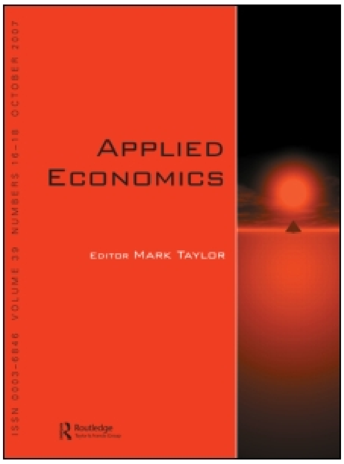

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Business cycle comovement in the G-7: common shocks or common transmission mechanisms?

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What are the sources of macroeconomic comovement among G-7 countries? Two main candidate explanations may be singled out: common shocks and common transmission mechanisms. In the article it is shown that they are complementary, rather than alternative, explanations. By means of a large-scale Factor Vector Autoregressive (FVAR) model, allowing for full economic and statistical identification of all global and idiosyncratic shocks, it is found that both common disturbances and common transmission mechanisms of global and country-specific shocks account for business cycle comovement in the G-7 countries. Moreover, spillover effects of foreign idiosyncratic disturbances seem to be a less important factor than the common transmission of global or domestic shocks in the determination of international macro-economic comovements.

I. Introduction

What are the sources of macroeconomic comovement among countries? Two main candidate explanations may be singled out: common shocks and common transmission mechanisms. Yet, rather than being alternative explanations, they may be held as complementary. In fact, while a common shock is necessary in order to contemporaneously destabilize both the domestic and foreign economies, the propagation of the shock may lead to common macro-economic fluctuations only if similar transmission mechanisms are at work. Several articles have recently dealt with the above issue, mainly focusing on the role of global shocks in affecting the synchronization and volatility of output fluctuations for G-7 countries. Three key results can be pointed out.

First, the degree of synchronization of cyclical fluctuations for the G-7 economies has changed over time. For instance, Kose *et al.* (2005) have found that business cycle synchronization has increased in the 'globalization' period (1986–2001) relative to the 'Bretton Woods' period (1960–1972), but has

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decreased with respect to the 'common shocks' years (1973–1985).[1] Several explanations, also related to the so-called 'great moderation'[2] can be suggested for the above findings, such as a decrease in the prominence of common shocks, structural change in the composition of output, as well as better macroeconomic policies. In this respect, since a key role for US macroeconomic shocks in the determination of global shocks can be expected, the moderation in output fluctuations in the US might have spilled over to the other G-7 countries. Changes in the transmission mechanism, as well as in domestic shocks, should however not be excluded. For instance, in the light of the prolonged Japanese stagnation of the 1990s and therefore of the more idiosyncratic behaviour shown by this latter country relative to the other G-7 economies, the moderation in Japan's output fluctuations is likely to be related more to domestic economic developments rather than to the size of global shocks or to US spillovers. Interestingly, changes in business cycle synchronization have also affected the G-7 members differently, leading to increased economic coordination within fairly homogeneous groups, such as the English speaking countries and the Eurozone countries and to a reduction in the coordination between the two groups.[3]

Second, the importance of global shocks relative to domestic disturbances has increased over time at all forecasting horizons. In fact, while in the 1960s and 1970s the own shocks were the dominant factors for output fluctuations in the short term and global shocks were the main source of output variability in the medium to long term, in the 1980s and 1990s, apart from Japan, fluctuations were determined by the global shocks at all the forecasting horizons (Kose *et al*., 2005). Moreover, the nature of the global shocks has changed over time. In fact, while for the 1960s and 1970s the global shocks could be related to US monetary policy, the oil price and the price of industrial materials (Stock and Watson, 2003), in more recent periods the global shocks could be linked to productivity changes and monetary policy disturbances (Kose *et al*., 2005). Similarly, Bagliano and Morana (2006) found a key role for global demand and productivity shocks since the 1980s for the G-7 countries, while global stock market and oil price shocks have been less important to explain macroeconomic fluctuations. Evidence of a similar transmission mechanism of global shocks for the G-7 countries, particularly for the US, the UK, Canada and the Euro area, is also found by Bagliano and Morana (2006) and Canova and de Nicolò (2003), while the more idiosyncratic behaviour found for Japan is fully coherent with the structural change associated with the long-stagnation suffered from this latter country during the 1990s.

Finally, common economic fluctuations may also be related to the spillover of domestic shocks among G-7 countries. Stock and Watson (2003) documented a small but not negligible contribution of domestic shocks to other countries' economic fluctuations, particularly at long-forecasting horizons. Interestingly, a leading role for US domestic shocks in affecting other economies, with the US leading the beginning and end of recessions among the G-7 and other industrialized countries, particularly in the 1970s and 1990s, has also been pointed out (Chauvet and Yu, 2006). Moreover, Pesaran *et al*. (2004) and Dees *et al*. (2007) found that a negative US stock market shock leads to a contraction in all foreign stock markets, followed also by a slowdown in real activity in all countries. On the other hand, a positive US short (long)-term rate shock leads to a permanent increase in the US short (long)-term rate, but only to a temporary increase in the short (long)-term rate for the Euro area.

In light of available evidence, therefore, while the interactions related to global shocks have been studied in depth for the G-7 economies, a thorough assessment of the role of domestic shocks and economic spillovers in explaining common economic fluctuations is still lacking. In fact, while there is a large number of studies devoted to the analysis of the effects of domestic shocks, carried out by means of

[1] See also Doyle and Faust (2002), Heathcote and Perri (2002), Helbling and Bayoumi (2003) and Monfort *et al*. (2003), for evidence of a reduction in G-7 business cycle syncronization over the most recent period.
[2] See for instance Stock and Watson (2003). See also, Justiniano and Primiceri (2006) and Fogli and Perri (2006) for recent contributions.
[3] Kose *et al*. (2005) have found, for instance, evidence of a regional factor for the US and Canada. Also, Helbling and Bayoumi (2003) have found evidence of geographical clusters, pointing to two groups of countries, namely, the US, the UK, Canada and France, Italy, Germany, respectively. Moreover, Stock and Watson (2005b) point to the existence of a common Eurozone factor for the 1984 to 2003 period. Also, Bagliano and Morana (2006) have found that regional similarities seem to characterize more the real side of the economy than the nominal side. Finally, interesting regional similarities have been pointed out by Andreano and Savio (2007) concerning asymmetries in business cycle fluctuations and by Furceri and Karras (2007) concerning comovements within the Eurozone.

single-country small scale macroeconometric models, few attempts have been made so far to set the analysis in the framework of a multi-country, large-scale model. This latter framework is likely to lead to a more accurate description of economic interactions within and across countries, since the estimation of domestic shocks is carried out conditionally onto the identification and estimation of common global shocks. Moreover, the multi-country framework allows for a more accurate analysis of spillover effects than two-country macroeconometric models.

Hence, the key advantage of the approach proposed in this article is in the accurate estimation of domestic shocks, which is carried out conditionally on a large information set composed of nominal and real variables for five regions: the US, Japan, the Euro-12 area, the UK and Canada. In this multi-country, large-scale macroeconometric model the role of common transmission mechanisms and international spillovers of domestic shocks has been further assessed by means of a new econometric approach, based on Stock and Watson (2005a) Factor Vector Autoregressive Approach (F-VAR). The proposed approach modifies the Stock–Watson F-VAR model in order to allow for a more straightforward interpretation of the global shocks and for the full economic and statistical identification of all idiosyncratic (region-specific) disturbances.

The key findings of this article are as follows. First, we find that both common shocks and common transmission mechanisms explain business cycle comovements for the G-7 countries. Second, not only global shocks, but also idiosyncratic domestic shocks, matter. Yet, common shocks are only a necessary but not sufficient condition for generating comovements, since without a common transmission mechanism the initial impulse provided by the shock would not be similarly transmitted across countries over time. In this respect, some stylized facts can be noted. For instance, responses of the short- and long-term interest rates consistent with a 'Taylor-rule' monetary policy and with the expectation theory of the term structure of interest rates find empirical support for the G-7 economies. Moreover, evidence of significant wealth/Tobin's 'q' effects can be found, as well as of stagflationary effects of oil price shocks and the effectiveness of the external demand channel in boosting output in the short term. Third, the spillover effects of idiosyncratic shocks, though not negligible, seem to be a less important factor than the common transmission of own domestic or global shocks in the determination of macroeconomic comovements among the G-7 countries. After this introduction, the article is organized as follows. In Section II the econometric methodology is introduced, while in Section III the data and the empirical results are presented and discussed; Section IV summarizes our main conclusions.

