absolute value in relation to global GDP.

The model successively brings into play four external variables. Each one is regarded as exogenous in relation to domestic variables<sup>9</sup>. Furthermore, thanks to the work of Blanchard and Quah (1989) and Clarida and Gali (1994) we can impose the following restrictions:

- a local monetary shock does not have a long-term effect on GDP:  $\sum_{i=0}^{\infty} c_{24,i} = 0$  ;
- a local crisis in demand does not have a long-term effect on GDP:  $\sum_{i=0}^{\infty} c_{23,i} = 0$  ;
- a local monetary shock does not have a long-term effect on the domestic real effective exchange rate:  $\sum_{i=0}^{\infty} c_{34,i} = 0$  .

## 2. 2. Analysis of the contributions of external crises

In this section we analyse the contribution of external crises to the variance of domestic variables. For this purpose we have used the methodology developed by Maćkowiak (2007)<sup>10</sup>. We estimate a SVAR model by positing exogeneity. An estimate of this sort reduces the number of parameters we need to estimate, which in turn limits reduction of the degree of freedom and improves the effectiveness of estimates (Sosa, 2008). We start from the model developed in section 2.1 to which we have made some changes. The SVAR form may thus be rewritten with an exogeneity hypothesis as follows:

$$\sum_{s=0}^p \begin{bmatrix} A_{11}(s) & A_{12}(s) \\ A_{21}(s) & A_{22}(s) \end{bmatrix} \begin{bmatrix} y_{1(t-s)} \\ y_{2(t-s)} \end{bmatrix} = \begin{bmatrix} \varepsilon_1(t) \\ \varepsilon_2(t) \end{bmatrix} \quad (5)$$

where  $A_{12}(s) = 0$  for each  $s = 0, 1, \dots, \infty$ . The vector  $\varepsilon(t)$  must fulfil the following properties:  $E[\varepsilon(t)|y_{t-s}, s > 0] = 0$  and  $E[\varepsilon(t)\varepsilon(t)'|y_{t-s}, s > 0] = I$  with  $I$  as the identity matrix. The  $y_{1(t-s)}$  variable is a vector containing all the external variables whereas  $y_{2(t-s)}$  is a vector containing all the domestic variables.  $\varepsilon_1(t)$  is the vector of external structural shocks and  $\varepsilon_2(t)$  corresponds to the domestic shocks vector. This model is estimated for each country in the *modified* eurozone. The external shocks vector consists of global imbalances, the real price of oil, the S&P 500 US stock market index and the US short-term interest rate. We impose the exogeneity hypothesis,  $A_{12}(s) = 0$  for each  $s = 0, 1, \dots, \infty$ . This implies that domestic structural shocks,  $\varepsilon_2(t)$ , do not affect the external vectors variable  $y_{1(t-s)}$  at date  $t$  or  $t - s$ .

<sup>9</sup> Here we have drawn on the work of Allégret and Sand-Zantman (2007), Gimet (2007), Maćkowiak (2007), Sato et alii (2009).

<sup>10</sup> We may also cite Cushman and Zha (1997), and Zha (1999).

In the external block it is assumed that oil prices are not affected by the three other external shocks, regardless of the number of lags. Furthermore, it is assumed that in the short term the US interest rate is not affected by stock market variations and global imbalances, and that global imbalances do not affect the S&P 500 index in the short term (Sato *et alii*, 2009). We then carried out an estimate using the Seemingly Unrelated Regression Equations (Sure) method, including the exogeneity hypotheses and imposing short and long-term restrictions in order to identify structural shocks.

### 2.3. Data

Quarterly data were used, covering the period from the first quarter of 1980 to the last quarter of 2008. The sample covers the following countries: Germany, Austria, Spain, France, Italy, Netherlands, Portugal and the United Kingdom. For our purposes the eurozone comprises the previous countries, except the UK, so it is a *modified* eurozone, consisting of seven of its original 12 members. We removed Belgium, Luxembourg, Finland, Greece and Ireland from the sample due to the lack of data for all or part of the variables studied over the relevant period.

The figures for GDP and current account balances were taken from the International Financial Statistics published by the International Monetary Fund. The real effective exchange rates were published by the Bank for International Settlements and are based on trade with the 27 main trading partners. Monthly data was consolidated to obtain quarterly figures. OECD data, from 30 member countries, was used to obtain global GDP.

