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Common shocks, common dynamics, and the international business cycle

Marco Centoni, *Università del Molise, Campobasso, Italy*
Gianluca Cubadda, *Università del Molise, Campobasso, Italy*
Alain Hecq, *University of Maastricht, Maastrich, The Netherlands*

Common Shocks, Common Dynamics, and the International Business Cycle*

Marco Centoni† Università del Molise

Gianluca Cubadda‡ Università del Molise

Alain Hecq§ University of Maastricht

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Abstract

This paper develops an econometric framework to understand whether co-movements observed in the international business cycle are the consequences of common shocks or common transmission mechanisms. Then we propose a new statistical measure of the importance of domestic and foreign shocks over the national business cycle. We show how to decompose the business cycle effects of permanent-transitory shocks into those due to their domestic and foreign components. We apply our analysis to G7 outputs.

Keywords: Domestic-Foreign Shocks, International Business Cycles, Permanent-Transitory Decomposition.

JEL: C32

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†Dipartimento SEGeS, Università del Molise, Via De Sanctis, 86100 Campobasso, Italy. E-mail: centoni@unimol.it.

‡Dipartimento SEGeS, Università del Molise, Via De Sanctis, 86100 Campobasso, Italy. E-mail: gianluca.cubadda@uniroma1.it.

§Department of Quantitative Economics, Maastricht University, P.O.box 616, 6200 MD Maastricht, The Netherlands. E-mail: a.hecq@ke.unimaas.nl. Homepage: www.personeel.unimaas.nl/a.hecq.

1 Introduction

The expression "international business cycle" refers to the presence of co-movements in the cyclical behavior of outputs across countries, (see e.g. Backus et al., 1995). However there exists a debate among economists and econometricians about how to measure these co-movements. In particular, the question of the importance of common shocks versus common propagation mechanisms is far from being resolved, (see e.g. Canova and Marrinan, 1998). So is the discussion about the influence of foreign shocks over the national business cycle as well as the distinction between permanent and transitory (henceforth, PT) effects of such foreign shocks. Indeed, it is crucial for economic policy purposes to understand whether national business cycles are affected by permanent technological shocks or transitory demand shocks. For instance, if demand shocks are largely responsible of fluctuations, there may be a role for aggregate Keynesian-type policies. It is also important for policy makers to know if the shocks have dominant domestic or foreign origins.

Consequently, the goal of our paper is twofold. First, we analyze the sources of co-movements in international business cycles and in particular whether the observed fluctuations are due to common shocks, common propagation mechanisms or both. We exploit the low frequency co-movements coming from a cointegration analysis to identify groups of shocks according to whether their effects are permanent or transitory. A common serial correlation analysis shows whether there exist some common dynamics, namely some common transmission mechanisms of these shocks. Imposing these restrictions also help to estimate more accurately the responses to the shocks because redundant parameters are excluded.

Second, we propose a statistical measure of the importance of domestic and foreign components of the PT shocks over the business cycle. We depart from the usual strategy that consists in extracting a unique component summarizing the worldwide effect that influences the outputs of a set of countries, (see e.g. Gregory et al., 1997). Instead, the permanent [transitory] foreign shocks for each country are defined as the components of the common permanent [transitory] shocks that are independent from the national permanent [transitory] shock on that country output. Consequently, we single out a specific set of PT foreign shocks for each country as it is desirable. We then asses the importance of such foreign shocks over the national output fluctuations with a 2-8 year period. In our opinion this approach evaluates the contribution of domestic and foreign shocks to the business cycles more appropriately than the traditional impulse responses or variance decompositions.

Noticeably, our measures of the business cycle effects of the PT domestic and foreign shocks do not resort to economic theory for identifying such shocks. Indeed, if theoretical reasoning can help to disentangle the source of the various shocks within a structural VAR analysis of different variables for a country and the rest of the world, (see e.g. Kwark 1999), it is less informative when modelling the same variable, such as output, for a larger set of countries.

The proposed approach allows us to answer a series of questions such that: 1°) Do international outputs co-move because of the existence of common shocks, common dynamics or both? 2°) What is the importance of PT foreign shocks over national business cycles, and consequently what is the degree of openness of economies? 3°) Are the business cycles mainly affected by the permanent or transitory components of domestic and foreign shocks? Similarly to most studies (see e.g. King et al, 1991), our analysis confirms that permanent shocks are the main source of the business cycles. But in contrast to Canova and Marrinan (1998) and Mellander et al. (1992), our results suggest that foreign shocks account for a small portion of the cyclical fluctuations of the non-European G7 countries (about 13% for Japan and 25% for the US). Ahmed et al. (1993) reached a similar conclusions using a structural VAR approach. This portion is around 50% for our panel of European countries. Moreover, thanks to a finer measurement of the sources of the shocks, we deduce that the domestic component is responsible for most of the business cycle effects of transitory shocks for all the G7 countries whereas the foreign component dominates the cyclical variability that is due to permanent shocks in France, Germany and Italy.

This paper is organized as follows. In Section 2, we briefly review a PT decomposition such that a set of cointegrated time series is separated into independent components (Centoni and Cubadda, 2003), and the notion of serial correlation common feature (Engle and Kozicki, 1993). In Section 3, we propose a statistical measure of the importance of domestic and foreign shocks over the business cycles and we show how to implement it in practice. The contribution of the PT components of domestic and foreign shocks is also investigated. Section 4 illustrates these concepts with an empirical analysis of the G7 output series from 1974:Q1 to 2002:Q3.

