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Abstract

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 paper 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 macroeconomic comovements.

Keywords: business cycle comovement, factor vector autoregressive model, transmission mechanisms.

JEL classification: C32, E32.

1 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 macroeconomic fluctuations only if similar transmission mechanisms are at work. Several papers 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, Otrok and Whiteman (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 decreased with respect to the "common shocks" years (1973-1985).[1] Several explanations have been suggested for the above findings, such as a decrease in the prominence of common shocks, structural change in the composition of output, improved inventory management and financial developments, as well as better macroeconomic policies (Stock and Watson, 2003). 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 behavior 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 than to the size of global shocks. 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 euro-zone countries, and to a reduction in the coordination between the two groups.[2]

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[1] See also Doyle and Faust (2002), Heathcote and Perri (2002), Helbling and Bayoumi (2003) and Monfort, Renne, Rufle and Vitale (2003), for evidence of a reduction in G-7 business cycle syncronization over the most recent period.

[2] Kose, Otrok and Whiteman (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. Moreover, Stock and Watson (2005b) point to the existence of a common euro zone factor for the 1984-2003 period. Finally, Bagliano and Morana (2006b) have found that regional similarities seems to characterize more the real side of the economy than the nominal side.

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, Otrok and Whiteman, 2005). Moreover, also 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, Otrok and Whiteman, 2005). Similarly, Bagliano and Morana (2006b) 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. Interestingly, the relative importance of demand and supply shocks would not be the same among G-7 countries. For instance, Bagliano and Morana (2006b) found that the global demand and supply shocks tend to provide a similar contribution to output fluctuations for Canada and the US and in the long term only for the euro area, while the aggregate supply shock has a dominant role for all other real and nominal variables in all economies.[3] 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 (2006b) and Canova and de Nicolò (2003), while the more idiosyncratic behavior found for Japan is fully coherent with the structural change associated with the long stagnation suffered from this latter country over the 1990s.[4]

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, Chauvet and Yu (2006) have found 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. Moreover, Pesaran, Schuermann and Weiner

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[3] Differently, Canova and de Nicolò (2003) found a dominant role of demand shocks for output fluctuations at all horizons for all countries, while supply shocks matter only for the US, France and the UK.

[4] Canova and de Nicolò (2003) actually point out that the synchronization of the G-7 business cycles is likely to depend more on similarities in the transmission mechanisms than on common sources of shocks.

(2004) and Dees, di Mauro, Pesaran and Smith (2005), 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 the light of the 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 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 the 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.[5]

Hence, the key advantage of the approach proposed in this paper is in the accurate estimation of domestic shocks, which is carried out conditionally on a large information sets composed of nominal and real variables for five regions: the US, Japan, the Euro-12 area, the UK and Canada. As discussed in detail below, the macroeconometric model (estimated over the 1980-2005 period) is composed of 39 equations: the first 35 refer to the seven endogenous variables (real output growth, inflation, the nominal short- and long-term interest rates, nominal money growth, real exchange rate returns, and real stock returns) for the five regions, and the latter 4 refer to the "global factors", driving comovements across countries. In this multi-country, large scale macroeconometric model the role of common transmission mechanisms and of the international spillovers of domestic shocks has been further assessed by means of a new econometric approach, based on the Stock and Watson (2005a) Factor Vector Autoregressive Approach (F-VAR). The proposed approach modifies the Stock-Watson F-VAR model in order to allow

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[5] While the Pesaran, Schuermann and Weiner (2004) and Dees, di Mauro, Pesaran and Smith (2005) framework allows for a thorough investigation of the effects of domestic and foreign idiosyncratic shocks, the methodology has not been employed with this aim so far. The idiosyncratic shock analysis has in fact been limited to the investigation of the effects of few shocks, particularly related to US monetary policy. On the other hand, in the original Stock and Watson (2005a) framework a distinction between foreign and idiosyncratic shocks is not allowed for.

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 the paper 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 paper is organized as follows. In section two the econometric methodology is introduced, while in section three the data and their persistence properties are discussed. The empirical results are presented and discussed in section four; section five summarizes our main conclusions.

2 Econometric methodology

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

$$\begin{aligned} X_t &= \Lambda F_t + D(L)X_{t-1} + v_t & (1) \\ F_t &= \Phi(L)F_{t-1} + \eta_t, & (2) \end{aligned}$$

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 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 $E\left[\eta_{jt}v_{is}\right] = 0$ 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.

$$D(L) = \left[\begin{array}{ccc} \delta_{1,1}(L) & ... & \delta_{1,n}(L) \\ \vdots & \ddots & \vdots \\ \delta_{n,1}(L) & \dots & \delta_{n,n}(L) \end{array} \right], \Phi(L) = \left[\begin{array}{ccc} \phi_{r,r}(L) & ... & \phi_{1,r}(L) \\ \vdots & \ddots & \vdots \\ \phi_{r,1}(L) & \dots & \phi_{r,r}(L) \end{array} \right]$$