The price of (Brent) oil was taken from the Datastream base. We expressed this price in real terms, correcting it with the US GDP deflator. This variable was drawn from Federal Reserve Economic Data from the Federal Reserve Bank of Saint Louis. Here too monthly data was consolidated to obtain quarterly figures. The data for the S&P 500 US stock market index and the Federal Funds interest rate were taken from the Datastream base. The global imbalances variable tracks imbalances in the current account balance at a global level in absolute value – except for the European Union – in relation to global GDP. Data on GDP (or industrial output if appropriate) were deseasonalized<sup>11</sup>. The variables for each country were subjected to unit root tests (annex A). The first difference of all the variables appears to be stationary. This stationarity is an essential condition for applying long-term restrictions. Study of the cointegration of variables does not reveal any long-term relation between them, except for the

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<sup>11</sup> We used the Census X-12 additive method which is suitable for negative series such as the current account balance (Algieri and Bracke, 2007).

Netherlands where a cointegration relation exists. However, taking into account our methodological framework we reject the existence of a cointegration vector for the Netherlands (Arghyrou and Chortareas, 2008).

Finally we used the information criteria of Akaike, Schwartz and Hannan-Quinn, and the likelihood ratio, in order to specify the number of lags for the various models we tested. The results differ depending on the test being used. The maximum likelihood test suggests we should retain three or four lags. On the other hand the Akaike test suggests one or two lags. The Schwartz and Hannan-Quinn tests retain one lag or none at all. The following issues are at stake when choosing the number of lags: if the model is specified with too few lags it may result in a specification error. On the other hand if the model is specified with too many lags, there is a greater risk of multicollinearity and the degree of freedom is diminished which may spoil the quality of the estimate. To obtain an even result for all the countries we decided to use three lags for all them, except in the model involving a US interest rate shock<sup>12</sup>. In the latter case we observed that the coefficients estimated for three lags were not significant. So, just as Lee and Chinn (1998, 2006), we decided to modify the number of lags for one model<sup>13</sup>.

### **III. Results**

#### **3. 1. The effects of external shocks on the eurozone**

We shall start by looking at the impact of a shock to the real price of oil (table B.1). The current account balances of all the countries, except the Netherlands and the UK display a negative or weak reaction to this shock. These two countries are hydrocarbon producers. A rise in the price of oil consequently results in an increase in exports, whereas in other countries, which are oil consumers and not producers, imports increase. The impact of this shock on the growth differential and real effective exchange rate is less clear, varying a great deal from one country to another. For the eurozone as a whole there is exchange rate depreciation which partly compensates for the initial negative shock whereas growth continues at a rate close to that of the rest of the world. It should also be noted that in terms of growth, Germany, Spain and France withstand the oil price shock rather better than the rest of the world.

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<sup>12</sup> Furthermore, in order to allow for the effects of German reunification and the introduction of the euro, two dummy variables were added to the estimate of each of the VAR processes for 1990 and 1999. However they do not seem significant.

<sup>13</sup> The choice of the same number of lags for all the external shocks, regardless of which country is under study, also makes estimates of each of the processes and the calculation of correlation coefficients consistent. Allegret and Sand-Zantman (2007), and Gimet (2007) also adopt this approach. The details of cointegration tests and data criteria are available from the authors on request.

A US interest rate shock impacts negatively on the growth differential of almost all the countries (table B.2). When the US Federal Reserve decides to increase its base rate, the eurozone suffers more from the consequences of the slowdown in US business than the rest of the world. The impact of the shock is more uneven in its effect on other domestic variables. In most cases the shock causes depreciation of the real effective exchange rate except in Spain, Portugal and the UK. The impact on the current account balance is negative in all countries except the Netherlands and Germany where, in keeping with the theory, an increase in the US base rate prompts a net capital outflow.

A shock to the US stock market (S&P index shock) has a very similar impact to a US interest rate shock: it reduces the growth differential in all countries and has an ambiguous effect on the real effective exchange rate (table B.3). There are nevertheless several differences from the previous shock. The current account balances of the modified eurozone (comprising seven countries), and of France and Italy improve following the shock whereas the Dutch current account balance deteriorates. So a rise in the S&P index prompts net capital outflows from Germany, France, Italy and the modified eurozone.

