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INTERNATIONAL SHOCKS AND NATIONAL HOUSE PRICES

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International shocks and national house prices.

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Abstract

The paper investigates linkages between general macroeconomic conditions and the housing market for the G-7 area. Among the key results of the paper, it is found that the US are an important source of global fluctuations not only for real activity, nominal variables and stock prices, but also for housing prices. Yet, also regional factors may be relevant to account for house prices dynamics. Secondly, albeit distinct driving forces for real activity and financial factors can be pointed out, sizeable global interactions can be found. In particular, global supply-side shocks are found to be important determinant of G-7 house prices fluctuations. The linkage between housing prices and macroeconomic developments is however bidirectional, since evidence of significant wealth effects can be found, with investment showing in general a stronger reaction than consumption and output.

Keywords: G7, house prices, international business cycle, factor vector autoregressive models, common factors
JEL classification: C22, E31, E32.

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1 Introduction

Since the late 1990s, housing prices have been increasing at a very rapid pace in the G-7 countries, apart from Japan, in the framework of generally favorable macroeconomic conditions. Since 1999 house prices have increased at an yearly average real rate of about 5% in the US, the euro area and Canada, and to an even larger rate in the UK (close to 9%). Over the same time span, average real output growth has been in the range 2% to 3%, while nominal interest rates and inflation have been low (3% to 5% and 2% to 2.6%, respectively) and broad liquidity has grown at generous rates (6% to 8%). On the other hand, stock prices have shown alternating dynamics, i.e. a rapid contraction starting in 2000:4 and recovery since 2003:2. The housing market outlook has started turning negative since early 2007, as real prices have started decreasing in the US.[1]

The similarity of the rising price pattern detected for the major economies raises a question concerning the existence of common international factor affecting house prices, perhaps due to global macroeconomic developments. Recent empirical evidence of Case et al. (1999), for instance, does point to significant linkages between real estate prices and both local and global GDP components, suggesting that international housing price comovements are at least partially explained by common exposure to global business cycles. Similarly, Ahearne et al. (2005) and Otrok and Terrones (2005) point to global real interest rate dynamics as a factor behind the international comovement in house prices.

The recent global housing price surge may also be due to non fundamental based mechanisms as, for instance, "extravagant expectations" of future price increases, spreading according to social epidemics (Shiller, 2007), or mispricing related to the combination of inflation and money illusion (Brunnermeier and Julliard, 2005). The recent empirical evidence is mixed, with some studies pointing to a cumulated overvaluation in housing prices of about 30% since 2004, not only for the US, but also for the OECD area (Girouard et al., 2006; Finicelli, 2007; Gros, 2007). Yet, Jacobsen and Naug (2005) do not find any evidence of housing price overvaluation in the US, compared with fundamental values determined by interest rates, households income,

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[1] Very different macroeconomic and housing price conditions can be found for Japan, with housing prices contracting, over the time period considered, at an yearly rate of about -4%, output expanding at an annual rate of 1.5%, virtually zero nominal short term rates, deflation persisting at an average annual inflation rate of -0.5% and money growth expanding at an average rate of 2%. These latter findings are obviously related to the very different macroeconomic framework (depression), which has affected Japan only since the beginning of the 1990s.

unemployment and housing supply. Similar findings are pointed out by Himmelberg et al. (2005) and McCarthy and Peach (2004), who also control for demographic factors. The non fundamental based mechanism is moreover hard to reconcile with the common international pattern, unless overvaluation itself is coordinated across countries through some common and unknown mechanism.

Interesting questions naturally arise. Is there a common global factor driving the cycle in international real estate prices? What is the relevance of global macroeconomic factors and of global house price factors in determining local prices? What is the relative role of demand and supply shocks in moving house prices? Do house prices have an impact on the business cycle and is such an impact comparable to that associated with stock market shocks? The aim of the paper is to provide a joint assessment of the linkages between general macroeconomic conditions and the housing market, as well as to investigate the feedback effects of housing price shocks on the real economy. Data on eleven macroeconomic variables (GDP, private consumption and investment, CPI inflation, short- and long-term interest rates, monetary aggregates, real house prices, real stock prices, real effective exchange rates and the oil price), for the period 1980 through 2007, for the US, Japan, the Euro-12 Area, the UK and Canada, are investigated in their dynamic interactions at business cycle horizons.

The studies which are most closely related to the current research are Otrok and Terrones (2005), Chirinko et al. (2004) and Case et al. (1999). Different from Chirinko et al. (2004), who implement structural VAR analysis country by country, or Case et al. (1999), who employ multi-step univariate regression methods, the analysis is carried out in the framework of a large scale multi-country macroeconometric model, suitable to control for international and domestic interactions occurring across variables. The model is a modified version of the Stock and Watson (2005a) Factor-Augmented Vector Autoregressive (F-VAR) model, proposed by Bagliano and Morana (2008), which is further refined in the current paper in order to allow for improved estimation properties. Differently from Otrok and Terrones (2005), the proposed estimation strategy allows for a more straightforward economic interpretation of the unobservable global factors, which are extracted optimally from observed variables, rather than estimated as latent variables.

The key findings of the paper are as follows. Comovement in international house prices can be related to both house pice and macroeconomic global shocks, which are found to be largely related to US financial and macroeconomic shocks. While the house price shock accounts, on average, for about 20% of global fluctuations, the average contribution of global macroeconomic shocks is, on the other hand, close to 40%. The finding is consistent with, and better qualify, previous evidence on the linkage between global output fluctuations and real housing price dynamics, as pointed out by Otrok and Terrones (2005) and Case et al. (1999). In particular, evidence of a procyclic and inelastic response of real global house prices to global supply-side developments is found. The linkage between housing prices and macroeconomic developments is however bidirectional, with investment showing in general a stronger reaction than consumption and output to real house price shocks. Real house price shocks have a larger role than stock market shocks on the business cycle. The findings are consistent with previous results in the literature (see for instance Carrol et al., 2006; Case et al. 2005; Lettau and Ludvingson, 2004), but are more general given the modelling framework employed.

The rest of the paper is organized as follows. In the next section the econometric methodology is introduced, while in section 3 the data and their properties are presented. Then, in section 4 the F-VAR model is estimated and the contribution of global factors to housing prices fluctuations, as well as the feedback effects originating from global housing price shocks on key macroeconomic variables, is assessed. Finally, conclusions are drawn in section 5.

2 Econometric methodology

2.1 The Factor Vector Autoregressive model

The joint dynamics of q macroeconomic variables for each of the m countries (or regions) of interest are modelled by means of the following reduced form dynamic factor model:

$$
\begin{aligned}
(\mathbf{X}_t - \boldsymbol{\mu}_t) &= \boldsymbol{\Lambda}\,\mathbf{F}_t + \mathbf{D}(L)\left(\mathbf{X}_{t-1} - \boldsymbol{\mu}_{t-1}\right) + \mathbf{v}_t \qquad (1)\\
\mathbf{F}_t &= \boldsymbol{\Phi}(L)\,\mathbf{F}_{t-1} + \boldsymbol{\eta}_t. \qquad (2)
\end{aligned}
$$

In (1) $(\mathbf{X}_t - \boldsymbol{\mu}_t)$ is the n-variate vector of the weakly stationary variables of interest, $\boldsymbol{\mu}_t$ is a vector of deterministic components, including an intercept term, and linear or non linear trends components[2], $\mathbf{F}_t$ is an r-variate vector of unobserved common factors, with $r \leq q < n$, $\boldsymbol{\Lambda}$ is the corresponding $n \times r$ matrix of loading coefficients (capturing the weight of each factor for each variable in $\mathbf{X}$), $\mathbf{D}(L)$ is a $n \times n$ matrix lag polynomial of appropriate

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[2] In the paper the deterministic component included in the ith equation of (1) is specified as $\mu_{i,t} = \mu_{i,0} + \mu_{i,1}t + \mu_{i,2}\sin(2\pi t/T) + \mu_{i,3}\cos(2\pi t/T)$. A justification for the specification choice is going to be provided in the section on data properties.

order p, and $\mathbf{v}_t$ is the n-variate vector of the reduced-form idiosyncratic (iid) disturbances. In particular, in the current paper the $D(L)$ matrix is specified in such a way that not only the own lags are included in each equation, but also the lags for all the other own country variables. This specification allows for idiosyncratic macroeconomic interactions within each country (differently from Stock and Watson, 2005a), but not across countries (differently from Bagliano and Morana, 2008). Moreover, $\mathbf{\Phi}(L)$ is a $r \times r$ matrix lag polynomial of order p, and $\boldsymbol{\eta}_t$ is a vector of global shocks driving the common factors with $E\left[\eta_{jt} v_{is}\right] = 0$ for all i, j, t, s.

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

$$\begin{pmatrix} \mathbf{F}_t \\ (\mathbf{X}_t - \boldsymbol{\mu}_t) \end{pmatrix} = \begin{pmatrix} \mathbf{\Phi}(L) & \mathbf{0} \\ \mathbf{\Lambda}\,\mathbf{\Phi}(L) & \mathbf{D}(L) \end{pmatrix} \begin{pmatrix} \mathbf{F}_{t-1} \\ (\mathbf{X}_{t-1} - \boldsymbol{\mu}_{t-1}) \end{pmatrix} + \begin{pmatrix} \boldsymbol{\varepsilon}_t^F \\ \boldsymbol{\varepsilon}_t^X \end{pmatrix}, \quad (3)$$

where

$$\begin{pmatrix} \boldsymbol{\varepsilon}_t^F \\ \boldsymbol{\varepsilon}_t^X \end{pmatrix} = \begin{pmatrix} \mathbf{I} \\ \mathbf{\Lambda} \end{pmatrix} \boldsymbol{\eta}_t + \begin{pmatrix} \mathbf{0} \\ \mathbf{v}_t \end{pmatrix},$$

with variance covariance matrix

$$E(\boldsymbol{\varepsilon}_t \boldsymbol{\varepsilon}_t') = \mathbf{\Sigma}_\varepsilon = \begin{pmatrix} \mathbf{\Sigma}_\eta & \mathbf{\Sigma}_\eta\,\mathbf{\Lambda}' \\ \mathbf{\Lambda}\,\mathbf{\Sigma}_\eta & \mathbf{\Lambda}\,\mathbf{\Sigma}_\eta \mathbf{\Lambda}' + \mathbf{\Sigma}_v \end{pmatrix},$$

where $E(\boldsymbol{\eta}_t \boldsymbol{\eta}_t') = \mathbf{\Sigma}_\eta$ and $E(\mathbf{v}_t \mathbf{v}_t') = \mathbf{\Sigma}_v$. The F-VAR form in (3) can be inverted to obtain the reduced vector moving average (VMA) form for the $\mathbf{X}_t$ process:

$$(\mathbf{X}_t - \boldsymbol{\mu}_t) = \mathbf{B}(L)\,\boldsymbol{\eta}_t + \mathbf{C}(L)\,\mathbf{v}_t \quad (4)$$

where $\mathbf{B}(L) = \left[\mathbf{I} - \mathbf{D}(L)L\right]^{-1} \mathbf{\Lambda} \left[\mathbf{I} - \mathbf{\Phi}(L)L\right]^{-1}$ and $\mathbf{C}(L) = \left[\mathbf{I} - \mathbf{D}(L)L\right]^{-1}$. See the Appendix for details on the identification of the structural shocks.

