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Abstract

We investigate the sources of macroeconomic (output and inflation) variability in selected European countries within and outside the European Monetary Union: Germany, Italy, Austria, the UK and Poland. Using quarterly data from 1985:1 to 2005:4, we estimate a Global Vector Autoregressive (GVAR) model that includes fifteen countries and regions, covering more than 90 per cent of the World GDP. We find that domestic factors explain most of the macroeconomic variability over the short horizon, i.e. from zero to four quarters, but become progressively dominated by international ones at larger horizons. Regional factors appear to be particularly important. As for output, we detect no significant differences between countries currently members of the European Monetary Union and non-members. As for inflation, on the contrary, regional factors are more influential than those of the rest of the world for the EMU member countries, differently from non-members.

Keywords

Business cycle, inflation, European Monetary Union, Global VAR (GVAR)

JEL Classification

C32, E32

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1. Introduction

Quantifying the proportion of open economies' macroeconomic fluctuations that originates abroad rather than domestically is an important task of macroeconomic research. Policymakers need evidence on this issue in order to adequately track international economic developments to conduct monetary policies as well as to choose the exchange rate regime. On the other hand, macroeconomic theorists need it in order to decide whether to include external variables in large as well as small open economy models.

The empirical literature on the sources of business cycle shocks includes Kose et al. (2003), Kose et al. (2008), Mumtaz et al. (2011) and Kose et al. (2012) who employ dynamic latent factor models to estimate the world, regional and country-specific components in output, consumption and investment of a broad cross-section of countries. As far as output is concerned, Kose et al. (2003) find that a large fraction of economic fluctuations in developed countries is explained by the world factors, while in developing countries the country-specific and idiosyncratic components are more important. The same authors also find that the regional component is irrelevant in explaining aggregate volatility except for North America. Kose et al. (2008) focus on the evolution of the common, country-specific and variable-specific factors in the G-7 countries business cycle in the period spanning 1960-2003, finding that the world-wide factor accounts on average for more than 26 per cent of output variation and that the importance of this common factor has increased in the period from 1986.

Mumtaz et al. (2011) use a dynamic factor model and find that the bulk of output growth and inflation in a panel of 36 countries over a period of 75 years is explained by regional factors, while the importance of the global component is large but decreasing over the post Wold War II period. Furthermore, international business cycles are decoupling, meaning that the similarity of business cycles within regions and the differences between regions are both increasing. Similarly, in a sample of 106 countries, Kose et al. (2012) find that the world factor has become less important for explaining macroeconomic fluctuations in the period 1985-2005 with respect to 1960-1985, and that the convergence of business cycle features has occurred at a group-specific level, i.e. within industrial countries and within emerging markets economies, with a concomitant divergence of business cycles between these two groups of countries.

Our paper contributes to the debate on the role played by domestic versus international factors in shaping the European macroeconomic (output and inflation) variability. We quantify the relative contribution of domestic, regional and international factors to the fluctuations of output and inflation using a Global Vector Autoregressive (GVAR) model, an econometric methodology recently developed by Pesaran et al. (2004a). Besides being a topic worth investigating *per se*, it also relates to the investigation of the affiliation of business cycles, as the paper by Kose et al. (2012) shows. Uncovering such affiliations is crucial to the analysis of the actual and, especially, future members of currency areas, which give up their monetary policy independence on the presumption that their business cycle is, or at least should increasingly become, synchronized with those of the other members.

Our paper focuses on European countries, therefore adding to the macroeconomic literature that concentrates on this issue for the European Monetary Union (EMU). The closely related question is whether the adoption of the Euro as a common currency has increased the member countries' business cycle synchronization. No widespread consensus has emerged so far. Artis (2003), for example, using data only up to 2001, concludes that a sample of twenty-three countries shows no evidence of homogeneous European business cycle. Similarly, Camacho et al. (2006) adopt a wide array of methods to investigate the existence of a European business cycle, either as associated to some leading economies in the area, or as a weighted average of different economies. A formal test of the hypothesis of a common European business cycle yields a negative answer, finding that the adoption of a common currency has been irrelevant for the synchronization of old European Union (EU) members' business cycles, which, further, is larger than across the recently acceded countries. These authors attribute such lack of correlation to dissimilarities in the structures of the economies, as well as in the behaviour of fiscal variables. Similar evidence is offered by Darvas and Szapáry (2008) for the Eastern European countries. Using annual data on level and growth rates of real *per capita* GDP, Giannone et al. (2010) also find that the relationship among single countries' and the European aggregate business cycle is unchanged since the beginning of the EMU. Those countries whose business cycles were already synchronized in the seventies remain so after the establishment of the EMU; similarly, those countries whose economic activity was heterogeneous at the beginning of the sample period remain less correlated with the rest of the Euro area even over the entire sample period.

By contrast, Altavilla (2004) finds that the EMU members' business cycle became increasingly correlated with the Euro area aggregate business cycle. Likewise, Furceri and Karras (2008) find that the countries in their sample increased their correlation with the EMU-wide economy in the post-EMU period (1999-2004). In the same vein, Savva et al. (2010) find a significant increase in business cycle correlation of core, periphery, new EU and negotiating countries with the Euro area aggregate business cycle. More specifically, using an econometric methodology that allows for time-varying shifts in correlation coefficients, these authors find an increase in the business cycle synchronization dating at the end of the 1990s for Austria and Germany, and to 2004 for Poland.

Unlike the previous literature, rather than by comparing business cycle correlation before and after a certain event (the Maastricht treaty or the adoption of the Euro), our paper addresses the role of the Euro in making European business cycles more similar by comparing the business cycle across EMU member and non-member countries. We focus on the following five European economies: a group of three large countries, two of which among the founders of the EU, i.e. Germany, Italy and the UK; and a group of two smaller ones, i.e. Austria and Poland. Within each group, the countries share many similarities (e.g., geographical location, participation to the EU, economic size and structure), but differ with respect to their participation to the EMU. Therefore, comparing Germany and Italy to the UK and Austria to Poland can highlight the role of EMU participation on the business cycle variability of countries with otherwise similar characteristics. This sort of "cross-country test" on the effect of participating to EMU on the business cycle can be seen as a way to circumvent the logical problems arising in counterfactual exercises.[2]

This study is also meant to contribute to the literature on the determinants of business cycles in Eastern European countries by treating Poland as a single economy rather than including it in the Eastern European region. The choice of Poland among the willing-to-enter-EMU countries has been made because its similarities to Austria in terms of economy structure, size and closeness to Germany. This facilitates the comparison between an EMU member country (Austria) and a non-member country (Poland). Relevant related studies are those of Mackoviak (2005), which shows that a sizable portion of the macroeconomic fluctuations in the Czech Republic, Hungary and Poland are due to external shocks, specifically to German interest rate shocks, and Dibooglu and Kutan (2005), who find that monetary shocks affect inflation and output movements in Poland, while this is true for Hungary only in the short run.