2 Common Shocks, Common Propagation Mechanisms and Co-movements

Let X_t be a n-vector time series such that

$$A(L)X_t = \Phi D_t + \varepsilon_t, \quad t = 1, ..., T \tag{1}$$

for fixed values of $X_{-p+1}, ..., X_0$ and where $A(L) = I_n - \sum_{i=1}^{p} A_i L^i$, D_t is a vector of fixed elements such a constant, a linear trend, and seasonal dummies, and ε_t are i.i.d. $N_n(0, \Omega)$ errors. Let us assume that

$$|A(c)| = 0 \text{ implies that } c = 1 \text{ or } |c| > 1, \tag{2}$$

then there exist $n \times r$-matrices α and β of rank r such that $A(1) = -\alpha\beta'$. The matrix $\alpha'_\perp \Gamma \beta_\perp$ has full rank, $\alpha_\perp$ and $\beta_\perp$ are $n \times (n-r)$-matrices of rank $(n-r)$ such that $\alpha'_\perp \alpha = \beta'_\perp \beta = 0$, $\Gamma = I_n - \sum_{i=1}^{p-1} \Gamma_i$ and $\Gamma_i = -\sum_{j=i+1}^{p} A_j$ for $i = 1, 2, ..., p-1$. The process X_t is cointegrated of order (1,1), the columns of β span the cointegrating space, the elements of α are the corresponding adjustment coefficients. We can rewrite Equation (1) in the following Vector Error-Correction Models (henceforth, VECM)

$$\Gamma(L)\Delta X_t = \Phi D_t + \alpha\beta' X_{t-1} + \varepsilon_t, \tag{3}$$

with $\Delta = (1-L)$, and $\Gamma(L) = I_n - \sum_{i=1}^{p-1} \Gamma_i L^i$ (see e.g. Johansen, 1996).

Series X_t also admit the following Wold representation

$$\Delta X_t = \Theta D_t + C(L)\varepsilon_t,$$

where $\Theta D_t = C(L)\Phi D_t$, and $C(L) = I_n + \sum_{i=1}^{\infty} C_i L^i$ is such that $\sum_{j=1}^{\infty} j\,|C_j| < \infty$.

Under these assumptions, Centoni and Cubadda (2003) derived a PT decomposition where the common permanent and transitory shocks are respectively given by

$$u_t^P = \alpha'_\perp \varepsilon_t \quad \text{and} \quad u_t^T = \alpha' \Omega^{-1} \varepsilon_t.$$

Then the permanent and transitory components of series X_t are respectively P_t and T_t, where $X_t = \widetilde{\Theta}\widetilde{D}_t + P_t + T_t$, $\Delta\widetilde{\Theta}\widetilde{D}_t = \Theta D_t$, $\Delta P_t = P(L)u_t^P$, $\Delta T_t = T(L)u_t^T$, and

$$P(L) = C(L)\Omega\alpha_\perp(\alpha'_\perp\Omega\alpha_\perp)^{-1}, \tag{4}$$
$$T(L) = C(L)\alpha(\alpha'\Omega^{-1}\alpha)^{-1}. \tag{5}$$

Since we know from the Granger representation theorem that $C(1) = \beta_\perp \left(\alpha'_\perp \Gamma \beta_\perp\right)^{-1} \alpha'_\perp$ (see e.g. Johansen, 1996), and in view of equations (4) and (5), we obtain $P(1) = C(1)$ and $T(1) = 0$. Hence, the shocks u_t^P only have permanent effects on series X_t as required.[1] Moreover, it is easy to verify that the components P_t and T_t are uncorrelated at all lags and leads.[2]

After isolating the common permanent and transitory shocks by exploiting the low frequency co-movements of the data, we define what we call common transmission mechanisms. In particular, we rely on the notion of Serial Correlation Common Feature (henceforth, SCCF) proposed by

[1] The assumption that $\alpha'_\perp \varepsilon_t$ are the permanent shocks is rather common in the literature, see *inter alia* Warne (1993), Gonzalo and Granger (1995), Johansen (1998), Yang (1998), and Gonzalo and Ng (2001).

[2] Remarkably, the above decomposition is invariant to rotation of the matrices $\alpha_\perp$ and α and non-singular linear transformations of the set of common shocks u_t^P and u_t^T. Hence, series X_t can be separated into independent PT components without using *a priori* economic theory.

Engle and Kozicki (1993) and Vahid and Engle (1993). In this context, series ΔX_t have s SCCF relationships iff there exists a $n \times s$ matrix δ with full column rank and such that $\delta' C(L) = \delta'$. Hence, SCCF implies that the impulse response functions of series ΔX_t are collinear. In view of equation (3), it is easy to verify that SCCF imposes the following restrictions on the VECM parameters: *i)* $\delta'\alpha = 0$, and *ii)* $\delta'\Gamma_i = 0$ for $i = 1 \ldots p-1$.

In order to stress that SCCF denotes the presence of common propagation mechanisms among series ΔX_t, we can rewrite the VECM (3) in the following common factor representation

$$\Delta X_t = \Phi D_t + \delta_\perp A' W_{t-1} + \varepsilon_t \equiv \Phi D_t + \delta_\perp F_{t-1} + \varepsilon_t, \tag{6}$$

where A is a $(r+n(p-1)) \times (n-s)$ full-rank matrix, and $W_{t-1} = (X'_{t-1}\beta, \Delta X'_{t-1}, \ldots, \Delta X'_{t-p+1})'$. Importantly enough, the main characteristic of representation (6) is that all the dynamics of the system is included in the common factors F_{t-1}. This is not generally the case in the traditional dynamic factor modeling where the idiosyncratic terms may be more cyclical than the factor itself. A possible drawback of the SCCF approach is that a matrix such δ may not exist. However, we can use the less stringent condition that there exists a $n \times s$ polynomial SCCF matrix $\delta(L) \equiv \delta_0 + \delta_1 L$ such that $\delta(L)'C(L) = \delta'_0$, see Cubadda and Hecq (2001) for details. Nevertheless, anticipating the results of the empirical analysis in Section 4, we will see that SCCF is quite appropriate to restrict our statistical model of the G7 outputs.