The last external shock concerns global imbalances, in other words how current account imbalances in the rest of the world affect the eurozone (table B.4). A global imbalances shock cuts the growth differential in the eurozone, which in turn improves the balance of trade but also causes appreciation of the real effective exchange rate, which damages the balance of trade. The ultimate effect on the current account balance is positive. Germany responds in much the same way as the modified eurozone. The reaction in France is also similar, except for the current account balance which deteriorates.

Regarding domestic variables, our results are close to those obtained by Giuliadori (2004) for the US, but with two differences: a supply-side shock boosts the real effective exchange rate but damages the long-term current account balance.

### **3. 2. Analysis of the correlation of reactions to shocks**

We focussed analysis in particular on how the current account balance responded to each of the various shocks<sup>14</sup>. Analysis of the correlation of reactions enabled us to distinguish several factors (annex C).

The correlation of the reaction to an oil-price shock (table C.1) is significant and positive for all the countries except the UK and the Netherlands. This result seems to coincide with our

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<sup>14</sup> An analysis of the reactions of the other variables is available from the authors on request.

expectations, including for the UK and the Netherlands, which both produce oil. Apart from these two countries European countries display relatively strong dependence on oil. In 2006 oil-related products accounted for about half of all energy consumption in Spain and Portugal, 35% of the total in Germany and France, and 35% to 40% in the UK and the Netherlands (IEA, 2009). The correlation of the responses in Portugal seem relatively insignificant compared with those in other countries.

The correlation of the reaction to a US interest-rate shock (table C.2) is significant and positive for all the countries except Germany, the Netherlands and the UK. Although they are both part of the eurozone Germany and Netherlands have a current account surplus. The current account balances of these countries therefore react in the opposite way to countries running a current account deficit. The reaction of the UK may be explained by it not being part of the eurozone. This result also confirms the “special” position of the British financial market (the City), in the global sense of the term, in the European financial space.

The correlation of reactions to a shock to the S&P 500 stock market index (table C.3) clearly shows a positive link between all the countries except the Netherlands for which correlation of the responses is weaker. This fact is confirmed by correlation of the responses for the eurozone with all the countries.

The correlations of reactions to a global imbalances shock (table C.4) seem uneven, revealing two groups of countries: in the first group (France, Netherlands and Spain) the correlations of the responses are mainly negative; in the second group (UK, Italy, Portugal and Austria) the correlations of the responses are mainly positives. The correlations with the eurozone confirm these observations.

### **3. 3. Analysis of the contribution of external shocks**

Table D.1 (annexe D) recapitulates the estimates of the contribution of external shocks to the variance of domestic variables in the sample countries. Over the long term external shocks account for one-third of real effective exchange rate variance. On the other hand they only explain one-fifth of variations in the current account balance and growth differential, an oil-price shock explaining most of these fluctuations. This result seems to confirm that adjustment to external shocks in the eurozone is achieved more through appreciation of its real effective exchange rate than through external imbalances or a slowdown in relative growth.

The build-up of global imbalances is the main source of fluctuation in the real effective exchange rate in Germany, Austria and Netherlands. These imbalances also contribute a great

deal to variations in the real effective exchange rate of the eurozone and France. For all these countries a global imbalances shock has a positive impact on the real effective exchange rate. This credits the idea that adjustment of external imbalances between the US and China is achieved through appreciation of the European currency.

External shocks make very uneven contributions to the variance of domestic variables in the eurozone. In France and the Netherlands external shocks account for less than 15% of variance in the current account balance whereas that figure rises to 40% in Portugal. The average for the other countries ranges from 15% to 25%. On the other hand external shocks explain to a large extent variance in the real effective exchange rate except for Spain, Italy and the United Kingdom. Lastly external shocks account for, on average, from 20% to 30% of variance in the growth differential except for the Netherlands and Italy where their contribution is about 10%.

Two major differences between the eurozone and the UK are worth noting: *(i)* external shocks play a larger part in the British growth differential; *(ii)* the contribution of external shocks to variance in the real effective exchange rate is half as great in the UK as in the eurozone.

