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International house prices and macroeconomic fluctuations

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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, we find that the US are an important source of global fluctuations not only for real activity, nominal variables and stock prices, but also for real housing prices. Secondly, albeit distinct driving forces for real activity and financial factors can be pointed out, sizeable global interactions are also evident. In particular, global supply-side shocks are an important determinant of G-7 house prices fluctuations. The linkage between real housing prices and macroeconomic developments is however bidirectional, with investment showing in general a stronger reaction than consumption and output to housing price shocks. Implications for the real effects of the sub-prime crisis are also explored.

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 (up to 2007:2) 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 2–3%, while nominal interest rates and inflation have been low (3–5% and 2–2.6%, respectively) and broad liquidity has grown at generous rates (6–8%). 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 factors affecting house prices, perhaps due to global macroeconomic developments. 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 related to non fundamental based mechanisms as, for instance, "extravagant expectations" of future price increases, spreading through social

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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.

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epidemics (Shiller, 2007), or mispricing related to the combination of inflation and money illusion (Brunnermeier and Julliard, 2008). 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 some other OECD member countries (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, 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 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. The main contribution actually lies in the investigation of global factors driving international house prices, an issue not thoroughly assessed in the literature so far. 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 1980:1 through 2007:2, for the US, Japan, the Euro-12 Area, the UK and Canada, are investigated in their dynamic interactions at business cycle horizons. A Factor-Augmented Vector Autoregressive (F-VAR) model is used to parsimoniously incorporate this rich information set in few relevant factors, allowing to account for both global (common) and national (idiosyncratic) forces driving macroeconomic developments.

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 (2005) 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 is due to both macroeconomic and own-market (i.e. housing market) factors, that are mainly originated in the US. While the house price shock accounts, on average, for about 20% of global fluctuations, the average contribution of global macroeconomic shocks is 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). Second, there is evidence of a procyclic and inelastic response of real global house prices to global supply-side shocks. Third, the linkage between housing prices and macroeconomic developments is bidirectional, with investment showing in general a stronger reaction than consumption and output to real house price shocks. Fourth, real house price shocks have a larger role on the business cycle than stock market shocks. 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 above results may be of interest for portfolio models used to study international diversification, as the large role played by propagation of macroeconomic shocks may reduce the usefulness of international diversification of residential investments. The results may also be of interest to policy-makers, who should not ignore the comovement in business cycles across countries, as well as the linkages with house price dynamics. House (and stock) prices play a powerful role and affect important macroeconomic variables. Indeed, according to the Case–Shiller index, US real house prices have contracted about 24% in 2008. Real S&P 500 stock prices have fallen about 45% over the same period. By considering the latter figures as the size of the global assets price shocks, and neglecting the expected impact of the stabilization policies currently in progress, a conditional (on the size of the assets price shock) worst case scenario for the expected GDP costs of the subprime crisis has been computed. Downturn is predicted to be a "Great Recession" for all the G-7 countries, particularly for the US (−12%) and Japan (−20%), but still very deep for Canada (−7.5%), the UK and the euro area (−4.7% and −4.5%, respectively). The above figures are impressive, yet not unreasonable in the light of what actually occurred during the Great Depression of the 1930s, when very large financial shocks (−30% and −70% for US real house and stock prices, respectively) also occurred.

The rest of the paper is organized as follows. In the next section the econometric methodology is introduced, while in Section 3 the data are presented and the F-VAR model is estimated. Then, in Section 4 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. Methodology and data

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:

$$(\mathbf{X}_t - \boldsymbol{\mu}_t) = \boldsymbol{\Lambda}\mathbf{F}_t + \mathbf{D}(L)(\mathbf{X}_{t-1} - \boldsymbol{\mu}_{t-1}) + \mathbf{v}_t, \qquad (2.1)$$
$$\mathbf{F}_t = \boldsymbol{\Phi}(L)\mathbf{F}_{t-1} + \boldsymbol{\eta}_t. \qquad (2.2)$$