2.1.1 Estimation

As in Stock and Watson (2005a), estimation is carried out by solving iteratively the following minimization problem

$$\min_{F_1,\ldots,F_T,\Lambda,D(L)} T^{-1} \sum_{t=1}^{T} \left[(\mathbf{I} - \mathbf{D}(L)L)\ (\mathbf{X}_t - \boldsymbol{\mu}_t) - \mathbf{\Lambda}\,\mathbf{F}_t\right]' \left[(\mathbf{I} - \mathbf{D}(L)L)\ (\mathbf{X}_t - \boldsymbol{\mu}_t) - \mathbf{\Lambda}\,\mathbf{F}_t\right]$$

where T is the sample size. Given a preliminary estimate of $\mathbf{F}_t$ obtained by the application of PCA analysis to the actual $\mathbf{X}_t$ series, a preliminary estimate of the $\mathbf{D}(L)$ matrix is attained by OLS estimation of equation (1). Then, a new estimate of the common factors can be obtained as the principal components of the filtered variables $(\mathbf{X}_t - \hat{\boldsymbol{\mu}}_t) - \hat{\mathbf{D}}(L)\left(\mathbf{X}_{t-1} - \hat{\boldsymbol{\mu}}_{t-1}\right)$. Conditional on the new estimated factors, updated estimates of $\mathbf{\Lambda}$ and $\mathbf{D}(L)$ can be obtained by OLS from (1). This procedure is then iterated until convergence. Once the final estimate of $\mathbf{F}_t$ is available, the $\mathbf{\Phi}(L)$ matrix is obtained by applying OLS to (2). Finally, by also employing the final estimates of $\mathbf{\Lambda}$ and $\mathbf{D}(L)$, the restricted VAR coefficients in (3) can be obtained.

Although a formal proof is beyond the scope of this paper, it is conjectured, that the above estimation procedure should lead, at least, to consistent estimation of the parameters and quantities of interest. In fact, the procedure is based on the use of consistent and asymptotically normal estimators, as recent theoretical results also validate the use of PCA in the case of weakly dependent processes (Bai, 2003).[3] Moreover, albeit multi-step, the procedure is iterated to improve efficiency.

Factor estimation Differently from Stock and Watson (2005a), principal components analysis is not directly applied to the whole set of variables in $\mathbf{X}_t$, but, following the lead in Bernanke and Boivin (2003) and Bagliano and Morana (2008), the data set is divided into categories of variables, and the common factors are estimated sequentially as the first principal component for each sub-set of series. For instance, a "global house price factor" is estimated as the first principal component from the set of the house price series for the countries under study, a "global stock market price factor" is estimated as the first principal component from the set of all the stock market price series, and so on. Therefore, the r static factors in $\mathbf{F}_t$ are separately estimated as the first principal components from the relevant sub-sets of variables, each including m series.

The sub-set strategy adopted is preferable to the whole set strategy for two main reasons. Firstly, it can make easier to give an economic content to the factors. Secondly, it avoids contamination from series potentially unrelated to the phenomenon of interest, which could undermine the asymptotic theory justifying the use of principal components analysis. In fact, the latter assumes that the variability of the common component is not too small and that the cross-correlation in the idiosyncratic errors is not too large. If noise is added to the information set it can be expected that, as more variables are included, the average size of the common factors will decrease, while the correlation across idiosyncratic components will increase. Hence, beyond a

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[3] In particular, Bai (2003) establishes consistency and asymptotic normality of PCA 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.

certain threshold, increasing the cross-sectional dimension of the information set is not desirable, and could also negatively affect the explanatory power of the model (see Boivin and Ng (2006) for an extensive discussion of this issue). Moreover, Monte Carlo results reported in Morana (2007) show that principal components analysis is a very effective tools to extract common factors from a set of dependent variables even in small samples (the cross sectional dimension can be as low as two units), which provide small (cross-sectional) sample support for the use of a procedure which is only justified when the cross-sectional dimension diverges. Interestingly, results in Bagliano and Morana (2008) point to significant accuracy improvements in estimation of the proposed approach, as measured by information criteria, relatively to the original Stock and Watson (2005a) approach.[4]

3 The data

We use time series data for the US, Japan, the Euro-12 Area, the UK and Canada, over the period 1980:1-2007:2. Although only three out of twelve Euro-12 area members, i.e. Germany, France and Italy, are also G-7 member countries, in the light of the dominant contribution of these three latter countries to euro area GDP (75%), the five countries investigated have been referred, for simplicity, as the G-7 countries. Eleven variables for each country have been considered, i.e. real GDP, private consumption and investment, the CPI price index, nominal money balances[5], the nominal short- and long-term interest rates[6], real house prices[7], the real effective exchange rate, the real oil price, and the real stock market price index[8]. The latter four variables have been obtained from the corresponding nominal quantities using the CPI index

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[4] In the recent literature several other approaches to global macroeconometric models estimation have been proposed (Giannone et al., 2002; Favero et al., 2005; Bernanke et al., 2005; Pesaran et al., 2004; Dees et al., 2007). We point to Bagliano and Morana (in press) for a comparative discussion of the strengths and weaknesses of the procedure implemented.

[5] 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.

[6] The short-term rate refers to three-month government bills, while the long-term rate to ten-year government bonds.

[7] Real house price data have provided by the Economics Department of the OECD. The sources and methodology are described in OECD Economics Department working paper No 475.

[8] The stock price series are OECD all shares price indexes for the US, Japan, Canada and the UK. On the other hand, for the euro area the Euro Stoxx 325 index has been employed.

as deflator. All series are sampled at a quarterly frequency and seasonally adjusted when appropriate.[9]

The choice of the time span is dictated both by data availability and modelling convenience. In fact, over the selected time period homogeneous series across countries can be gathered, and reliable euro-area aggregates are available. Moreover, in view of the change in the pattern of common cyclical fluctuations among the major world's economies in the 1980s and 1990s (see Stock and Watson, 2005b, among others), focusing on the post-1980 period should reduce the possibility of parameter instability problems in estimation.

The persistence properties of the data have been assessed by means of unit roots and stationarity tests. In addition to the ADF test (Said and Dickey 1984) and the KPSS test (Kwiatkowski et al. 1992), also the Enders and Lee (2005) ADF test and the Beckers et al. (2006) 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 various forms of non linear smooth deterministic trends, but also being able to account for the presence of sharp breaks (see Enders and Lee, 2005).

The tests have been carried out directly on the series used in the empirical analysis, i.e. the growth rates of real GDP (denoted by g), private consumption (c) and investment (i), the rate of CPI 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 house price (h), the real effective exchange rate (e), the real stock price (f), and the real price of oil (o). The unit root tests show slightly different results for real and nominal variables.[10] While the findings are clear-cut for all the real variables, apart from real output growth for Japan, pointing to I(0) stationarity, for the nominal variables, as well as for real output growth for Japan, stationarity can be found only for the series in deviation from a non linear deterministic component. As far as the nominal variables are concerned, the latter, as argued in Bierens (2000) and Morana (2006), can be associated with successful long-run monetary policy management. In fact, the outcome 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.[11] Differently, for real output growth

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[9] The source of the euro-area aggregate data is the European Central Bank. All the other data are taken from the OECD main economic indicators database and from *Datastream.*

[10] Detailed results are not reported for reasons of space, but are available upon request from the authors.

[11] 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

for Japan the nonlinear component accounts for the slowdown in economic growth due to the stagnation of the 1990s.

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

4 The F-VAR model: estimation and policy analysis

As described in the methodological section, the F-VAR model requires an initial estimate of the global factors $\mathbf{F}_t$ in the first step of the iterative procedure. The latter is obtained by means of principal components analysis, carried out on sub-sets of homogeneous variables. For each sub-set, the global factor is estimated by the first principal component, provided that the candidate global factor (i) explains a sufficiently large fraction of the total variance of the variable set from which it is extracted, and (ii) its relevance is not limited to only one or two regions but is evenly spread across countries. Results are reported in Table 1, showing the proportion of the total variance of the series attributable to each PC_i (with $i = 1, ...5$),[12] followed by the fraction of the variance of each individual variable explained by each PC_i.

As shown in Table 1, the findings are coherent with previous evidence provided in the literature (Kose et al., 2005; Bagliano and Morana, 2006; Canova et al., 2007; Morana and Beltratti, 2008; Ehrmann et al., 2005; Ciccarelli and Mojon, 2005). Firstly, the evidence of global dynamics is in general stronger for nominal variables than for real variables. For instance, the first principal component explains a proportion of total variance in the range of 72% to 96% for inflation and nominal interest rates. For nominal money growth the proportion of explained total variance is still large, but lower than for the other nominal variables, i.e. 45%. On the other hand, the evidence is mixed for the other variables, with the proportion of explained total variance being larger for the asset variables (68% for stock prices and 43% for housing prices) than for GDP (40%) and its components (38% for consumption and 32% for investment). Not surprisingly the evidence in favour of a global factor is also very strong for real oil prices (95%), since heterogeneity in the latter sub-set of series is only due to the exchange rate component. Differ-

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short and long term interest rates series.

[12] The fraction of the total variance attributed to PC_j is given by $\lambda_j / \left(\sum_{i=1}^{5} \lambda_i \right)$, where λ_j is the j-th largest characteristic root of the sample variance-covariance matrix of the series.

ently, the first principal component from the sub-set of real exchange rates is heavily influenced by the US series (77%), with only a minor impact on the UK and Canada (8% and 11%, respectively). The evidence of separate global factors for real activity and house and stock prices is consistent with Otrok and Terrones (2005) and Kose et al. (2005), as well as with Case et al. (1999), concerning the presence of global dynamics in house prices.[13]

Secondly, additional insights on global comovements are provided by principal components analysis carried out on two sub-sets of series, composed of the nominal variables (twenty series) on the one hand and GDP growth and its components (fifteen series) on the other hand. The empirical evidence (Table 2) points to a single common factor explaining 64% of total variance for the nominal variables and 30% for the real activity variables. In both cases, the evidence is in favour of a single global factor, as the average proportion of variance explained for each nominal variable is close to 70% when the more idiosyncratic money supply growth series for the US and Canada are neglected, while for the real variables the average figure is about 40%, once the more idiosyncratic figures for Japan are neglected.

Hence, the evidence points to five "statistical" global factors affecting the investigated series, i.e. a "nominal" factor (extracted from inflation, interest rates and money growth), a "real activity" factor (extracted from the growth rates of GDP, consumption and investment), a "real stock price" factor, a "real house price" factor, and a "real oil price" factor. Despite their having been obtained from separate group analysis, the estimated factors are not strongly correlated, as the average (absolute) correlation for the innovations is about 0.10, with maximum and minimum values equal to 0.29 and 0.01, respectively. Finally, given the dominant impact of the factors on the US variables (51%, 56%, 60% and 80% of variance explained for real activity, nominal variables, house prices and stock prices, respectively), it is possible to associate the latter to US macroeconomic and financial markets developments.