It is interesting to compare these results with those obtained by Maćkowiak (2007) for emerging countries. Logically external shocks contribute more to variance in domestic variables in emerging countries than in their European counterparts. Furthermore our results show that the contribution of a US interest-rate shock to exchange-rate variance is similar in Europe and emerging countries. However there are limits to this comparison, as Maćkowiak (2007) does not use a real effective exchange rate but a nominal bilateral exchange rate.

#### **IV. Conclusion**

The aim of this paper was to study the impact of the main external shocks on the current account balances of the eurozone and its member countries. For this purpose we used the SVAR methodology, distinguishing four types of shock: one external and three domestic. Our numerous results show that the four major external shocks we studied – related to an oil-price hike, global imbalances, and financial and monetary upsets in the US – had varying impacts on the eurozone. The results confirm the uneven response of the current account balances of eurozone countries to shocks related to the S&P 500 index and global imbalances. On the other hand the effect of the oil shock leads to deterioration in the current account balance of all the countries, except hydrocarbon producers on which it has a positive impact. External shocks explain about one-fifth of the variance in the current account balance and growth

differential, and about one-third of variance in the real effective exchange rate in the eurozone. This suggests that the consequences for Europe of external shocks have resulted more in adjustment of its exchange rate than in broadening of its trade imbalance or a slowdown in growth compared with the rest of the world. Predictably the impact of the oil shock is particularly large in most cases. Also of note is the importance of global imbalances in explaining appreciation of the real effective exchange rate in the eurozone. Oil prices exert greater influence on exchange-rate fluctuations but a price hike depreciates the rate of exchange. This work seems therefore to indicate that the rise in the value of the euro in recent years is to a large extent linked to current account imbalances in the rest of the world.

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## Annex A

### Unit root tests

The unit root tests are carried out on the logarithmic variables of relative GDP, the real effective exchange rate for each of the countries in the sample, the S&P 500 index and the real price of oil. For the US base rate, the current account balance ratios and the global imbalances variable (GI), the tests were carried out directly on the variables, not on the corresponding logarithms.

The order of integration was studied using Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests<sup>15</sup>. The two tests were carried out starting from different models (with trend and constant; without trend but with constant; with neither trend nor constant). As they are the most commonly used, we have not attempted to introduce these tests. Tables A.1 and A.2 detail the results for the order of integration  $d$ , denoted  $I(d)$ , of the series<sup>16</sup>.

For the three domestic variables the results very largely suggest non-stationarity in level. External variables appear to be first-order integrated.

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<sup>15</sup> Break tests were also carried out, using the Perron (1989) methodology. The studied variables also appear not to be stationary despite the presence of a break.

<sup>16</sup> The details of these tests and the tests with a break are available from the authors on request.

Table A.1: Unit root tests without a structural break

Variables	ADF	PP
7-member eurozone		
$y/y^*$	I(1)	I(1)
$r_{eer}$	I(1)	I(1)
$ca/y$	I(1)	I(1)
Germany		
$y/y^*$	I(1)	I(1)
$r_{eer}$	I(1)	I(1)
$ca/y$	I(1)	I(1)
Austria		
$y/y^*$	I(1)	I(1)
$r_{eer}$	I(1)	I(1)
$ca/y$	I(1)	I(1)
Spain		
$y/y^*$	I(1)	I(1)
$r_{eer}$	I(1)	I(1)
$ca/y$	I(1)	I(1)
France		
$y/y^*$	I(1)	I(1)
$r_{eer}$	I(1)	I(1)
$ca/y$	I(1)	I(1)

Notes:  $y/y^*$ ,  $r_{eer}$ ,  $ca/y$  correspond to the logarithm of the real relative GDP, the logarithm of the real effective exchange rate and to the ratio between the current account balance and GDP.  $I(d)$  corresponds to the order of integration  $d$  of the series.

For the ADF tests, the number of lags was set using the Akaike information criterion (AIC). For the Phillips-Perron tests, following on from Newey and West (1987), the truncation parameter was set at 4.

The significance threshold was set at 5% unless otherwise mentioned (\*\*\* for a 1% significance threshold and \* for 10%).

The letters  $t$  and  $c$  indicate the presence of a significant trend and/or constant in the tests.