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

$$\left[\begin{array}{c} F_t \\ X_t \end{array} \right] = \left[\begin{array}{cc} \Phi(L) & 0 \\ \Lambda\Phi(L) & D(L) \end{array} \right] \left[\begin{array}{c} F_{t-1} \\ X_{t-1} \end{array} \right] + \left[\begin{array}{c} \varepsilon_{F_t} \\ \varepsilon_{X_t} \end{array} \right], \tag{3}$$

where

$$\left[\begin{array}{c} \varepsilon_{F_t} \\ \varepsilon_{X_t} \end{array} \right] = \left[\begin{array}{c} I \\ \Lambda \end{array} \right] \eta_t + \left[\begin{array}{c} 0 \\ v_t \end{array} \right],$$

with variance covariance matrix

$$E\varepsilon_t\varepsilon_t' = \Sigma_\varepsilon = \left[\begin{array}{cc} \Sigma_\eta{}' & \Sigma_\eta{}'\Lambda' \\ \Lambda\Sigma_\eta{}' & \Lambda\Sigma_\eta{}'\Lambda' + \Sigma_v \end{array} \right],$$

where $E\eta_t\eta_t' = \Sigma_\eta$ and $Ev_tv_t' = \Sigma_v$. The inversion of the FVAR form yields the vector moving average form (VMA) 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

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

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 OLS from (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 (2). Finally, by also employing the final estimates of Λ and $D(L)$, the restricted VAR coefficients in (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 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 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 the economic interpretation of the factors easier, and is applied in each step of the iteration process described above.

2.1 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 $E\left[\xi_t \xi_t'\right] = I_r$, and hence $H\Sigma_\eta H' = I_r$. The vector moving average (VMA) representation of the dynamic factor model in structural form can then be written as

$$X_t = B^*(L)\xi_t + C(L)v_t, \tag{4}$$

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 $E\left[\eta_t\eta_t'\right] = H^{-1}\Sigma_\eta \left(H^{-1}\right)' = I$, and hence $\hat{H}^{-1} = chol(\hat{\Sigma}_\eta)$.[6]

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 shochs, the VMA representation of the dynamic factor model in (4) can be written as

$$X_t = B^*(L)\eta_t + C^*(L)\psi_t, \tag{5}$$

where $C^*(L) = C(L)\Theta^{-1}$, and $\psi_t = \Theta v_t$, with Θ an $n \times n$ invertible matrix; moreover, $E\left[\psi_t\psi_t'\right] = I$ and $E\left[\psi_{i,t}\xi_{j,t}'\right] = 0$ 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 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).

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

Moreover, we impose a lower triangular structure also on each block on the main diagonal of C_0^* , i.e. (for $j = 1, ...r$)

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

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, $\hat{\Theta}^{-1} = chol(\hat{\Sigma}_v)$.

The identification scheme performed allows for exact identification of the 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 FVAR 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 Bai (2002, 2003) and Bai and Ng (2004), allowing for an accurate estimation of the factors in the current framework.[7] Moreover, differently from the F-VAR approach of Favero,

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[7] 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 heteroschedasticity in both their time-series and cross-sectional dimensions. In Bai (2002) consistency

Marcellino and Neglia (2005) and Bernanke, Boivin and Eliasz (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, Schuermann and Weiner (2004) and Dees, di Mauro, Pesaran and Smith (2006) 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, Schuermann and Weiner (2004) the interpretation is less straightforward.[8] Finally, while in our approach the weighting in the construction of the common factors is chosen optimally (by using principal components analysis), in Pesaran, Schuermann and Weiner (2004) the weighting is somewhat arbitrary, albeit based on sound economic justifications.

3 Data and persistence properties

Quarterly data for five countries or regions (the US, Japan, the Euro-12 Area, the UK, and Canada), have been employed over the period 1980:1-2005:2. 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[9] and the nominal short and long term interest rates (on three-month government bills and ten-

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and asymptotic normality is derived in the case of I(1) unobserved factors and I(0) idiosyncratic components, also allowing for heteroschedasticity 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 (2006b) support this conclusion.

[8] In fact, what is denoted as global factor in Pesaran, Schuermann and Weiner (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.

[9] 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 one usually employed to measure broad money in each of the countries investigated.

year government bonds, respectively).[10] 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, Phillips, Schmidt and Shin, 1992) tests, also the Enders and Lee (2005) ADF test and a modified version of the KPSS test have 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 non linear 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. As far as the real variables are concerned, the ADF and KPSS tests yield consistent results, strongly pointing to stationarity. Only for real output growth for Japan the tests yield conflicting results, rejecting both the I(1) and I(0) null hypotheses. However, once a non linear deterministic component is included in the KPSS auxiliary equation to account for the slowdown in economic growth due to the Japanese stagnation of the 1990s, the null of I(0) stationarity cannot be rejected any longer also for this latter country.

On the other hand, results are mixed for the nominal variables, albeit there are good reasons to model also this latter variables as weakly stationary (around a non linear deterministic trend). In fact, for nominal money growth and inflation, the null of I(1) non stationarity can always be rejected when the non linear trend is accounted for, with the exception of nominal money growth for Japan. Yet, while the null of I(0) stationarity is never rejected for money growth at the 1% level, for the inflation rate rejections of stationarity are found for the US, Japan and the euro area. Moreover, for the nominal interest rates series the results are inconclusive, since in general the ADF tests never point to the rejection of the null of I(1) non stationarity, while

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

the KPSS tests never point to the rejection of I(0) stationarity.[11],[12]