The above factors have then been included in the F-VAR model as starting estimates of the elements of vector $\mathbf{F}_t$ in the first step of the iterative procedure.

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[13] The mostly idiosyncratic behavior of Japan is evident from the results for the real variables, as the first principal component, different from the other countries, only explains a small proportion of variance for the Japanese variables, which is, on the other hand, accounted for by the second principal component. The findings are consistent with the long stagnation and depression which has characterized Japan over the 1990s and the beginning of the new century. Yet, somewhat surprising is the sizeable degree of correlation which can be found, on the basis of the second principal component, between Japan and the euro area, especially concerning GDP growth (and its components) and real housing prices.

4.1 F-VAR specification

On the basis of the BIC information criterion, the optimal lag length of the F-VAR system could be set to one lag. The optimal structure of the model is therefore very parsimonious. The first five equations correspond to the vector of common factors $\mathbf{F}_t$ with an ordering due to speed of adjustment: real activity factor, nominal factor, house price factor, oil price factor and stock market factor. Each equation has 9 parameters, of which 5 are for the lagged factor series and 4 are for the deterministic trend (including a constant, a linear and two non linear components, as described in data section). Vector $\mathbf{X}_t$ collects 10 endogenous macroeconomic variables (namely g, c, i, π, s, l, m, h, e, and f, in this order) for the 5 regions analyzed (within each variable group, the regions are ordered as: US, euro area, Japan, UK, and Canada).[14] Assuming an own-country block diagonal structure for the $D(L)$ matrix, each equation corresponding to the 50 elements of $\mathbf{X}_t$ has therefore 19 parameters: 10 for the own-country lagged endogenous variables, 5 for the lagged factors, and 4 for the deterministic components.

Following the thick modelling estimation approach (Granger and Jeon, 2004), estimation has however been based on both a first and second order structure of the model. The latter counts 34 parameters in each of the equations corresponding to the 50 elements of $\mathbf{X}_t$: 20 for the own-country lagged endogenous variables, 10 for the lagged factors, and 4 for the deterministic components. Both models have been simulated as well (1000 replications), and final estimates for all the relevant parameters have been obtained as median estimates from cross-sectional distributions with dimension of 2,000 units.

4.2 Structural shocks analysis

The identification of the structural shocks has been carried out by means of the double Choleski procedure described in the methodological Section. Cumulated impulse responses to a unitary shock, with 95% significance bands, have been computed up to a horizon of ten years, to show the dynamic reaction of the level of investigated variables ($\mathbf{X}_t$). Impulse response functions for the US and the euro area are reported in Figures 1-4, while in Table 3 results for the forecast error variance decomposition at the one-year (short-term)

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[14] The PC analysis carried out in the previous section showed that the variance of real oil prices in all regions is almost entirely attributable to a common factor, leaving a negligible role for idiosyncratic components. Therefore, the oil price factor is included as an element of $\mathbf{F}_t$, but the oil price series are not included as an element of $\mathbf{X}_t$.

and five-year (medium-term) horizons are reported.[15]

4.2.1 The transmission mechanism of global shocks

As shown in Table 3 the joint contribution of global shocks across countries is on average stronger in the medium-term (71%) than in the short-term (61%). Such contribution is in the range 39% to 95% (32% to 91%) for real activity variables in the medium-term (short-term), with similar figures for consumption (34% to 92%), GDP (35% to 79%) and investment (44% to 95%). An even stronger contribution of global shocks to fluctuations is found for nominal variables (43% to 98%), apart from euro area data in the short-term (16% to 71%), particularly for money growth (3% to 18%).

A sizeable contribution of the global shocks can also be found for asset prices: across countries, global shocks explain a proportion of medium-term (short-term) fluctuations in house prices and stock prices in the range 30% to 96% and 62% to 87% (12% to 91% and 54% to 90%), respectively. House prices are relatively more idiosyncratic than stock prices at both horizons due to the evidence associated with the euro area, that shows, particularly in the short-term, weaker dependence on global dynamics. Neglecting euro area data, in fact, figures are 51% to 91% and 67% to 87% (67% to 86% and 54% to 90%). Hence, in addition to global dynamics, regional factors may be relevant to explain house price fluctuations.

On the other hand, idiosyncratic shocks explain the bulk of exchange rates variability (55% to 90%), apart from Japan (about 30%), for which the linkage of the real exchange rate with the global nominal shock seems to be particularly strong (about 50%).

Neglecting the exchange rate series, on average global shocks explain about 73% of total fluctuations in the US macroeconomic and financial series, while the impact on euro area and Japanese variables is smaller (42% and 64%, respectively). On the other hand, a larger impact can be found for the UK and Canada (83% and 86%). The evidence is therefore consistent with the view assigning a dominant role to US shocks in causing international business cycle and financial markets fluctuations. Given the much smaller size of the UK and Canadian economies, relatively to the US economy, the large proportion of variance explained by the global shocks for these latter two countries may just point to strong economic and financial integration with the US economy.

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[15] For reason of space, only the impulse responses of US and euro area macroeconomic variables to global financial shocks are reported, as well as the response of US and euro area financial variables to global macroeconomic shocks. A full set of results is available upon request from the authors.

Interestingly, from the point of view of this research, such role extends to the housing market (at least in the medium-term), whose price movements are sometimes considered to be largely country-specific due to the impossibility to move land internationally, i.e. due to the local and isolated nature of each market. Differently, the findings of this paper indicate that shocks to the price of the US housing market are important in determining the variability of house prices in other countries. This may be indirectly due to the large role of both the US interest rate, representing a common valuation factor for international assets because of its influence on international interest rates, and US real activity dynamics, because of the strong international propagation of the US business cycle.

Given the scope of the analysis, and the above findings concerning the importance of global shocks in explaining economic fluctuations, the rest of the paper is focused on the responses to global shocks, neglecting a detailed analysis of the within country responses to the structural idiosyncratic shocks.

Macroeconomic consequences of global shocks to stock and house prices The impulse response analysis shows that global stock market shocks significantly lead output, consumption and investment dynamics for all countries, at least in the short-term (Figures 3-4). The response of real activity variables is inelastic in all cases, and larger for investment than GDP and consumption, and for the US than for the other countries. As far as GDP and consumption elasticities are concerned, median estimates are similar in magnitude, in the range 0.03 (euro area and Japan) to 0.13 (US) for GDP, and in the range 0.02 (euro area and Japan) to 0.11 (US) for consumption. On the other hand, estimates for investment elasticities are in the range 0.07 (euro area) to 0.43 (US). Medium-term elasticities do not differ much from the short-term ones, and are still statistically significant (see Table 4).

We are cautious to claim that the above findings reflect a causal relation, since forward-looking investors determine stock prices in anticipation of future economic events. Hence, the detected lead-lag relationship may simply result from the predictive ability of the stock market. Yet, by having separately identified the real activity factor from the stock price factor (and the house price factor, as well), the detected linkage should not be spuriously determined by a common unobserved factor driving both series, as, for instance, a factor reflecting future income prospects, to which, in addition to stock prices, also consumption would respond, or a financial liberalization factor (see Campbell and Cocco, 2007). Hence, the explanation for the empirical findings could also be found in wealth effects and Tobin's Q effects, with stock market shocks systematically affecting wealth and investment opportunities, and therefore agents' decisions. Overall, the large impact of the global stock market shocks on US real activity is consistent with the important role of the US stock market in consumption and production activities.

Similarly, the global house market shock significantly leads output and consumption dynamics in all countries, apart from Japan (Figures 1-2). GDP and consumption responses to house prices are still inelastic, but larger than what found for stock prices, and still larger for the US than for the other countries. As far as short-term GDP elasticities are concerned, figures are 0.25 for the US, 0.06 for the UK and 0.14 for Canada (see Table 4). For the euro area and Japan, on the other hand, medium-term elasticities only are significant, i.e 0.16 and 0.73, respectively. Similar figures can be found for consumption elasticities, i.e. 0.31, 0.15 and 0.13 for the US, the UK and Canada, and 0.18 for the euro area, while the response of consumption is never significant for Japan. A significant and even stronger impact can be found for investment in the medium-term (0.54 for the euro area, 0.37 for the UK, and 0.67 for Canada, 2.15 for Japan), albeit the impact is not significant for the US.

In the light of the separate identification of the global factors, and keeping into account the trend towards using the value of housing as a collateral for obtaining debt, there may be more a priori reasons to believe that the above results reflect true causality. The evidence then points to significant effects of asset values on real activity, with investment showing in general stronger sensitivity than GDP and private consumption, and real house price shocks having deeper effects on the macroeconomy than stock market shocks. The latter finding is consistent with previous literature on wealth effects (Chirinko et al., 2004; Carrol et al., 2006), showing that a real estate shock has a larger impact on consumption than a stock market shock, due to the larger proportion of wealth invested in the real estate market than in the stock market for the countries investigated, particularly for European countries and Japan.[16] Also, Lettau and Ludvigson (2004) show that a small fraction of variation in household net worth is associated with variation in aggregate consumer spending, as the majority of quarterly fluctuations in asset values are attributable to transitory innovations that have no association with consumption. Up to 88% of the postwar variation in household net worth is generated by transitory innovations primarily associated with fluctuations in the stock market. Only permanent changes in wealth (largely determined by shocks

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[16] For istance, recent estimates show that residential property accounts for about 25% of aggregate households wealth in the US and up to 35% for the UK. See Campbell and Cocco (2007).

to nonstock wealth) are associated with movements in consumption (about 5%).

Forecast error variance decomposition analysis (Table 3) shows the existence of an interesting asymmetry between the effects of stock market shocks and those of real estate shocks: the former has basically no impact on house prices for all the countries (0% to 1.8%, 0.7% on average), while the latter has a more sizeable impact on stock prices (0.3% to 22%, 6% on average). This is consistent with the central role played by the real estate market in the overall economy. Moreover, from the impulse response analysis it can be noted that an expansionary house price shock leads to an increase in stock prices, at least in the short-term, which is significant for all countries, apart from the euro area and the UK, while an expansionary stock price shock has mixed effects on house prices, i.e. negative for the euro area, positive for Japan, Canada and the UK, and not significant for the US. A change in wealth brought about by a reduction in house prices would then lead US investors to rebalance their portfolios (in the short-term) by selling stocks as well. Differently, a drop in stock prices would lead euro area investors to shift their portfolios in favour of the perceived safer housing market. It is however the former effect which seems to be the most relevant, given the results of the forecast error variance decomposition analysis. Yet, the latter effect well describes recent macroeconomic developments in financial markets, since, despite the contraction in stock prices of 2001-2002, housing prices have kept increasing rapidly.

Finally, still in terms of forecast error variance decomposition, the medium-term contribution of the own global shock to fluctuations is always sizeable for both cases, i.e. 4% to 47% (22% on average) for house prices, and 16% to 30% (27% on average) for stock prices, pointing therefore to non negligible "real estate (non-macro)" sources of comovement in house prices.