Maximum Likelihood (henceforth, ML) inference on SCCF requires to solve the following canonical correlation program,

$$CanCor\left\{\Delta Y_t, \begin{pmatrix} \hat{\beta}' Y_{t-1} \\ \Delta Y_{t-1} \\ \Delta Y_{t-2} \\ \vdots \\ \Delta Y_{t-p+1} \end{pmatrix} \mid D_t \right\}, \tag{7}$$

where $CanCor(Y, X \mid Z)$ denotes the partial canonical correlations between the elements of Y and X conditional on Z, and $\hat{\beta}$ is a superconsistent estimate of the cointegrating vectors. The likelihood ratio test for the null hypothesis that there exist at least s SCCF vectors is based on the statistic (see e.g. Anderson, 1984; Velu *et al.,* 1986)

$$LR = -T \sum_{i=1}^{s} \ln(1 - \hat{\lambda}_i), \qquad s = 1, \ldots, n-r \tag{8}$$

where $\hat{\lambda}_i$ is the $i-$th smallest squared canonical correlation coming from the solution of (7).

The test statistic (8) follows asymptotically a $\chi^2_{(v)}$ distribution under the null where $v = s \times (n(p-1)+r) - s(n-s)$. Moreover, the canonical variates coefficients of ΔX_t associated with the s smallest eigenvalues $\hat{\lambda}_1, ..., \hat{\lambda}_s$ provide the ML estimate of the SCCF matrix δ whereas the matrix A in equation (6) is estimated by the canonical variates coefficients of W_{t-1} associated to the $(n-s)$ largest eigenvalues $\hat{\lambda}_{s+1}, ..., \hat{\lambda}_n$. Finally, the matrix $\delta_\perp$ is estimated by a regression of ΔX_t on F'_{t-1}.

In addition, an efficient estimation of elements of δ, including the standard errors, is obtained by Full Information Maximum Likelihood (henceforth, FIML) in a model with s pseudo structural equations and additional $(n-s)$ unrestricted equations, see Vahid and Engle (1993) for details. Additional restrictions on δ can easily be tested within this FIML framework. As an example, it can be desirable to test whether common feature relationships correspond to real linkages among variables and not to time series with idiosyncratic behavior. The latter are represented by SCCF vectors with a single element equals to unity and the others equal to zero.

3 Measuring the Business Cycle Effects of Foreign and Domestic Shocks

In this section we propose a new statistical measure of the importance of foreign and domestic shocks over the business cycle. In particular, we show that the statistics proposed by Centoni and Cubadda (2003) can be modified to decompose the business cycle effects of PT shocks into those due to their domestic and foreign components. Hereafter we then assume that series X_t represent a set of n international output measures.

3.1 Statistical Measures

Let us start by decomposing into their permanent and transitory components the national shocks ε_t. From the equation

$$\varepsilon_t = \varepsilon_t^P + \varepsilon_t^T,$$

where

$$\varepsilon_t^P = \Omega\alpha_\perp(\alpha'_\perp\Omega\alpha_\perp)^{-1}\alpha'_\perp\varepsilon_t \quad \text{and} \quad \varepsilon_t^T = \alpha(\alpha'\Omega^{-1}\alpha)^{-1}\alpha'\Omega^{-1}\varepsilon_t,$$

we see that the jth country national shock ε_{jt}, for $j = 1, 2, ..., n$, can be separated into a permanent component ε_{jt}^P and a transitory component ε_{jt}^T.

Remarkably, the PT components of each national shock may affect the business cycles of other countries through two different channels. First, past PT shocks of a given country can produce their cyclical effects on foreign outputs through the propagation mechanism that is generated by the polynomial matrix $C(L)$. Second, a national permanent [transitory] shock can instantaneously influence the business cycles of other countries because elements of ε_t^P $[\varepsilon_t^T]$ are generally dependent.

Hence, let us isolate the components of the common permanent [transitory] shocks u_t^P $[u_t^T]$ that are explained by jth country permanent [transitory] shock ε_{jt}^P $[\varepsilon_{jt}^T]$. Under the assumption of normality, these components are respectively given by

$$u_{jt}^{P,D} = E(u_t^P \varepsilon_{jt}^P)[E(\varepsilon_{jt}^P)^2]^{-1}\varepsilon_{jt}^P \quad \text{and} \quad u_{jt}^{T,D} = E(u_t^T \varepsilon_{jt}^T)[E(\varepsilon_{jt}^T)^2]^{-1}\varepsilon_{jt}^T,$$

for $j = 1, 2, ..., n$.[3] We define $u_{jt}^{P,D}$ $[u_{jt}^{T,D}]$ as the permanent [transitory] domestic shocks of the jth country. Consequently, we require that the permanent [transitory] foreign shocks of the jth country are the components of the shocks u_t^P $[u_t^T]$ that are independent from jth country permanent [transitory] domestic shocks. Such permanent [transitory] foreign shocks respectively read

$$u_{jt}^{P,F} = u_t^P - E(u_t^P | \varepsilon_{jt}^P) \quad \text{and} \quad u_{jt}^{T,F} = u_t^T - E(u_t^T | \varepsilon_{jt}^T),$$

The identification of such PT domestic-foreign shocks allows us to decompose the jth country output X_{jt} as follows

$$X_{jt} = \widetilde{\Theta}_j \widetilde{D}_t + \underbrace{P_{jt}^D + P_{jt}^F}_{P_t} + \underbrace{T_{jt}^D + T_{jt}^F}_{T_t} \tag{9}$$

where $\widetilde{\Theta}_j = e_j' \widetilde{\Theta}$, $P_{jt}^D = e_j' P(L) u_{jt}^{P,D}$, $P_{jt}^F = e_j' P(L) u_{jt}^{P,F}$, $T_{jt}^D = e_j' T(L) u_{jt}^{T,D}$, $T_{jt}^F = e_j' T(L) u_{jt}^{T,F}$, and e_j is an n-vector with unity as its jth element and zeroes elsewhere.