Yet, the above mixed results can be explained in the light of two features which can be expected to characterize the nominal variables, i.e. structural change and long memory. First, as argued in Bierens (2000) and Morana (2006a), a non linear deterministic trend should be expected in the nominal variables, determined by successful long-run monetary policy management. In fact, the outcome of monetary policy decisions should shape the trend behavior of the nominal variables, and the latter should be better understood in terms of a deterministic rather than a stochastic process.[13] Second, many studies have already documented the presence of long memory in nominal macroeconomic variables such as inflation, nominal money growth, and nominal interest rates (see for instance Morana 2006a, for the euro area and Bagliano and Morana, 2006a, for the US, and the reference therein). The joint presence of long memory and structural change may then explain the non rejection of the unit root hypothesis for the interest rate series, as well as the rejection of the I(0) null for the inflation rates. Given the short sample available for the analysis carried out in this study, only indirect modelling of the long memory properties of the data, using the autoregressive representation of a fractional autoregressive moving average process (ARFIMA), is undertaken. Yet, structural change may be explicitly accounted for. Therefore, 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).[14]

4 Empirical results

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.

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[11] Yet, the ADF test points to the rejection of the unit root hypothesis for the US long term interest rates, while for Canada the evidence is more mixed.

[12] See the Table in the Appendix for a detailed description of the findings.

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

[14] Hence, the deterministic component included in the ith equation of (1) is specified as $\mu_{i,t} = \mu_{i,0} + \mu_{i,1}t + \mu_{i,2}\sin(2\pi t/T) + \mu_{i,3}\cos(2\pi t/T)$.

4.1 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.

Table 1, Panel A reports then, for each group of real variables, the proportion of the total variance of the series attributable to each principal component (PC_i), followed by the fraction of the variance of each individual variable explained by each PC_i. As far as the output series (g) are concerned, the global factor (PC_1) explains about 40% of total variability, also accounting for 66% of US output variability and 56% of output variability 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 case a single global factor explains a large proportion (about 60%) of total variability and the bulk of the variability of 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%).[15] 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.[16] 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 non-negligible 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 variability explained by the first principal component is equal to 56% for Japan and 74%

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[15] See also Ehrmann, Fratzscher and Rigobon (2005) for additional evidence in favour of the interpretation of US macroeconomic shocks in terms of global shocks.

[16] The real exchange rate changes (e) display litle evidence of comovements: the fraction of the overall variance attributable to PC_1 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.

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%).[17],[18] To explore in more depth the comovements in the inflation, money growth and interest rate series, Table 1, Panel B shows the results of the PC analysis applied to the whole set of the π, s, l, and m series, reporting the proportion of the variance attributable to the first ten PC_i. There is clear evidence of a global factor driving all nominal variables: in fact, PC_1 explains about 65% of total variance, and, 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 the 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 2.[19]

4.2 The F-VAR model

On the basis of misspecification tests, the lag length of the F-VAR is set equal to one.[20] 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, 4 on lagged endogenous factors, i.e. the oil price factor, the output growth factor, the stock returns factor, and the inflation factor, and 4 on the deterministic trend components). The remaining 4 equations refer to the global factors and contain 8 parameters each (4 on lagged endogenous factors, and 4 on the deterministic trend components). The estimation period is 1980:1-2005:2. The F-VAR model has been

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[17] The more idiosyncratic behavior 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.

[18] See the Appendix for details of PCA for sub-set of nominal variables.

[19] More detailed results of the first step of the analysis are reported in Bagliano and Morana (2006b).

[20] Evidence of serial correlation at the 1% level is detected only for the UK and US output growth rates 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.

estimated following the iterative procedure described in the methodological section.

4.3 Forecast error variance decomposition

Since, on the basis of previous evidence in the literature (Bierens, 2000; Morana, 2006a), the non-linear 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 (2006b), 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 2 reports, for each endogenous variable, the median forecast error variance decomposition at the one-quarter and five-year horizons, obtained from the structural VMA representation of the four-factor $F-VAR$ model in (5).[21] Some commonalities are found among the regions under study. In particular, two key results can be noted.

First, in all regions, global disturbances explain the bulk of variability for the nominal variables at all forecasting horizons. The percentage of the forecast error variance attributable to the global shocks for those series (inflation, interest rates, and money growth) is in fact in the range 92%-100% at the five-year horizon, with the exception of the euro-area money growth figure (55%), and in the 86%-99% range at the one-quarter horizon, with the exception of the euro-area inflation figure (15%). Instead, the real variables yield more mixed results. In fact, while for real output growth the global

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[21] 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 five-year period horizons have been reported in the tables. A full set of results is available from the authors upon request.

shocks tend to dominate at the five-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%), 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, it is possible to note that 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 the global demand (output) and supply shocks have similar effects at all horizons for the US and Canada (24%-25% and 16%-34% for the demand-side and supply-side disturbances, respectively), but 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. A similar finding holds for the real exchange rate series, albeit the importance of the non-own idiosyncratic disturbances (i.e. region-specific shocks to variables other than the exchange rate) is more noticeable. Hence, also idiosyncratic shocks spillovers may be expected for the 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, Otrok and Whiteman (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 (2006b) 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.

4.4 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. Firstly, 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 behavior 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 interet 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.[22]

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[22] See Bagliano and Morana (2006b) for additional details.