II. Econometric methodology

Following Stock and Watson (2005a), consider the factor model

$$X_t = \Lambda F_t + D(L)X_{t-1} + v_t \quad (1)$$

$$F_t = \Phi(L)F_{t-1} + \eta_t \quad (2)$$

where X_t is a n-variate vector of variables of interest, F_t is a r-variate vector of unobserved common factors, with $n \times r$ factor loadings in matrix Λ, v_t is a n-variate vector of idiosyncratic i.i.d. shocks, η_t is a r-variate vector of global i.i.d. shocks driving the common factors, with $E[\eta_{jt} v_{is}] = 0$ for all i, j, t, s and $D(L)$, $\Phi(L)$ are matrices of polynomials in the lag operator of order p with all the roots outside the unit circle, i.e.

$$D(L) = \begin{bmatrix} \delta_{1,1}(L) & \dots & \delta_{1,n}(L) \\ \vdots & \ddots & \vdots \\ \delta_{n,1}(L) & \dots & \delta_{n,n}(L) \end{bmatrix}$$

$$\Phi(L) = \begin{bmatrix} \phi_{r,r}(L) & \dots & \phi_{1,r}(L) \\ \vdots & \ddots & \vdots \\ \phi_{r,1}(L) & \dots & \phi_{r,r}(L) \end{bmatrix}$$

By substituting Equation 2 into Equation 1, the vector autoregressive form (F-VAR) of the factor model can be written as

$$\begin{bmatrix} F_t \\ X_t \end{bmatrix} = \begin{bmatrix} \Phi(L) & 0 \\ \Lambda\Phi(L) & D(L) \end{bmatrix} \begin{bmatrix} F_{t-1} \\ X_{t-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_{F_t} \\ \varepsilon_{X_t} \end{bmatrix} \quad (3)$$

where

$$\begin{bmatrix} \varepsilon_{F_t} \\ \varepsilon_{X_t} \end{bmatrix} = \begin{bmatrix} I \\ \Lambda \end{bmatrix} \eta_t + \begin{bmatrix} 0 \\ v_t \end{bmatrix}$$

with variance covariance matrix

$$E\varepsilon_t\varepsilon_t' = \Sigma_\varepsilon = \begin{bmatrix} \Sigma_\eta' & \Sigma_\eta'\Lambda' \\ \Lambda\Sigma_\eta' & \Lambda\Sigma_\eta'\Lambda' + \Sigma_v \end{bmatrix}$$

where $E\eta_t\eta_t' = \Sigma_\eta$ and $Ev_tv_t' = \Sigma_v$. The inversion of the F-VAR form yields the Vector Moving Average (VMA) form for the X_t process

$$X_t = B(L)\eta_t + C(L)v_t$$

where $B(L) = [I - D(L)L]^{-1}\Lambda[I - \Phi(L)L]^{-1}$ and $C(L) = [I - D(L)L]^{-1}$.

The estimation problem may be written as follows

$$\min_{F_1,\ldots,F_T,\Lambda,D(L),\Phi(L)} T^{-1}\sum_{t=1}^{T}[(I - D(L)L)X_t - \Lambda F_t]' \times [(I - D(L)L)X_t - \Lambda F_t]$$

where T is the sample size and solved following an iterative procedure, avoiding convergence problems associated with, for instance, one-step Kalman filter based estimation.

Given a preliminary estimate of $D(L)$, the common factors can be estimated as the principal components of the filtered variables $(I - D(L)L)X_t$. Then, conditional on the estimated factors, an estimate of Λ and an updated estimate of $D(L)$ can be obtained by Ordinary Least Squares (OLS) from Equation 1. This procedure is then iterated until convergence. Once the final estimate of $\{F_t\}$ is available, the $\Phi(L)$ matrix is obtained by applying OLS to Equation 2. Finally, by also employing the final estimates of Λ and $D(L)$, the restricted VAR coefficients in Equation 3 can be obtained. To obtain estimates of the common factors, Stock and Watson (2005a) apply the principal components analysis directly to the whole set of variables in X_t. This method exploits all available information in the observed series, but can make the economic interpretation of the factors extremely difficult. Therefore, to avoid this shortcoming, a different strategy is employed: the data set is divided into categories of variables and an estimate of the factors is obtained as the first principal component for each sub-set (category) of series. For example, a 'global output growth factor' is estimated as the first principal component from the set of the Gross Domestic Product (GDP) growth rates of the countries under study; a 'global stock price factor' is obtained in the same way from the set of the rates of change in real stock prices and so on. Therefore, the r static factors in F_t are separately estimated as the first principal components from the relevant sub-sets of variables. This estimation procedure can make it easier to give an economic content to the factors and is applied in each step of the iteration process described above. Moreover, separate estimation also avoids contamination from series potentially unrelated to the phenomenon of interest, which could undermine the asymptotic theory justifying the use of principal components analysis. In fact, the latter assumes that the variability of the common component is not too small and that the cross-correlation in the idiosyncratic errors is not too large. If noise is added to the information set it can be expected that, as more variables are included, the average size of the common factors will decrease, while the correlation across idiosyncratic components will increase. Hence, beyond a certain threshold, increasing the cross-sectional dimension of the information set is not desirable and could also negatively affect the explanatory power of the model (see Boivin and Ng, 2006). Finally, Monte Carlo results reported in Morana (2007) suggest that, despite the asymptotic results, in practice principal components analysis is a very effective tool (in terms of root mean square error) to extract common factors from a set of dependent variables also when the cross sectional dimension is as low as two units.

Identification of structural shocks

Since the shocks to the common factors in $\{\eta_t\}$ have the nature of reduced-form innovations, being linear combinations of underlying structural global disturbances, an identification scheme must be used in order to extract the structural shocks driving factor dynamics and to proceed to their economic interpretation. The identification of the structural shocks in the F-VAR model above can be carried out as follows. By denoting as ξ_t the r structural global shocks, the relation between reduced form and structural form disturbances can be written as $\xi_t = H\eta_t$, where H is square and invertible. The identification of the structural shocks amounts to the identification of the elements of the H matrix. It is assumed that $E[\xi_t\xi_t'] = I_r$, and hence $H\Sigma_\eta H' = I_r$. The VMA representation of the dynamic factor model in structural form can then be written as

$$X_t = B^*(L)\xi_t + C(L)v_t \quad (4)$$

where $B^*(L) = B(L)H^{-1}$. With r factors, $r(r-1)/2$ restrictions need to be imposed in order to exactly identify the structural shocks. Given the interpretation of the factor shocks in the present framework, the structuralization of the disturbances in $\{\eta_t\}$ is achieved by assuming a lower triangular structure for the H matrix, with the ordering based on plausible assumptions of the relative speed of adjustment to shocks. In particular, we order first the factors related to slow-moving variables (output growth, inflation), followed by the factors extracted from intermediate (interest rates, money growth) and relatively fast-moving variables (stock prices, exchange rates, oil price). The H matrix is then written as

$$H = \begin{bmatrix} h_{11} & & \\ \vdots & \ddots & \\ h_{r1} & \cdots & h_{rr} \end{bmatrix}$$

and estimated by the Choleski decomposition of $\hat{\Sigma}_\eta$: from $\xi_t = H^{-1}\eta_t$ we have $E[\eta_t \eta_t'] = H^{-1}\Sigma_\eta (H^{-1})' = I$ and hence $\hat{H}^{-1} = \text{chol}(\hat{\Sigma}_\eta)$.[4]

Finally, a similar procedure can be used to obtain structural disturbances from the vector of idiosyncratic shocks $\{v_t\}$. By denoting as ψ_t the n-variate vector of the idiosyncratic structural shocks, the VMA representation of the dynamic factor model in Equation 4 can be written as

$$X_t = B^*(L)\eta_t + C^*(L)\psi_t \qquad (5)$$

where $C^*(L) = C(L)\Theta^{-1}$ and $\psi_t = \Theta v_t$, with Θ being an $n \times n$ invertible matrix; moreover, $E[\psi_t \psi_t'] = I$ and $E[\psi_{i,t}\xi_{j,t}'] = 0$ for any i, j. We achieve the identification of the structural idiosyncratic shocks in ψ_t by imposing exclusion restrictions on their contemporaneous impact on the variables in X_t: this requires the identification of the elements of the $n \times n$ matrix $C_0^* = \Theta^{-1}$. To this aim, we first exploit the distinction between slow, intermediate and fast-moving variables introduced above and order the elements of X_t and ψ_t into r stacked sub-vectors, with the slow-moving variables (and the corresponding disturbances) in the upper position followed by the intermediate and fast-moving variables. Each sub-vector has m elements, containing the same variable for the m countries (or regions) under study. Within each sub-vector, the countries are ordered in terms of GDP size, placing the relatively large region first (the US, Japan and the Euro-12 area), followed by the smaller countries (the UK and Canada).

Then, the elements of C_0^* are identified by imposing a lower triangular structure of the form:

$$C_0^* = \begin{pmatrix} C_{0_{11}}^* & \cdots & 0 \\ \vdots & \ddots & \vdots \\ C_{0_{r1}}^* & \cdots & C_{0_{rr}}^* \end{pmatrix}$$

where each block $C_{0_{ij}}^*$ has a dimension $m \times m$. This structure implies that structural idiosyncratic shocks to relatively 'faster' variables (in any country) have no contemporaneous impact on 'slower' variables (in any country). Moreover, we impose a lower triangular structure also on each block on the main diagonal of C_0^*, i.e. (for $j = 1, \ldots, r$)

$$C_{0_{jj}}^* = \begin{pmatrix} c_{0_{jj,11}}^* & \cdots & 0 \\ \vdots & \ddots & \vdots \\ c_{0_{jj,m1}}^* & \cdots & c_{0_{jj,mm}}^* \end{pmatrix}$$

which implies that structural idiosyncratic disturbances to relatively 'smaller' regions do not have impact effects on 'larger' economies. Hence, for instance, the block $C_{0_{11}}^*$ contains the impact responses of the GDP growth rates for the various regions (in the order: US, Japan, the Euro area, the UK and Canada) to region-specific structural shocks to GDP growth. Operationally, the estimation of the Θ matrix is then carried out as follows:

(1) regress $\hat{\varepsilon}_{X,t}$ on $\hat{\xi}_t$ by OLS and obtain $\hat{v}_t$ as residuals;
(2) from $\psi_t = \Theta^{-1}v_t$ we have $E[\psi_t\psi_t'] = \Theta^{-1}\Sigma_v(\Theta^{-1})' = I$. Hence, $\hat{\Theta}^{-1} = \text{chol}(\hat{\Sigma}_v)$.