In (2.1) $(\mathbf{X}_t - \boldsymbol{\mu}_t)$ 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 $r \leqslant q < n$, $\boldsymbol{\Lambda}$ 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 order p, and $\mathbf{v}_t$ is the n-variate vector of the reduced-form idiosyncratic (i.i.d.) disturbances. The matrix $\mathbf{D}(L)$ is specified in such a way that each equation includes the lags for all the other own-country variables as well as the own lags. This specification allows for idiosyncratic macroeconomic interactions within each country (differently from Stock and Watson, 2005), but not across countries (differently from Bagliano

[2] In the paper the deterministic component included in the ith equation of (2.1) 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.

and Morana, 2008). Moreover, $\boldsymbol{\Phi}(L)$ is a $r \times r$ matrix lag polynomial of order p, and $\boldsymbol{\eta}_t$ is a vector of global i.i.d. shocks driving the common factors with $E[\eta_{jt} v_{is}] = 0$ for all i, j, t, s.

By substituting (2.2) into (2.1), the dynamic factor model can be written in vector autoregressive (F-VAR) form as

$$\begin{pmatrix} \mathbf{F}_t \\ (\mathbf{X}_t - \boldsymbol{\mu}_t) \end{pmatrix} = \begin{pmatrix} \boldsymbol{\Phi}(L) & 0 \\ \boldsymbol{\Lambda}\boldsymbol{\Phi}(L) & \mathbf{D}(L) \end{pmatrix} \begin{pmatrix} \mathbf{F}_{t-1} \\ (\mathbf{X}_{t-1} - \boldsymbol{\mu}_{t-1}) \end{pmatrix} + \begin{pmatrix} \boldsymbol{\varepsilon}_t^F \\ \boldsymbol{\varepsilon}_t^X \end{pmatrix}, \qquad (2.3)$$

where

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

Consistent estimation of the model can be carried out according to the iterative procedure discussed in Stock and Watson (2005). Differently from Stock and Watson (2005), following 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, and so on.

The F-VAR form in (2.3) can be inverted to obtain the reduced vector moving average (*VMA*) form for the $\mathbf{X}_t$ process:

$$(\mathbf{X}_t - \boldsymbol{\mu}_t) = \mathbf{B}(L)\boldsymbol{\eta}_t + \mathbf{C}(L)\mathbf{v}_t, \qquad (2.4)$$

where $\mathbf{B}(L) = [\mathbf{I} - \mathbf{D}(L)L]^{-1}\boldsymbol{\Lambda}[\mathbf{I} - \Phi(L)L]^{-1}$ and $\mathbf{C}(L) = [\mathbf{I} - \mathbf{D}(L)L]^{-1}$. Identification of the structural shocks can then be achieved by means of a double Choleski procedure. See the Appendix for details.

2.2. 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 of the 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. the growth rates[3] 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),[4] the nominal money growth rate (m),[5] and the rates of change of the real house price (h),[6] the real effective exchange rate (e), the real stock price (f),[7] and the real price of oil (o). The latter four variables have been obtained from the corresponding nominal quantities using the CPI index as deflator. All series are sampled at a quarterly frequency and seasonally adjusted when appropriate. 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*.

The persistence properties of the data have been assessed by means of unit roots and stationarity tests. In addition to the ADF test and the KPSS test, also the Enders and Lee (2005) ADF test and the Becker 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. On the basis of the persistence analysis, the stationary representation of the F-VAR model has been augmented by including the Gallant's flexible specification for the deterministic component.[8]