4.4.1 The effects of idiosyncratic domestic shocks

The results of the impulse response analysis of the region-specific disturbances are shown in Table 3, Panels A and B.[23] 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 three years (short term) and beyond three 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".[24] To give a broad picture of the impulse response results, panel B of Table 5 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 three years (short term, s), and beyond three 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 again detected. Moreover, long rates are broadly unaffected in all regions at all horizons; the same conclusion holds for real stock prices, with the only notable exception of the UK, where a significant decline occurs at all horizons. A less clear-cut (always temporary) response is found for nominal money balances. Finally, the evidence points to a depreciation of the real exchange rate for the US and Japan at all horizons, whereas in the euro area the impact depreciation is followed by an appreciation at longer horizons.

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 an only temporary effect in the same direction in Canada, while the

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

[24] Standard errors have been computed by simulation. The statistical significance has been evaluated at the 5% level.

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, 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 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, and a negative impact on the price level for Japan, the euro area and Canada. The impact of this disturbance on the price level is not significant for the US and is positive for the UK. Finally, while results for 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.

Fourth, the idiosyncratic *inflation shock*, with a positive and permanent impact on the price level in all regions, leads to a significant expansion in real output only in the US, the euro area and the UK. The short and long term interest rates also tend to increase in the US, Japan and the UK. Differently, for Canada and the euro area, some accommodation of the shock is found. On the other hand, more mixed results can be found for nominal money balances and the stock market, being negatively affected in Japan, Canada and the UK only. Finally, all exchange rates tend to appreciate, apart from the euro.

Fifth, 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. The shock also impacts negatively on output in the euro area, the UK and Canada, while in general the impact is not significant in the US and Japan. Moreover, the impact on real stock prices is negative in all countries in the short term, apart from the UK, while the short term impact on the exchange rate is positive, with the real exchange rate appreciating 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.[25]

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[25] The finding of price and liquidity puzzles, given the large information set employed in the modelling, is quite surprising. Yet, the evidence is coherent with previous results of

Sixth, a temporary increase in the *long term rate* tends to affect the short term rate temporarily, although the response of this latter variable is not univocal across countries. Moreover, apart from the US and Canada, the impact on real stock prices is negative, while the impact on the exchange rate is positive, with the exception of Japan, whereas the effects of the shock on output, nominal balances and the price level tend to be less clear-cut.

Finally, an increase in *nominal money balances* leads to non significant effects on real stock prices in all regions, apart from the euro area. Moreover, while for the euro area and the UK the money balances shock leads to an increase in the price level and in the short and long term interest rates, and to a decline in real output, for Japan and the US no significant impact is found. Differently, for Canada the effects on the price level, real output, and the short term rate are positive, while the impact on the long term interest rate is negative. Finally, only for the euro area, the UK and Canada significant effects on the exchange rate are found, with an exchange rate depreciation in the euro area and Canada, and appreciation in the UK.

Therefore, from the above specific findings and the overall picture reported in Panel B of 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 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 vari-

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Dees, di Mauro, Pesaran and Smith (2005), where an even larger information set is used.

ables under study. For instance, as far as the long-term interest rate shock is concerned, the results point to an appreciation of the real exchange rate at all horizons, and to a contraction in real stock prices in the very short term. On the other hand, a positive nominal money balance shock leads to a temporary reduction in the short term rate. Furthermore, a positive real stock price disturbance in general has a negative impact on the price level, leading also to an appreciation of the exchange rate and to an interest rate accommodation. Finally, even less interpretable results are found for the inflation shock, with effects close to the one expected for a domestic negative non-oil supply shock. This latter disturbance could lead to an increase in production prices and, if not offset by a policy reaction, to a contraction in real output. The evidence points to an accommodation of the shock, with an increase in nominal money balances and a decrease of the long-term interest rate in the very short term, while real output expands, the real exchange rate tends to appreciate, and the stock market being in general negatively affected over the short and the medium to long term horizons.

Hence, although differences in the transmission mechanism of domestic shocks can be observed across regions, they mostly concern the nominal shocks, which, according to the forecast error variance decomposition results, only explain a small proportion of the overall macroeconomic variability.[26]

4.4.2 The effects of idiosyncratic foreign shocks

Table 4 shows, 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 three years -short term-, and beyond three years -medium to long term-).[27] Panel A 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 (positive)

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[26] The robustness analysis, carried our 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.

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

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, Panel B 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 Panel A of the table: at the medium to long run horizon, the response of domestic variables to foreign shocks of all sources is (statistically) zero some 66% of the cases for the US, and 65% for the UK, whereas for Japan and the euro area the fraction is 57% and Canada displays the stronger long run reaction, with only 49% 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 this latter country, 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-three year horizon.

Additional information on the spillover effects of specific foreign disturbances are provided by Panel B of 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 three years, with the effect dying down 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 transitorily. 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 tempoarary 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.[28]

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[28] 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.

5 Conclusions

What are the sources of macroeconomic comovement among countries? The answer provided by this paper 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 1980-2005 period. These are investigated by means of a factor vector autoregressive ($F-VAR$) 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 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 behavior 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. The $F-VAR$ methodology applied here allows to investigate differences and similarities among the transmission mechanisms of region-specific domestic shocks, and among the effects of spillovers of foreign idiosyncratic disturbances onto the domestic economies.

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, 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. Moreover, 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. 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. The 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.

On the other hand, the 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 paper.