Financial consequences of macroeconomic shocks While the structural interpretation of the non-macro factor shocks in terms of global house price (ξ_h) and global stock price (ξ_f) shocks and oil price factor shock (ξ_o) is straightforward, for the real activity (ξ_{bc}) and nominal (ξ_n) factor shocks some additional issues should be considered.

Nominal factor Consistent with Bagliano and Morana (2006), the source of comovement in nominal variables may possibly be associated with the disinflationary policies carried out by the central banks of the countries investigated over the 1980s, and the successful inflation control thereafter. Such forces are accounted for by the non linear deterministic trend.[17] On the basis of previous evidence (Bierens 2000, Morana 2006), we interpret it as capturing a gradual downward trend in the level of inflation rates, interest rates and monetary growth, reflecting effective long-term monetary policy management, potentially related to the disinflationary policies carried out since the 1980s.

The structural shock (ξ_n) is therefore estimated from factor dynamics around the deterministic trend. Following Gordon (2005), pointing to an important role of productivity growth in determining US inflation dynamics, the structural disturbance to the nominal factor is then related to common supply-side/productivity forces. The proposed interpretation is coherent with the impulse response analysis, showing a negative supply-side shock leading to an increase in the price level and a contraction in output. According to the estimates (not reported), a 1% contraction in real activity can be associated with a 1.7% (1.4%) increase in the price level in the short-term (medium-term) for the US, while for the euro area the impact is significant and similar in size for the medium-term only. An elastic response can however be found also for the other countries at both horizons (in the range 1.4 to 3.4, for the UK and Canada).

A negative supply-side shock decreases housing and stock prices. This reinforces the validity of our interpretation of the factor as a productivity shock. A negative productivity shock would in fact decrease dividends/rents paid by assets, at the same time increasing the discount factor because of the increase in prices. Present discounted value equations for stocks and houses would therefore imply a direct positive relation between a productivity shock and asset prices. Other economic mechanisms could, however, be also at work. For instance, an increase in inflation may trigger a contraction in housing prices, since inflation reduces the after-tax user cost of housing, decreasing housing demand. Moreover, since under money illusion the evaluation of an asset is inversely related to the level of inflation, an increase in inflation would lead to lower asset prices (Brunnermeier and Julliard, 2005).

Our estimates point to a non negligible impact of the supply-side/productivity shock on house prices, particularly in the medium-term, which, in terms of forecast error variance decomposition, is dominating for the US (64%), and sizeable for Japan, Canada and the UK (34% to 42%), but not for the euro area (6%). Hence, the international comovement in house prices, in addition to the global house price factor, can also be related to global productivity dynamics. In terms of size of the impact, an elastic response of house prices

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

can in general be found for all countries in the medium-term, with a house price elasticity in the range 1.5 to 4.6 (Table 4). Overall, the evidence is then consistent with previous results of Otrok and Terrones (2005), as well as of Case et al. (1999), pointing to a direct linkage between expanding output (income) and housing demand and prices.

Finally, concerning stock prices, it should however be noted that while the point impact of the (negative) supply-side/productivity shock on stock prices is still negative in the medium-term (apart from Japan), it is in general not statistically significant. In terms of forecast error variance decomposition, the global productivity shock does however seem to affect stock prices (0.3% to 29%).

Real activity factor The real activity factor shock (ξ_{bc}) can be interpreted in terms of global demand-side shocks. This follows from two arguments.

Firstly, the real activity shock accounts for a non negligible proportion of output (8% to 14%), investment (6% to 16%) and consumption (2% to 17%) fluctuations at business cycle horizons, particularly for the US, the euro area and the UK (Table 3). A more idiosyncratic behavior is found for GDP for Canada (up to 4%), but not for its GDP components, and for Japan. For the latter country the result is not surprising, given the very different demand-side conditions over the 1990s.

Secondly, in terms of forecast error variance decomposition it can be noted that the shock has a negligible impact on the price level for all countries (0.3% to 2.7%), consistent with the role played by productivity advances in determining US inflation dynamics (Gordon, 2005), and the strong global transmission of US inflation/productivity shocks. Impulse response analysis confirms the non significant medium-term impact of the shock on prices for all the countries, apart from the UK and Japan (not reported).

Interestingly, while this latter shock only plays a minor effect on house prices fluctuations for all countries, in the range 0% to 2.3%, the contribution to stock market fluctuations is sizeable, in the range 18% to 45%, excluding Japan (up to 10%). In general the response of stock prices to the shock is elastic, and similar at both horizons (in the range –29.5 to -11.8). On the other hand, no significant response is found for house prices for the US and Canada, while a positive and elastic response is found for the UK and the euro area in the medium-term

Oil price factor Oil price shocks explain a sizeable proportion of returns variability for both stock (2% to 6%) and house prices (1% to 7%), with an increase in oil prices leading to a significant contraction in both stock and house prices for all countries, apart from Japan. This is coherent with the idea of a negative impact of the terms of trade on oil-importing countries and with the increase in production costs. It is also coherent with the significant contraction determined by the oil price shock on real activity, as well as with the increase in the price level (the elasticity of CPI relative to the oil price is in the range 0.10 to 0.40; not reported). Present discounted value model motivations, after-tax user cost of housing, and money illusion, may then still be the relevant mechanisms to explain the detected correlation.

Interestingly, while the medium-term response of the stock market is elastic (in the range -1.9 to -1.0), the response of the house market is mixed (-1.4 to -0.5). Differently, an inelastic response can be detected in the short-term for both cases.

5 Conclusions

In the paper a large scale macroeconometric model is employed to investigate the linkages between housing prices and macroeconomic developments for the G-7. The key findings of the paper are as follows.

Firstly, global macroeconomic and financial shocks can be largely interpreted in terms of US macroeconomic and financial shocks. In addition to real activity, nominal variables and stock returns, compelling evidence is also found for returns associated with owning houses. Secondly, global macroeconomic shocks play an important role in determining common house price fluctuations for the G-7, accounting on average for about 40% of total real house price fluctuations. Among the global shocks, productivity shocks are more important than demand shocks in determining house prices. Yet, macroeconomic shocks are not the only source of international comovement in house prices, as about 20% of total house price fluctuations are accounted for by a purely “real estate” shock. Third, regional factors are important for explaining house prices, particularly for the euro area. Fourth, the linkage between house prices and macroeconomic developments is bidirectional, with investment showing in general a stronger reaction than consumption and output to real house price shocks. Moreover, house price shocks produce larger effects on the macroeconomy than stock market shocks. Fifth, house price shocks have a relevant impact on stock price shocks, while stock price shocks do not strongly affect house prices.

Overall, the results show that residential real estate markets are interconnected across countries. The fact that such links take place through shocks to macroeconomic variables, mainly supply shocks and interest rates, may be interpreted as evidence favorable to rational pricing rather than to fads.

There is however also a residual role for international propagation of pure price shocks, a component which might be associated with speculation. The results are relevant for portfolio models used to study international diversification. The large role played by propagation of macroeconomic shocks means that international diversification may be less important for the residential market than it is for stock markets. The results may also be of interest for policy-makers, who should not ignore the international business cycle and the forces associated with house prices. House prices play in fact a powerful role and affect important macroeconomic variables.

In future research, it would be interesting to use a present discounted value model to give a more structural interpretation of the data and estimate a fundamental-related source of common shocks. The residual would represent an estimate of the price shock due to nonfundamental, speculative reasons. It would then be interesting to analyze the international propagation of the two components and test whether comovements are mainly associated with speculation or time-varying expectations of fundamentals. This would also be useful to better interpret price shocks (of houses and stocks) as true exogenous shocks rather than an anticipation of future movements of fundamentals. Current results would induce to think that the main reason for international propagation of house price shocks is actually the one associated with fundamentals.

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6 Appendix: Identification of structural disturbances

By denoting as $\boldsymbol{\xi}_t$ the vector of the r structural factor shocks, the relation between the reduced form and the structural factor disturbances can be written as $\boldsymbol{\xi}_t = \mathbf{H}\,\boldsymbol{\eta}_t$, where $\mathbf{H}$ is a $r \times r$ invertible matrix. By assumption the structural factor shocks are orthogonal and have unit variance, so that $E\left[\boldsymbol{\xi}_t\boldsymbol{\xi}_t'\right] = \mathbf{H}\,\boldsymbol{\Sigma}_\eta\,\mathbf{H}' = \mathbf{I}_r$. Given r factors, and the orthogonality conditions, $r(r-1)/2$ additional restrictions need then to be imposed to obtain exact identification of the structural disturbances.

Similarly, by denoting as $\boldsymbol{\psi}_t$ the n-variate vector of idiosyncratic structural shocks (uncorrelated with the structural factor shocks), related to the reduced form idiosyncratic disturbances $\mathbf{v}_t$ through $\boldsymbol{\psi}_t = \boldsymbol{\Theta}\,\mathbf{v}_t$, where $\boldsymbol{\Theta}$ is a $n \times n$ invertible matrix, the identification of the idiosyncratic structural disturbances, in addition to the orthogonality conditions $E\left[\boldsymbol{\psi}_t\boldsymbol{\psi}_t'\right] = \boldsymbol{\Theta}\,\boldsymbol{\Sigma}_\psi\,\boldsymbol{\Theta}' = \mathbf{I}_n$, requires additional $n(n-1)/2$ restrictions for exact identification.

The structural VMA representation of the dynamic factor model can then be written as

$$(\mathbf{X}_t - \boldsymbol{\mu}_t) = \mathbf{B}^*(L)\,\boldsymbol{\xi}_t + \mathbf{C}^*(L)\,\boldsymbol{\psi}_t, \tag{5}$$

where $\mathbf{B}^*(L) = \mathbf{B}(L)\,\mathbf{H}^{-1}$ and $\mathbf{C}^*(L) = \mathbf{C}(L)\,\boldsymbol{\Theta}^{-1}$ describe the impulse response functions of each variable in $\mathbf{X}_t$ to the structural factor ($\boldsymbol{\xi}_t$) and idiosyncratic ($\boldsymbol{\psi}_t$) shocks, respectively.

The additional $r(r-1)/2$ and $n(n-1)/2$ restrictions needed for the exact identification of all the structural shocks can be imposed through exclusion restrictions on the contemporaneous responses of the r factors in $\mathbf{F}_t$ to the structural factor shocks and the contemporaneous responses of the n variables in $\mathbf{X}_t$ to the structural idiosyncratic shocks, respectively.[18]

Factor shocks Since $\boldsymbol{\eta}_t = \mathbf{H}^{-1}\boldsymbol{\xi}_t$, the imposition of exclusion restrictions on the contemporaneous impact matrix amounts to imposing zero restrictions on the elements of the matrix $\mathbf{H}^{-1}$, for which a lower-triangular structure can be assumed. This latter assumption implies a precise "ordering" of the common factors in $\mathbf{F}_t$. Since the estimation of the common factors from sub-sets of variables, capturing different dimensions of the economy (output, inflation, etc.), allows for a more direct interpretation of the estimated factors, an ordering based on plausible assumptions on the relative speed of adjustment to shocks can be chosen, starting with the factor showing

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

the slowest speed of adjustment. The first factor is allowed to have a contemporaneous impact on all other factors, but reacts only with a one-period lag to the other structural disturbances; instead, the last factor is contemporaneously affected by all structural shocks, having only lagged effects on all other factors. Operationally, $\mathbf{H}^{-1}$ (with the $r(r-1)/2$ zero restrictions necessary for exact identification imposed) is estimated by the Choleski decomposition of the factor innovation variance matrix $\boldsymbol{\Sigma}_{\eta}$: $\hat{\mathbf{H}}^{-1}$ =chol$(\hat{\boldsymbol{\Sigma}}_{\eta})$.