3. Estimation of the F-VAR model

The F-VAR model requires an initial estimate of the global factors $\mathbf{F}_t$ in the first step of the iterative procedure. As shown in Table 1 (Panels A, B and C), 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. In fact, a single common factor explains 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 neglecting the money supply growth series for the US and Canada, while for real variables the average figure is about 40% once Japan is neglected.[9] Moreover, the proportion of explained total variance is 68% for real stock prices and 43% for real housing prices. Not surprisingly the proportion of total variance accounted for by the first principal component is also very strong for real oil prices, i.e. 95%, since heterogeneity in the latter sub-set of series is only due to the exchange rate component.[10] Differently, 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). 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 former to US macroeconomic and financial markets developments. Overall the findings are coherent with previous evidence provided in the literature for nominal, real activity and stock price series (Kose et al., 2005; Bagliano and Morana, 2008; Canova et al., 2007; Morana and Beltratti, 2008; Ehrmann et al., 2005; Ciccarelli and Mojon, 2005). The evidence of separate global factors for real activity and asset prices is also consistent with Otrok and Terrones (2005) and Kose et al.

[3] Growth rates have been computed from log transformed variables.

[4] The short-term rate refers to three-month government bills, while the long-term rate to 10-year government bonds.

[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] 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. Euro area data have been computed by averaging available member countries data, using GDP weights.

[7] 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.

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

[9] A similar evidence of common dynamics across nominal and real activity series is provided by the sub-group analysis (Panel A). For instance, the first principal component explains a proportion of total variance in the range 72–96% for inflation and nominal interest rates. For nominal money growth (45%), GDP (40%) and its components (38% for consumption and 32% for investment) the proportion of explained total variance is still large, but lower than for the other variables.

[10] On the basis of the latter results, showing that the variance of real oil prices in all regions is almost entirely attributable to a single common factor, in the estimation of the F-VAR model we include the oil price factor as an element of $\mathbf{F}_t$, but we exclude the oil price series from the vector $\mathbf{X}_t$.

Table 1
Principal components analysis.

All	g	c	i	π	s	l	m	h	e	f	o
	0.40	0.38	0.32	0.72	0.87	0.96	0.45	0.43	0.36	0.68	0.95
Panel A: separate sub-sets of variables											
US	0.65	0.56	0.36	0.77	0.82	0.94	0.32	0.60	0.77	0.82	0.96
EA	0.30	0.13	0.50	0.68	0.83	0.97	0.36	0.42	0.39	0.76	0.96
JA	0.04	0.13	0.09	0.59	0.90	0.93	0.63	0.10	0.45	0.33	0.93
UK	0.43	0.52	0.24	0.80	0.87	0.97	0.71	0.50	0.08	0.78	0.95
CA	0.59	0.57	0.42	0.77	0.94	0.98	0.25	0.50	0.11	0.72	0.96

All	π	s	l	m
	0.64			
Panel B: inflation, interest rates and money growth as a group				
US	0.43	0.84	0.88	0.09
EA	0.68	0.74	0.86	0.19
JA	0.44	0.87	0.92	0.50
UK	0.68	0.83	0.93	0.30
CA	0.64	0.92	0.90	0.05

All	g	c	i
	0.30		
Panel C: output, consumption and investment as a group			
US	0.56	0.49	0.50
EA	0.29	0.15	0.29
JA	0.06	0.11	0.01
UK	0.40	0.32	0.15
CA	0.46	0.46	0.32

Panel A reports the results of the principal components (*PC*) analysis conducted on 11 sub-sets of series, each comprising the same variable for all the five regions. For each set the first row shows the fraction of total variance explained by the first principal component; the subsequent five rows display the fraction of the variance of the individual series attributable to the first principal components. The fraction of the total variance attributed to PC_1 is given by $\lambda_1/\left(\sum_{i=1}^{5}\lambda_i\right)$, where λ_1 is the largest characteristic root of the sample variance–covariance matrix of the series. The proportion of variance of the *i*th variable accounted by the first principal component can be computed as $\pi_{i1} = a_{i1}^2\Lambda_1/\left(\sum_{j=1}^{q}a_{ij}^2\Lambda_1\right)$, where a_{i1} is the *i*1th entry in the eigenvector matrix *A* and Λ_1 is the first element of the diagonal eigenvalues matrix. Panels B and C report similar results when the analysis is carried out on two sub-group of series, i.e. inflation rates, the short-and long-term interest rates and the nominal money growth rates for all regions and real output, consumption and investment growth rates for all regions, respectively. The *PC* analysis is carried out on the standardized variables.