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Table 1, Panel A

Principal components analysis on separate sub-sets of real variables

	PC_1	PC_2	PC_3	PC_4	PC_5		PC_1	PC_2	PC_3	PC_4	PC_5
g (all)	0.40	0.23	0.16	0.13	0.08	e (all)	0.37	0.24	0.21	0.18	0.01
g_{US}	0.66	0.07	0.06	0.00	0.21	e_{US}	0.76	0.04	0.18	0.01	0.02
g_{JA}	0.04	0.64	0.24	0.08	0.00	e_{JA}	0.31	0.30	0.13	0.24	0.01
g_{EA}	0.32	0.27	0.09	0.31	0.00	e_{EA}	0.58	0.28	0.06	0.06	0.02
g_{UK}	0.43	0.01	0.31	0.25	0.00	e_{UK}	0.04	0.54	0.23	0.19	0.00
g_{CA}	0.56	0.16	0.10	0.00	0.18	e_{CA}	0.15	0.03	0.43	0.39	0.00
f (all)	0.57	0.19	0.13	0.08	0.03	o (all)	0.95	0.02	0.02	0.01	0.00
f_{US}	0.82	0.02	0.07	0.00	0.09	o_{US}	0.96	0.03	0.00	0.00	0.01
f_{JA}	0.07	0.92	0.01	0.00	0.00	o_{JA}	0.93	0.01	0.05	0.00	0.00
f_{EA}	0.55	0.00	0.32	0.12	0.00	o_{EA}	0.96	0.02	0.01	0.02	0.00
f_{UK}	0.69	0.00	0.07	0.23	0.01	o_{UK}	0.95	0.01	0.02	0.01	0.00
f_{CA}	0.70	0.02	0.19	0.03	0.05	o_{CA}	0.96	0.03	0.00	0.00	0.01

Table 1, Panel B

Principal components analysis: inflation, interest rates and money growth as a group

	PC_1	PC_2	PC_3	PC_4	PC_5	PC_6	PC_7	PC_8	PC_9	PC_{10}
π, s, l, m (all)	0.65	0.08	0.04	0.04	0.04	0.03	0.02	0.02	0.02	0.01
π_{US}	0.45	0.11	0.18	0.04	0.06	0.01	0.01	0.00	0.06	0.06
π_{JA}	0.44	0.00	0.12	0.00	0.08	0.28	0.00	0.05	0.01	0.01
π_{EA}	0.71	0.01	0.00	0.17	0.01	0.02	0.00	0.00	0.00	0.02
π_{UK}	0.63	0.09	0.06	0.00	0.02	0.00	0.01	0.09	0.03	0.05
π_{CA}	0.62	0.04	0.00	0.12	0.02	0.04	0.01	0.00	0.04	0.01
s_{US}	0.83	0.00	0.01	0.01	0.04	0.04	0.00	0.00	0.00	0.01
s_{JA}	0.83	0.07	0.00	0.00	0.01	0.01	0.03	0.00	0.00	0.01
s_{EA}	0.83	0.10	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.00
s_{UK}	0.81	0.00	0.00	0.05	0.00	0.04	0.01	0.04	0.01	0.01
s_{CA}	0.91	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00
l_{US}	0.88	0.02	0.01	0.00	0.00	0.02	0.00	0.01	0.01	0.01
l_{JA}	0.90	0.05	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01
l_{EA}	0.96	0.10	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.00
l_{UK}	0.93	0.02	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00
l_{CA}	0.94	0.01	0.00	0.00	0.00	0.02	0.00	0.01	0.00	0.00
m_{US}	0.09	0.05	0.53	0.06	0.17	0.01	0.08	0.00	0.00	0.00
m_{JA}	0.47	0.08	0.10	0.15	0.01	0.00	0.07	0.01	0.06	0.00
m_{EA}	0.35	0.00	0.08	0.19	0.25	0.07	0.03	0.00	0.00	0.00
m_{UK}	0.47	0.21	0.05	0.05	0.00	0.00	0.03	0.09	0.07	0.01
m_{CA}	0.05	0.59	0.05	0.00	0.11	0.00	0.16	0.01	0.01	0.00

This table reports the results of the principal components (PC) analysis conducted on the 4 sub-sets of real variables and on the sub-set of all the nominal variables, each comprising the same variable for all the 5 regions. For each set the first row shows the fraction of the total variance explained by each PC_i ($i = 1, ...$); the subsequent five rows display the fraction of the variance of the individual series attributable to each PC_i. The PC analysis is carried out on the standardized variables.

Table 2

Variance decomposition based on the four-factor $F-VAR$

	Horizon (quarters)	Global shocks					Idiosyncratic shocks	
		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**
π_{EA}	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**

(continued)

(Table 2 continued)

	Horizon (quarters)	Global shocks					Idiosyncratic shocks	
		output	inflation	stock mkt.	oil price	**All**	own	**All**
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**
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**

This table reports for each endogenous variable the median forecast error variance decomposition at the one-quarter and five-year horizons obtained from the structural VMA representation of the four-factor $F-VAR$ model in (5) by Monte Carlo simulation as suggested in Granger and Jean (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).

Table 3

Panel A: median orthogonal impulse responses to domestic shocks

	Response of domestic variables:						
Idiosyncratic shock to:	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 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 three years (short term), beyond three years (medium/long term). For example, the first row reports the effect of a disturbance to the US output on the US series. "0" 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.