Moreover, since each component in the right hand side of equation (9) is independent from the others, we can write spectrum $F_j(\omega)$ of the jth country output as follows

$$F_j(\omega) = F_{Pj}^D(\omega) + F_{Pj}^F(\omega) + F_{Tj}^D(\omega) + F_{Tj}^F(\omega) \tag{10}$$

where

$$F_j(\omega) = \frac{1}{2\pi} e_j' C^*(z) \Omega C^*(z^{-1})' e_j,$$

[3] In the case that normality does not hold, $u_{jt}^{P,D}$ $[u_{jt}^{T,D}]$ would generally be a non-linear function of the random variable ε_{jt}^P $[\varepsilon_{jt}^T]$.

$$F_{Pj}^{D}(\omega)=\frac{1}{2\pi}e_j'P^*(z)\Omega_j^{P,D}P^*(z^{-1})'e_j,$$

$$F_{Pj}^{F}(\omega)=\frac{1}{2\pi}e_j'P^*(z)\Omega_j^{P,F}P^*(z^{-1})'e_j,$$

$$F_{Tj}^{D}(\omega)=\frac{1}{2\pi}e_j'T^*(z)\Omega_j^{T,D}T^*(z^{-1})'e_j,$$

$$F_{Tj}^{F}(\omega)=\frac{1}{2\pi}e_j'T^*(z)\Omega_j^{T,F}T^*(z^{-1})'e_j,$$

$\Omega_j^{P,D}=E(u_{jt}^{P,D}u_{jt}^{P,D\prime})$, $\Omega_j^{T,D}=E(u_{jt}^{T,D}u_{jt}^{T,D\prime})$, $\Omega_j^{P,F}=E(u_{jt}^{P,F}u_{jt}^{P,F\prime})$, $\Omega_j^{T,F}=E(u_{jt}^{T,F}u_{jt}^{T,F\prime})$, $\Delta C^*(L)=C(L)$, $\Delta P^*(L)=P(L)$, $\Delta T^*(L)=T(L)$, $z=\exp(-i\omega)$ for $\omega\in(0,\pi]$,[4] and $C^*(z)=[\Gamma(z)(1-z)-\alpha\beta' z]^{-1}$, for $z\neq 1$.[5]

The spectra in the right hand side of equation (10) can be interpreted as follows. The spectrum $F_{Pj}^{F}(\omega)$ $[F_{Tj}^{F}(\omega)]$ measures the variability of the jth country output at frequency ω that is explained by the jth country permanent [transitory] foreign shocks. Similarly, the spectrum $F_{Pj}^{D}(\omega)$ $[F_{Tj}^{D}(\omega)]$ measures the variability of the jth country output at frequency ω that is explained by the jth country permanent [transitory] domestic shocks. We can finally propose our measures of the contribution of PT foreign [domestic] shocks to the variability of the jth country output at the business cycle frequency band.

Definition 1 (***Measures of the business cycle effects of PT foreign shocks***). *Let $I_{Pj}^{F}(\omega_0,\omega_1)$ $[I_{Pj}^{F}(\omega_0,\omega_1)]$ indicates the relative measure of the spectral mass of the jth country output at the business cycle frequency band $[\omega_0,\omega_1]$ that is explained by the jth country permanent [transitory] foreign shocks, where $0<\omega_0<\omega_1\leq\pi$. Then we have*

$$I_{Pj}^{F}(\omega_0,\omega_1)=\frac{\int_{\omega_0}^{\omega_1}F_{Pj}^{F}(\omega)d\omega}{\int_{\omega_0}^{\omega_1}F_j(\omega)d\omega}\quad and\quad I_{Tj}^{F}(\omega_0,\omega_1)=\frac{\int_{\omega_0}^{\omega_1}F_{Tj}^{F}(\omega)e_jd\omega}{\int_{\omega_0}^{\omega_1}F_j(\omega)d\omega},$$

for $j=1,...,n$.

Definition 2 (***Measures of the business cycle effects of PT domestic shocks***). *Let $I_{Pj}^{D}(\omega_0,\omega_1)$ $[I_{Tj}^{D}(\omega_0,\omega_1)]$ indicates the relative measure of the spectral mass of the jth country*

[4] We do not consider the case $\omega=0$ since the pseudo-spectral density matrix of series X_t is unbounded at frequency zero due to the presence of unit roots at that frequency.

[5] As noticed in Cubadda and Centoni (2003), the matrix $A(z)\equiv[\Gamma(z)(1-z)-\alpha\beta' z]$ is invertible for $z\neq 1$ due to Assumption (2).

output at the business cycle frequency band $[\omega_0, \omega_1]$ that is explained by the jth country permanent [transitory] domestic shocks. Then we have

$$I_{Pj}^D(\omega_0,\omega_1) = \frac{\int_{\omega_0}^{\omega_1} F_{Pj}^D(\omega)d\omega}{\int_{\omega_0}^{\omega_1} F_j(\omega)d\omega} \quad and \quad I_{Tj}^D(\omega_0,\omega_1) = \frac{\int_{\omega_0}^{\omega_1} F_{Tj}^D(\omega)d\omega}{\int_{\omega_0}^{\omega_1} F_j(\omega)d\omega},$$

for $j = 1, ..., n$.

Remark 3 *In view of equations* (9) *and* (10), *we see that the measures of the business cycle effects of the PT shocks proposed by Centoni and Cubadda (2003) are respectively given by*

$$I_{Pj}(\omega_0,\omega_1) = I_{Pj}^F(\omega_0,\omega_1) + I_{Pj}^D(\omega_0,\omega_1) \quad and \quad I_{Tj}(\omega_0,\omega_1) = I_{Tj}^F(\omega_0,\omega_1) + I_{Tj}^D(\omega_0,\omega_1)$$

for $j = 1, ..., n$.