In line with the literature on the GVAR methodology, the rest of the world countries is grouped in regions in order to simplify the analysis focusing on the single countries of interest while, at the same time, estimating a model of the world economy. Our GVAR model is obtained by aggregating Vector Error Correction (VEC) models estimated for each of the fifteen countries and geographical areas describing the world economy. GVAR models have proved to be a convenient tool to perform dynamic simulation exercises on the international business cycle (see Dees et al., 2007, and Boschi and Girardi, 2011, among others). Our empirical analysis is mainly based on the generalized forecast error variance decomposition (GFEVD), through which we measure the importance of domestic versus external factors, further distinguishing between regional (neighbouring European countries) and rest of the world factors in determining the forecast error variance of output and inflation, which we interpret as a sensible indicator of macroeconomic variability.[3]

The main advantage of this approach is that the data availability constraint is less binding. Another advantage is that we consider the linkages between the business cycle of the countries of interest and a number of areas and countries of the world economy in a truly multi-country setting, while the previous literature only limits the analysis to the European economies. The further, crucial, advantage of the GVAR methodology is that it allows for a geographical identification of the shocks hitting the domestic economy, as explained in Section 2. This means that we can not only estimate the contribution of domestic versus foreign shocks, but we can also distinguish, within foreign factors, the specific source country from which

[2] See Pesaran et al. (2007) for a different counterfactual exercise using the GVAR methodology.
[3] See Boschi and Girardi (2011) for a similar exercise on Latin American countries.

the shock originated. To the best of our knowledge, this result is unavailable using alternative methodologies employed in the literature surveyed above.

Our main findings can be summarized as follows. Domestic factors explain most of the output and inflation variability over the short horizon (from zero to four quarters), but become progressively dominated by international factors. Over a ten-year horizon, foreign factors explain almost all of the output and inflation variability in the European countries examined. Among the foreign factors, regional ones are particularly important for the macroeconomic variability of all countries. Moreover, while there emerge no EMU membership-related differences in the contribution of regional factors to output variability (Germany and Italy versus UK on one hand and Austria versus Poland on the other hand in order to take account of the country size), as for inflation, on the contrary, we find that the influence of regional factors is generally more important than that of world factors in the case of the three economies participating to the EMU. The opposite is true both for the UK and for Poland.

The remainder of the paper is structured as follows. Section 2 outlines the empirical methodology and identification of shocks. It also briefly describes the underlying data and measurement issues. The main empirical findings are presented in Section 3. Section 4 concludes.

2. The GVAR model and the data

2.1 The model

Our global macro-model includes the following single countries: the UK, Germany, Italy, Austria, Poland (which constitute the focus of our analysis), the USA, and Japan. Beside the European countries which are treated as single economies according to the reasons detailed in the introduction, the USA are dealt with separately because they are the largest and most significant economy in the world, while Japan, besides being also one of the largest economies in the world, is hardly includable in a region with other Asian countries given its peculiar economic structure.

In line with the GVAR methodology, the rest of the world is aggregated into the following regions: Western Europe, Europe 2005, other European, Asia, NAFTA, Oceania and South Africa, rest of Africa and Middle East, Latin America (see the Appendix for more details). Thus, in total, seven single countries and eight geographical areas are represented in the model, covering more than 90 per cent of World GDP. Three of the single countries are currently EMU members, namely Germany, Italy and Austria. The comparison with representative non EMU members such as the UK and Poland is one of the aims of this paper. Additionally, the distinction between groups of countries allows us to detect larger trends related to the geographical origin of the sources of business cycles.

For each of the fifteen countries and areas of the world economy, the following VEC model is estimated using the Maximum Likelihood procedure by Johansen (1988, 1991):

$$\begin{aligned}\Delta \mathbf{y}_{it} = \boldsymbol{\gamma}_{i0} + \boldsymbol{\gamma}_{i1}\mathbf{t} - \left(\mathbf{I}_{n_i} - \boldsymbol{\Gamma}_{i1} - \boldsymbol{\Gamma}_{i2}\right)\mathbf{y}_{i,t-1} - \boldsymbol{\Gamma}_{i2}\Delta \mathbf{y}_{i,t-1} + \boldsymbol{\Phi}_{i0}\Delta \mathbf{y}^{*}_{it} - \left(-\boldsymbol{\Phi}_{i0} - \boldsymbol{\Phi}_{i1} - \boldsymbol{\Phi}_{i2}\right)\mathbf{y}^{*}_{i,t-1} - \\ + \boldsymbol{\Phi}_{i2}\Delta \mathbf{y}^{*}_{i,t-1} + \boldsymbol{\Lambda}_{i0}\Delta \mathbf{h}_{t} - \left(-\boldsymbol{\Lambda}_{i0} - \boldsymbol{\Lambda}_{i1} - \boldsymbol{\Lambda}_{i2}\right)\mathbf{h}_{t-1} + \boldsymbol{\Lambda}_{i2}\Delta \mathbf{h}_{t-1} + \mathbf{u}_{it},\end{aligned} \tag{1}$$