The identification scheme performed allows for the exact identification of n structural idiosyncratic shocks, imposing $n(n-1)/2$ zero restrictions on the contemporaneous impact matrix.

By following a thick modelling estimation approach (Granger and Jeon, 2004) and computing generalized impulse response functions (Pesaran and Shin, 1998) as well, the problem of sensitivity of the results to the ordering of the variables chosen for the identification of both the factor and idiosyncratic innovations can be accounted for.

The proposed methodology can be considered as a special case of the F-VAR approach of Stock and Watson (2005a), holding when the number of static and dynamic factors is equal. Differently from Stock and Watson, the global factors are estimated using the relevant sub-sets of variables, rather than the entire data set; this approach has the advantage of allowing for a more clear-cut interpretation of the global shocks. Moreover, the issue of the identification of all the idiosyncratic shocks is explicitly addressed.

Concerning the proposed estimation procedure, the use of the principal components estimator for the estimation of persistent processes has been justified by recent theoretical developments of

[4] See Stock and Watson (2005a) for details on alternative identification strategies.

Bai (2003, 2004) and Bai and Ng (2004), allowing for an accurate estimation of the factors in the current framework.[5] Moreover, differently from the F-VAR approach of Favero *et al*. (2005) and Bernanke *et al*. (2005), the proposed method has the advantage of using an iterated procedure in estimation, recovering, asymptotically, full efficiency and also allowing the imposition of appropriate restrictions concerning the lack of Granger causality of the variable versus the factors, as in Stock and Watson (2005a).

In addition, relatively to the approach employed by Pesaran *et al*. (2004) and Dees *et al*. (2007) to study the international transmission of shocks, we model all variables as endogenous from the outset, instead of modelling each country separately, with foreign variables treated as weakly exogenous. Moreover, in our framework the unobservable factors can be interpreted as global factors, while in Pesaran *et al*. (2004) the interpretation is less straightforward.[6] Finally, while in our approach the weighting in the construction of the common factors is chosen optimally (by using principal components analysis), in Pesaran *et al*. (2004) the weighting is somewhat arbitrary, albeit based on sound economic justifications.

III. Empirical Results

Data

Quarterly data for five countries or regions (the US, Japan, the Euro-12 Area, the UK and Canada), have been employed over the period Jaunary 1980 to February 2005. Eight variables for each country have been considered: real GDP, the real oil price, the real stock market price index, the real effective exchange rate, the CPI price index, nominal money balances[7] and the nominal short- and long-term interest rates (on 3-month government bills and 10-year government bonds, respectively).[8] The persistence properties of the data have been assessed by means of unit roots tests. In addition to the standard ADF (Said and Dickey, 1984) and KPSS (Kwiatkowski *et al*. 1992) tests, the Enders and Lee (2005) ADF test and a modified version of the KPSS test have also been employed in order to account for structural change. In those tests the deterministic component μ_t is modelled by means of the Gallant (1984) flexible functional form, whereby $\mu_t = \mu_0 + \mu_1 t + \mu_2 \sin(2\pi t/T) + \mu_3 \cos(2\pi t/T)$, capturing not only a deterministic process of gradual change in a time-varying intercept, but also the presence of sharp breaks and of various forms of nonlinear trends (Enders and Lee, 2005). In the case of the KPSS test with the adaptive trend, critical values have been obtained by means of Monte Carlo simulation with 10 000 replications.

The tests have been carried out directly on the series used in the empirical analysis, i.e. the growth rate of real GDP (denoted by g), the rate of inflation (π), the levels of the long-term and short-term nominal interest rates (l and s, respectively), the nominal money growth rate (m), and the rates of change of the real effective exchange rate (e), the real stock price (f) and the real price of oil (o). The unit root tests reported show slightly different results for real and nominal variables. While the findings are clear-cut for all the real variables, apart from real output growth for Japan, pointing to $I(0)$ stationarity, for the nominal variables, as well as for real output growth for Japan, stationarity can be found only for the series in deviation from a nonlinear deterministic component. As far as the nominal variables are concerned, the latter, as argued in Bierens (2000) and Morana (2006), can be associated with successful long-run monetary policy management. In fact, the outcome

[5] In particular, Bai (2003) considers the generalization of the principal components analysis to the case in which the series are weakly dependent processes, establishing consistency and asymptotic normality when both the unobserved factors and the idiosyncratic components show limited serial correlation and the latter also display heteroscedasticity in both their time-series and cross-sectional dimensions. In Bai (2002) consistency and asymptotic normality is derived in the case of $I(1)$ unobserved factors and $I(0)$ idiosyncratic components, also allowing for heteroscedasticity in both the time-series and cross-sectional dimensions of the latter component. Moreover, Bai and Ng (2004) have established consistency also for the case of $I(1)$ idiosyncratic components. As pointed out by Bai and Ng (2004), consistent estimation should also be achieved by principal components techniques in the intermediate case of long-memory processes and Monte Carlo results reported in Morana (2007) support this conclusion.

[6] In fact, what is denoted as global factor in Pesaran *et al*. (2004) is just a summary feature for all the variables which may have an impact on a given country, but for parsimony reasons are not modelled in detail. This is because when the unobserved component is estimated, the own country variables are neglected. However, it is hard, for instance, to justify the exclusion of US data when the global factors for the US are computed.

[7] Nominal money balances are given by M2 for the US, M2+CD for Japan, M3 for the Euro area and Canada and M4 for the UK. The aggregates employed are the ones usually employed to measure broad money in each of the countries investigated.

[8] The source of the Euro-area aggregate data is the European Central Bank. All other data are taken from *Datastream*.

of monetary policy decisions should shape the trend behaviour of the nominal variables and the latter should be better understood in terms of a deterministic rather than a stochastic process.[9] Differently, for real output growth for Japan the nonlinear component accounts for the slowdown in economic growth due to the stagnation of the 1990s.

On the basis of the above results, the stationary representation of the F-VAR model has been augmented by including the adaptive specification for the deterministic component suggested by Enders and Lee (2005).[10]

The F-VAR model

The econometric analysis has been implemented in two steps. In the first step global macroeconomic dynamics have been investigated in order to specify the F-VAR model. Then, in the second step, the F-VAR model has been estimated and impulse response analysis and forecast error variance decomposition carried out.

Common macroeconomic factors. As pointed out in the theoretical section, principal components analysis has been carried out on each sub-set of variables and the common factor, within each sub-set, has been estimated by the first principal component. In fact, for all the sub-sets of series of interest, only the latter can be interpreted in terms of global factor, affecting all the variables belonging to each subgroup and explaining a sizable proportion of their variability.

As far as the output series (g) are concerned, the global factor (first principal component) explains about 40% of total variance, also accounting for 66% of US output variance and 56% of output variance for Canada, while figures for the UK and the Euro area are somewhat lower (43 and 32%, respectively) and only 4% for Japan. On the other hand, all the remaining factors are idiosyncratic. On the basis of the large proportion of variance of the US series explained by the factor it is possible to associate the global output factor to business cycle developments in the US. A similar finding holds for the real stock return series (f) as well. In fact, also in this latter case a single global factor explains a large proportion (about 60%) of total variance and the bulk of the variance for US stock returns (80%). The corresponding figures for the other regions are also high: 70% for Canada and the UK and 55% for the Euro area. Again, the global factor does not capture fluctuations of the Japanese stock returns (4%).[11] A single factor can also be detected for the oil price (o) series, explaining over 90% of total variance, as well as the variance of each single oil price series. This latter finding is expected, since heterogeneity among the oil price series is only due to the exchange rate component.[12] Finally, as far as the nominal variables are concerned, the common global factor explains about 95% and 88% of total variance for the long-term (l) and short-term (s) nominal interest rates, respectively, and about 70% and 49% of total variance for inflation (π) and nominal money growth (m), respectively. Hence, only for nominal money growth there is evidence of nonnegligible idiosyncratic factors. Moreover, apart from the nominal interest rate series, for which the proportion of variance explained by the first principal component ranges between 82% and 97% for all individual series, the proportion of inflation variance explained by the first principal component is equal to 56% for Japan and 74% on average for the other four countries, while for nominal money growth the figure for Japan (70%) is greater than the average figure for the other four countries (43%).[13] To explore in more depth the comovements in the nominal variables, principal components analysis has been carried out on the whole set of series. According to the results, there is clear evidence of a global factor driving all nominal variables, since the first principal components explains about 65% of total variance and,

[9] For instance, the setting of the policy interest rate by the central bank renders the latter a step-wise deterministic process, inducing a nonlinear deterministic trend both in short- and long-term interest rates series.

[10] Hence, the deterministic component included in the i-th equation of Equation 1 is specified as $\mu_{i,t} = \mu_{i,0} + \mu_{i,1}t + \mu_{i,2}\sin(2\pi t/T) + \mu_{i,3}\cos(2\pi t/T)$. Detailed results are not reported for reasons of space, but are available upon request from the authors. See also Bagliano and Morana (2006).

[11] See also Ehrmann *et al.* (2005) and Hamori (2000) for additional evidence in favour of the interpretation of US macroeconomic shocks in terms of global shocks. See also Harvey and Mills (2005) for additional evidence of comovements in G-7 macroeconomic variables.