Remark 4 *Based on decomposition* (9), *the relative contributions of foreign and domestic shocks to the variability of the jth country business cycle respectively read*

$$I_j^F(\omega_0,\omega_1) = I_{Pj}^F(\omega_0,\omega_1) + I_{Tj}^F(\omega_0,\omega_1) \quad and \quad I_j^D(\omega_0,\omega_1) = I_{Pj}^D(\omega_0,\omega_1) + I_{Tj}^D(\omega_0,\omega_1)$$

for $j = 1, ..., n$.

3.2 Estimation

Estimation of the statistics $I_{Pj}^F(\omega_0,\omega_1)$, $I_{Tj}^F(\omega_0,\omega_1)$, $I_{Pj}^D(\omega_0,\omega_1)$, and $I_{Tj}^D(\omega_0,\omega_1)$ can be summarized by the following six steps:

Step 1 Test for cointegration and SCCF and consequently fix r and s. Estimate then a VECM, possibly under the SCCF restrictions, and derive consistent estimates of α, $\alpha_\perp$, β, $\Gamma(L)$, and Ω respectively denoted by $\widehat{\alpha}$, $\widehat{\alpha}_\perp$, $\widehat{\beta}$, $\widehat{\Gamma}(L)$, and $\widehat{\Omega}$;[6]

Step 2 Based on the VECM residuals $\widehat{\varepsilon}_t$, construct $\widehat{u}_t^P = \widehat{\alpha}'_\perp\widehat{\varepsilon}_t$, $\widehat{\varepsilon}_t^P = \widehat{\Omega}\widehat{\alpha}'_\perp(\widehat{\alpha}'_\perp\widehat{\Omega}\widehat{\alpha}_\perp)^{-1}\widehat{u}_t^P$, $\widehat{u}_t^T = \widehat{\alpha}'\widehat{\Omega}^{-1}\widehat{\varepsilon}_t$, and $\widehat{\varepsilon}_t^T = \widehat{\alpha}(\widehat{\alpha}'\widehat{\Omega}^{-1}\widehat{\alpha})^{-1}\widehat{u}_t^T$;

Step 3 Compute $\widehat{u}_{jt}^{P,D}$ [$\widehat{u}_{jt}^{T,D}$] as the fitted values of a regression of $\widehat{u}_t^P$ [$\widehat{u}_t^T$] on $\widehat{\varepsilon}_{jt}^P$ [$\widehat{\varepsilon}_{jt}^T$] and construct $\widehat{u}_{jt}^{P,F} = \widehat{u}_t^P - \widehat{u}_{jt}^{P,D}$ for $j = 1, 2, ..., n$;

Step 4 Obtain $\widehat{\Omega}_j^{P,D}$, $\widehat{\Omega}_j^{T,D}$, and $\widehat{\Omega}_j^{P,F}$ respectively as the sample covariance matrices of the vector series $\widehat{u}_{jt}^{P,D}$, $\widehat{u}_{jt}^{T,D}$, and $\widehat{u}_{jt}^{P,F}$ for $j = 1, 2, ..., n$;

[6] See e.g. Gonzalo and Granger (1995) on estimation of $\alpha_\perp$.

Step 5 Construct $\widehat{C}^*(z_k) = [\widehat{\Gamma}(z_k)(1 - z_k) - \widehat{\alpha}\widehat{\beta}' z_k]^{-1}$, $\widehat{P}^*(z_k) = \widehat{C}^*(z_k)\widehat{\Omega}\widehat{\alpha}_\perp(\widehat{\alpha}_\perp'\widehat{\Omega}\widehat{\alpha}_\perp)^{-1}$, and $\widehat{T}^*(z_k) = \widehat{C}^*(z_k)\widehat{\alpha}(\widehat{\alpha}'\widehat{\Omega}\widehat{\alpha})^{-1}$, where $z_k = \exp(-i\omega_k)$, and $\omega_k = \omega_0(\frac{m-k}{m}) + \omega_1(\frac{k}{m})$ for $k = 0, 1, ..., m$;

Step 6 Obtain

$$\widehat{I}_{Pj}^D(\omega_0, \omega_1) = \left[\sum_{k=0}^{m} e_j'\widehat{P}^*(z_k)\widehat{\Omega}_j^{P,D}\widehat{P}^*(z_k^{-1})'e_j\right]\left[\sum_{k=0}^{m} e_j'\widehat{C}^*(z_k)\widehat{\Omega}\widehat{C}^*(z_k^{-1})'e_j\right]^{-1},$$

$$\widehat{I}_{Tj}^D(\omega_0, \omega_1) = \left[\sum_{k=0}^{m} e_j'\widehat{T}^*(z_k)\widehat{\Omega}_j^{T,D}\widehat{T}^*(z_k^{-1})'e_j\right]\left[\sum_{k=0}^{m} e_j'\widehat{C}^*(z_k)\widehat{\Omega}\widehat{C}^*(z_k^{-1})'e_j\right]^{-1},$$

$$\widehat{I}_{Pj}^F(\omega_0, \omega_1) = \left[\sum_{k=0}^{m} e_j'\widehat{P}^*(z_k)\widehat{\Omega}_j^{P,F}\widehat{P}^*(z_k^{-1})'e_j\right]\left[\sum_{k=0}^{m} e_j'\widehat{C}^*(z_k)\widehat{\Omega}\widehat{C}^*(z_k^{-1})'e_j\right]^{-1},$$

$$\widehat{I}_{Tj}^F(\omega_0, \omega_1) = 1 - \widehat{I}_{Pj}^D(\omega_0, \omega_1) - \widehat{I}_{Tj}^D(\omega_0, \omega_1) - \widehat{I}_{Pj}^F(\omega_0, \omega_1),$$

for $j = 1, ..., n$.