(2005), as well as with Case et al. (1999) and Gros (2007), concerning the presence of global dynamics in house prices.[11]

On the basis of the BIC information criterion, the optimal lag length of the F-VAR system can 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. Vector $\mathbf{X}_t$ collects 10 endogenous macroeconomic variables (namely $g, c, i, \pi, s, l, m, h, e$, and f, in this order) for the five regions analyzed (within each variable group, the regions are ordered as US, euro area, Japan, UK, and Canada).

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. 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 2000 units.

4. Structural shocks analysis

The identification of the structural shocks has been carried out by means of the double Choleski procedure described in the methodological Appendix. 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 ($\mathbf{X}_t$). Figs. 1–4 report the impulse response functions for the US and the euro area, while Table 2 reports the forecast error variance decomposition at the one-year (short-term) and five-year (medium-term).[12]

4.1. The relevance of global shocks

As shown in Table 2 (sixth column) 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 39–95% (32–91%) for real activity variables in the medium-term (short-term), with similar figures for consumption (34–92%), GDP (35–79%) and investment (44–95%). An even stronger contribution of global shocks to fluctuations is found for nominal variables (43–98%), apart from euro area data in the short-term (16–71%), particularly for money growth (3–18%). This finding is consistent with the relevance of global factors for nominal variables, as interest rates are set in international capital markets and inflation rates propagated by trade across countries. Regional fiscal policies as well as region-specific demand and supply shocks contribute to idiosyncratic behavior in goods markets, also in the medium-term.

A sizeable contribution of 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

[11] 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 which has characterized Japan over the 1990s and the beginning of the new century. Yet, somewhat surprising is the sizeable degree of correlation, detected 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.

[12] For reason of space detailed results for the impulse response analysis are reported for the US and euro area only. A full set of results is available upon request from the authors.