[12] The real exchange rate changes (e) display little evidence of comovements: the fraction of the overall variance attributable to the first principal component amounts to 0.37 and is widely dispersed across regions (being heavily influenced by the US series). On this basis we conclude that there is no compelling evidence of a global factor driving real exchange rates.

[13] The more idiosyncratic behaviour of the Japanese economy over the time span investigated is consistent with the very different macroeconomic conditions (economic stagnation) which have characterized this country, relative to the other economies, over the 1990s.

on average, 57% of total inflation variance, 84% of total nominal short-term rates variance, 92% of total nominal long-term rates variance and 35% of total nominal money growth variance.

Hence, in light of the above findings, four global factors have been retained for the F-VAR analysis, namely an 'output growth factor', a 'stock returns factor', a real 'oil price factor' and an 'inflation factor', the latter capturing the common driving force of the whole set of nominal variables. The estimated factors have then been included in the F-VAR model as starting estimates of the elements of vector F_t, in the first step of the iterative procedure described in Section II.[14]

Policy analysis. On the basis of misspecification tests, the lag length of the F-VAR is set equal to one.[15] Overall, the econometric model is composed of 39 equations. The first 35 equations refer to the endogenous variables (real output growth, inflation, the nominal short-term interest rate, the nominal long-term rate, nominal money growth, real exchange rate returns and real stock returns) for the five regions in the system; each equation contains 43 parameters (35 on lagged endogenous variables, four on lagged endogenous factors, i.e. the oil price factor, the output growth factor, the stock returns factor and the inflation factor and four on the deterministic trend components). The remaining four equations refer to the global factors and contain eight parameters each (four on lagged endogenous factors and four on the deterministic trend components). The estimation period is January 1980 to Febuary 2005. The F-VAR model has been estimated following the iterative procedure described in the methodological section.

Forecast error variance decomposition. Since, on the basis of previous evidence in the literature (Bierens, 2000; Morana, 2006), the nonlinear deterministic component in the inflation factor (capturing a gradual downward trend in the level of inflation rates, interest rates and monetary growth) is likely to reflect the true common nominal component related to effective long-term monetary policy management, the structural disturbance to the inflation factor may reflect other macroeconomic forces. In particular, in the light of recent results by Gordon (2005), pointing to an important contribution provided by productivity growth in determining US inflation dynamics, this latter shock may be related to the supply side of the economy (i.e. a common productivity disturbance). Consistently with the results of the impulse response analysis, the disturbance to the output growth factor may capture global demand-side shocks and the remaining factor disturbances capture innovations to the common factors driving real stock returns and real oil price changes. As shown in Bagliano and Morana (2006), the proposed interpretations for the global shocks are fully consistent with the results of the impulse response analysis.

To assess the relative contribution of global and idiosyncratic disturbances to macroeconomic fluctuations in each region, Table 1 reports, for each endogenous variable, the median forecast error variance decomposition at the one-quarter and 5-year horizons, obtained from the structural VMA representation of the four-factor F-VAR model in (5).[16] Some commonalities are found among the regions under study. In particular, two key results can be noted.

First, nominal variables (inflation, interest rates and money growth) seem to be driven by global dynamics. In fact, in all regions global disturbances explain the bulk of their variability at all forecasting horizons (92–100% at the 5-year horizon and 86–99% at the one-quarter horizon, with the exception of the Euro-area money growth (55%) and inflation (15%) figures). Differently, for the real variables more mixed results are found. In fact, while for real output growth the global shocks tend to dominate at the 5-year horizon (50–89%), apart from the UK (39%), in the very short term the idiosyncratic disturbances slightly dominate in the US, the UK and Canada (50–72%), but not in the Euro area (34%) and in Japan (5%). In the case of real stock returns, the global shocks dominate at all forecasting horizons in the US, in the Euro area and in the UK (53–87%), but not in Canada and Japan (23–36%). Finally, the bulk of variability of the real exchange rate changes is explained by the idiosyncratic shocks in all regions at all forecasting horizons (79–100%),

[14] More detailed results of the first step of the analysis are reported in Bagliano and Morana (2006).
[15] Evidence of serial correlation at the 1% level is detected only for the UK and US output growth rate equations. Significant ARCH effects are found for the UK output growth and short-term rate equations and for the Euro area long-term rate equation.
[16] The median forecast error variance decomposition, as the median impulse response functions, have been obtained using Monte Carlo simulation, as suggested in Granger and Jeon (2004). For reasons of space, only the results for the within period and the 5-year period horizons have been reported in the tables. A full set of results is available from the authors upon request.

Table 1. Variance decomposition based on the four-factor *F*-VAR

		Global shocks					Idiosyncratic shocks	
	Horizon (quarters)	Output	Inflation	Stock mkt	Oil price	All	Own	All
g_{US}	1	24.9	23.3	1.4	0.0	**49.6**	50.4	**50.4**
	20	25.1	33.9	3.7	0.0	**62.9**	13.9	**37.1**
π_{US}	1	0.5	96.9	0.1	0.2	**97.7**	2.3	**2.3**
	20	1.8	95.2	0.5	0.9	**98.3**	0.7	**1.7**
s_{US}	1	0.0	98.7	0.0	0.1	**98.8**	1.2	**1.2**
	20	0.3	97.1	0.1	0.3	**97.8**	1.7	**2.2**
l_{US}	1	0.0	98.4	0.0	0.1	**98.5**	0.3	**1.5**
	20	0.4	95.3	0.1	0.4	**96.3**	0.4	**3.7**
m_{US}	1	0.1	90.9	0.0	0.0	**91.0**	4.5	**9.0**
	20	1.0	90.2	0.1	0.6	**91.9**	2.5	**8.1**
e_{US}	1	8.4	2.8	0.1	0.0	**11.2**	37.3	**88.8**
	20	1.3	15.9	0.7	2.9	**20.7**	13.9	**79.3**
f_{US}	1	25.0	45.4	0.6	1.6	**72.6**	12.4	**27.4**
	20	32.4	45.2	0.2	2.4	**80.3**	3.5	**19.7**
g_{JA}	1	13.8	80.4	0.5	0.1	**94.9**	5.1	**5.1**
	20	16.3	70.7	1.5	0.3	**88.8**	2.2	**11.2**
π_{JA}	1	1.5	89.3	0.0	0.0	**90.9**	7.0	**9.1**
	20	0.2	91.1	0.1	0.8	**92.2**	3.1	**7.8**
s_{JA}	1	0.0	98.4	0.0	0.1	**98.5**	0.4	**1.5**
	20	0.2	93.9	0.0	0.4	**94.4**	1.0	**5.6**
l_{JA}	1	0.0	98.5	0.0	0.1	**98.6**	0.1	**1.4**
	20	0.2	96.5	0.0	0.3	**97.0**	0.2	**3.0**
m_{JA}	1	0.3	95.1	0.0	0.1	**90.9**	7.0	**9.1**
	20	0.2	91.1	0.1	0.8	**92.2**	3.1	**7.8**
e_{JA}	1	6.3	0.4	0.4	0.0	**7.1**	20.5	**92.9**
	20	6.3	1.7	0.5	0.0	**8.5**	5.8	**91.5**
f_{JA}	1	0.7	30.7	0.5	0.0	**31.9**	25.4	**68.1**
	20	1.3	19.8	0.7	0.8	**22.5**	14.1	**77.5**
g_{EA}	1	8.9	57.2	0.1	0.1	**66.2**	28.0	**33.8**
	20	16.9	31.4	1.7	0.4	**50.4**	16.0	**49.6**
$\pi_{\varepsilon\alpha}$	1	2.4	11.5	1.1	0.1	**15.0**	74.9	**85.0**
	20	4.7	67.6	1.7	4.9	**78.9**	1.1	**21.1**
s_{EA}	1	0.0	98.7	0.0	0.1	**98.8**	0.4	**1.2**
	20	0.2	96.1	0.1	0.4	**96.7**	0.6	**3.3**
l_{EA}	1	0.0	98.6	0.0	0.1	**98.7**	0.1	**1.3**
	20	0.3	96.0	0.1	0.5	**96.9**	0.1	**3.1**
m_{EA}	1	0.0	87.8	0.0	0.0	**87.8**	5.7	**12.2**
	20	0.5	53.3	0.0	1.2	**55.0**	6.2	**45.0**
e_{EA}	1	1.0	56.6	0.1	0.0	**57.6**	9.4	**42.4**
	20	0.7	6.2	2.4	2.2	**11.5**	13.7	**88.5**
f_{EA}	1	23.7	28.0	0.2	1.0	**52.8**	17.1	**47.2**
	20	23.4	31.5	0.7	1.9	**57.4**	9.2	**42.6**
g_{UK}	1	8.0	19.2	0.2	0.6	**27.9**	56.6	**72.1**
	20	3.8	32.2	0.1	3.2	**39.4**	13.6	**60.6**
π_{UK}	1	0.0	97.8	0.0	0.1	**97.9**	1.5	**2.1**
	20	0.4	95.9	0.1	0.5	**96.9**	1.4	**3.1**
s_{UK}	1	0.0	97.9	0.0	0.1	**99.1**	0.3	**0.9**
	20	0.1	99.0	0.0	0.2	**98.2**	0.3	**1.8**
l_{UK}	1	0.0	99.0	0.0	0.1	**99.0**	0.1	**1.0**
	20	0.2	98.1	0.0	0.2	**99.6**	0.2	**1.4**
m_{UK}	1	0.1	97.8	0.0	0.0	**97.9**	1.2	**2.1**
	20	0.7	91.4	0.1	0.2	**92.3**	0.1	**7.7**
e_{UK}	1	0.0	0.1	0.0	0.2	**0.3**	29.5	**99.7**
	20	1.1	2.1	0.2	0.2	**3.6**	12.9	**96.4**
f_{UK}	1	6.0	70.0	1.2	1.0	**78.2**	7.4	**21.8**
	20	14.5	68.4	1.5	2 7	**87.1**	3.0	**12.9**