where $i = 0,1,...,N$ indicates countries/areas, with 0 being the reference country (the USA, in this case); $\mathbf{y}_{it}$ is a $n_i \ x \ 1$ vector containing the endogenous variables, that may vary across countries/areas (see below for details); $\mathbf{y}_{it}^{*}$ is the $n_i^{*} \ x \ 1$ vector of the country-specific international (foreign) variables; $\boldsymbol{\Gamma}_{i1}$ and $\boldsymbol{\Gamma}_{i2}$ are $n_i \ x \ n_j$ matrices of coefficients associated to the endogenous, domestic, variables; $\boldsymbol{\Phi}_{i0}$, $\boldsymbol{\Phi}_{i1}$, $\boldsymbol{\Phi}_{i2}$, are $n_i \ x \ n_j$ matrices of coefficients associated to the weakly exogenous, foreign, variables; $\mathbf{h}_t$ is the $mx1$ vector of global, exogenous variables (in our model, the price of oil), and the related $\boldsymbol{\Lambda}_{i0}$, $\boldsymbol{\Lambda}_{i1}$, $\boldsymbol{\Lambda}_{i2}$ are $n_i \ x \ m$ matrices (we depart from this general notation by assuming that $\boldsymbol{\Lambda}_{i0} = 0$, i.e. we impose stationarity to the evolution of the exogenous variables).[4] The $n_i \ x \ 1$ vectors $\boldsymbol{\gamma}_{i0}$ and $\boldsymbol{\gamma}_{i1}$ indicate the deterministic constant and trend; $\mathbf{u}_{it}$ is a $n_i \ x \ 1$ vector of idiosyncratic shocks distributed as follows: i.i.d.~$N(0,\boldsymbol{\Sigma}_{ji})$, where $\boldsymbol{\Sigma}_{ji}$ is the $n_j \ x \ n_i$ variance-covariance matrix of the endogenous variables of the i-th country/area. We assume this matrix to be time invariant, a common assumption when working with quarterly data (see Pesaran et al. 2004b). Although equation (1) suggests that the lag structure of the endogenous variables is the same as the international ones, the estimates do not require this condition to be satisfied, being the aggregation of the models independent from the lags of the VEC models.

The rank of the $n_i \ x \ (n_i+n_i^{*}+m)$ matrix $\boldsymbol{\Pi}_i = \left(\mathbf{I}_{n_i} - \boldsymbol{\Gamma}_{i1} - \boldsymbol{\Gamma}_{i2}, -\boldsymbol{\Phi}_{i0} - \boldsymbol{\Phi}_{i1} - \boldsymbol{\Phi}_{i2}, -\boldsymbol{\Lambda}_{i0} - \boldsymbol{\Lambda}_{i1}\right)$ identifies the number of long-run cointegrating relationships among the variables: given that $rank(\boldsymbol{\Pi}_i) = r_i$ and $r_i \leq n_i$, then the number of cointegrating relationships is equal to r_i. As in Pesaran et al. (2000), we assume $\boldsymbol{\gamma}_{i1} = \boldsymbol{\Pi}_i\boldsymbol{\lambda}_i$ to avoid a quadratic trend in the data (a non-desirable feature resulting from $\boldsymbol{\Pi}_i$ being rank-deficient and from the non-restricted trend), where $\boldsymbol{\lambda}_i$ is a $(n_i+n_i^{*}+m) \ x \ 1$ vector.

The set of endogenous variables is not the same across the fifteen countries/areas. In particular, the following variables are included for Italy, Germany, Austria and Poland: real GDP, unemployment rate, real wage rate, CPI inflation, stock market performance (proxied by country-specific price indices and returns mostly taken from Datastream), real money supply (either M2 or M3 have been used, depending on data availability), short term (three months) interest rate. The variables for the rest of the economies do not include the unemployment rate and the real wage, except Europe 2005 and other European for which the

[4] It is worth noting that the distinction between the international and the exogenous variables at the single VEC model level is not crucial, as both types of variables are treated as weakly exogenous.

stock market performance, the real money supply and the real exchange rate are also not observed (for details, see Table 1). The price of oil is included in our models as an exogenous variable.

The country-specific international variables $\mathbf{y}_{\mathbf{it}}^*$ are constructed using a trade weighting scheme that takes into account every other country/area in the world according to its importance for the country considered. Therefore, vectors calculating the degree of trade integration of the *i*-th economy with the generic *j*-th commercial partner (and, consequently, the rest of the world) have been created according to the following formula:

$$w_{i,j} = 100 * \frac{\sum_{t=2002}^{2006} (VX_{i,j,t} + VX_{j,i,t})}{\sum_{t=2002}^{2006} (VX_{i,.,t} + VX_{.,i,t})}, \qquad (2)$$

where $VX_{i,j,t}$ ($VX_{j,i,t}$) are the exports in current dollars of the *i*-th (*j*-th) to the *j*-th (*i*-th) trading partner in year *t*, and $VX_{i,.,t}$ ($VX_{.,j,t}$) are the total exports (imports) of the *i*-th country. These trade data are taken from the FIPICE dataset published by Prometeia.

Following Pesaran et al. (2004a), we estimate the parameters of each country-specific model separately and then stack the coefficient estimates in a GVAR model. To this end, we collect all country/area-specific variables in the global vector $\mathbf{y_t} = \left(\mathbf{y}'_{\mathbf{0t}}, \mathbf{y}'_{\mathbf{1t}}, \ldots, \mathbf{y}'_{\mathbf{Nt}}\right)'$, we define the $(n_i + n_i^*)$ *x n* matrix $\mathbf{W_i}$ containing the trade weights of every economy defined in equation (2), where $n = \sum_{i=0}^{N} n_i$ indicates the total number of endogenous variables of the model, so that we can aggregate the fifteen VEC models into a single global system, and, finally, we stack the *N*+1 systems to obtain the following GVAR model in inverse form for estimation purposes:

$$\mathbf{y_t} = \mathbf{G}^{-1}\boldsymbol{\gamma}_\mathbf{0} + \mathbf{G}^{-1}\boldsymbol{\gamma}_\mathbf{1}\mathbf{t} + \mathbf{G}^{-1}\mathbf{H}_1\mathbf{y}_{\mathbf{t-1}} + \mathbf{G}^{-1}\mathbf{H}_2\mathbf{y}_{\mathbf{t-2}} + \mathbf{G}^{-1}\boldsymbol{\Lambda}_\mathbf{0}\mathbf{h_t} + \mathbf{G}^{-1}\boldsymbol{\Lambda}_\mathbf{1}\mathbf{h}_{\mathbf{t-1}} + \mathbf{G}^{-1}\boldsymbol{\Lambda}_2\mathbf{h}_{\mathbf{t-2}} + \mathbf{G}^{-1}\mathbf{u_t} \qquad (3)$$