Idiosyncratic shocks Since $\boldsymbol{\psi}_t = \boldsymbol{\Theta}^{-1}\mathbf{v}_t$, the imposition of exclusion restrictions on the contemporaneous impact matrix amounts to imposing zero restrictions on the elements of the matrix $\boldsymbol{\Theta}^{-1}$. In order to comply with the assumed structure of the $D(L)$ matrix, which allows for own country interactions of idiosyncratic shocks only, the distinctions between large and small countries and slow-moving and fast-moving variables can be exploited at the country level. The elements of $\mathbf{X}_t$ and $\boldsymbol{\psi}_t$ are then stacked into m country sub-vectors, ordered according to GDP size, and therefore placing the relatively large regions first (the US, the Euro-12 area, Japan), followed by the smaller countries (the UK and Canada). Within each of the m sub-vectors, then a speed of adjustment based ordering is followed, placing the slow-moving variables (and the corresponding disturbances) in the upper position followed by the fast-moving variables.

In practice, the elements of $\boldsymbol{\Theta}^{-1}$ are identified by imposing a block diagonal structure for each block of country variables:

$$\boldsymbol{\Theta}^{-1} = \begin{bmatrix} \Theta_{11} & 0 & \cdots & 0 \\ 0 & \Theta_{22} & \cdots & \vdots \\ \vdots & \cdots & \ddots & 0 \\ 0 & 0 & \cdots & \Theta_{rr} \end{bmatrix},$$

where each block Θ_{jj} has dimension $q \times q$. The latter implies that structural idiosyncratic shocks are not transmitted across countries. Then, a lower triangular structure is imposed on each of the Θ_{jj} matrices, implying that the relatively "faster" variables (in any country) have no contemporaneous impact on the "slower" variables (within any country):

$$\Theta_{jj} = \begin{pmatrix} \theta_{jj,11} & 0 & \cdots & 0 \\ \theta_{jj,21} & \theta_{jj,22} & 0 & \vdots \\ \vdots & \cdots & \ddots & \vdots \\ \theta_{jj,m1} & \cdots & \cdots & \theta_{jj,mm} \end{pmatrix}.$$

Hence, for instance, block $\boldsymbol{\Theta}_{11}$ would contain the impact responses of the US macroeconomic variables, in the order: output growth, consumption growth, investment growth, inflation, nominal short and long term interest rates, money growth, house price returns, exchange rate returns, stock market returns. Then, block $\mathbf{\Theta}_{22}$ contains the impact responses of the euro area macroeconomic variables in the same order as above, and so on.

Operationally, the estimation of the $\mathbf{\Theta}^{-1}$ matrix is carried out as follows. First, the estimate of the F-VAR innovations $\hat{\boldsymbol{\varepsilon}}_t^X$ from (3) is regressed on $\hat{\boldsymbol{\xi}}_t$ by OLS to obtain an estimate of the idiosyncratic disturbances, $\hat{\mathbf{v}}_t$. Then, each of the $\mathbf{\Theta}_{jj}^{-1}$ (with the $q(q-1)/2$ zero restrictions necessary for exact identification of each block imposed) is estimated by the Choleski decomposition of the own country idiosyncratic shocks variance matrix $\mathbf{\Sigma}_{v_{jj}}$: $\hat{\mathbf{\Theta}}_{jj}^{-1} = \text{chol}(\hat{\mathbf{\Sigma}}_{v_{jj}})$. In total $mq(q-1)/2$ zero restrictions are imposed by the proposed procedure on the contemporaneous impact for the relevant variables in the full block diagonal structure. Given the cross-country orthogonality assumption concerning the idiosyncratic shocks, no additional restrictions are needed to obtain the desired block diagonal structure for $\mathbf{\Theta}^{-1}$.[19]

The suggested approach implicitly assumes that cross-country interactions between the $\hat{\mathbf{v}}_t$ innovations are null, i.e. $\mathbf{\Sigma}_{v_{ij}} = \mathbf{0}$, $i \neq j$. If this is not the case, before the computation of the $\mathbf{\Theta}_{jj}^{-1}$ sub-matrices $m-1$ orthogonalization steps can be implemented. The first step requires the OLS regression of $\hat{\mathbf{v}}_t^m$ on $\hat{\mathbf{v}}_t^{-m}$, to obtain an estimate of the idiosyncratic disturbances for the mth country, $\tilde{\mathbf{v}}_t^m$, not correlated with the idiosyncratic disturbances for all the other non-m countries, $\hat{\mathbf{v}}_t^{-m}$ ($\hat{\mathbf{v}}_t^{-m} = [\hat{\mathbf{v}}_t^{1\prime}\ \hat{\mathbf{v}}_t^{2\prime}\ ...\ \hat{\mathbf{v}}_t^{m-1\prime}\ ]'$). Then, an equivalent step should be repeated for the previous $m-1$ country, i.e. the OLS regression of $\hat{\mathbf{v}}_t^{m-1}$ on $\hat{\mathbf{v}}_t^{-(m-1)}$ is carried out, with $\hat{\mathbf{v}}_t^{-(m-1)}$ neglecting data for the mth country ($\hat{\mathbf{v}}_t^{-(m-1)} = [\hat{\mathbf{v}}_t^{1\prime}\ ...\ \hat{\mathbf{v}}_t^{m-2\prime}\ ]'$). Then, the procedure is repeated for the remaining countries.

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[19] Given the cross-country orthogonality assumptions for the idiosyncratic shocks, the procedure is equivalent to computing the Cholesky decomposition of the block diagonal $n \times n$ variance-covariance matrix for the idiosyncratic innovations directly.

Table 1: Principal components analysis
Separate sub-sets of 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	0.22	0.18	0.12	0.08	m (all)	0.45	0.21	0.14	0.12	0.07
g_{US}	0.65	0.00	0.13	0.02	0.20	m_{US}	0.32	0.38	0.04	0.26	0.00
g_{EA}	0.30	0.33	0.15	0.22	0.00	m_{EA}	0.36	0.13	0.47	0.04	0.00
g_{JA}	0.04	0.77	0.07	0.11	0.00	m_{JA}	0.63	0.00	0.11	0.14	0.12
g_{UK}	0.43	0.00	0.34	0.21	0.02	m_{UK}	0.71	0.04	0.03	0.01	0.21
g_{CA}	0.59	0.01	0.22	0.01	0.18	m_{CA}	0.25	0.52	0.06	0.15	0.02
c (all)	0.38	0.21	0.17	0.13	0.11	h (all)	0.43	0.22	0.14	0.12	0.10
c_{US}	0.56	0.00	0.15	0.02	0.28	h_{US}	0.60	0.08	0.00	0.00	0.31
c_{EA}	0.13	0.53	0.30	0.03	0.01	h_{EA}	0.42	0.23	0.03	0.30	0.02
c_{JA}	0.13	0.52	0.34	0.01	0.01	h_{JA}	0.10	0.74	0.05	0.02	0.09
c_{UK}	0.52	0.01	0.00	0.46	0.02	h_{UK}	0.50	0.00	0.41	0.02	0.07
c_{CA}	0.57	0.00	0.03	0.15	0.23	h_{CA}	0.50	0.06	0.19	0.24	0.01
i (all)	0.32	0.23	0.20	0.13	0.11	e (all)	0.36	0.26	0.20	0.16	0.02
i_{US}	0.36	0.38	0.00	0.02	0.24	e_{US}	0.77	0.01	0.20	0.00	0.03
i_{EA}	0.50	0.13	0.00	0.37	0.00	e_{EA}	0.39	0.45	0.01	0.14	0.02
i_{JA}	0.09	0.60	0.09	0.16	0.06	e_{JA}	0.45	0.36	0.00	0.17	0.02
i_{UK}	0.24	0.01	0.62	0.08	0.06	e_{UK}	0.08	0.36	0.26	0.22	0.01
i_{CA}	0.42	0.07	0.28	0.02	0.21	e_{CA}	0.11	0.12	0.55	0.22	0.00
π (all)	0.72	0.12	0.07	0.05	0.04	f (all)	0.68	0.15	0.09	0.05	0.03
π_{US}	0.77	0.01	0.15	0.02	0.05	e_{US}	0.82	0.07	0.01	0.02	0.08
π_{EA}	0.68	0.18	0.11	0.00	0.04	e_{EA}	0.76	0.00	0.10	0.15	0.00
π_{JA}	0.59	0.30	0.09	0.02	0.00	e_{JA}	0.33	0.66	0.00	0.00	0.00
π_{UK}	0.80	0.01	0.01	0.17	0.01	e_{UK}	0.78	0.01	0.09	0.09	0.03
π_{CA}	0.77	0.10	0.01	0.04	0.09	e_{CA}	0.72	0.02	0.23	0.01	0.03
s (all)	0.87	0.06	0.04	0.02	0.01	o (all)	0.95	0.02	0.02	0.01	0.00
s_{US}	0.82	0.14	0.03	0.01	0.01	o_{US}	0.96	0.03	0.00	0.00	0.01
s_{EA}	0.83	0.11	0.05	0.01	0.00	o_{EA}	0.96	0.02	0.01	0.02	0.00
s_{JA}	0.90	0.04	0.01	0.05	0.00	o_{JA}	0.93	0.01	0.06	0.02	0.00
s_{UK}	0.87	0.00	0.11	0.01	0.01	o_{UK}	0.95	0.02	0.02	0.01	0.00
s_{CA}	0.94	0.02	0.00	0.01	0.03	o_{CA}	0.96	0.04	0.00	0.00	0.01
l (all)	0.96	0.02	0.01	0.01	0.00						
l_{US}	0.94	0.04	0.02	0.00	0.00						
l_{EA}	0.97	0.00	0.01	0.02	0.00						
l_{JA}	0.93	0.06	0.02	0.00	0.00						
l_{UK}	0.97	0.01	0.01	0.02	0.00						
l_{CA}	0.98	0.01	0.00	0.00	0.01						

The table reports the results of the principal components (PC) analysis conducted on 11 sub-sets of 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.