The suggested measures are rather involved functions of the estimated VECM parameters and this complicates the analytical evaluation of their sample variability. Hence, we rely on a bootstrap procedure similar as the one suggested by Gonzalo and Ng (2001). First, we fix both r and s and estimate the VECM by the ML procedure.[7] Second, we obtain the residuals $\widehat{\varepsilon}_t$ by replacing the unknown parameters in equations (3) or (9) with their estimated values. Third, a new sample of data is constructed using a random sample of $\widehat{\varepsilon}_t$ with replacement and the initial estimates of the VECM parameters. Fourth, the VECM is re-estimated with the new sample and the associated estimates of the spectral measures are stored. This procedure is repeated 5000 times and the quantiles of the empirical distributions of the bootstrapped $\widehat{I}_{Pj}^F(\omega_0, \omega_1)$, $\widehat{I}_{Tj}^F(\omega_0, \omega_1)$, $\widehat{I}_{Pj}^D(\omega_0, \omega_1)$, and $\widehat{I}_{Tj}^D(\omega_0, \omega_1)$ are then used to construct confidence intervals.

4 Empirical Analysis

We apply the previous measures to the gross domestic product in volume of G7 countries, i.e. Canada, US, UK, Germany, Italy, France and Japan. Quarterly seasonally adjusted indexes

[7] The coefficients of β and δ matrices are estimated even though r and s are fixed.

	$\widehat{\lambda}$	$Trace$	$p-$values
$r = 0$	0.34	183.54	0.00
$r \leq 1$	0.33	134.17	0.00
$r \leq 2$	0.21	88.02	0.06
$r \leq 3$	0.19	60.23	0.10
$r \leq 4$	0.14	35.96	0.21
$r \leq 5$	0.09	18.54	0.32
$r \leq 6$	0.05	6.58	0.40

Table 1: Johansen's Trace Test for Cointegration

(1995=100) are taken from OECD databases. Canova and Dellas (1993) among others documented that after 1973 (i.e. the first oil shock) the presence of common disturbances plays a role in accounting for international output co-movements. We then use the sample that spans 1974:Q1 to 2002:Q3, namely $T = 115$ observations.

Figure 1 reports for each country taken individually, the log-level and the growth rate of the GDP.[8] There exists a trending behavior in the log-levels of all series, so we first test for the presence of common permanent and transitory shocks by a cointegration analysis. A VAR(3) seems to appropriately characterize the covariance structure of the data according to the Akaike Information Criterion (AIC). Indeed, we do not reject the null of no autocorrelation in all the individual equations of the VAR.[9] Hence, we use the Johansen's trace statistics for cointegration with a deterministic trend included in the long-run in order to capture the differences among the average growth rates of the various national outputs. Table 1 reports the eigenvalues, the value of the asymptotic trace statistics as well as the associated $p-$values. We do not reject the presence of two cointegrating vectors. This implies that the G7 outputs are driven by five common permanent shocks and two common transitory shocks.

The output growth rates exhibit a cyclical pattern whose similarity is tested through the SCCF analysis. We fix at $r = 2$ the number of cointegrating vectors and we continue with the SCCF analysis. Table 2 reports eigenvalues, the value of SCCF test statistics, their degrees of freedom (df) as well as the $p-$values associated with both the LR test statistic in (8) and a small-sample corrected version ($p-$values^{ss}) considered by Hecq (2000). It emerges that we cannot exclude the presence of four SCCF vectors. AIC also indicates $s = 4$. We conclude that there are three common transmission mechanisms of the national shocks through the G7 economies.[10]

[8] The data for Germany for the period 1974:Q1-1990:Q4 were reconstructed by using the GDP of West Germany.

[9] The $p - values$ associated to the Lagrange multiplier test statistics for fourth-order residual autocorrelation are 0.61, 0.81, 0.87, 0.29, 0.11, 0.07, 0.51 for respectively $\ln Can_t, \ln US_t, \ln Jap_t, \ln Fr_t, \ln Ger_t, \ln It_t$ and $\ln UK_t$.

[10] For the sake of completeness, we estimate the system by FIML and test whether some of these four SCCF vectors have a single element equal to unity and the others equal to zero. The presence of such trivial SCCF vectors is rejected with $p - values$ less than 0.001 for each variable. We also reject at conventional significance