where $\boldsymbol{\gamma}_\mathbf{0} = \begin{pmatrix} \gamma_{00} \\ \gamma_{10} \\ \cdots \\ \gamma_{N0} \end{pmatrix}$; $\boldsymbol{\gamma}_\mathbf{1} = \begin{pmatrix} \gamma_{01} \\ \gamma_{11} \\ \cdots \\ \gamma_{N1} \end{pmatrix}$; $\mathbf{G} = \begin{pmatrix} \mathbf{A}_{00}\mathbf{W}_0 \\ \mathbf{A}_{10}\mathbf{W}_1 \\ \cdots \\ \mathbf{A}_{N0}\mathbf{W}_N \end{pmatrix}$; $\mathbf{H}_1 = \begin{pmatrix} \mathbf{A}_{00}\mathbf{W}_0 \\ \mathbf{A}_{10}\mathbf{W}_1 \\ \cdots \\ \mathbf{A}_{N0}\mathbf{W}_N \end{pmatrix}$; $\mathbf{H}_2 = \begin{pmatrix} \mathbf{A}_{02}\mathbf{W}_0 \\ \mathbf{A}_{12}\mathbf{W}_1 \\ \cdots \\ \mathbf{A}_{N2}\mathbf{W}_N \end{pmatrix}$; $\boldsymbol{\Lambda}_\mathbf{0} = \begin{pmatrix} \boldsymbol{\Lambda}_{00}\mathbf{W}_0 \\ \boldsymbol{\Lambda}_{10}\mathbf{W}_1 \\ \cdots \\ \boldsymbol{\Lambda}_{N0}\mathbf{W}_N \end{pmatrix}$;

$\boldsymbol{\Lambda}_\mathbf{1} = \begin{pmatrix} \boldsymbol{\Lambda}_{01}\mathbf{W}_0 \\ \boldsymbol{\Lambda}_{11}\mathbf{W}_1 \\ \cdots \\ \boldsymbol{\Lambda}_{N1}\mathbf{W}_N \end{pmatrix}$, $\mathbf{A_{i0}} = \left(\mathbf{I}_{\mathbf{n_i}}, -\boldsymbol{\Phi}^*_{\mathbf{i0}}\right)$; $\mathbf{A_{i1}} = \left(\boldsymbol{\Gamma}_{\mathbf{i1}}, -\boldsymbol{\Phi}^*_{\mathbf{i1}}\right)$; $\mathbf{A_{i2}} = \left(\boldsymbol{\Gamma}_{\mathbf{i2}}, -\boldsymbol{\Phi}^*_{\mathbf{i2}}\right)$, and the *n x n* ***G*** matrix is non-singular.

2.2 Analysis strategy

We study the determinants of the business cycle in five European countries, as proxied by the forecast error variance of output and inflation, using the GFEVD developed by Koop et al. (1996) and Pesaran and Shin (1998). This exercise permits us to gauge the effect of being an EMU member country on business cycle affiliation by comparing the proportion of output and inflation forecast error variance determined by regional factors in member and non-member countries. In particular, we compare the GFEVD of Austria with that of Poland and those of Germany and Italy with that of UK looking at the proportion of variance explained by regional factors.

The GFEVD measures the proportion of the variance of the *n*-step ahead forecast error of the variables of interest (i.e., real GDP and inflation) which is explained by conditioning on the non-orthogonalized shocks $\mathbf{G}^{-1}\mathbf{u}_{\mathbf{t}}, \mathbf{G}^{-1}\mathbf{u}_{\mathbf{t}+1}, ..., \mathbf{G}^{-1}\mathbf{u}_{\mathbf{t}+m}$ and allowing for contemporaneous correlations between these shocks and the shocks to the other equations in the system (therefore encompassing simpler methods used to assess cross-country business cycle asymmetry such as the correlation analysis of shocks - see Berg et al. 2002). This methodology overcomes the identification problem by meaningfully characterizing the dynamic responses of variables of interest to typically observable shocks. The GFEVD is also invariant to the ordering of the variables. Although it does not permit an economically structural identification of the shocks[5], these can be interpreted as "geographically structural": an external shock is truly external if its contemporaneous correlation with internal shocks is weak. In the GVAR framework this is accomplished by conditioning the estimation of country/region specific VEC models on foreign variables considered as proxies of "common" global factors, which will leave only a modest degree of correlation of the remaining shocks across countries/regions.

We derive the analytic expression of the GFEVD by re-expressing the model in equation (3) in its moving average form:

$$\mathbf{y}_{\mathbf{t}} = \mathbf{\Phi}_3 \mathbf{d}_{\mathbf{t}} + \sum_{\mathbf{j=0}}^{\infty} \mathbf{A}_{\mathbf{j}} \boldsymbol{\varepsilon}_{\mathbf{t-j}}, \qquad (4)$$

where: $\mathbf{A}_{\mathbf{j}} = \mathbf{F}_1 \mathbf{A}_{\mathbf{j-1}} + \mathbf{F}_2 \mathbf{A}_{\mathbf{j-2}}$, $j = 1,2,3,...$; $\mathbf{F}_1 = \mathbf{G}^{-1}\mathbf{H}_1$; $\mathbf{F}_2 = \mathbf{G}^{-1}\mathbf{H}_2$;

[5] A different strand of literature studies the business cycle fluctuations concentrating on either productivity shocks (Smets and Wouters, 2007) or demand shocks (Canova and De Nicoló, 2003).

$$\mathbf{A_0} = \mathbf{I_n};\ \mathbf{A_j} = 0 \text{ for } j < 0;\ \mathbf{\Phi_3} = \begin{bmatrix}\mathbf{b_0}, & \mathbf{b_1}, & \mathbf{\Theta_0}, & \mathbf{\Theta}_1, & \mathbf{\Theta}_2\end{bmatrix};\ \mathbf{d_t} = \begin{bmatrix}\mathbf{1}\\ \mathbf{t}\\ \mathbf{h_t}\\ \mathbf{h_{t\text{-}1}}\\ \mathbf{h_{t\text{-}2}}\end{bmatrix};\ \mathbf{b_0} = \mathbf{G^{-1}}\boldsymbol{\gamma}_\mathbf{0};\ \mathbf{b_1} = \mathbf{G^{-1}}\boldsymbol{\gamma}_\mathbf{1};;$$

$\mathbf{\Theta_0} = \mathbf{G^{-1}\Lambda_0}$; $\mathbf{\Theta_1} = \mathbf{G^{-1}\Lambda_1}$; $\mathbf{\Theta}_2 = \mathbf{G^{-1}\Lambda}_2$; $\boldsymbol{\varepsilon}_\mathbf{t} = \mathbf{G^{-1}u_t}$.