(*continued*)

Table 1. Continued

	Horizon (quarters)	Global shocks: Output	Inflation	Stock mkt.	Oil price	All	Idiosyncratic shocks: Own	All
g_{CA}	1	24.0	15.7	1.4	0.0	**41.2**	41.7	**58.8**
	20	25.3	27.1	4.0	0.4	**56.8**	16.6	**43.2**
π_{CA}	1	0.1	85.6	0.0	0.1	**85.8**	11.1	**14.2**
	20	2.0	91.4	0.5	1.3	**95.3**	1.6	**4.7**
s_{CA}	1	0.0	98.6	0.0	0.1	**98.7**	0.5	**1.3**
	20	0.6	96.3	0.2	0.5	**97.5**	0.6	**2.5**
l_{CA}	1	0.0	98.8	0.0	0.1	**98.9**	0.1	**1.1**
	20	0.5	96.6	0.1	0.5	**97.7**	0.1	**2.3**
m_{CA}	1	0.3	91.5	0.1	0.0	**91.9**	3.7	**8.1**
	20	0.4	70.0	0.1	0.1	**70.6**	3.6	**29.4**
e_{CA}	1	5.1	3.2	0.0	0.2	**8.5**	45.2	**91.5**
	20	0.7	0.7	0.0	0.3	**1.7**	12.2	**98.3**
f_{CA}	1	22.1	0.0	0.8	1.5	**24.4**	17.4	**75.6**
	20	28.7	3.9	0.5	2.9	**36.0**	3.4	**64.0**

Notes: This table reports for each endogenous variable the median forecast error variance decomposition at the one-quarter and 5-year horizons obtained from the structural VMA representation of the four-factor *F*-VAR model in Equation 5 by Monte Carlo simulation as suggested in Granger and Jeon (2004). For each variable the table shows the percentage of forecast error variance attributable to each global factor shock ('output', 'inflation', 'stock market' and 'oil price') together with their sum ('All', in bold). The last two columns report for each variable the percentage of the forecast error variance attributable to the own-country idiosyncratic shock to that variable ('own') and the proportion due to all (domestic and foreign) idiosyncratic disturbances ('All', in bold).

with the only exception of the Euro area in the very short term (42%). Hence, differently from the nominal side, idiosyncratic shocks do seem to play a significant role in explaining real-side macroeconomic variability.

Second, when the specific source of shocks (global and idiosyncratic) is investigated, further differences between the nominal and real variables can be noted. In fact, while the global supply side (inflation) disturbance explains the bulk of variability of the nominal variables at all horizons (53–99%), apart from the Euro-area inflation in the very short term (11%), for the real output series both the global supply and demand (output) shocks are important determinants, exercising similar effects, at all horizons, for the US and Canada (24–25% and 16–34%, respectively). Differently, for the Euro area, Japan and the UK the supply side shock has a dominant role (19–80%). Moreover, except for Canada, the supply disturbance also dominates the fluctuations in real stock returns (19–70%). On the other hand, the output idiosyncratic shock (i.e. the region-specific disturbance to the output growth series) seems to matter most for output fluctuations, explaining almost all the residual variability in all regions, particularly at the very short-term horizon, while in the longer term other idiosyncratic shocks matter as well. The latter findings are interesting, possibly pointing to a different role of demand/fiscal policy in the various countries. While productivity dynamics tend to be global affecting both real and nominal variables, more heterogeneity can be found for demand policies, which seems to be carried out more effectively in the US, given the medium term impact which can be detected for this latter country only.

Moreover, for the real exchange rate series also idiosyncratic shocks do matter, albeit the importance of the nonown idiosyncratic disturbances (i.e. region-specific shocks to variables other than the exchange rate) is more noticeable, pointing to stronger spillover effects than for the other real variables. Finally, the oil price and global stock market shocks play only a minor role in explaining macroeconomic fluctuations at all forecasting horizons.

Overall, our findings are broadly consistent with previous evidence for the G-7 countries. In particular, the important role of global shocks in explaining output fluctuations since the 1980s pointed out by Stock and Watson (2005b) is further qualified, since our analysis allows to disentangle the contribution of global supply and demand shocks and to account for the contribution of idiosyncratic shocks. Moreover, the evidence that output fluctuations are determined by a small number of global shocks is consistent with the findings of Kose *et al*. (2003), although, differently from previous results in the literature (Canova and de Nicolò, 2003), a dominant role of demand over supply shocks is not found. And, again differently from Canova and de Nicolò (2003), our findings suggest that the synchronization of the G-7 business cycle may depend also on common sources of shocks, rather than only on similarities in the transmission mechanism. Indeed, as shown by the results of the impulse response analysis in Bagliano and Morana (2006) summarized below, a similar transmission mechanism for the global shocks holds for the G-7 countries. Finally, as in Stock and Watson (2005b), we find a negligible role for global oil price shocks (and global stock market disturbances) in shaping common international macroeconomic dynamics.

Impulse response functions. The analysis of the impulse response functions allows to assess differences and commonalities across regions in the transmission mechanisms of various disturbances. As far as the global shocks are concerned, we briefly summarize the main findings, given that the focus of the study is on the transmission of idiosyncratic shocks. First, there is evidence of a similar transmission mechanism of global disturbances for the regions under study, particularly for the US, the UK, Canada and the Euro area, while the more idiosyncratic behaviour of Japan can be explained by this country's much different macroeconomic framework, especially in the 1990s. More specifically, a positive global demand shock has a positive and permanent impact on both output and prices in all regions, leading to a temporary increase in short-term and long-term interest rates (a response consistent with a 'Taylor-rule' monetary policy reaction and with the expectations theory of the term structure) and in real stock prices. A negative global supply (productivity) disturbance has negative impact on output and a positive impact on prices, also leading to a temporary increase in interest rates, with significantly negative effects on real stock prices in the US and the UK. In addition, a positive oil price shock, leading to a contraction in real output and in real stock prices and to an increase in prices, is partially accommodated by the monetary authorities since nominal money balances tend to increase, while the temporary reaction of interest rates is weak. Finally, some evidence of a significant 'wealth' or Tobin's 'q' effects is found, with a positive global stock market shock leading to a permanent increase in real stock prices, real output, the price level and nominal money balances.[17]

The effects of idiosyncratic domestic shocks. The results of the impulse response analysis of the region-specific disturbances are shown in Table 2, Panels A and B.[18] In the first panel, the signs of the average effects of each shock over three horizons, i.e. within quarter (very short term), beyond one quarter and within 3 years (short term) and beyond 3 years (medium to long term), are reported: a positive significant effect is denoted by '+', a negative significant effect is denoted by '−' and a null or not significant effect is denoted by '0'.[19] To give a broad picture of the impulse response results, Table 3 reports the number of regions (from 0 to 5) showing a negative, zero and positive response of each variable (in columns) to the domestic idiosyncratic shocks (in rows) for three forecasting horizons, i.e. within quarter (very short term, *vs*), beyond one-quarter and within 3 years (short term, *s*) and beyond 3 years (medium to long term, *ml*).

Several findings can be noted. First, a positive idiosyncratic *output shock*, which has a permanent and significant impact on real output, determines on impact a significant decline in the price level in Japan, the UK and Canada. In the medium to long term the price level decline is significant only in the Euro area, whereas no significant response is detected in the US at any horizon. This pattern is broadly consistent with the interpretation of the idiosyncratic output shock as a domestic productivity disturbance. Moreover, the lack of significance for the US provides further support to the interpretation of global output shocks in terms of US shocks. Short-term interest rates show a significant decrease on impact in three regions (the Euro area, the UK and Canada), pointing to monetary policy accommodation, whereas in the US no significant reaction of the short-rate is, consistently, again detected. On the other hand, no interesting consequences can be detected for the other variables.

[17] See Bagliano and Morana (2006) for additional details.
[18] For reasons of space, plots are not reported. They are, however, available upon request from the authors.
[19] SEs have been computed by simulation. The statistical significance has been evaluated at the 5% level.