Table A.2: Unit root tests without a structural break

Variables	ADF	PP
Italy		
$y/y^*$	I(1) c	I(1) c
$r_{eer}$	I(1)	I(1)
$ca/y$	I(1)	I(1)
Netherlands		
$y/y^*$	I(1)	I(1)
$r_{eer}$	I(1)	I(1)
$ca/y$	I(1)	I(1)
Portugal		
$y/y^*$	I(1)	I(1)
$r_{eer}$	I(1)	I(1)
$ca/y$	I(1)	I(1)
UK		
$y/y^*$	I(1)	I(1)
$r_{eer}$	I(1)	I(1)
$ca/y$	I(1)	I(1)
External shocks		
Brent_r	I(1)	I(1)
S&P 500	I(1) c	I(1) c
Fed Funds	I(1)	I(1)
GI	I(1)***	I(1)

Notes:  $y/y^*$ ,  $r_{eer}$ ,  $ca/y$  correspond to the logarithm of the real relative GDP, the logarithm of the real effective exchange rate and to the ratio between the current account balance and GDP.  $I(d)$  corresponds to the order of integration  $d$  of the series.

*Brent\_r*, *S&P 500*, *Fed Funds* et *GI* correspondent au prix du pétrole Brent en terme réel (déflaté par le déflateur du PIB américain), l'indice boursier américain, les taux d'intérêt de la Réserve Fédérale américaine et les global imbalances.

For the ADF tests, the number of lags was set using the Akaike information criterion (AIC). For the Phillips-Perron tests, following on from Newey and West (1987), the truncation parameter was set at 4.

The significance threshold was set at 5% unless otherwise mentioned (\*\* for a 1% significance threshold and \* for 10%).

The letters *t* and *c* indicate the presence of a significant trend and/or constant in the tests.

## **Annex B**

### Reactions to external shocks

Table B.1 – Reaction of domestic variables to a real oil-price shock

Variable	Horizon (quarters)	Modified eurozone	Germany	Austria	Spain	France	Italy	Netherlands	Portugal	UK
GDP/GDP*	1 – 4	-0.0003	0.0005	-0.0009	0.0004	-0.0006	-0.0007	0.0000	-0.0019	-0.0021
	5 – 20	0.0000	0.0016	-0.0007	0.0013	0.0003	-0.0002	-0.0003	-0.0038	-0.0033
	21 – 40	-0.0001	0.0015	-0.0007	0.0014	0.0005	-0.0002	-0.0003	-0.0040	-0.0033
REER	1 – 4	-0.0002	-0.0003	-0.0001	0.0013	0.0022	-0.0013	-0.0014	0.0004	0.0071
	5 – 20	-0.0047	-0.0049	-0.0018	0.0044	0.0003	-0.0045	-0.0061	0.0011	0.0051
	21 – 40	-0.0049	-0.0050	-0.0018	0.0046	0.0001	-0.0047	-0.0063	0.0012	0.0050
Current account balance (% GDP)	1 – 4	-0.0906	-0.1454	-0.0041	-0.0201	-0.1337	-0.1041	0.0778	-0.1730	0.1927
	5 – 20	-0.1400	-0.2349	-0.1490	0.0059	-0.2002	-0.1847	0.2145	-0.1198	0.2006
	21 – 40	-0.1351	-0.2264	-0.1494	0.0027	-0.2045	-0.1835	0.2236	-0.1015	0.2001

Notes: the reactions for GDP/GDP\* and REER are based on the logarithm of these variables. 1 – 4 corresponds to the average between the 1st and 4th quarters following the shock. 5 – 20 corresponds to the average between the 5th and 20th quarters following the shock. 21 – 40 corresponds to the average between the 21st and 40th quarters following the shock.

Table B.2 – Reaction of domestic variables to a US interest rates shock (Fed Funds)