In this framework the GFEVD is defined as follows:

$$GFEVD = \frac{\boldsymbol{\sigma}_{jj}^{-1}\sum_{s=0}^{T}\left(\mathbf{e}_j'\mathbf{A}_s\mathbf{G}^{-1}\Sigma_u\mathbf{e}_s\right)^2}{\sum_{s=0}^{T}\left(\mathbf{e}_j'\mathbf{A}_s\mathbf{G}^{-1}\Sigma_u\mathbf{G}^{-1}{}'\mathbf{A}_s{}'\mathbf{e}_s\right)^2} \qquad (5)$$

Equation (5) shows the percentage of the variance of the forecast error of x_t T steps ahead explained by non-orthogonalized shocks, allowing for contemporaneous correlations among the variables..

2.3 Data

We use quarterly data over the period 1986:1-2005:4 to estimate the fifteen VEC models that contain the variables listed above for the seven countries and the eight geographical areas.[6] The original data for the sixty-four countries are both quarterly and annual data coming from: national sources (Central Banks and national institutes of statistics), IMF (International Financial Statistics and Directions Of Trade Statistics), OECD (mainly the Economic Outlook), and the World Bank (World Development Indicators). The data have been harmonized along several dimensions, including deseasonalization and the use of 2000 as the base year to express the series in real terms.

Standard unit root tests showed that the series were generally non-stationary, a fact that is taken into account by the error correction specification of the models.[7] Detailed results on data analysis are not reported for sake of brevity, but are available upon request.

3. Estimation results

3.1 Preliminary analysis

[6] The choice of the sample period aims at excluding the extraordinary effects of the ongoing financial and fiscal crisis. Mizrach (2008) finds that the ABX index, a benchmark of the performance of a variety of credit default swaps on asset backed securities, exhibits significant jumps as early as mid-2006, well before any problems in the mortgage market were discussed in the press.

[7] The series referring to the developing countries proved to be particularly problematic, so that the choice of the period under investigation is also dictated by the need to eliminate outliers.

Table 1 contains a brief summary of the characteristics of the fifteen VEC models (detailed country-specific results are available upon request).

INSERT TABLE 1 ABOUT HERE

The standard information criteria (Akaike, Schwarz-Bayesian, and the log-likelihood ratio statistic) have been used to select the lags to be included in the VEC models. The search for the cointegrating order of the models has been made using maximum likelihood tests with five different hypotheses regarding the deterministic components: (i) neither constant or trend; (ii) restricted constant but no trend; (iii) unrestricted constant but no trend; (iv) unrestricted constant and restricted trend; (v) unrestricted constant and trend. It is worth noting that the power of the test is low, particularly so because of the (relatively) small number of observations for the economies under observation. Therefore, in addition to the information criteria and the results of the tests, both the lag lengths and the cointegrating orders of the models have been chosen considering: (a) the best match between the theoretical correlations among residuals derived from the GVAR model and the unconditional correlations computed on the raw series; (b) the consistency between the impulse responses of the country/area-specific VEC models and those of the GVAR model. The final versions of the VEC models include two lags either for the endogenous and the exogenous variables and use the above hypothesis (iv) for the deterministic components. Given our interest on the short-run properties of the GVAR model, we avoid discussing and testing economically significant long-run restrictions on the cointegrating space, but rather let the data suggest the cointegration rank.[8]

As for the properties of the GVAR model, we make sure that the three conditions that grant that the GVAR estimation procedure is indeed equivalent to the simultaneous estimation of the VAR model of the world economy pointed out by Pesaran et al. (2004a) are satisfied. Namely, the GVAR is dynamically stable as ensured by the estimated eigenvalues (not reported, but available upon request); trade weights are such that $\sum_{j=0}^{N} w_{i,j}^2 \to 0$ as $N \to \infty$ for all i, which is ensured by considering a sufficiently large number of countries such that the resulting trade weights are small enough; the cross-dependence of the idiosyncratic shocks is sufficiently small, which implies cross-sectionally weakly correlated idiosyncratic shocks. This assumption permits to consider the foreign variables of the country/area-specific VEC models as "common" global factors, leaving only a small degree of correlation of the remaining shocks across countries and areas. More importantly, this is the assumption that leads to the geographical interpretation of the disturbances in the GFEVD: external shocks should exhibit low correlation with internal shocks to be considered so. Table 2

[8] See Boschi (2012) for an example of long-run structural GVAR model.

reports the averages of the correlation coefficients between the residuals of each equation with the rest of the other country/area equations residuals. Two-tailed *t*-tests are reported to show their statistically insignificant difference from zero, implying that the model successfully captures the effect of common factors driving domestic variables; the foreign variables and the oil price are indeed weakly exogenous in the country-region specific models. Following Pesaran et al. (2004a), this hypothesis has been examined by testing the joint significance of the error correction terms in auxiliary equations of the country/region-specific foreign variables and the oil price (results available on request).

INSERT TABLE 2 ABOUT HERE

3.2 GFEVD analysis

In this Section we identify the source of disturbances to output (real GDP) and inflation according to their geographical origin, with a particular focus on business cycle affiliation. We also distinguish the contribution of "real" variables (i.e., GDP and unemployment rate) from that of the rest of the variables (labelled “nominal”), although the GVAR identification strategy requires one to read this additional results with some caution, as explained in Section 2.2. Table 3 reports the GFEVD of real GDP of Germany, Italy, Austria, the UK and Poland over a simulation horizon of 40 quarters.

INSERT TABLE 3 ABOUT HERE

The first column indicates the countries of interest; the second one indicates the quarter ahead of the shock. The following columns report the percentage contribution to the output forecast error variance of shocks originating from different geographical areas of the world, distinguishing among the contributions of domestic country-specific factors, regional factors (i.e. originating from the rest of the Western European countries, including those object of the analysis), and factors pertaining to the rest of the world economies included in the GVAR model. The last column summarizes the contribution of all the foreign factors, i.e. the sum of regional and rest of the world ones.