Table 2. Median orthogonal impulse responses to domestic shocks and domestic idiosyncratic orthogonal shocks effects

Panel A: Median orthogonal impulse responses to domestic shocks

Idiosyncratic shock to	Response of domestic variables						
	y	π	s	l	m	e	f
y_{US}	+ + +	000	000	000	000	− − −	000
π_{US}	0 + +	+ + +	000	+ + 0	+00	− − 0	+ + +
s_{US}	000	0 − −	+ + 0	+ + 0	−00	+ + +	+00
l_{US}	00+	0 − −	0+0	+ + 0	000	+ + +	0 + +
m_{US}	000	0 − −	000	000	+ + +	−00	−00
e_{US}	0 + +	0+0	000	0+0	000	+ + +	0 + +
f_{US}	0+0	000	0+0	0+0	000	0 + +	+ + +
y_{JA}	+ + +	−00	0−0	0−0	000	− − −	000
π_{JA}	000	+ + +	+ + 0	+ + 0	+ − −	+ + +	0 − −
s_{JA}	000	0 + +	+ + 0	+ + 0	+ − −	− + +	− − −
l_{JA}	0 − −	000	000	+00	+ − 0	000	− − −
m_{JA}	000	0 − −	0−0	0−0	+ + +	−00	+0+
e_{JA}	0 − −	00−	000	000	000	+ + +	− − 0
f_{JA}	000	0 − −	000	000	0 + +	000	+ + +
y_{EA}	+ + +	+0−	− − 0	000	0 − −	− + +	000
π_{EA}	0 + +	+ + +	−00	−00	+ + +	−00	+ + +
s_{EA}	0 − −	0 + +	+ + 0	+ + 0	− + +	+ + 0	− − −
l_{EA}	000	000	000	+00	+00	+ + +	− − −
m_{EA}	0 − −	0 + +	0+0	0+0	+ + +	+ − −	0 + +
e_{EA}	0 − −	0 − −	000	000	0 + +	+ + +	− − −
f_{EA}	00+	0 − −	0−0	000	0 − −	0 + +	+ + +
y_{UK}	+ + +	−00	−00	−00	+ + +	−00	− − −
π_{UK}	0 + +	+ + +	+00	+00	00+	+ + +	− − −
s_{UK}	0 − −	000	+ + 0	+00	+00	−00	000
l_{UK}	0 + +	000	0−0	+00	− + +	0 + +	−00
m_{UK}	0 − −	0+0	0+0	0+0	+ + 0	+ + +	000
e_{UK}	000	000	0−0	000	0 + +	+ + +	00−
f_{UK}	000	0 + +	000	000	0 + +	0 + +	+ + +
y_{CA}	+ + +	−00	− + 0	000	−00	0+0	+00
π_{CA}	000	+ + +	−00	− − 0	−00	0+ +	0 − −
s_{CA}	0 − −	0 + +	+00	+00	+ + +	0+ +	−00
l_{CA}	0 − −	0 + +	000	+00	− + +	+ + +	000
m_{CA}	0+0	0 + +	0+0	0−0	+ + +	− − 0	+00
e_{CA}	0−0	0 − −	0−0	000	0 + +	+ + +	+ + +
f_{CA}	0 + +	0 − −	0−0	000	0 − −	0 − −	+ + +

Panel B: Domestic idiosyncratic orthogonal shocks effects

		Response of											
		y			π			s			l		
Shock to		V*s*	*s*	*ml*	*vs*	*s*	*ml*	*vs*	*s*	*ml*	*vs*	*s*	*ml*
	−	0	0	0	3	0	1	3	2	0	1	2	0
y	0	0	0	0	1	5	4	2	2	5	4	2	5
	+	5	5	5	1	0	0	0	1	0	0	1	0
	−	0	0	0	0	0	0	2	0	0	2	2	0
π	0	5	2	2	0	0	0	1	4	5	0	1	5
	+	0	3	3	5	5	5	2	1	0	3	2	0
	−	0	3	3	0	1	1	0	0	0	0	0	0
s	0	5	2	2	5	1	1	0	1	5	0	2	5
	+	0	0	0	0	3	3	5	4	0	5	3	0
	−	0	2	2	0	1	1	0	1	0	0	0	0
l	0	5	2	1	5	3	3	5	3	5	0	4	5
	+	0	1	2	0	1	1	0	1	0	5	1	0
	−	0	2	2	0	2	2	0	1	0	0	2	0
m	0	5	2	3	5	0	1	5	1	5	5	1	5
	+	0	1	0	0	3	2	0	3	0	0	2	0
	−	0	3	2	0	2	3	0	2	0	0	0	0

(*continued*)

Table 2. Continued

Panel B: Domestic idiosyncratic orthogonal shocks effects

		Response of											
		y			*π*			*s*			*l*		
Shock to		V*s*	*s*	*ml*	*vs*	*s*	*ml*	*vs*	*s*	*ml*	*vs*	*s*	*ml*
e	0	5	1	2	5	2	2	5	3	5	5	4	5
	+	0	1	1	0	1	0	0	0	0	0	1	0
	−	0	0	0	0	3	3	0	2	3	0	0	0
f	0	5	3	3	5	1	1	5	2	1	5	4	5
	+	0	2	2	0	1	1	0	1	1	0	1	0

		m			*e*			*f*		
Shock to		*vs*	*s*	*ml*	*vs*	*s*	*ml*	*vs*	*s*	*ml*
	−	3	3	0	4	2	2	1	1	1
y	0	1	1	5	1	1	2	3	4	4
	+	1	1	0	0	2	1	1	0	0
	−	1	1	1	2	1	0	1	3	3
π	0	1	3	2	1	1	2	2	0	0
	+	3	1	2	2	3	3	2	2	2
	−	2	0	1	2	0	0	3	2	2
s	0	0	2	2	1	1	2	1	3	3
	+	3	2	2	2	4	3	1	0	0
	−	2	1	0	0	0	0	3	2	2
l	0	2	2	3	2	1	1	2	2	2
	+	1	2	2	3	4	4	0	1	1
	−	0	0	0	3	2	1	1	0	0
m	0	0	0	1	0	2	3	2	4	3
	+	5	5	4	2	1	1	2	1	2
	−	0	1	1	0	0	0	2	2	2
e	0	5	2	2	0	0	0	2	1	1
	+	0	2	2	5	5	5	1	2	2
	−	0	2	2	0	1	1	0	0	0
f	0	5	1	1	5	1	1	0	0	0
	+	0	2	2	0	3	3	5	5	5

Notes: Panel A reports the median orthogonal impulse responses of the domestic variables (indexing the columns) to idiosyncratic domestic shocks (indexing the rows) for the US, Japan, the Euro area, the UK and Canada, over three forecast horizons, i.e. within quarter (impact), beyond one-quarter and within 3 years (short term), beyond 3 years (medium/long term). For example, the first row reports the effect of a disturbance to the US output on the US series. '+' denotes a positive (and significant at the 5% level) effect, a negative significant effect is denoted by '−' and a null or not significant effect is denoted by '0'. Hence, '0 + −' denotes that the shock has a zero (or not significant) within quarter impact on the given variable, positive short-term effects and negative medium to long-term effects. Panel B reports the number of regions (from 0 to 5) showing a negative, zero and positive response of each variable (in columns) to each domestic idiosyncratic shocks (in rows) for three forecasting horizons, i.e. within quarter (very short term, *vs*), beyond one-quarter and within 3 years (short term, *s*) and beyond 3 years (medium to long term, *ml*).

Second, a positive shock to (i.e. an appreciation of) the real exchange rate has a permanently negative effect on real output in the Euro area, Japan and only a temporary effect in the same direction in Canada, while the effect is permanently positive for the US and not significant for the UK. This latter finding shows that a decrease in competitiveness is going to affect negatively the countries that are more sensitive to international trade conditions (Euro area, Japan), possibly through a weakening of the external demand channel. In fact, the medium to long-run impact on the price level is negative for Japan, the Euro area and Canada. An opposite reaction can be found for the US economy, where the appreciation of the exchange rate increases both output and (in the short term) the price level. Moreover, with few exceptions, nominal interest rates tend to be unaffected, while the reaction of stock prices and nominal balances is mixed.

Third, a temporary increase in the *short-term rate* leads to a similar temporary increase in the long-term interest rate in all regions, consistently with standard interpretations of the transmission of shocks along the term structure based on the expectation theory.

Table 3. Foreign idiosyncratic orthogonal shocks effects

		Response of											
		y			*π*			*s*			*l*		
Shock to		*vs*	*s*	*ml*	*vs*	*s*	*ml*	*vs*	*s*	*ml*	*vs*	*s*	*ml*
	–	0.0	0.15	0.2	0.2	0.35	0.35	0.65	0.45	0.0	0.55	0.55	0.0
y	0	0.6	0.35	0.3	0.7	0.45	0.4	0.35	0.45	1	0.45	0.45	1
	+	0.4	0.5	0.5	0.1	0.2	0.25	0.0	0.1	0.0	0.0	0.0	0.0
	–	0.0	0.25	0.35	0.05	0.2	0.15	0.3	0.1	0.0	0.2	0.3	0.0
π	0	1	0.45	0.4	0.7	0.25	0.45	0.2	0.65	1	0.2	0.35	0.95
	+	0.0	0.3	0.25	0.25	0.55	0.4	0.5	0.25	0.0	0.6	0.35	0.05
	–	0.0	0.15	0.2	0.0	0.3	0.35	0.05	0.25	0.0	0.15	0.15	0.0
s	0	1	0.65	0.45	1	0.5	0.45	0.6	0.6	1	0.2	0.45	1
	+	0.0	0.2	0.35	0.0	0.2	0.2	0.35	0.15	0.0	0.65	0.4	0.0
	–	0.0	0.3	0.3	0.0	0.35	0.3	0.0	0.35	0.0	0.0	0.4	0.0
l	0	1	0.4	0.45	1	0.35	0.45	1	0.6	1	0.55	0.35	1
	+	0.0	0.3	0.25	0.0	0.3	0.25	0.0	0.05	0.0	0.45	0.25	0.0
	–	0.0	0.2	0.25	0.0	0.4	0.4	0.0	0.15	0.0	0.0	0.45	0.0
m	0	1	0.5	0.5	0.95	0.3	0.25	1	0.6	1	1	0.25	1
	+	0.0	0.3	0.25	0.05	0.3	0.35	0.0	0.25	0.0	0.0	0.3	0.0
	–	0.0	0.35	0.3	0.0	0.2	0.2	0.0	0.35	0.0	0.0	0.1	0.0
e	0	1	0.25	0.3	1	0.5	0.6	1	0.45	1	1	0.55	1
	+	0.0	0.4	0.4	0.0	0.3	0.2	0.0	0.2	0.0	0.0	0.35	0.0
	–	0.0	0.35	0.35	0.0	0.3	0.15	0.0	0.1	0.0	0.0	0.2	0.0
f	0	1	0.45	0.45	1	0.3	0.65	1	0.75	1	1	0.65	1
	+	0.0	0.25	0.25	0.0	0.4	0.2	0.0	0.15	0.0	0.0	0.15	0.0