Variable	Horizon (quarters)	Modified eurozone	Germany	Austria	Spain	France	Italy	Netherlands	Portugal	UK
GDP/GDP*	1 – 4	-0.0012	-0.0022	-0.0020	-0.0001	-0.0009	-0.0008	-0.0001	-0.0010	-0.0018
	5 – 20	-0.0008	-0.0023	-0.0021	0.0016	-0.0002	-0.0004	0.0003	-0.0009	-0.0015
	21 – 40	-0.0008	-0.0023	-0.0021	0.0017	-0.0002	-0.0004	0.0003	-0.0009	-0.0015
REER	1 – 4	-0.0042	-0.0060	-0.0027	0.0072	-0.0026	-0.0056	-0.0069	0.0028	0.0087
	5 – 20	-0.0050	-0.0065	-0.0033	0.0139	-0.0040	-0.0065	-0.0073	0.0032	0.0085
	21 – 40	-0.0050	-0.0065	-0.0033	0.0142	-0.0040	-0.0064	-0.0073	0.0032	0.0085
Current account balance (% GDP)	1 – 4	-0.0473	-0.0074	-0.1722	-0.1160	-0.0356	-0.0751	0.1112	-0.5144	-0.0489
	5 – 20	-0.0515	0.0554	-0.1825	-0.3108	-0.0636	-0.0867	0.1194	-0.5731	-0.0836
	21 – 40	-0.0514	0.0555	-0.1831	-0.3207	-0.0648	-0.0871	0.1216	-0.5729	-0.0838

Notes: the reactions for GDP/GDP\* and REER are based on the logarithm of these variables. 1 – 4 corresponds to the average between the 1st and 4th quarters following the shock. 5 – 20 corresponds to the average between the 5th and 20th quarters following the shock. 21 – 40 corresponds to the average between the 21st and 40th quarters following the shock.

Table B.3 – Reaction of domestic variables to an *S&P 500* index shock

Variable	Horizon (quarters)	Modified eurozone	Germany	Austria	Spain	France	Italy	Netherlands	Portugal	UK
GDP/GDP*	1 – 4	-0,0010	-0,0012	-0,0004	-0,0020	-0,0007	0,0006	0,0000	0,0005	-0,0015
	5 – 20	-0,0021	-0,0035	-0,0022	-0,0036	-0,0012	-0,0010	0,0000	-0,0002	-0,0027
	21 – 40	-0,0021	-0,0035	-0,0022	-0,0036	-0,0012	-0,0010	0,0000	-0,0001	-0,0027
REER	1 – 4	-0.0008	-0.0010	-0.0013	0.0003	0.0004	0.0012	-0.0035	-0.0025	0.0061
	5 – 20	-0.0011	-0.0019	-0.0006	0.0013	0.0024	0.0016	-0.0047	-0.0014	0.0090
	21 – 40	-0.0011	-0.0021	-0.0005	0.0014	0.0024	0.0016	-0.0048	-0.0014	0.0089
Current account bal. (% GDP)	1 – 4	0.0331	0.0773	-0.1721	-0.1391	0.0932	0.0839	-0.1741	-0.2029	-0.0399
	5 – 20	0.0456	0.1066	-0.2785	-0.1234	0.1400	0.1052	-0.2753	-0.5276	-0.0399
	21 – 40	0.0464	0.1126	-0.2837	-0.1207	0.1400	0.1048	-0.2755	-0.5359	-0.0396

Notes: the reactions for GDP/GDP\* and REER are based on the logarithm of these variables. 1 – 4 corresponds to the average between the 1st and 4th quarters following the shock. 5 – 20 corresponds to the average between the 5th and 20th quarters following the shock. 21 – 40 corresponds to the average between the 21st and 40th quarters following the shock.

Table B.4 – Reaction of domestic variables to a global imbalances shock

Variable	Horizon (quarters)	Modified eurozone	Germany	Austria	Spain	France	Italy	Netherlands	Portugal	UK
GDP/GDP*	1 – 4	-0.0001	-0.0009	0.0011	-0.0013	-0.0005	-0.0006	0.0004	-0.0015	0.0011
	5 – 20	-0.0010	-0.0034	0.0011	-0.0012	-0.0008	-0.0007	0.0005	-0.0030	0.0026
	21 – 40	-0.0009	-0.0034	0.0011	-0.0012	-0.0009	-0.0007	0.0006	-0.0031	0.0027
REER	1 – 4	0.0032	0.0047	0.0031	-0.0013	0.0026	-0.0028	0.0071	-0.0047	0.0004
	5 – 20	0.0069	0.0105	0.0048	-0.0042	0.0047	-0.0001	0.0115	-0.0067	0.0011
	21 – 40	0.0070	0.0106	0.0047	-0.0043	0.0048	-0.0001	0.0117	-0.0066	0.0013
Current account bal. (% GDP)	1 – 4	0.0370	0.1260	0.0783	-0.0531	-0.0187	0.0396	-0.1851	0.4054	-0.0050
	5 – 20	0.0529	0.1853	0.2163	-0.0975	-0.0242	0.0607	-0.2854	0.6834	0.0266
	21 – 40	0.0508	0.1815	0.2162	-0.0996	-0.0234	0.0594	-0.2905	0.6991	0.0274

Notes: the reactions for GDP/GDP\* and REER are based on the logarithm of these variables. 1 – 4 corresponds to the average between the 1st and 4th quarters following the shock. 5 – 20 corresponds to the average between the 5th and 20th quarters following the shock. 21 – 40 corresponds to the average between the 21st and 40th quarters following the shock.