Domestic factors are predominant at the beginning of the forecast horizon, but their importance constantly diminishes over the 40 quarters. This is particularly true for Italy, the UK and, to a lesser extent, Germany, while the importance of the Austrian and Polish domestic factors keeps relatively higher. The results for Austria support evidence provided by Cheung and Westermann (2000) that most of the fluctuation in Austrian output is determined by domestic shocks, and that external variables only exert a weak influence. Regional factors show the opposite pattern, with an initial contribution between 11 per cent (Germany) and 22 per cent (Italy) that steadily increases over the forecast horizon. Ten years from the shock, regional factors explain more than half of output variability in Italy and the UK (52 per cent and 53 per cent, respectively), while being important also in Germany (39 per cent), Austria (35 per cent) and Poland (37 per cent). This evidence is consistent with previous research adopting similar econometric methods such as VAR models (see Favero, 2010). More generally, the high importance of regional factors has been documented by Fidrmuc and Korhonen (2006) using meta-analysis of 35 publications on the business cycle correlation between the EMU and the Central and Eastern European countries (CEECs). By contrast, Kose et al. (2003), using a different econometric methodology, find a much smaller role for regional factors in the variance decomposition of output, though they cannot estimate such contribution at different times from the shock, whereas in our model regional factors' importance is relatively small at short horizons and increases at longer ones. Notice that Mumtaz et al. (2011), using a methodology similar to Kose et al. (2003), find completely different results attributing to the regional component almost all of the output variance. The contribution of external factors to Polish output variation, ranging from 56 per cent on impact to more than 83 per cent after 40 quarters (see the last column of Table 3), is larger than that estimated by Mackowiak (2005), whose study, however, does not distinguish among different sources of external shocks.

The last columns of Table 3 quantify the contribution of the sources outside the countries of interest and their regional neighbours. The estimates show that there is a high degree of similarity in how these factors affect the variability of real GDP of the five European countries subject of the analysis, the exception being that most of the short-term output fluctuations in the UK and in Poland are attributable to international other-than-regional shocks. The real-versus-nominal-variables differentiation suggests that the former are crucial determinants of output variability over the short horizon, but their importance gradually (in some cases, rapidly) diminishes in favour of the latter.

Table 4 reports the GFEVD of inflation of Germany, Italy, Austria, the UK and Poland over a simulation horizon of 40 quarters. We see this second piece of evidence as crucial to gauge the sources of macroeconomic variability in the countries under investigation.

INSERT TABLE 4 ABOUT HERE

Most of the evidence on the inflation forecast error variance supports the findings obtained from the analysis of output variability. In the short-run (up to 8 quarters) regional factors are less important than domestic ones, with the exception of the two small countries, Austria and Poland, where this is true only for the first 4 quarters of the forecast horizon. At $t=0$ regional factors explain between 10 per cent (Italy) and 25 per cent (Poland) of the inflation variability, and all these percentages increase as t increases. As for the contribution of the domestic factors, it is once again predominant at the beginning of the horizon (at $t=0$ it ranges between 55 per cent for Germany and 62 per cent for Poland), and remains important over time as well. It can be noted that the rest of the world factors are considerably more important than regional factors in the case of the UK and Poland, the two countries outside the EMU, at short horizons, while this is true only for Poland over all the forecast period. The results for the Polish inflation variability are in line with Mackowiak's (2005) findings that external shocks account for about 59.3 per cent of inflation short-run variance and about 82 per cent of the long-run one. As for the world factors, USA factors matter more in determining inflation than output variability, possibly because of the prominent role of the USA in the international financial market (detailed results not reported but available upon request). Finally, and contrarily to the output case, nominal variables crucially determine inflation variability over the full simulation horizon, always prevailing over the real ones.

Our findings confirm some previous evidence on the importance of external factors in determining macroeconomic variability. Qualitatively similar results are offered by Cushman and Zha (1997) for Canada; Del Negro and Obiols-Hums (2001) for Mexico; Canova (2005) and Boschi and Girardi (2011) for Latin America; Kim (2001) for the G-6 countries; Kose et al. (2008) for G-7 countries; Kose et al. (2003) and Kose et al. (2012) a broader set of countries.

Our results on the sources of output variability do not permit to draw strong conclusions on the differences between EMU-member and non-member countries. However, the analysis based on inflation variance offers a somewhat different scenario being the inflation of EMU non-member countries more influenced by the rest of the world factors with respect to EMU member countries. These mixed results are unsurprising, due to previous conflicting evidence on the effect of the monetary union on the European business cycles (see e.g. Giannone et al. 2010 and Furceri and Karras 2008). This lack of neat results could also be due to the fact that the sample period only covers the first few years of the adoption of the Euro.

4. Conclusions

In this paper we quantify the contribution of domestic, regional and international factors to the output and inflation fluctuations of Germany, Italy, Austria, the UK and Poland using the GVAR model developed by Pesaran et al. (2004a) estimated for fifteen countries and geographical areas describing the world economy.

We find that domestic factors explain most of the output variability over the short horizon, but get progressively dominated by international factors over time. Over a ten-year horizon, the external factors explain most of the output volatility, with regional factors being particularly important for the UK and Italy. We are unable to detect any significant difference between countries currently members of the EMU and non-members when analysing output variability, while the investigation of the inflation forecast error variance highlights some meaningful differences. Our results highlight the importance of international factors (and regional ones in particular) in shaping output variability in all the EU countries under analysis, and only provide limited evidence in favour of the existence of differences among countries currently members of the EMU and non-members. This mixed evidence adds to the existing literature on business cycle affiliation in Europe that has not reached a consensus yet on the degree of synchronization reached by the countries that adopted the common currency. Therefore, it is hard to conclude on the issue of the adoption of the Euro by the UK and Poland. However, the fact that most of the short-term output fluctuations in the UK and in Poland are attributable to international other-than-regional shocks would suggest caution in adopting the Euro. The results based on the inflation GFEVD also goes in the same direction. The recent difficulties experienced by EMU peripheral countries (e.g., Portugal, Ireland, Italy, Greece and Spain) during the sovereign debt crisis that followed the 2007-2009 financial crisis show that additional factors such as competitiveness and the lack of coordination between fiscal and monetary policy are also crucial in determining the advantages and disadvantages associated to a common currency.