		m			*e*			*f*		
Shock to		*vs*	*s*	*ml*	*vs*	*s*	*ml*	*vs*	*s*	*ml*
	–	0.25	0.15	0.1	0.35	0.2	0.15	0.2	0.2	0.15
y	0	0.25	0.35	0.45	0.25	0.35	0.5	0.6	0.5	0.55
	+	0.5	0.5	0.45	0.5	0.45	0.35	0.2	0.3	0.3
	–	0.5	0.3	0.25	0.35	0.3	0.3	0.1	0.1	0.1
π	0.0	0.2	0.45	0.55	0.25	0.3	0.5	0.45	0.6	0.55
	+	0.3	0.25	0.2	0.4	0.4	0.2	0.45	0.3	0.35
	–	0.4	0.35	0.35	0.35	0.5	0.45	0.3	0.15	0.1
s	0.0	0.25	0.4	0.45	1	0.35	0.45	0.3	0.5	0.5
	+	0.35	0.25	0.2	0.45	0.15	0.1	0.4	0.35	0.4
	–	0.3	0.25	0.2	0.4	0.3	0.4	0.25	0.25	0.25
l	0.0	0.3	0.45	0.55	0.3	0.4	0.35	0.4	0.35	0.3
	+	0.4	0.3	0.25	0.3	0.3	0.25	0.35	0.4	0.45
	–	0.3	0.5	0.4	0.45	0.45	0.45	0.3	0.2	0.2
m	0	0.45	0.1	0.2	0.2	0.25	0.3	0.5	0.5	0.45
	+	0.25	0.4	0.4	0.35	0.3	0.25	0.2	0.3	0.35
	–	0.0	0.1	0.15	0.45	0.6	0.65	0.25	0.35	0.35
e	0	1	0.5	0.45	0.5	0.2	0.2	0.3	0.15	0.15
	+	0.0	0.4	0.4	0.05	0.2	0.15	0.45	0.5	0.5
	–	0.0	0.2	0.15	0.0	0.3	0.35	0.1	0.1	0.1
f	0.0	1	0.55	0.6	1	0.4	0.35	0.65	0.45	0.45
	+	0.0	0.25	0.25	0.0	0.3	0.3	0.25	0.45	0.45

Notes: This table reports the proportion of negative (and statistically significant at the 5% level), zero and positive (and statistically significant) responses of each variable (in columns) in all five regions to all foreign idiosyncratic orthogonal shocks to the variables in rows (for a total of 20 impulse responses), over three forecasting horizons, i.e. within quarter (*vs*), beyond one-quarter and within 3 years (*s*) and beyond 3 years (*ml*). Hence, entry (1,1), 0, indicates that within one-quarter in no region a positive foreign output shock led to a contraction in domestic real activity. Moreover, according to entries (2,1) and (3,1), 60% of the within quarter reactions have been null and the remaining 40% turned out positive.

Consistent with standard economic assumptions, the restrictive monetary policy also exercises a negative impact on output (significant for the Euro area, the UK and Canada only) and stock prices (apart from the UK), leading to a real appreciation of the exchange rate in all regions. Finally, the impact of the shock on the price level and on nominal money balances is less clear-cut, with some evidence of price and liquidity puzzles.[20] Similar effects concerning the impact on the exchange rate and stock prices can be found for the *long-term rate* shock, while the impact on the other variables is less clear-cut.

Fourth, a positive shock to real *stock prices* has a (significant) positive impact on real output only for the US (in the short-run), Canada and the Euro area, pointing to significant wealth effects. Finally, while results for the price level and money balances are mixed, an appreciation of the real exchange rate is found for the US, the Euro area and the UK, possibly reflecting second-round effects related to capital inflows.

Finally, concerning the impact of idiosyncratic *inflation* and *money balance* shocks, interesting similarities can be found across the G-7 countries, with the inflation shock yielding a positive and permanent impact on the price level in all regions and a significant expansion in real output only in the US, the Euro area and the UK, while the money balance shock leads to nonsignificant effects on real stock prices in all regions (apart from the Euro area). Moreover, while for the Euro area and the UK an increase in the price level and in the short- and long-term interest rates and a decline in real output can be found, for Japan and the US no significant impacts are found. Differently, for more mixed results can be found for Canada.

Therefore, from the above specific findings and the overall picture reported in Table 3, some broad conclusions on the existence of commonalities in the transmission mechanism of domestic shocks can be drawn. First, the output shock, which can be interpreted in terms of a domestic productivity shock in the light of the (short term) negative correlation with the price level, triggers a broadly similar monetary policy reaction in the short-term in several countries, with the short-term rate showing some accommodation and the long-term rate and the stock market mostly unaffected. Also the real exchange rate tends to depreciate. Second, an 'exchange rate channel' seems to be effective to stimulate the domestic economy through an external demand effect, as a real depreciation tends to have a positive short-term impact on output, prices and the stock market, with interest rates mostly unaffected. The output effect seems to be stronger for the regions for which international trade is more important, such as the Euro area and Japan. Third, evidence of a transmission mechanism for interest rate shocks, working through the term structure of interest rates (in a manner broadly consistent with the expectation theory), is found in all regions in the short term. Moreover, a short-term rate increase in general leads to a contraction in the output level, while the exchange rate tends to appreciate over the short- and the medium- to long-term horizons and the stock market falls, particularly in the very short term.

The impulse responses to other idiosyncratic disturbances yield more mixed results, with clear-cut evidence available only for some of the variables under study. Yet, although differences in the transmission mechanism of domestic shocks can then be observed across regions, the latter mostly concern the nominal shocks, which, according to the forecast error variance decomposition results, only explain a small proportion of the overall macro-economic variability.[21]

The effects of idiosyncratic foreign shocks. Tables 3 and 4 show, for each region, the effects of idiosyncratic foreign shocks on the domestic endogenous variables over the three forecasting horizons used above (i.e. within the quarter – very short term, beyond one-quarter and within 3 years – short term and beyond 3 years – medium to long-term).[22] Table 3 reports the proportion of negative (and statistically significant at the 5% level), zero and positive (and statistically significant) responses of each variable (in columns) in each region

[20] The finding of price and liquidity puzzles, given the large information set employed in the modelling, is quite surprising. The above puzzles are in fact usually related to misspecification of the information set and, for instance, the inclusion of commodity prices tends to lessen the problem. Yet, the evidence is coherent with previous results of Dees *et al*. (2007), where an even larger information set is used.

[21] The robustness analysis, carried out by comparing the orthogonal impulse responses with the generalized impulse responses (Pesaran and Shin, 1998), in general, supports the above findings, particularly for the real output shock and the real effective exchange rate shock. In fact, the comparison allows to strengthen the interpretation of the former shock in terms of a productivity disturbance, since a negative correlation between real output and prices is found in all regions, apart from the Euro area. Moreover, the negative correlation between the exchange rate and output developments is also a robust finding, as well as the transmission of interest rate shocks along the term structure and the effects of short-term rate shocks on real output (with the only exception of the UK). Detailed results are available upon request from the authors.

[22] For reasons of space, plots are not reported. They are, however, available upon request from the authors.

Table 4. Effects of foreign idiosyncratic orthogonal shocks

		Response of											
		y			π			*s*			*l*		
Region		*vs*	*s*	*ml*	*vs*	*s*	*ml*	*vs*	*s*	*ml*	*vs*	*s*	*ml*
	−	0.0	0.29	0.32	0.0	0.14	0.18	0.11	0.11	0.0	0.11	0.32	0.0
US	0	1	0.32	0.25	1	0.64	0.57	0.82	0.71	1	0.68	0.43	1
	+	0.0	0.39	0.43	0.0	0.22	0.25	0.07	0.18	0.0	0.21	0.25	0.0
	−	0.0	0.29	0.32	0.07	0.43	0.36	0.21	0.46	0.0	0.18	0.46	0.0
JA	0	1	0.46	0.43	0.89	0.32	0.43	0.68	0.32	1	0.68	0.29	1
	+	0.0	0.25	0.25	0.04	0.25	0.21	0.11	0.22	0.0	0.14	0.25	0.0
	−	0.0	0.18	0.14	0.04	0.29	0.29	0.11	0.29	0.0	0.11	0.32	0.0
EA	0	0.92	0.53	0.57	0.92	0.32	0.47	0.85	0.42	1	0.64	0.32	1
	+	0.08	0.29	0.29	0.04	0.39	0.24	0.04	0.29	0.0	0.25	0.36	0.0
	−	0.0	0.21	0.21	0.07	0.25	0.14	0.18	0.18	0.0	0.11	0.14	0.0
UK	0	0.93	0.29	0.43	0.82	0.36	0.57	0.68	0.71	1	0.64	0.72	1
	+	0.07	0.50	0.36	0.11	0.39	0.29	0.14	0.11	0.0	0.25	0.14	0.0
	−	0.0	0.29	0.32	0.0	0.36	0.32	0.11	0.21	0.0	0.11	0.29	0.0
CA	0	0.89	0.42	0.39	0.89	0.36	0.39	0.75	0.68	1	0.58	0.42	1
	+	0.11	0.29	0.29	0.11	0.28	0.29	0.14	0.11	0.0	0.31	0.29	0.0