## Annex C

### Correlation of the responses of the current account balance to the various shocks

Table C.1: Real oil price shock

	Germany	Austria	Spain	France	Italy	Netherlands	Portugal	UK	eurozone
Germany	1	<b>0.83</b>	<b>-0.52</b>	<b>0.77</b>	<b>0.79</b>	<b>-0.74</b>	<b>0.43</b>	<b>-0.95</b>	<b>0.98</b>
Austria		1	<b>-0.74</b>	<b>0.98</b>	<b>0.83</b>	<b>-0.94</b>	0.02	<b>-0.85</b>	<b>0.86</b>
Spain			1	<b>-0.67</b>	<b>-0.61</b>	<b>0.77</b>	0.07	0.67	-0.54
France				1	<b>0.75</b>	<b>-0.96</b>	-0.10	-0.81	0.78
Italy					1	<b>-0.73</b>	<b>0.50</b>	<b>-0.81</b>	0.87
Netherlands						1	0.09	0.85	-0.74
Portugal							1	-0.36	<b>0.47</b>
UK								1	<b>-0.93</b>
eurozone									1

Notes: the significant correlations are in bold characters. The significance threshold was set at 5%.

The correlation coefficients were calculated over 30 quarters. The eurozone corresponds to the seven-member modified eurozone.

Table C.2: US interest-rate shock

	Germany	Austria	Spain	France	Italy	Netherlands	Portugal	UK	eurozone
Germany	1	-0.43	-0.94	-0.63	-0.88	0.83	-0.59	-0.76	0.11
Austria		1	<b>0.52</b>	<b>0.73</b>	<b>0.67</b>	-0.34	<b>0.92</b>	-0.25	<b>0.65</b>
Spain			1	<b>0.82</b>	<b>0.89</b>	<b>-0.65</b>	<b>0.62</b>	<b>0.62</b>	0.16
France				1	<b>0.75</b>	-0.20	<b>0.74</b>	0.12	<b>0.66</b>
Italy					1	<b>-0.73</b>	<b>0.84</b>	<b>0.44</b>	0.23
Netherlands						1	<b>-0.47</b>	<b>-0.68</b>	<b>0.42</b>
Portugal							1	-0.06	<b>0.54</b>
UK								1	<b>-0.63</b>
eurozone									1

Notes: the significant correlations are in bold characters. The significance threshold was set at 5%.

The correlation coefficients were calculated over 30 quarters. The eurozone corresponds to the seven-member modified eurozone.

Table C.3: S&P 500 index shock

	Germany	Austria	Spain	France	Italy	Netherlands	Portugal	UK	eurozone
Germany	1	<b>0.96</b>	<b>0.92</b>	<b>0.83</b>	<b>0.92</b>	<b>0.48</b>	<b>0.84</b>	<b>0.96</b>	<b>0.98</b>
Austria		1	<b>0.87</b>	<b>0.69</b>	<b>0.83</b>	0.26	<b>0.77</b>	<b>0.97</b>	<b>0.92</b>
Spain			1	<b>0.91</b>	<b>0.95</b>	<b>0.52</b>	<b>0.94</b>	<b>0.96</b>	<b>0.96</b>
France				1	<b>0.97</b>	<b>0.80</b>	<b>0.91</b>	<b>0.79</b>	<b>0.92</b>
Italy					1	<b>0.70</b>	<b>0.92</b>	<b>0.89</b>	<b>0.98</b>
Netherlands						1	<b>0.50</b>	0.34	<b>0.58</b>
Portugal							1	<b>0.86</b>	<b>0.91</b>
UK								1	<b>0.95</b>
eurozone									1

Notes: the significant correlations are in bold characters. The significance threshold was set at 5%.