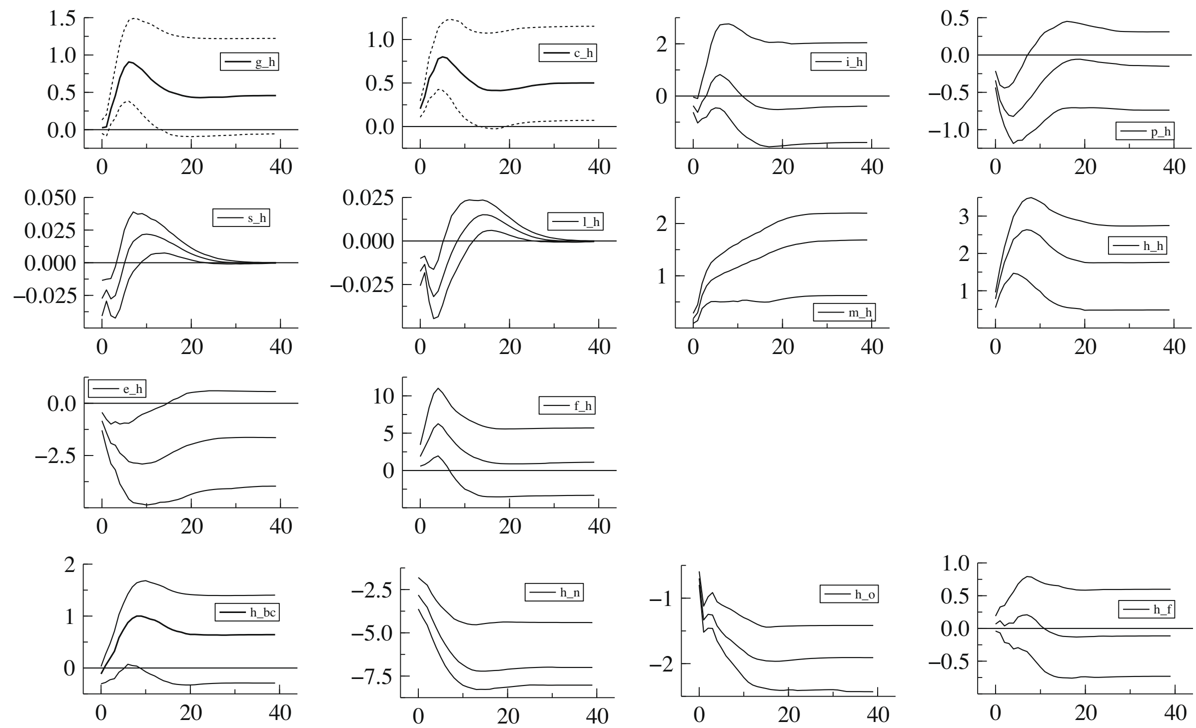

Fig. 1. Impulse response functions to global house price shocks: United States: The figure displays the median impulse responses of the level of output (*g*), consumption (*c*), investment (i), the price level (*p*), the short-term interest rate (*s*), the long-term interest rate (*l*), the nominal money 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 10-year horizon.