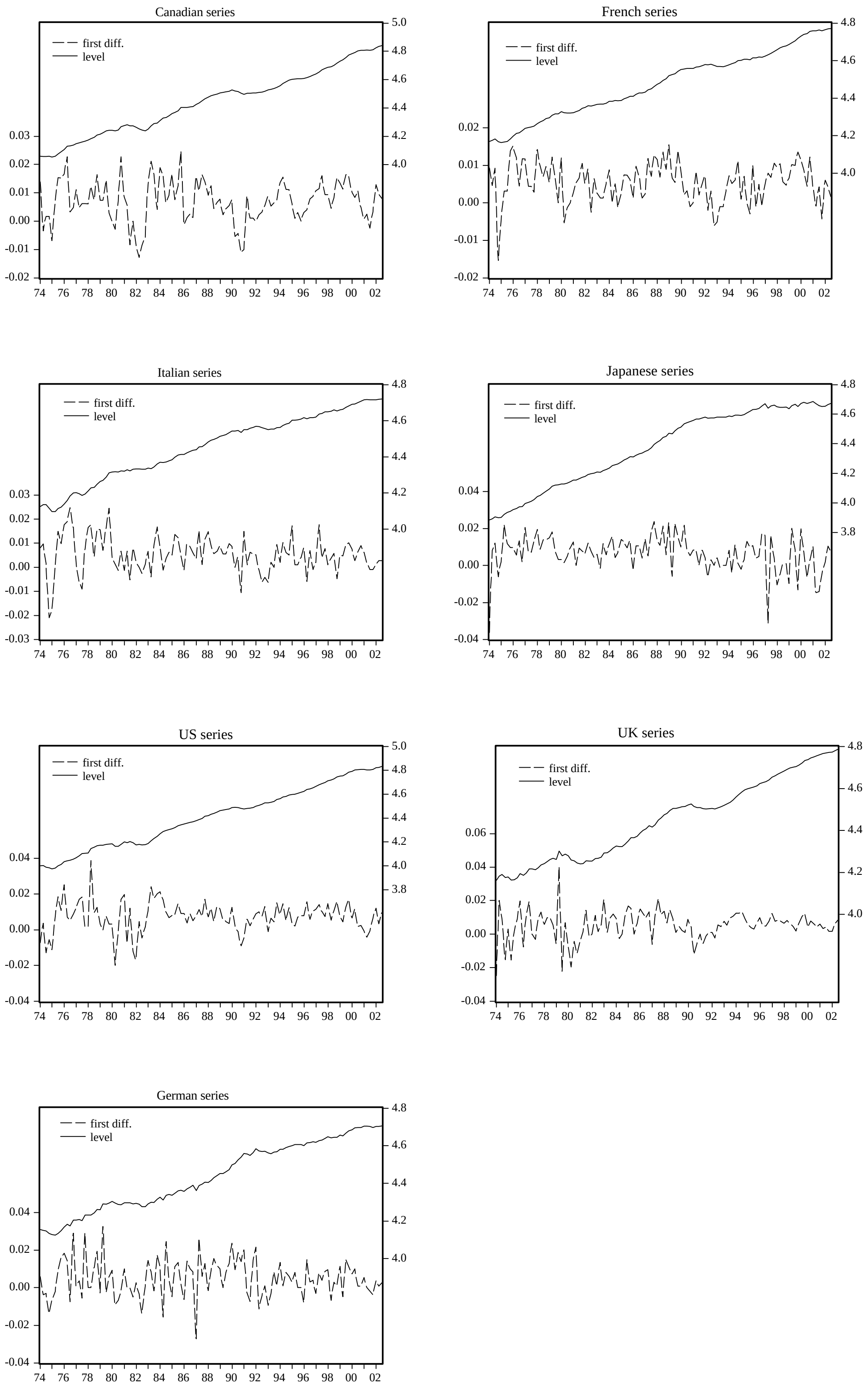

Figure 1: G7 output growths and log-levels

	$\widehat{\lambda}$	LR	df	$p-$values	$p-$values^{ss}
$s \geq 1$	0.05	6.43	10	0.77	0.85
$s \geq 2$	0.12	21.37	22	0.49	0.68
$s \geq 3$	0.13	38.25	36	0.36	0.61
$s \geq 4$	0.21	65.99	52	0.09	0.30
$s \geq 5$	0.35	117.07	70	<0.001	0.01

Table 2: LR Test for SCCF

In order to asses the relative importance of common PT domestic and foreign shocks over the national business cycles, we apply the measures proposed in the previous section. We compute such measures with and without imposing the SCCF restrictions in order to evaluate the efficiency gains coming from the imposition of the common propagation mechanisms. We then estimate the VECM model fixing both $s = 0$ and $s = 4$ and derive from the estimated parameters the spectra of each output and its components at the frequencies corresponding to 8-32 quarter periods. In particular, these spectra are computed for $\omega_k = \frac{\pi}{16}(\frac{199-k}{199}) + \frac{\pi}{4}(\frac{k}{199})$ and $k = 0, 1, ..., 199$. Table 3 and 4 report for respectively $s = 0$ and $s = 4$ the estimated measures along with in brackets the 95% bootstrapped confidence bounds.

First, the results clearly indicate the dominant role of the permanent shocks over the business cycles. Permanent shocks account for about 85% for European countries and Japan and up to 95% for the US and Canada. The imposition of the SCCF restrictions does not alter the main conclusion about these proportions but it leads to more precise estimates of the business cycle effects of PT shocks. Indeed, the relative confidence interval width of such business cycle effects[11] reduces on average of 15.44% when $s = 4$ is imposed in estimation.

Second, we turn to evaluating the importance of the domestic and foreign shocks on the different economies at the business cycle frequencies. Both fixing $s = 0$ and $s = 4$, it emerges that for the US, Japan and Canada the foreign component is small ranging between 12% and 30%. Due to their higher degree of openness, European countries are more sensitive to foreign shocks with proportions around 40% for UK and reaching 56% for Italy. Again, the main consequence of imposing the SCCF restrictions is that the relative confidence interval width of these business cycle effects reduces on average of 8.87%.

Third, for all the G7 economies, the foreign component of the business cycle is almost entirely generated by permanent shocks. This result is consistent with the view that international trade of input goods is an important propagation mechanism of permanent technology shocks across countries. Since new technology is embodied in traded inputs, countries that extensively rely on

levels the null hypothesis that one variable can simultaneously be excluded for the four common feature vectors.

[11]Such relative confidence interval width is computed as the 95% bootstraped confidence interval width of $I_{Pj}(\omega_0, \omega_1)$ or $I_{Tj}(\omega_0, \omega_1)$ divided by the minimum of $\{\widehat{I}_{Pj}(\omega_0, \omega_1), \widehat{I}_{Tj}(\omega_0, \omega_1)\}$ for $j = 1, 2, ..., n$.