Table 2: 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)	0.64	0.09	0.07	0.05	0.04	0.03	0.02	0.02	0.01	0.01
π_{US}	0.43	0.29	0.08	0.04	0.04	0.03	0.01	0.02	0.00	0.01
π_{EA}	0.68	0.01	0.00	0.17	0.00	0.06	0.00	0.01	0.00	0.03
π_{JA}	0.44	0.04	0.16	0.01	0.02	0.18	0.09	0.02	0.04	0.00
π_{UK}	0.68	0.09	0.04	0.00	0.02	0.01	0.00	0.00	0.08	0.03
π_{CA}	0.64	0.07	0.00	0.07	0.04	0.05	0.00	0.00	0.00	0.10
s_{US}	0.84	0.00	0.01	0.01	0.03	0.01	0.00	0.00	0.01	0.00
s_{EA}	0.74	0.16	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00
s_{JA}	0.87	0.03	0.02	0.00	0.00	0.02	0.01	0.00	0.01	0.00
s_{UK}	0.83	0.00	0.01	0.01	0.01	0.03	0.00	0.02	0.03	0.03
s_{CA}	0.92	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
l_{US}	0.88	0.04	0.00	0.01	0.00	0.01	0.00	0.01	0.02	0.00
l_{EA}	0.86	0.09	0.01	0.01	0.00	0.00	0.00	0.01	0.00	0.00
l_{JA}	0.92	0.01	0.02	0.00	0.00	0.01	0.01	0.00	0.00	0.00
l_{UK}	0.93	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
l_{CA}	0.90	0.05	0.00	0.01	0.00	0.01	0.00	0.00	0.01	0.00
m_{US}	0.09	0.00	0.56	0.00	0.26	0.06	0.03	0.00	0.00	0.00
m_{EA}	0.19	0.00	0.25	0.32	0.16	0.03	0.02	0.01	0.00	0.00
m_{JA}	0.50	0.02	0.08	0.17	0.01	0.00	0.02	0.15	0.02	0.01
m_{UK}	0.30	0.17	0.19	0.09	0.03	0.02	0.08	0.09	0.03	0.00
m_{CA}	0.05	0.67	0.00	0.00	0.08	0.00	0.15	0.01	0.03	0.00

Output, consumption and investment growth as a group

	PC_1	PC_2	PC_3	PC_4	PC_5	PC_6	PC_7	PC_8	PC_9	PC_{10}
g, c, i (all)	0.30	0.17	0.11	0.08	0.07	0.05	0.04	0.04	0.03	0.03
g_{US}	0.56	0.01	0.14	0.00	0.10	0.00	0.02	0.04	0.01	0.03
g_{EA}	0.29	0.33	0.16	0.07	0.03	0.00	0.00	0.00	0.01	0.02
g_{JA}	0.06	0.63	0.18	0.02	0.00	0.00	0.01	0.01	0.00	0.00
g_{UK}	0.40	0.00	0.07	0.21	0.03	0.05	0.01	0.00	0.08	0.05
g_{CA}	0.46	0.01	0.15	0.06	0.04	0.07	0.00	0.02	0.10	0.00
c_{US}	0.49	0.02	0.03	0.08	0.08	0.02	0.03	0.00	0.14	0.05
c_{EA}	0.15	0.31	0.14	0.04	0.01	0.11	0.04	0.06	0.01	0.11
c_{JA}	0.11	0.39	0.21	0.06	0.00	0.01	0.04	0.04	0.02	0.05
c_{UK}	0.32	0.00	0.00	0.12	0.32	0.06	0.02	0.07	0.01	0.03
c_{CA}	0.46	0.00	0.05	0.03	0.03	0.10	0.20	0.01	0.01	0.00
i_{US}	0.50	0.03	0.12	0.00	0.17	0.03	0.02	0.00	0.00	0.01
i_{EA}	0.29	0.24	0.20	0.04	0.00	0.03	0.00	0.06	0.02	0.04
i_{JA}	0.01	0.64	0.06	0.02	0.01	0.03	0.09	0.02	0.04	0.02
i_{UK}	0.15	0.00	0.08	0.37	0.01	0.26	0.01	0.07	0.00	0.03
i_{CA}	0.32	0.01	0.05	0.09	0.18	0.01	0.12	0.18	0.02	0.01

The table reports results for the first ten principal components (PC) extracted from the inflation rates, the short- and long-term interest rates and the nominal money growth rates for all regions and from real output, consumption and investment growth rates for all regions. The first row shows the fraction of the total variance explained by each PC_i ($i = 1, ...10$); the subsequent 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 3: Forecast error variance decomposition

	Horizon (quarters)	Response of actual variables								
		Global shocks						Idiosyncratic shocks		
		$\boldsymbol{\xi}_{bc}$	$\boldsymbol{\xi}_{n}$	$\boldsymbol{\xi}_{h}$	$\boldsymbol{\xi}_{o}$	$\boldsymbol{\xi}_{f}$	**All**	*own*	*other*	**All**
g_{US}	4	7.7	50.3	0.7	0.5	6.0	**65.1**	22.9	12.0	**34.9**
	20	7.4	63.3	1.9	0.5	5.5	**78.7**	13.0	8.3	**21.3**
c_{US}	4	1.8	82.4	1.5	1.6	2.4	**89.8**	7.5	2.8	**10.3**
	20	2.4	82.6	1.4	1.1	2.9	**90.4**	4.5	5.1	**9.6**
i_{US}	4	6.0	41.8	0.3	0.1	11.4	**59.5**	17.9	22.7	**40.6**
	20	5.8	51.0	0.2	0.0	10.9	**67.9**	9.0	23.1	**32.1**
π_{US}	4	0.3	77.6	2.4	5.5	0.6	**86.3**	11.7	2.0	**13.7**
	20	0.4	86.4	0.8	5.5	0.5	**93.5**	5.0	1.5	**6.5**
s_{US}	4	0.2	72.3	0.7	1.8	0.5	**75.5**	10.9	13.7	**24.6**
	20	0.3	71.3	1.6	3.1	1.6	**77.8**	9.2	13.0	**22.2**
l_{US}	4	0.1	37.2	2.3	2.5	0.5	**42.5**	16.4	41.1	**57.5**
	20	0.3	49.0	3.1	4.2	1.8	**58.4**	9.6	32.0	**41.7**
m_{US}	4	0.0	66.1	2.1	0.1	0.0	**68.3**	17.9	13.8	**31.8**
	20	0.5	65.7	4.7	1.1	1.1	**73.1**	8.0	19.0	**27.0**
h_{US}	4	0.1	44.8	9.0	5.1	0.0	**59.1**	25.8	15.1	**40.9**
	20	1.0	64.0	7.7	4.9	0.0	**77.5**	12.9	9.6	**22.5**
e_{US}	4	0.1	1.5	3.3	1.6	3.1	**9.6**	64.0	26.4	**90.4**
	20	0.2	14.5	5.0	6.3	6.0	**31.9**	37.4	30.8	**68.2**
f_{US}	4	27.5	14.1	2.8	4.6	24.6	**73.5**	22.1	4.4	**26.5**
	20	42.4	3.3	2.1	5.7	15.9	**69.3**	24.7	6.0	**30.7**
g_{EA}	4	10.0	21.7	0.1	0.2	3.3	**35.3**	59.0	5.7	**64.8**
	20	12.5	37.6	4.5	0.3	4.2	**59.2**	27.9	12.9	**40.8**
c_{EA}	4	4.2	27.7	0.1	0.8	1.4	**34.2**	37.2	28.7	**65.8**
	20	14.9	9.6	9.4	0.3	5.0	**39.2**	18.3	42.6	**60.8**
i_{EA}	4	12.3	28.7	0.1	0.2	2.7	**44.1**	22.5	33.4	**55.9**
	20	15.1	40.7	5.6	0.4	3.2	**64.9**	7.5	27.5	**35.1**
π_{EA}	4	0.8	3.1	6.5	8.6	1.5	**20.5**	35.4	44.2	**79.5**
	20	2.7	48.6	2.5	9.2	0.6	**63.6**	11.7	24.7	**36.4**
s_{EA}	4	1.9	8.7	2.8	2.1	0.8	**16.3**	15.6	68.0	**83.7**
	20	3.6	45.3	4.4	4.1	0.5	**57.9**	7.1	35.0	**42.1**
l_{EA}	4	0.5	54.6	1.6	3.3	0.2	**60.2**	28.6	11.2	**39.9**
	20	1.6	61.8	2.6	4.7	0.5	**71.1**	18.9	10.0	**28.9**
m_{EA}	4	0.0	0.1	1.2	0.0	1.2	**2.6**	61.2	36.2	**97.4**
	20	0.1	15.6	0.6	0.3	1.9	**18.4**	42.3	39.3	**81.6**
h_{EA}	4	0.1	4.0	6.1	0.7	0.7	**11.5**	74.2	14.3	**88.5**
	20	2.3	5.8	19.2	2.2	0.7	**30.2**	49.4	20.3	**69.8**
e_{EA}	4	2.2	5.4	0.9	0.4	10.9	**19.9**	60.7	19.4	**80.1**
	20	3.3	2.1	1.3	0.3	6.6	**13.5**	59.7	26.8	**86.5**
f_{EA}	4	18.0	20.3	0.3	3.4	27.0	**69.0**	22.2	8.8	**31.0**
	20	23.6	6.1	0.6	4.1	27.5	**61.9**	24.3	13.8	**38.1**