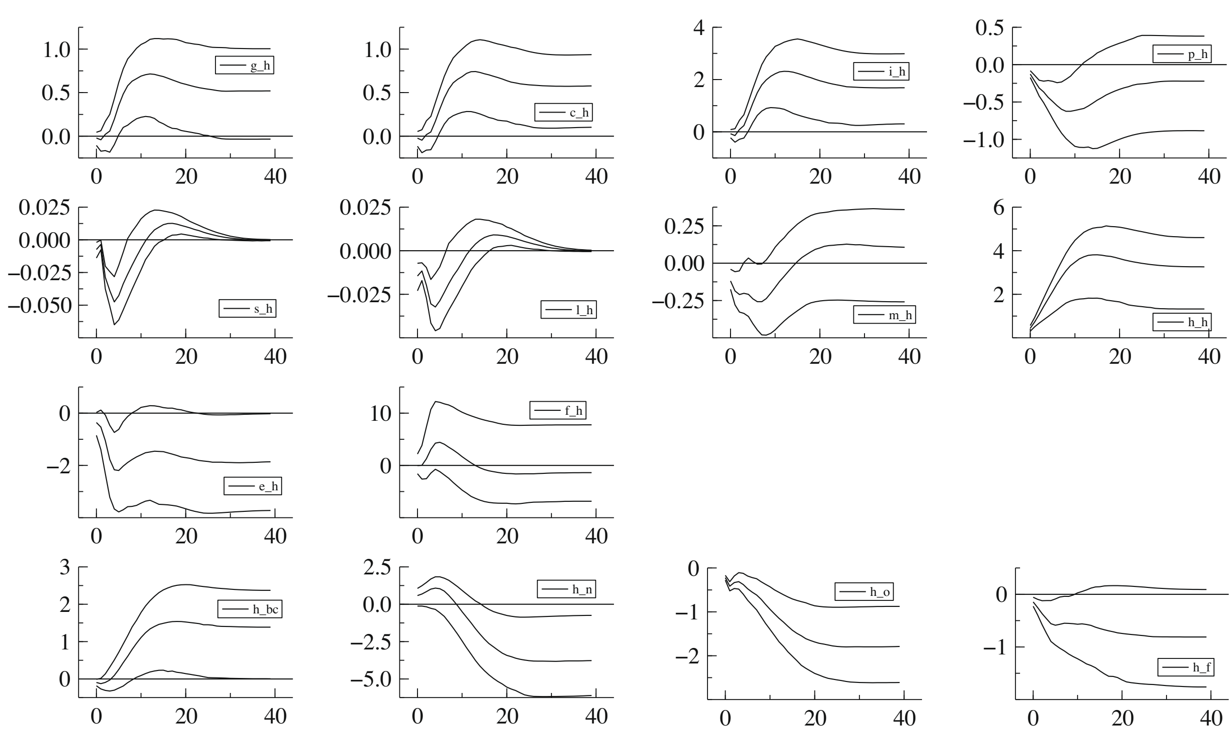

Fig. 2. Impulse response functions to global house price shocks: Euro Area The figure displays the median impulse responses of the level of output (*g*), consumption (*c*), investment (*i*), the price level (*p*), the short-term interest rate (*s*), the long-term interest rate (*l*), the nominal money 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 10-year horizon.

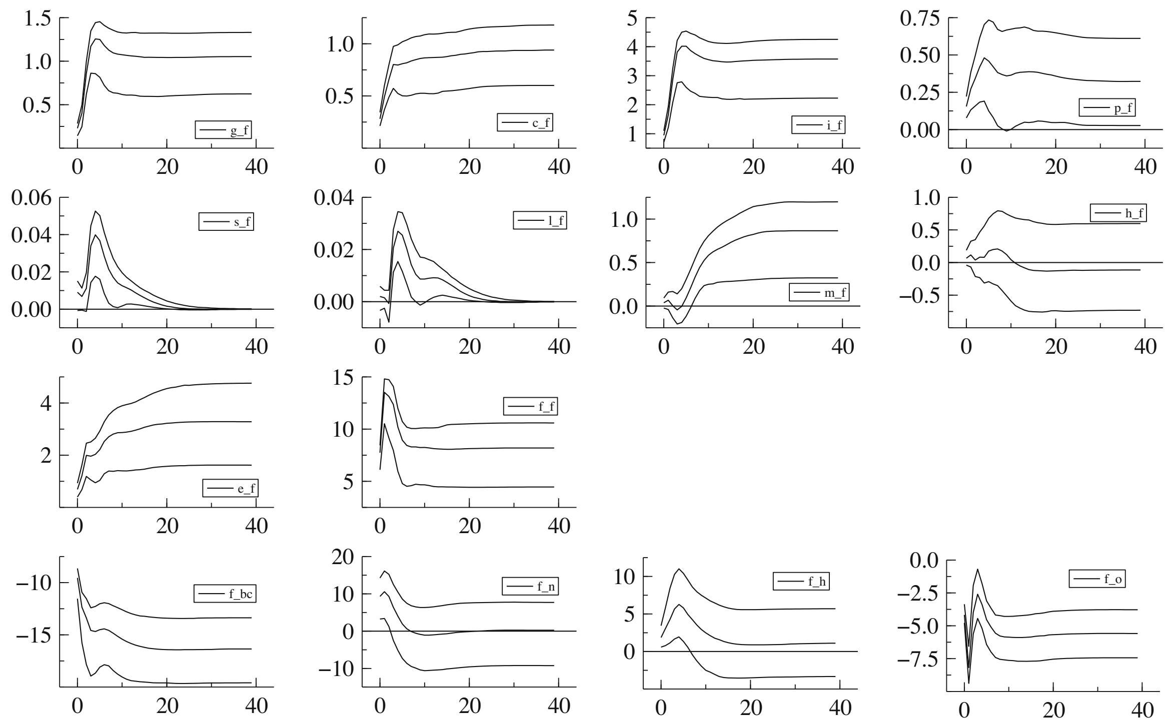

Fig. 3. Impulse response functions to global stock price shocks: United States The figure displays the median impulse responses of the level of output (g), consumption (c), investment (i), the price level (p), the short-term interest rate (s), the long-term interest rate (l), the nominal money aggregate (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 10-year horizon.