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Figures and tables

Table 1. Structure of the VEC models

Countries	**Variables**											**Model structure**
	Endogenous							**Weakly exogenous**			**Exogenous**	
	GDP	*Infl*	*Wage*	*Unempl.*	*Stock index*	*Int. rate*	*Money*	*Int. rate*	*GDP*	*Exch. rate*	*Oil price*	Coint. Order
Germany	X	X	X	X	X	X	X	X	X	X	X	5
Italy	X	X	X	X	X	X	X	X	X	X	X	5
Austria	X	X	X	X	X	X	X	X	X	X	X	3
UK	X	X			X	X	X	X	X	X	X	3
Poland	X	X	X	X	X	X	X	X	X	X	X	4
Western Europe	X	X			X	X	X	X	X	X	X	2
Europe 2005	X	X				X		X	X	X	X	1
Other European	X	X				X		X	X	X	X	2
USA	X	X			X	X	X	X	X		X	4
Japan	X	X			X	X	X	X	X	X	X	2
Asia	X	X			X	X	X	X	X		X	3
NAFTA	X	X			X	X	X	X	X		X	2
Latin America	X	X			X	X	X	X	X		X	2
Oceania and S. Africa	X	X			X	X	X	X	X	X	X	3
Rest of Africa & Middle East	X	X			X	X	X	X	X		X	2

Table 2: Average cross-section correlations of residuals

	USA	Latin America	Asia	Austria	Germany	EU2005	Other European	Western Europe
Unemployment				0.025	0.006			
				(0.219)	(0.052)			
GDP	0.015	0.017	0.003	0.007	-0.027	-0.007	-0.023	0.007
	(0.133)	(0.150)	(0.023)	(0.065)	(-0.232)	(-0.060)	(-0.197)	(0.059)
Wage				-0.006	0.024			
				(-0.050)	(0.214)			
Inflation	-0.018	0.051	0.043	0.028	-0.019	-0.017	0.023	-0.004
	(-0.159)	(0.449)	(0.373)	(0.241)	(-0.167)	(-0.147)	(0.203)	(-0.033)
Stock market	0.087	0.016	0.059	0.065	0.084			0.088
	(0.765)	(0.143)	(0.517)	(0.568)	(0.736)			(0.770)
Money	-0.015	-0.021	0.004	-0.031	-0.019			-0.010
	(-0.129)	(-0.186)	(0.031)	(-0.269)	(-0.168)			(-0.083)
Interest rate	0.005	-0.015	0.003	0.030	0.026	0.017	0.015	0.000
	(0.048)	(-0.130)	(0.025)	(0.264)	(0.228)	(0.147)	(0.128)	(-0.002)

(continued)	UK	Italy	Japan	NAFTA	Africa & Middle East	Oceania & S. Africa	Poland
Unemployment		-0.023					0.020
		(-0.204)					(0.172)
GDP	0.003	-0.014	-0.005	-0.012	0.013	0.045	-0.015
	(0.025)	(-0.122)	(-0.050)	(-0.108)	(0.117)	(0.391)	(-0.131)
Wage		-0.024					-0.035
		(-0.206)					(-0.302)
Inflation	0.001	0.000	0.018	0.040	-0.020	-0.011	0.013
	(0.006)	(-0.000)	(0.156)	(0.345)	(-0.173)	(-0.093)	(0.111)
Stock market	0.087	0.073	0.073	0.048	0.051	0.074	0.058
	(0.765)	(0.640)	(0.638)	(0.419)	(0.444)	(0.649)	(0.509)
Money	0.024	0.048	0.000	0.013	-0.001	0.013	0.009
	(0.211)	(0.416)	(0.001)	(0.115)	(-0.006)	(0.112)	(0.081)
Interest rate	0.041	0.047	0.016	-0.021	-0.025	0.024	0.043
	(0.358)	(0.411)	(0.138)	(-0.184)	(-0.216)	(0.213)	(0.375)

Note: we report the average correlations of the residuals of the equation (variable) on the corresponding row for the country/area on the corresponding column with the rest of the countries/areas endogenous variables residuals. Two-tailed *t*-test statistics with 76 degrees of freedom (5 per cent critical value = 1.992) are reported in parenthesis: the null hypothesis is no correlation.

Table 3: GFEVD of output

	Horizon	**Domestic factors**			**Regional factors**			**Rest of the world factors**			**All foreign**
		real	*nominal*	*all*	*real*	*nominal*	*all*	*real*	*nominal*	*all*	
Germany	0	58.05	8.61	66.66	2.13	8.45	10.59	7.89	14.86	22.75	33.34
	4	18.41	17.95	36.36	4.07	26.28	30.35	8.80	24.49	33.29	63.64
	8	11.47	17.09	28.56	3.87	29.34	33.21	8.58	29.65	38.23	71.44
	12	8.70	16.19	24.88	3.82	30.44	34.26	8.30	32.55	40.85	75.12
	20	5.66	13.58	19.23	3.72	32.21	35.93	7.26	37.58	44.84	80.77
	40	2.40	9.31	11.72	3.95	35.28	39.24	5.50	43.54	49.05	88.28
Italy	0	41.42	5.73	47.15	10.63	10.98	21.61	8.94	22.30	31.23	52.84
	4	8.93	12.30	21.23	15.13	28.11	43.25	10.82	24.71	35.53	78.78
	8	3.57	9.29	12.86	11.70	36.97	48.67	11.20	27.27	38.47	87.14
	12	2.59	9.44	12.03	10.89	39.15	50.04	10.92	27.00	37.92	87.96
	20	1.92	9.09	11.01	10.39	40.76	51.14	10.04	27.80	37.85	88.99
	40	1.33	6.03	7.36	9.60	42.75	52.35	8.72	31.57	40.29	92.64
UK	0	45.82	5.92	51.74	2.92	11.22	14.13	3.29	30.84	34.13	48.26
	4	6.90	4.65	11.55	12.23	14.71	26.94	9.81	51.70	61.51	88.45
	8	0.72	7.84	8.56	14.39	30.10	44.49	12.07	34.88	46.95	91.44
	12	0.47	8.94	9.41	12.91	34.90	47.80	11.97	30.82	42.79	90.60
	20	0.43	9.14	9.57	11.72	38.48	50.20	11.65	28.58	40.23	90.43
	40	0.25	7.14	7.39	10.97	41.72	52.69	11.66	28.26	39.92	92.62
Austria	0	51.78	6.94	58.72	5.16	11.57	16.74	6.27	18.27	24.55	41.28
	4	26.24	17.94	44.18	5.85	21.42	27.27	6.56	21.99	28.55	55.82
	8	14.67	17.46	32.13	5.23	26.26	31.49	6.89	29.49	36.38	67.87
	12	12.48	16.93	29.41	5.65	25.96	31.61	6.97	32.01	38.98	70.59
	20	11.18	16.31	27.49	6.12	26.06	32.17	5.90	34.44	40.33	72.50
	40	8.48	13.85	22.33	6.14	29.20	35.34	4.22	38.11	42.33	77.67
Poland	0	41.29	2.56	43.85	8.77	11.04	19.81	16.26	20.07	36.33	56.14
	4	26.95	10.62	37.57	6.98	14.08	21.06	13.17	28.20	41.37	62.43
	8	14.65	18.67	33.32	3.03	23.21	26.24	9.19	31.26	40.44	66.68
	12	9.12	17.22	26.34	1.81	27.90	29.70	8.14	35.82	43.96	73.66
	20	7.57	14.29	21.86	1.84	30.07	31.91	7.36	38.87	46.23	78.14
	40	6.04	10.56	16.60	3.41	34.00	37.41	5.03	40.96	45.99	83.40