Table 3 (continued): Forecast error variance decomposition

	Horizon (quarters)	Response of actual variables								
		Global shocks						Idiosyncratic shocks		
		$\boldsymbol{\xi}_{bc}$	$\boldsymbol{\xi}_n$	$\boldsymbol{\xi}_h$	$\boldsymbol{\xi}_o$	$\boldsymbol{\xi}_f$	**All**	*own*	*other*	**All**
g_{JA}	4	2.5	22.3	3.3	1.5	2.8	**32.4**	59.2	8.3	**67.6**
	20	3.4	28.3	16.0	3.4	5.0	**56.0**	34.7	9.3	**44.0**
c_{JA}	4	0.1	77.4	0.5	3.2	0.6	**81.8**	11.0	7.2	**18.2**
	20	0.1	84.7	0.2	4.1	0.9	**90.0**	5.5	4.5	**10.0**
i_{JA}	4	7.8	27.2	5.5	0.5	3.9	**44.9**	24.4	30.7	**55.1**
	20	11.4	24.9	21.2	0.3	5.9	**63.6**	16.2	20.2	**36.4**
π_{JA}	4	0.4	55.6	4.5	1.6	1.0	**63.0**	27.3	9.7	**37.0**
	20	1.5	67.0	3.9	2.8	0.7	**76.0**	17.3	6.7	**24.0**
s_{JA}	4	1.6	57.7	5.2	3.3	0.1	**67.8**	17.1	15.1	**32.2**
	20	3.9	61.2	7.7	3.6	0.3	**76.6**	11.1	12.3	**23.4**
l_{JA}	4	1.8	58.3	3.9	4.3	0.6	**68.8**	5.7	25.4	**31.1**
	20	3.6	63.3	5.2	4.7	0.5	**77.3**	3.7	18.9	**22.6**
m_{JA}	4	0.8	58.6	0.5	2.7	2.1	**64.5**	28.0	7.5	**35.5**
	20	2.4	54.9	4.1	3.5	3.7	**68.5**	22.8	8.7	**31.5**
h_{JA}	4	0.7	48.2	0.4	1.5	0.6	**51.4**	27.5	21.2	**48.6**
	20	0.3	34.2	4.4	2.3	1.8	**43.0**	22.4	34.6	**57.0**
e_{JA}	4	0.4	46.9	15.1	6.1	0.0	**68.6**	22.5	8.9	**31.4**
	20	2.3	51.3	8.0	5.1	1.0	**67.7**	17.5	14.8	**32.3**
f_{JA}	4	9.6	0.3	14.1	1.7	28.0	**53.6**	32.9	13.5	**46.4**
	20	5.8	16.9	22.4	2.3	19.3	**66.6**	24.6	8.8	**33.4**
g_{UK}	4	12.0	41.1	1.1	1.3	5.8	**61.2**	32.0	6.9	**38.9**
	20	13.8	53.2	1.8	1.3	6.2	**76.3**	16.2	7.5	**23.7**
c_{UK}	4	5.4	25.7	6.4	0.6	6.2	**44.3**	37.0	18.8	**55.8**
	20	16.8	4.4	17.6	0.8	11.4	**51.0**	29.8	19.2	**49.0**
i_{UK}	4	14.2	72.8	2.2	0.1	2.1	**91.2**	7.3	1.5	**8.8**
	20	16.4	70.7	3.7	0.1	4.0	**94.8**	3.7	1.5	**5.2**
π_{UK}	4	2.4	84.6	2.3	2.1	0.0	**91.5**	6.1	2.3	**8.5**
	20	2.7	88.1	1.1	2.7	0.0	**94.8**	3.7	1.5	**5.2**
s_{UK}	4	3.2	82.5	2.8	1.6	0.2	**90.2**	6.1	3.7	**9.8**
	20	3.7	81.2	4.0	2.1	0.3	**91.3**	5.3	3.5	**8.7**
l_{UK}	4	2.2	83.6	3.5	2.2	0.2	**91.7**	3.5	4.8	**8.3**
	20	2.6	82.8	3.9	2.7	0.2	**92.3**	3.4	4.4	**7.8**
m_{UK}	4	0.1	96.2	0.1	1.2	0.3	**97.9**	1.4	0.7	**2.1**
	20	1.0	91.9	2.7	1.8	0.9	**98.3**	0.9	0.8	**1.7**
h_{UK}	4	3.3	30.7	30.2	2.9	0.9	**68.0**	18.3	13.6	**32.0**
	20	9.6	40.8	32.1	2.3	1.5	**86.2**	5.6	8.2	**13.8**
e_{UK}	4	4.7	8.7	2.6	1.5	1.0	**18.5**	41.5	40.0	**81.5**
	20	2.7	11.1	14.8	0.5	2.5	**31.6**	33.1	35.3	**68.4**
f_{UK}	4	33.0	0.7	1.0	4.7	44.0	**83.4**	11.6	5.0	**16.6**
	20	44.8	6.6	1.0	3.5	30.3	**86.0**	10.2	3.8	**14.0**

Table 3 (continued): Forecast error variance decomposition

	Horizon (quarters)	Response of actual variables								
		Global shocks						Idiosyncratic shocks		
		ξ_{bc}	ξ_n	ξ_h	ξ_o	ξ_f	**All**	*own*	*other*	**All**
g_{CA}	4	.2.0	21.8	14.5	0.3	10.0	**48.7**	37.7	13.6	**51.3**
	20	3.5	49.8	16.4	0.7	7.0	**77.3**	15.1	7.6	**22.7**
c_{CA}	4	3.6	39.3	18.1	0.7	13.0	**74.7**	17.2	8.2	**25.4**
	20	4.1	67.7	13.9	1.5	4.9	**92.0**	5.1	2.9	**8.0**
i_{CA}	4	5.8	48.5	13.7	1.6	13.8	**83.4**	14.1	2.5	**16.6**
	20	7.4	54.0	23.0	1.1	8.3	**93.7**	5.0	1.3	**6.3**
π_{CA}	4	0.3	76.0	1.4	4.7	0.3	**82.7**	12.5	4.9	**17.4**
	20	0.1	86.2	0.8	6.1	0.8	**94.0**	3.6	2.5	**6.1**
s_{CA}	4	1.4	80.7	4.9	3.8	0.1	**90.8**	6.0	3.2	**9.2**
	20	1.3	81.0	5.3	4.1	0.7	**92.5**	4.4	3.1	**7.5**
l_{CA}	4	0.9	61.5	7.9	4.4	0.1	**74.8**	13.2	12.0	**25.2**
	20	0.9	67.6	6.4	5.2	1.5	**81.5**	8.7	9.8	**18.5**
m_{CA}	4	0.6	92.2	0.1	1.4	0.6	**94.9**	4.2	0.9	**5.1**
	20	0.2	87.0	4.3	1.2	0.5	**93.0**	4.0	3.0	**7.0**
h_{CA}	4	1.6	18.1	63.8	7.1	0.6	**91.2**	5.0	3.8	**8.8**
	20	0.4	41.8	47.2	6.5	0.1	**96.0**	1.8	2.2	**4.0**
e_{CA}	4	6.4	4.4	5.2	0.3	16.3	**32.6**	41.0	26.4	**67.4**
	20	1.9	4.2	25.2	0.1	13.7	**45.0**	31.8	23.2	**55.0**
f_{CA}	4	26.1	29.0	4.9	1.9	28.2	**90.1**	6.2	3.8	**9.9**
	20	43.3	9.2	5.4	4.9	24.4	**87.2**	7.8	5.0	**12.8**

The table reports for each endogenous variable the median forecast error variance decomposition at the one-year and five-year horizons. For each variable the first six columns of the table show the percentage of forecast error variance attributable to each global factor shock ("real activity/demand-side", "nominal/supply-side" (n), "house market" (h), "stock market" (f) and "oil price" (o)) together with their sum ("All", in bold); the last three columns report the percentage of the forecast error variance attributable to the own-country and variable idiosyncratic shock ("own"), all the other own country idyosincratic shocks ("other") and the proportion of variance due to all own-country idiosyncratic disturbances ("All", in bold).

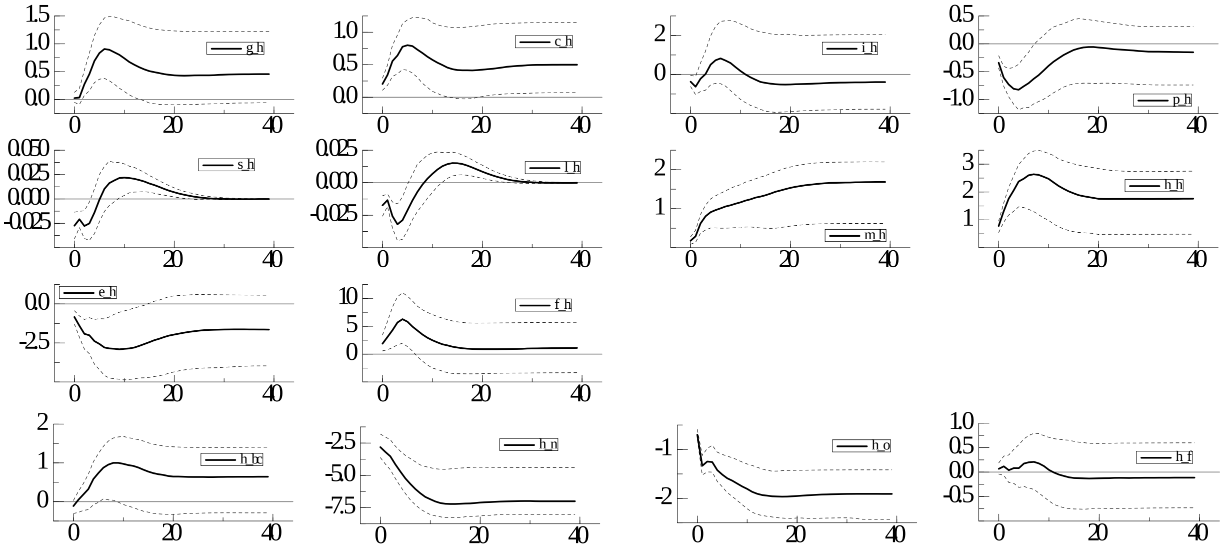
Table 4: Selected elasticities

	Horizon (quarters)	shocks			Horizon (quarters)	shocks		
		$\boldsymbol{\xi}_h$	$\boldsymbol{\xi}_f$			$\boldsymbol{\xi}_{bc}$	$\boldsymbol{\xi}_n$	$\boldsymbol{\xi}_o$
g_{US}	4	0.22*	0.09*	h_{US}	4	0.28	1.63*	-0.32*
	20	0.25	0.13*		20	0.55	1.81*	-048*
g_{EA}	4	0.04	0.03*	h_{EA}	4	-0.04	-1.22	-0.08*
	20	0.16*	0.04*		20	1.45*	1.46*	-1.41*
g_{JA}	4	-2.38	0.03*	h_{JA}	4	-0.99*	2.17*	0.17*
	20	0.73*	0.06*		20	0.50	2.47*	0.28*
g_{UK}	4	0.06*	0.06*	h_{UK}	4	2.60*	3.83*	-0.47*
	20	0.02	0.07*		20	4.37*	4.59*	-0.71*
g_{CA}	4	0.14*	0.06*	h_{CA}	4	-0.56	4.11*	-0.72*
	20	0.13*	0.09*		20	0.94	3.76*	-1.32*
c_{US}	4	0.31*	0.06*	f_{US}	4	-12.9*	-2.52	-0.67*
	20	0.23	0.11*		20	-13.7*	0.05	-1.41*
c_{EA}	4	0.03	0.02*	f_{EA}	4	-21.8*	-12.6	-0.44
	20	0.18*	0.03*		20	-14.9*	1.90	-1.65*
c_{JA}	4	1.20	0.02*	f_{JA}	4	-18.7*	-1.2	-0.27
	20	0.09	0.04*		20	-11.8*	-10.3*	-1.46*
c_{UK}	4	0.15*	0.06*	f_{UK}	4	-12.3*	1.24	-0.31
	20	0.15*	0.10*		20	-13.4*	2.14	-1.00*
c_{CA}	4	0.13*	0.05*	f_{CA}	4	-29.5*	-10.1*	-0.36
	20	0.11*	0.06*		20	-27.4*	0.59	-1.91*
i_{US}	4	0.01	0.31*					
	20	-0.29	0.43*					
i_{EA}	4	0.17	0.07*					
	20	0.54*	0.09*					
i_{JA}	4	-6.94	0.09*					
	20	2.15*	0.17*					
i_{UK}	4	0.47*	0.27*					
	20	0.37*	0.38*					
i_{CA}	4	0.48*	0.27*					
	20	0.67*	0.35*					

The table reports, for selected endogenous variables, the median elasticity relative to a given global factor shock ("real activity/demand-side" (bc), "nominal/supply-side" (n), "house market" (h), "stock market" (f) and "oil price" (o)) at the one-year and five-year horizons. "$*$" denotes statistical significance at the 5% level. Elasticities are computed by taking ratios of the impulse responses at selected horizons for the relevant variables. For instance, the elasticity of US output to the global house price shock is computed as $irf^k_{g_{US,h}}/irf^k_{h_{US,h}}$, where $irf^k_{g_{US,h}}$ is the impulse response of US GDP to the unitary global house price factor shock, and $irf^k_{h_{US,h}}$ is the impulse response of the US house price to the same global shock. Similarly for the global stock market shock. Differently, for the elasticity of the financial variables to the global demand-side and supply-side shocks, the normalization has been computed relatively to the own country GDP response. For instance, the elasticity of the US house price to the global supply-side shock is computed as $irf^k_{h_{US,n}}/irf^k_{g_{US,n}}$, where $irf^k_{h_{US,n}}$ is the impulse response of the US house price to the unitary supply-side factor shock, and $irf^k_{g_{US,n}}$ is the impulse response of US GDP to the same global shock. Differently, the elasticity of all the variables relative to the global oil price shocks have been computed as $irf^k_{y_{i,o}}/irf^k_{o_o}$, where $irf^k_{y_{i,j}}$ is the impulse response of country's i variable y, at horizon k, to a unitary global oil price shock and $irf^k_{o_o}$ is the impulse response of the global oil price factor, at horizon k, to his own unitary shock.