(Table 3, continued)

Panel B: domestic idiosyncratic orthogonal shocks effects

Shock to:		Response of: y			π			s			l		
		vs	s	ml	vs	s	ml	vs	s	ml	vs	s	ml
y	$-$	0	0	0	3	0	1	3	2	0	1	2	0
	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
π	$-$	0	0	0	0	0	0	2	0	0	2	2	0
	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
s	$-$	0	3	3	0	1	1	0	0	0	0	0	0
	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
l	$-$	0	2	2	0	1	1	0	1	0	0	0	0
	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
m	$-$	0	2	2	0	2	2	0	1	0	0	2	0
	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
e	$-$	0	3	2	0	2	3	0	2	0	0	0	0
	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
f	$-$	0	0	0	0	3	3	0	2	3	0	0	0
	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

Shock to:		Response of: m			e			f		
		vs	s	ml	vs	s	ml	vs	s	ml
y	$-$	3	3	0	4	2	2	1	1	1
	0	1	1	5	1	1	2	3	4	4
	$+$	1	1	0	0	2	1	1	0	0
π	$-$	1	1	1	2	1	0	1	3	3
	0	1	3	2	1	1	2	2	0	0
	$+$	3	1	2	2	3	3	2	2	2
s	$-$	2	0	1	2	0	0	3	2	2
	0	0	2	2	1	1	2	1	3	3
	$+$	3	2	2	2	4	3	1	0	0
l	$-$	2	1	0	0	0	0	3	2	2
	0	2	2	3	2	1	1	2	2	2
	$+$	1	2	2	3	4	4	0	1	1
m	$-$	0	0	0	3	2	1	1	0	0
	0	0	0	1	0	2	3	2	4	3
	$+$	5	5	4	2	1	1	2	1	2
e	$-$	0	1	1	0	0	0	2	2	2
	0	5	2	2	0	0	0	2	1	1
	$+$	0	2	2	5	5	5	1	2	2
f	$-$	0	2	2	0	1	1	0	0	0
	0	5	1	1	5	1	1	0	0	0
	$+$	0	2	2	0	3	3	5	5	5

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 three years (short term, *s*) and beyond three years (medium to long term, *ml*).

Table 4

Panel A: Effects of foreign idiosyncratic orthogonal shocks

Response of:

Region:		y			π			s			l		
		vs	s	ml	vs	s	ml	vs	s	ml	vs	s	ml
	−	.0	.29	.32	.0	.14	.18	.11	.11	.0	.11	.32	.0
US	0	1	.32	.25	1	.64	.57	.82	.71	1	.68	.43	1
	+	.0	.39	.43	.0	.22	.25	.07	.18	.0	.21	.25	.0
	−	.0	.29	.32	.07	.43	.36	.21	.46	.0	.18	.46	.0
JA	0	1	.46	.43	.89	.32	.43	.68	.32	1	.68	.29	1
	+	.0	.25	.25	.04	.25	.21	.11	.22	.0	.14	.25	.0
	−	.0	.18	.14	.04	.29	.29	.11	.29	.0	.11	.32	.0
EA	0	.92	.53	.57	.92	.32	.47	.85	.42	1	.64	.32	1
	+	.08	.29	.29	.04	.39	.24	.04	.29	.0	.25	.36	.0
	−	.0	.21	.21	.07	.25	.14	.18	.18	.0	.11	.14	.0
UK	0	.93	.29	.43	.82	.36	.57	.68	.71	1	.64	.72	1
	+	.07	.50	.36	.11	.39	.29	.14	.11	.0	.25	.14	.0
	−	.0	.29	.32	.0	.36	.32	.11	.21	.0	.11	.29	.0
CA	0	.89	.42	.39	.89	.36	.39	.75	.68	1	.58	.42	1
	+	.11	.29	.29	.11	.28	.29	.14	.11	.0	.31	.29	.0

Response of:

Region:		m			e			f			TOT		
		vs	s	ml	vs	s	ml	vs	s	ml	vs	s	ml
	−	.11	.11	.14	.36	.42	.42	.11	.18	.11	.11	.24	.12
US	0	.68	.50	.61	.43	.29	.29	.46	.46	.54	.73	.48	.66
	+	.21	.29	.25	.21	.29	.29	.43	.36	.36	.16	.28	.22
	−	.18	.21	.21	.32	.43	.43	.32	.29	.32	.18	.37	.25
JA	0	.50	.36	.36	.29	.32	.50	.46	.50	.47	.65	.37	.57
	+	.32	.43	.43	.39	.25	.07	.22	.21	.21	.17	.26	.18
	−	.25	.29	.25	.29	.39	.36	.14	.11	.11	.12	.27	.20
EA	0	.57	.39	.50	.50	.25	.28	.54	.43	.43	.72	.38	.57
	+	.18	.32	.25	.21	.36	.36	.32	.47	.47	.16	.35	.23
	−	.25	.25	.21	.28	.33	.25	.21	.25	.21	.16	.23	.15
UK	0	.64	.39	.43	.36	.39	.61	.61	.46	.50	.67	.47	.65
	+	.11	.36	.36	.36	.28	.14	.18	.29	.29	.17	.30	.20
	−	.32	.36	.29	.36	.29	.43	.10	.21	.21	.14	.29	.22
CA	0	.36	.43	.50	.39	.46	.29	.54	.25	.25	.63	.43	.49
	+	.32	.21	.21	.25	.25	.29	.36	.54	.54	.23	.28	.23

Panel A 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 three years (*s*), and beyond three 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).