Notes: share of the *k*-step ahead forecast error variance of domestic output explained by the shocks on the corresponding column. Entries have been normalised so that they sum to 100. Each entry in the column "All foreign" is the sum of the corresponding percentages for the Regional and Rest of the world factors in the previous columns.

Table 4: GFEVD of inflation

	Horizon	Domestic factors			Regional factors			Rest of the world factors			All foreign
		real	*nominal*	*all*	*real*	*nominal*	*all*	*real*	*nominal*	*all*	
Germany	0	6.27	49.20	55.47	5.56	10.53	16.09	10.14	18.29	28.44	44.53
	4	16.58	36.96	53.54	6.23	14.26	20.49	7.97	18.00	25.97	46.46
	8	15.70	36.28	51.98	6.33	15.40	21.73	7.92	18.37	26.29	48.02
	12	13.25	31.25	44.50	6.26	17.62	23.88	8.54	23.08	31.62	55.50
	20	7.56	18.14	25.70	6.44	22.16	28.60	9.11	36.59	45.70	74.30
	40	3.82	9.15	12.97	6.71	27.69	34.40	6.01	46.63	52.64	87.04
Italy	0	2.34	57.70	60.04	5.88	3.68	9.56	4.21	26.19	30.40	39.96
	4	8.70	44.54	53.24	9.13	8.67	17.80	4.58	24.38	28.96	46.75
	8	6.38	27.76	34.14	9.18	22.35	31.53	7.22	27.12	34.34	65.86
	12	5.40	22.83	28.23	8.94	26.85	35.79	7.79	28.20	35.99	71.78
	20	4.06	17.84	21.90	8.88	29.78	38.66	7.59	31.85	39.44	78.10
	40	1.92	9.80	11.72	8.66	34.77	43.43	6.41	38.44	44.85	88.28
UK	0	0.16	55.90	56.06	3.86	11.95	15.81	5.93	22.21	28.14	43.95
	4	0.63	38.40	39.03	5.37	18.17	23.54	8.79	28.64	37.43	60.97
	8	0.53	27.63	28.16	6.80	18.30	25.09	10.04	36.70	46.74	71.84
	12	0.52	18.07	18.59	9.80	24.09	33.90	10.41	37.11	47.52	81.42
	20	0.59	13.48	14.07	10.61	32.15	42.76	10.42	32.75	43.17	85.93
	40	0.41	10.54	10.95	10.39	37.74	48.14	10.49	30.43	40.92	89.05
Austria	0	0.61	57.12	57.73	8.39	14.64	23.03	7.08	12.16	19.24	42.27
	4	1.29	37.40	38.69	8.01	27.04	35.05	7.33	18.93	26.26	61.31
	8	1.01	21.88	22.89	8.01	36.23	44.24	7.12	25.76	32.88	77.11
	12	0.73	14.88	15.61	7.47	39.95	47.42	6.89	30.08	36.97	84.39
	20	0.88	9.28	10.16	6.34	41.97	48.31	6.24	35.30	41.53	89.84
	40	2.00	4.25	6.25	4.35	42.92	47.27	5.12	41.36	46.48	93.75
Poland	0	7.30	54.25	61.55	9.46	15.05	24.52	3.70	10.22	13.93	38.44
	4	3.78	29.67	33.45	5.88	18.75	24.63	5.85	36.07	41.92	66.55
	8	3.19	20.95	24.14	4.72	23.62	28.34	8.59	38.93	47.53	75.87
	12	3.05	19.69	22.74	4.82	23.83	28.65	8.58	40.03	48.61	77.26
	20	2.92	18.19	21.11	5.23	25.18	30.41	8.61	39.87	48.48	78.89
	40	3.17	16.66	19.83	5.43	27.16	32.59	8.60	38.98	47.57	80.17

Notes: share of the *k*-step ahead forecast error variance of domestic output explained by the shocks on the corresponding column. Entries have been normalised so that they sum to 100. Each entry in the column “All foreign” is the sum of the corresponding percentages for the Regional and Rest of the world factors in the previous columns.

Appendix

Countries included in the eight geographical areas:

- Western Europe: Belgium, Denmark, Spain, Finland, France, Greece, Ireland, Luxembourg, the Netherlands, Norway, Portugal, Sweden, Switzerland;
- Europe 2005: Czech Republic, Estonia, Hungary, Lithuania, Lettonia, Slovenia, Slovakia;
- other European: Albania, Bulgaria, Croatia, Romania, Russia, Turkey, Ukraine;
- Asia: Hong Kong, Indonesia, India, South Korea, Malaysia, Philippines, Singapore, Thailand, Taiwan;
- NAFTA: Canada, Mexico;
- Oceania and South Africa: Australia, New Zealand, South Africa;
- rest of Africa and Middle East: United Arab Emirates, Algeria, Egypt, Iran, Israel, Libano, Libya, Morocco, Saudi Arabia, Tunisia;
- Latin America: Argentina, Brazil, Colombia, Chile, Peru, Venezuela.