Figure 1

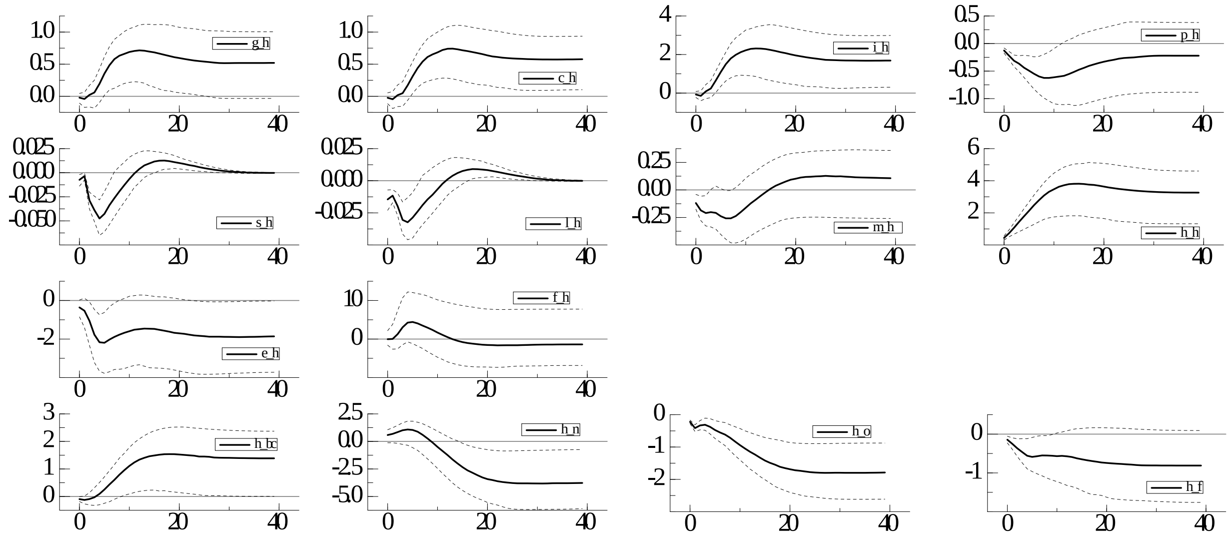
Impulse response functions to common factor shocks: United States



The figure displays the median impulse responses of the level of output (g), consumption (c), investment (i), the price level (p), the short-term interest rate (s), the long-term interest rate (l), the nominal money aggregate (m), the house price level (h), the real effective exchange rate (e) and the real stock price index (f) to a unitary shock to the global “house price” factor (h) (plots in the first three rows). The median impulse responses of the house price level to a unitary shock to the global “real activity/demand-side” factor (bc), the global “nominal/supply side” factor (n), the oil price factor (o), and the global “stock market” factor (f) are plotted as well (last row). Apart from the “supply side” factor (n) shock, which is negative, all the other shocks are positive. A 95% confidence interval, obtained by Monte Carlo simulation, is shown in each plot. The responses are displayed over a ten-year horizon.

Figure 2

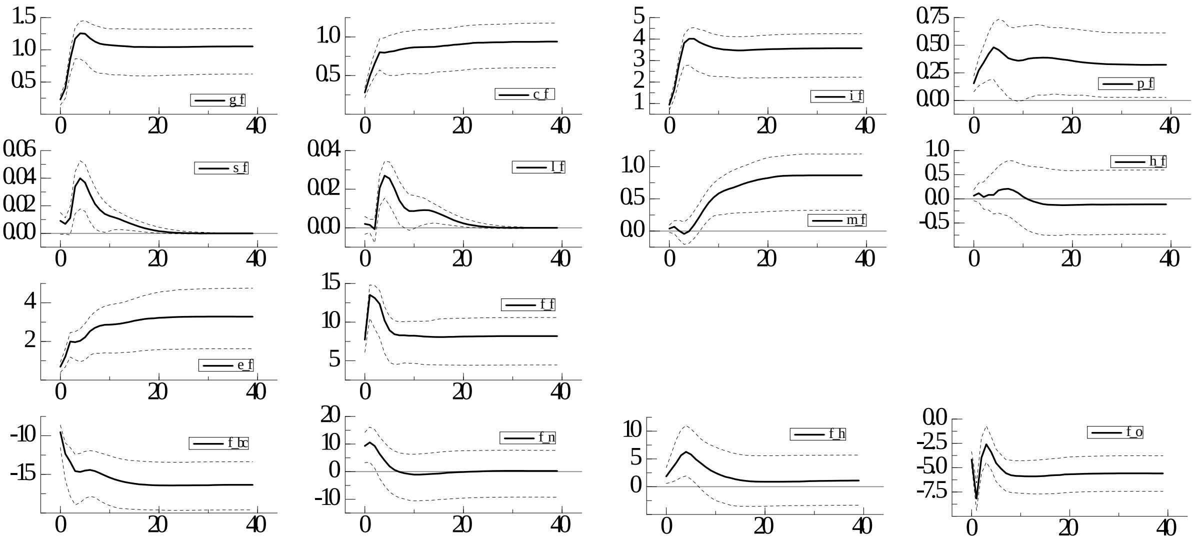
Impulse response functions to common factor shocks: Euro Area



The figure displays the median impulse responses of the level of output (g), consumption (c), investment (i), the price level (p), the short-term interest rate (s), the long-term interest rate (l), the nominal money aggregate (m), the house price level (h), the real effective exchange rate (e) and the real stock price index (f) to a unitary shock to the global "house price" factor (h) (plots in the first three rows). The median impulse responses of the house price level to a unitary shock to the global "real activity/demand-side" factor (bc), the global "nominal/supply side" factor (n), the oil price factor (o), and the global "stock market" factor (f) are plotted as well (last row). Apart from the "supply side" factor (n) shock, which is negative, all the other shocks are positive. A 95% confidence interval, obtained by Monte Carlo simulation, is shown in each plot. The responses are displayed over a ten-year horizon.

Figure 3

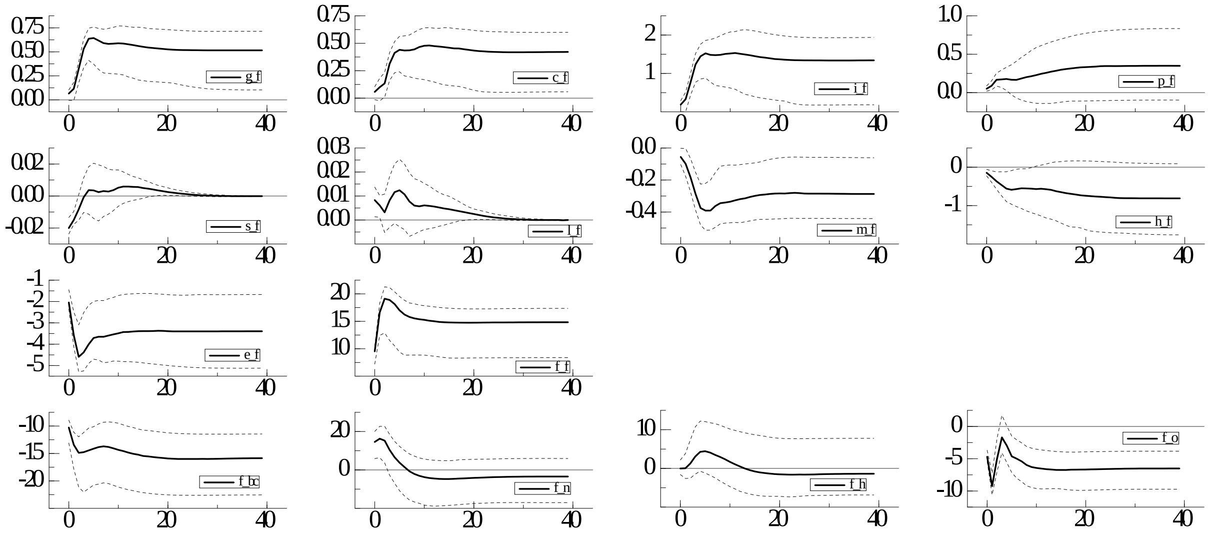
Impulse response functions to common factor shocks: United States



The figure displays the median impulse responses of the level of output (g), consumption (c), investment (i), the price level (p), the short-term interest rate (s), the long-term interest rate (l), the nominal money aggregate (m), the house price level (h), the real effective exchange rate (e) and the real stock price index (f) to a unitary shock to the global "stock price" factor (f) (plots in the first three rows). The median impulse responses of the stock price level to a unitary shock to the global "real activity/demand-side" factor (bc), the global "nominal/supply side" factor (n), the oil price factor (o), and the global "house price" factor (h) are plotted as well (last row). Apart from the "supply side" factor (n) shock, which is negative, all the other shocks are positive. A 95% confidence interval, obtained by Monte Carlo simulation, is shown in each plot. The responses are displayed over a ten-year horizon.

Figure 4

Impulse response functions to common factor shocks: Euro Area



The figure displays the median impulse responses of the level of output (g), consumption (c), investment (i), the price level (p), the short-term interest rate (s), the long-term interest rate (l), the nominal money aggregate (m), the house price level (h), the real effective exchange rate (e) and the real stock price index (f) to a unitary shock to the global "stock price" factor (f) (plots in the first three rows). The median impulse responses of the stock price level to a unitary shock to the global "real activity/demand-side" factor (bc), the global "nominal/supply side" factor (n), the oil price factor (o), and the global "house price" factor (h) are plotted as well (last row). Apart from the "supply side" factor (n) shock, which is negative, all the other shocks are positive. A 95% confidence interval, obtained by Monte Carlo simulation, is shown in each plot. The responses are displayed over a ten-year horizon.