(Table 4, continued)

Panel B: Foreign idiosyncratic orthogonal shocks effects

Response of:

Shock to:		y			π			s			l		
		vs	s	ml	vs	s	ml	vs	s	ml	vs	s	ml
	−	.0	.15	.2	.2	.35	.35	.65	.45	.0	.55	.55	.0
y	0	.6	.35	.3	.7	.45	.4	.35	.45	1	.45	.45	1
	+	.4	.5	.5	.1	.2	.25	.0	.1	.0	.0	.0	.0
	−	.0	.25	.35	.05	.2	.15	.3	.1	.0	.2	.3	.0
π	0	1	.45	.4	.7	.25	.45	.2	.65	1	.2	.35	.95
	+	.0	.3	.25	.25	.55	.4	.5	.25	.0	.6	.35	.05
	−	.0	.15	.2	.0	.3	.35	.05	.25	.0	.15	.15	.0
s	0	1	.65	.45	1	.5	.45	.6	.6	1	.2	.45	1
	+	.0	.2	.35	.0	.2	.2	.35	.15	.0	.65	.4	.0
	−	.0	.3	.3	.0	.35	.3	.0	.35	.0	.0	.4	.0
l	0	1	.4	.45	1	.35	.45	1	.6	1	.55	.35	1
	+	.0	.3	.25	.0	.3	.25	.0	.05	.0	.45	.25	.0
	−	.0	.2	.25	.0	.4	.4	.0	.15	.0	.0	.45	.0
m	0	1	.5	.5	.95	.3	.25	1	.6	1	1	.25	1
	+	.0	.3	.25	.05	.3	.35	.0	.25	.0	.0	.3	.0
	−	.0	.35	.3	.0	.2	.2	.0	.35	.0	.0	.1	.0
e	0	1	.25	.3	1	.5	.6	1	.45	1	1	.55	1
	+	.0	.4	.4	.0	.3	.2	.0	.2	.0	.0	.35	.0
	−	.0	.35	.35	.0	.3	.15	.0	.1	.0	.0	.2	.0
f	0	1	.45	.45	1	.3	.65	1	.75	1	1	.65	1
	+	.0	.25	.25	.0	.4	.2	.0	.15	.0	.0	.15	.0

Response of:

Shock to:		m			e			f		
		vs	s	ml	vs	s	ml	vs	s	ml
	−	.25	.15	.1	.35	.2	.15	.2	.2	.15
y	0	.25	.35	.45	.25	.35	.5	.6	.5	.55
	+	.5	.5	.45	.5	.45	.35	.2	.3	.3
	−	.5	.3	.25	.35	.3	.3	.1	.1	.1
π	.0	.2	.45	.55	.25	.3	.5	.45	.6	.55
	+	.3	.25	.2	.4	.4	.2	.45	.3	.35
	−	.4	.35	.35	.35	.5	.45	.3	.15	.1
s	.0	.25	.4	.45	1	.35	.45	.3	.5	.5
	+	.35	.25	.2	.45	.15	.1	.4	.35	.4
	−	.3	.25	.2	.4	.3	.4	.25	.25	.25
l	.0	.3	.45	.55	.3	.4	.35	.4	.35	.3
	+	.4	.3	.25	.3	.3	.25	.35	.4	.45
	−	.3	.5	.4	.45	.45	.45	.3	.2	.2
m	0	.45	.1	.2	.2	.25	.3	.5	.5	.45
	+	.25	.4	.4	.35	.3	.25	.2	.3	.35
	−	.0	.1	.15	.45	.6	.65	.25	.35	.35
e	0	1	.5	.45	.5	.2	.2	.3	.15	.15
	+	.0	.4	.4	.05	.2	.15	.45	.5	.5
	−	.0	.2	.15	.0	.3	.35	.1	.1	.1
f	.0	1	.55	.6	1	.4	.35	.65	.45	.45
	+	.0	.25	.25	.0	.3	.3	.25	.45	.45

Panel B 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 three years (*s*) and beyond three 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.

6 Appendix: further results

The findings below are summarized in sections 3 and 4 of the main text.