		Permanent	Transitory	Total
Canada	Domestic	0.802 [0.507-0.893]	0.058 [0.017-0.090]	0.860 [0.559-0.931]
	Foreign	0.132 [0.061-0.425]	0.007 [0.002-0.029]	0.139 [0.068-0.440]
	Total	0.934 [0.894-0.971]	0.066 [0.029-0.105]	
		Permanent	Transitory	Total
US	Domestic	0.690 [0.421-0.821]	0.055 [0.016-0.084]	0.745 [0.465-0.861]
	Foreign	0.250 [0.135-0.520]	0.003 [0.001-0.028]	0.254 [0.138-0.534]
	Total	0.941 [0.907-0.974]	0.058 [0.025-0.092]	
		Permanent	Transitory	Total
Japan	Domestic	0.718 [0.436-0.827]	0.150 [0.060-0.212]	0.868 [0.580-0.918]
	Foreign	0.126 [0.072-0.412]	0.004 [0.001-0.022]	0.131 [0.081-0.418]
	Total	0.845 [0.776-0.934]	0.154 [0.065-0.223]	
		Permanent	Transitory	Total
France	Domestic	0.401 [0.153-0.685]	0.156 [0.051-0.204]	0.558 [0.275-0.784]
	Foreign	0.441 [0.215-0.724]	0.000 [0.000-0.001]	0.441 [0.215-0.724]
	Total	0.842 [0.795-0.947]	0.157 [0.052-0.204]	
		Permanent	Transitory	Total
Germany	Domestic	0.398 [0.161-0.675]	0.123 [0.037-0.176]	0.519 [0.266-0.751]
	Foreign	0.465 [0.238-0.722]	0.014 [0.002-0.023]	0.480 [0.247-0.733]
	Total	0.864 [0.811-0.954]	0.136 [0.045-0.189]	
		Permanent	Transitory	Total
Italy	Domestic	0.296 [0.127-0.559]	0.143 [0.045-0.196]	0.439 [0.245-0.644]
	Foreign	0.556 [0.349-0.752]	0.004 [0.001-0.010]	0.561 [0.355-0.754]
	Total	0.853 [0.798-0.951]	0.147 [0.049-0.201]	
		Permanent	Transitory	Total
UK	Domestic	0.484 [0.187-0.683]	0.111 [0.052-0.161]	0.595 [0.292-0.768]
	Foreign	0.346 [0.194-0.656]	0.058 [0.018-0.088]	0.404 [0.231-0.707]
	Total	0.831 [0.774-0.916]	0.169 [0.082-0.225]	

Table 3: Measures of the BC effects of Domestic-Foreign PT shocks (s=0)

		Permanent	Transitory	Total
Canada	Domestic	0.826 [0.545-0.892]	0.046 [0.017-0.073]	0.872 [0.587-0.927]
	Foreign	0.112 [0.059-0.397]	0.014 [0.004-0.033]	0.127 [0.072-0.412]
	Total	0.939 [0.907-0.972]	0.061 [0.028-0.092]	
		Permanent	Transitory	Total
US	Domestic	0.614 [0.330-0.781]	0.067 [0.028-0.096]	0.682 [0.385-0.831]
	Foreign	0.312 [0.163-0.605]	0.005 [0.001-0.016]	0.317 [0.168-0.613]
	Total	0.926 [0.896-0.965]	0.073 [0.034-0.103]	
		Permanent	Transitory	Total
Japan	Domestic	0.650 [0.421-0.822]	0.161 [0.062-0.202]	0.811 [0.556-0.918]
	Foreign	0.184 [0.078-0.437]	0.004 [0.001-0.011]	0.184 [0.081-0.442]
	Total	0.834 [0.792-0.936]	0.166 [0.063-0.207]	
		Permanent	Transitory	Total
France	Domestic	0.372 [0.147-0.642]	0.130 [0.044-0.156]	0.502 [0.237-0.722]
	Foreign	0.497 [0.275-0.762]	0.000 [0.000-0.001]	0.497 [0.276-0.762]
	Total	0.869 [0.843-0.954]	0.130 [0.045-0.157]	
		Permanent	Transitory	Total
Germany	Domestic	0.414 [0.227-0.660]	0.135 [0.053-0.154]	0.549 [0.327-0.752]
	Foreign	0.445 [0.245-0.669]	0.004 [0.000-0.007]	0.450 [0.247-0.672]
	Total	0.860 [0.840-0.945]	0.139 [0.054-0.159]	
		Permanent	Transitory	Total
Italy	Domestic	0.408 [0.234-0.661]	0.101 [0.033-0.126]	0.509 [0.307-0.724]
	Foreign	0.488 [0.272-0.691]	0.002 [0.001-0.004]	0.490 [0.275-0.692]
	Total	0.897 [0.871-0.964]	0.103 [0.035-0.128]	
		Permanent	Transitory	Total
UK	Domestic	0.506 [0.254-0.720]	0.124 [0.055-0.153]	0.631 [0.360-0.801]
	Foreign	0.343 [0.182-0.611]	0.026 [0.009-0.036]	0.368 [0.198-0.638]
	Total	0.849 [0.820-0.932]	0.150 [0.068-0.179]	

Table 4: Measures of the BC effects of Domestic-Foreign PT shocks (s=4)

imported input goods are more exposed to foreign permanent shocks. Frankel and Rose (1998), *inter alia*, argue that closer international trade links result in more coherent national business cycles.

Finally, the domestic component clearly dominates the cyclical effects of transitory shocks, especially for European countries. This finding is in line with the interpretation that transitory shocks are mainly connected to country-specific monetary and fiscal policies.

5 Conclusions

The empirical example of the previous section shows that the methods proposed in this paper are useful to tackle, in an coherent and integrated setting, issues that were often analyzed independently in previous studies. These issues are precise definitions of common shocks and common propagation mechanisms as well as an assessment of the relative importances of the sources of the business cycles, namely domestic-permanent, foreign-permanent, domestic-transitory and foreign-transitory shocks. With these elements in hand, it is thus possible to provide a detailed picture of the macroeconomic fluctuations that could be efficiently used by policy makers and economists.

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