		m			*e*			*f*			TOT		
Region		*vs*	*s*	*ml*	*vs*	*s*	*ml*	*vs*	*s*	*ml*	*vs*	*s*	*ml*
	−	0.11	0.11	0.14	0.36	0.42	0.42	0.11	0.18	0.11	0.11	0.24	0.12
US	0	0.68	0.50	0.61	0.43	0.29	0.29	0.46	0.46	0.54	0.73	0.48	0.66
	+	0.21	0.29	0.25	0.21	0.29	0.29	0.43	0.36	0.36	0.16	0.28	0.22
	−	0.18	0.21	0.21	0.32	0.43	0.43	0.32	0.29	0.32	0.18	0.37	0.25
JA	0	0.50	0.36	0.36	0.29	0.32	0.50	0.46	0.50	0.47	0.65	0.37	0.57
	+	0.32	0.43	0.43	0.39	0.25	0.07	0.22	0.21	0.21	0.17	0.26	0.18
	−	0.25	0.29	0.25	0.29	0.39	0.36	0.14	0.11	0.11	0.12	0.27	0.20
EA	0	0.57	0.39	0.50	0.50	0.25	0.28	0.54	0.43	0.43	0.72	0.38	0.57
	+	0.18	0.32	0.25	0.21	0.36	0.36	0.32	0.47	0.47	0.16	0.35	0.23
	−	0.25	0.25	0.21	0.28	0.33	0.25	0.21	0.25	0.21	0.16	0.23	0.15
UK	0	0.64	0.39	0.43	0.36	0.39	0.61	0.61	0.46	0.50	0.67	0.47	0.65
	+	0.11	0.36	0.36	0.36	0.28	0.14	0.18	0.29	0.29	0.17	0.30	0.20
	−	0.32	0.36	0.29	0.36	0.29	0.43	0.10	0.21	0.21	0.14	0.29	0.22
CA	0	0.36	0.43	0.50	0.39	0.46	0.29	0.54	0.25	0.25	0.63	0.43	0.49
	+	0.32	0.21	0.21	0.25	0.25	0.29	0.36	0.54	0.54	0.23	0.28	0.23

Notes: This table reports the proportion of negative (and statistically significant at the 5% level), zero and positive (and statistically significant) responses of each variable (in columns) in each region (in rows), to the idiosyncratic orthogonal disturbances to all (28) foreign variables, over three forecasting horizons, i.e. within quarter (*vs*), beyond one-quarter and within 3 years (*s*) and beyond 3 years (*ml*). The last three columns ('TOT') report the same proportions referred to the responses of all variables in each region to all foreign shocks (for a total of 196 impulse responses).

(in rows), to (positive) idiosyncratic orthogonal disturbances to all foreign variables, for a total of 28 impulse responses for each cell. The last three columns of the panel ('TOT') report the same proportions referred to the responses of all variables in each region to all foreign shocks (for a total of 196 impulse responses). To summarize information for the whole of the regions considered, Table 3 displays the proportion of negative (and significant), zero and positive (and significant) responses of each variable (in columns) in all five regions to all foreign idiosyncratic orthogonal (positive) shocks to the variables in rows (for a total of 20 impulse responses for each cell), over the same three forecasting horizons.

A general impression about the overall importance of spillovers of foreign disturbances on the domestic economies can be gathered by looking at the last three columns of Table 4 at the medium to long-run horizon, the response of domestic variables to foreign shocks of all sources is (statistically) zero in about 70% of the cases for the US and the UK, whereas for Japan and the Euro area the fraction is about 60%; Canada displays the stronger long-run reaction, with only about 50% of zero responses. Yet, it is difficult to determine clear-cut patters of response of domestic variables to foreign shocks, since in general the fractions of positive and negative reactions to foreign shocks are similar. However, it is possible to note that, in general, for all the regions, apart from Canada, the variable showing the strongest reactivity to foreign shocks is the real exchange rate. Inflation and the money supply also show a strong reactivity to foreign shocks in all countries, with the exception of the US. In US, as in the UK, real output shows a fairly high proportion of significant responses. While the stock market is the variable which shows the strongest reactivity for Canada, for all other regions it does not appear to be strongly affected by foreign shocks. Finally, in all regions domestic interest rates do not show any significant reaction in the long-run to any foreign disturbance; moreover, especially in the US, the UK and Canada, the short-term rate (firmly controlled by the monetary policymaker) does not react even over the one-quarter 3-year horizon.

Additional information on the spillover effects of specific foreign disturbances are provided by Table 4. First, a positive foreign output shock is more likely to affect positively domestic output (50% of the times in the short- and medium- to long-term horizons) than leaving it unaffected or negatively affected. As shown by the reaction of the nominal interest rates and money balances, the foreign output shock is in general accommodated over the intermediate horizon, with nominal interest rates being more likely to decrease or remain unchanged and the money supply to increase or remain unchanged. Finally, the evidence points to a likely transitory appreciation of the real exchange rate, while the domestic stock market is largely unaffected by the shock.

Second, a positive foreign inflation shock leaves domestic output in general unaffected in the short term; also domestic inflation is in general not affected within one-quarter, but positively affected within 3 years, with the effect fading away at the longer horizon. In general, the monetary policy response is not accommodating, with nominal interest rates increasing on impact and the money supply contracting, albeit only transitory. Finally, the real exchange rate tends to appreciate in the short term only, while the stock market is likely to remain unaffected over the intermediate and longer horizons.

Third, a positive foreign short-term interest rate shock is likely to leave the domestic real output, the price level and the short-term interest rate unaffected at all horizons. On the other hand, the long-term rate shows a temporary increase (leading to a temporary steepening of the slope of the yield curve), which disappears in the longer run. Broadly similar effects are detected for the responses of domestic variables to a foreign disturbance to the long-term interest rate.

Furthermore, a positive foreign nominal money shock is likely to leave domestic output, real stock prices and the short-term interest rate unaffected at all forecasting horizons, whereas the long-term interest rate shows a temporary decrease in the short term. In the long run, domestic money supply is more likely to be unaffected and the real exchange rate to depreciate.

A positive foreign exchange rate shock is likely to leave the domestic price level, the short- and long-term rates and the money supply unaffected at all horizons and to cause a permanent depreciation of the domestic exchange rate, with positive effects on domestic output and the stock market.

Finally, a positive foreign stock market shock is likely to leave unaffected interest rates and money balances at all horizons and the domestic price level in the long-run, whereas the domestic stock market is as likely to show an expansion as to remain unchanged in the long term and ambiguous effects are found on output and the real exchange rate.[23]

IV. Conclusions

What are the sources of macroeconomic comovement among countries? The answer provided by this article is that both common shocks and common transmission mechanisms explain comovements of macroeconomic variables for the US, Japan, the Euro area, the UK and Canada over the 1980 to 2005 period. These are investigated by means of an F-VAR model, allowing for the identification of structural global and idiosyncratic (i.e. region-specific) disturbances and forecast error variance decomposition and impulse response analyses. Several results stand out.

There is clear evidence of four global factors, driving real output growth, oil price growth, real

[23] In general, the analysis of the generalized impulse responses support the results obtained from the orthogonalized shocks, particularly as far as the foreign output shocks (apart from the effects on the exchange rate at the within quarter horizon), the foreign inflation shock (except for the effects on the domestic stock market in the long term), the foreign stock market shock (apart from the effects on the stock market). On the other hand, less robust results are found for the nominal money balance and interest rate shocks. Finally, the findings are in general robust also across countries, apart from Japan, for which, when the generalized shocks are employed, no reaction to foreign shocks is found in the short term.

stock market returns and the block of nominal variables (money growth, inflation and interest rates) in all regions. The forecast error variance decomposition shows that global shocks play a very important role in explaining international macroeconomic comovements, almost entirely attributable to the output growth and inflation factors, broadly interpreted as reflecting demand-side and supply-side forces, respectively. Yet, the existence and relevance of global shocks are only necessary but not sufficient conditions for generating widespread comovements, given that without a common transmission mechanism the initial impulses provided by the global shocks would not be similarly transmitted across countries over time. The impulse response analysis yields evidence of broadly similar transmission mechanisms of global disturbances, particularly in the US, the UK, Canada and the Euro area, while the more idiosyncratic behaviour of Japan can be attributed to this country's much different macroeconomic framework, especially in the 1990s.

Yet, global shocks and the associated transmission mechanisms may not be the only determinants of similarities of macroeconomic fluctuations across countries. Actually, the impulse response analysis detects various similarities across regions in the reaction to domestic shocks. For instance, a domestic productivity shock triggers a broadly similar monetary policy reaction in the short term in several countries. Moreover, an 'exchange rate channel' seems to be effective to stimulate the domestic economy through an external demand effect. In addition, evidence of transmission mechanism for interest rate shocks, working through the term structure of interest rates (in a manner broadly consistent with the expectation theory), is found in all regions in the short term. Differently, spillover effects of foreign idiosyncratic disturbances, though not negligible, seem to be a less important factor than the common transmission of global or domestic shocks in the determination of macroeconomic comovements.

Albeit our empirical results are conditional on a specific identification strategy, the robustness analysis, carried out by means of generalized impulse response functions, fully supports the findings of this article.

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