Table A1

Unit-root tests

	ADF_m	ADF_t	ADF_{nlt}	$KPSS_m$	$KPSS_t$	$KPSS_{nlt}$
g_{US}	-3.82**	-3.53**	-6.86**	0.12	0.08	0.07*
g_{JA}	-8.15**	-8.90**	-10.04**	0.87**	0.16*	0.04
g_{EA}	-8.02**	-8.18**	-8.01**	0.20	0.18	0.09**
g_{UK}	-6.49**	-6.49**	-6.48**	0.20	0.10	0.09**
g_{CA}	-5.96**	-5.93**	-5.46**	0.09	0.05	0.05
π_{US}	-8.07**	-8.60**	-7.68**	1.31**	0.17	0.08**
π_{JA}	-2.86	-3.52*	-8.79**	0.49*	0.14	0.12**
π_{EA}	-3.37*	-2.84	-7.55**	0.26	0.09	0.10**
π_{UK}	-3.45**	-3.37	-5.01**	0.86**	0.08	0.05
π_{CA}	-6.93**	-7.95**	-6.98**	0.44	0.10	0.04
s_{US}	-1.52	-2.92	-3.89	0.39	0.05	0.02
s_{JA}	-1.53	-2.37	-3.57	0.35	0.01	0.01
s_{EA}	-1.17	-2.36	-2.81	0.35	0.03	0.02
s_{UK}	-1.13	-2.04	-2.80	0.24	0.04	0.04
s_{CA}	-1.66	-4.27**	-2.90	0.19	0.03	0.03
l_{US}	-2.20	-4.26**	-5.80**	0.27	0.07	0.02
l_{JA}	-1.73	-2.06	-2.14	0.33	0.03	0.03
l_{EA}	-1.56	-3.16	-3.57	0.37	0.02	0.02
l_{UK}	-1.17	-2.79	-3.66	0.24	0.03	0.03
l_{CA}	-2.08	-4.88**	-4.91*	0.20	0.05	0.03
m_{US}	-5.39**	-5.45**	-7.72**	0.41	0.25**	0.07*
m_{JA}	-1.95	-3.02	-4.16	0.28	0.10	0.06
m_{EA}	-2.39	-2.15	-7.48**	0.35	0.13	0.04
m_{UK}	-2.35	-1.90	-6.06**	0.40	0.05	0.03
m_{CA}	-3.10*	-3.08	-8.07**	0.20	0.13	0.06
e_{US}	-8.30**	-8.26**	-8.88**	0.17	0.15	0.03
e_{JA}	-7.51**	-7.77**	-7.87**	0.21	0.03	0.03
e_{EA}	-6.98**	-6.93**	-7.50**	0.12	0.07	0.02
e_{UK}	-7.81**	-7.86**	-7.96**	0.05	0.04	0.03
e_{CA}	-6.95**	-6.97**	-7.51**	0.15	0.15*	0.04
f_{US}	-9.28**	-9.36**	-9.59**	0.10	0.08	0.04
f_{JA}	-11.49**	-11.67**	-12.54**	0.25	0.08	0.05
f_{EA}	-6.35**	-6.46**	-6.55**	0.08	0.05	0.05
f_{UK}	-10.61**	-10.83**	-11.26**	0.18	0.04	0.04
f_{CA}	-8.93**	-8.88**	-8.96**	0.06	0.03	0.03
o_{US}	-7.89**	-7.96**	-8.79**	0.32	0.03	0.02
o_{JA}	-7.48**	-7.84**	-8.41**	0.30	0.04	0.03
o_{EA}	-7.38**	-7.96**	-8.54**	0.22	0.05	0.03
o_{UK}	-7.96**	-7.43**	-8.74**	0.23	0.04	0.03
o_{CA}	-8.13**	-8.14**	-9.04**	0.31	0.03	0.02

The first (last) three numeric columns report the ADF (KPSS) tests for three specifications of the deterministic trend: a constant (ADF_m and $KPSS_m$), a constant plus a linear trend ((ADF_t and $KPSS_t$), and a constant plus a non linear trend (Enders and Lee, 2005) (ADF_{nlt} and $KPSS_{nlt}$). For the ADF tests critical values are -2.89 (-3.50), -3.46 (-4.06), and -4.35 (-4.95), for the 5% (1%) significance level. The corresponding values for the $KPSS$ tests are 0.46 (0.73) , 0.15 (0.22), and 0.06 (0.08). Critical values for the $KPSS_{nlt}$ test have been tabulated by means of Monte Carlo simulations with 10.000 replications.

* and ** denote significance at the 5% and 1% level respectively. Definitions of the series are given in the text.

Table A2

Principal components analysis on separate sub-sets of nominal variables

	PC_1	PC_2	PC_3	PC_4	PC_5		PC_1	PC_2	PC_3	PC_4	PC_5
π (all)	0.70	0.11	0.08	0.06	0.04	m (all)	0.49	0.20	0.14	0.12	0.06
π_{US}	0.72	0.00	0.18	0.08	0.02	m_{US}	0.28	0.40	0.25	0.07	0.00
π_{JA}	0.56	0.36	0.06	0.00	0.01	m_{JA}	0.70	0.00	0.01	0.18	0.12
π_{EA}	0.71	0.09	0.13	0.00	0.07	m_{EA}	0.46	0.02	0.34	0.18	0.00
π_{UK}	0.76	0.00	0.04	0.20	0.00	m_{UK}	0.75	0.01	0.00	0.07	0.16
π_{CA}	0.76	0.11	0.00	0.01	0.12	m_{CA}	0.24	0.56	0.09	0.10	0.01
s (all)	0.88	0.06	0.04	0.02	0.01	l (all)	0.95	0.02	0.01	0.01	0.01
s_{US}	0.82	0.15	0.01	0.02	0.00	l_{US}	0.94	0.05	0.00	0.00	0.01
s_{JA}	0.88	0.09	0.04	0.02	0.02	l_{JA}	0.94	0.04	0.02	0.00	0.00
s_{EA}	0.90	0.04	0.00	0.00	0.02	l_{EA}	0.96	0.00	0.03	0.01	0.00
s_{UK}	0.86	0.00	0.13	0.00	0.00	l_{UK}	0.96	0.01	0.00	0.03	0.00
s_{CA}	0.93	0.02	0.00	0.04	0.01	l_{CA}	0.97	0.01	0.00	0.00	0.02

This table reports the results of the principal components (PC) analysis conducted on the 4 sub-sets of nominal series, each comprising the same variable for all the 5 regions. For each set the first row shows the fraction of the total variance explained by each PC_i $(i = 1, ...5)$; the subsequent five rows display the fraction of the variance of the individual series attributable to each PC_i. The PC analysis is carried out on the standardized variables.