The correlation coefficients were calculated over 30 quarters. The eurozone corresponds to the seven-member modified eurozone.

Table C.4: Global imbalances shock

	Germany	Austria	Spain	France	Italy	Netherlands	Portugal	UK	eurozone
Germany	1	<b>0.85</b>	<b>-0.46</b>	<b>-0.40</b>	<b>0.99</b>	<b>-0.66</b>	<b>0.86</b>	<b>0.67</b>	<b>0.97</b>
Austria		1	<b>-0.67</b>	<b>-0.71</b>	<b>0.83</b>	<b>-0.94</b>	<b>0.95</b>	<b>0.51</b>	<b>0.71</b>
Spain			1	<b>0.54</b>	<b>-0.47</b>	<b>0.79</b>	<b>-0.62</b>	<b>-0.77</b>	-0.27
France				1	<b>-0.43</b>	<b>0.70</b>	<b>-0.46</b>	-0.12	-0.23
Italy					1	<b>-0.64</b>	<b>0.82</b>	<b>0.69</b>	<b>0.96</b>
Netherlands						1	<b>-0.90</b>	<b>-0.49</b>	<b>-0.51</b>
Portugal							1	<b>0.56</b>	<b>0.76</b>
UK								1	<b>0.60</b>
eurozone									1

Notes: the significant correlation are in bold characters. The significance threshold was set at 5%.

The correlation coefficients were calculated over 30 quarters. The eurozone corresponds to the seven-member modified eurozone.

## Annex D

### The fraction of the variance due to external shocks

Table D.1: The fraction of the variance of domestic variables due to external shocks

Variables	Source of perturbation	Horizon (quart.)	Modified eurozone	Germany	Austria	Spain	France	Italy	Netherlands	Portugal	UK
$y/y^*$	Shock 1	1 - 4	6	10	4	4	4	3	0	3	12
		5 - 20	10	20	5	6	6	4	0	5	14
	Shock 2	1 - 4	2	1	5	1	3	2	5	4	3
		5 - 20	3	1	6	2	7	3	8	7	7
	Shock 3	1 - 4	5	5	2	5	9	0	0	2	2
		5 - 20	6	5	5	10	12	1	0	2	3
	Shock 4	1 - 4	2	1	3	1	1	2	3	5	3
		5 - 20	4	2	4	2	1	3	3	7	5
	<i>Sum of external shocks</i>	1 - 4	15	16	14	11	17	7	8	14	20
		5 - 20	23	28	21	20	26	10	12	21	30
$r$	Shock 1	1 - 4	5	3	3	0	5	1	3	2	4
		5 - 20	12	10	7	2	10	3	8	3	5
	Shock 2	1 - 4	5	6	2	6	4	3	14	5	5
		5 - 20	6	5	3	10	10	5	12	10	7
	Shock 3	1 - 4	2	2	2	1	1	1	2	2	1
		5 - 20	4	4	2	1	1	2	3	3	2
	Shock 4	1 - 4	6	9	7	1	5	2	13	4	1
		5 - 20	9	13	8	1	7	4	16	4	2
	<i>Sum of external shocks</i>	1 - 4	18	21	14	8	15	8	31	12	11
		5 - 20	31	33	20	14	28	14	39	20	16
$ca/y$	Shock 1	1 - 4	8	11	5	1	3	7	0	4	6
		5 - 20	11	16	6	3	3	9	2	5	6
	Shock 2	1 - 4	2	3	5	7	3	2	1	22	2
		5 - 20	4	4	8	11	6	2	1	28	4
	Shock 3	1 - 4	0	0	3	2	2	2	3	2	1
		5 - 20	1	0	3	3	3	3	4	3	2
	Shock 4	1 - 4	2	2	2	2	0	1	1	1	2
		5 - 20	4	3	4	3	1	1	2	2	3
	<i>Sum of external shocks</i>	1 - 4	12	16	14	13	8	11	6	30	11
		5 - 20	19	23	21	20	13	15	10	39	15

Notes:  $y/y^*$ ,  $r$  and  $ca/y$  correspond, respectively, to the growth differential, REER and current account balance as a percentage of GDP. Shocks 1, 2, 3 and 4 correspond, respectively to an oil-price shock, a US monetary shock, a US stock market shock and a global imbalances shock.