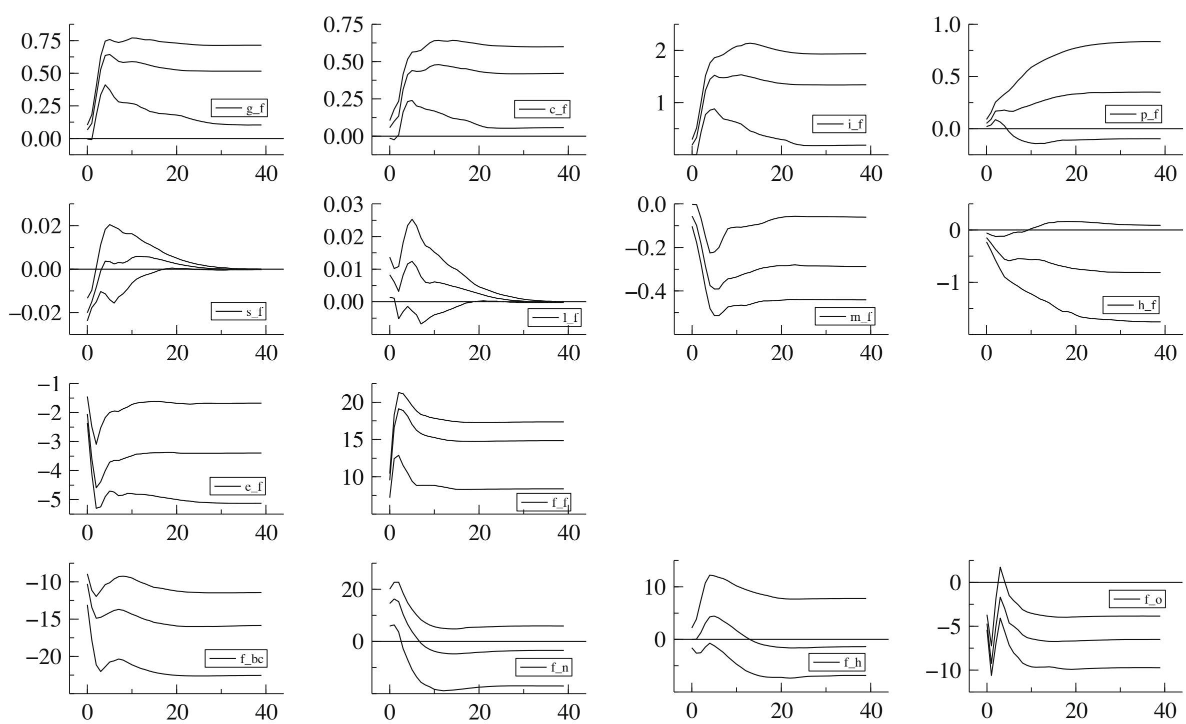

Fig. 4. Impulse response functions to global stock price shocks: Euro Area The figure displays the median impulse responses of the level of output (g), consumption (c), investment (i), the price level (p), the short-term interest rate (s), the long-term interest rate (l), the nominal money aggregate (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 10-year horizon.

Table 2
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_{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**
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**

(*continued on next page*)

Table 2 (*continued*)

	Horizon (quarters)	Response of actual variables								
		Global shocks						Idiosyncratic shocks		
		ξ_{bc}	ξ_n	ξ_h	ξ_o	ξ_f	All	*Own*	*Other*	All
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**
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).

stock prices in the range 30–96% and 62–87% (12–91% 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. Interestingly, there are little differences between the short-term and the medium-term as far as the impact of global shocks is concerned. This is consistent with the interpretation of stock markets reacting to external shocks in largely permanent ways. On the contrary, global shocks are more relevant for house price fluctuations in the medium-term than in the short-term, consistently with the idea that adjustment costs may prevent a full adjustment of prices in the short-term.

The large role of global shocks extends to the housing market (at least in the medium-term). This is not coherent with the view according to which house price movements are 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 global factors

Table 3
Selected elasticities.

	Horizon (quarters)	Shocks			Horizon (quarters)	Shocks		
		ξ_h	ξ_f			ξ_{bc}	ξ_n	ξ_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. Finally, 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.

are important in determining the variability of international house prices. 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.

4.1.1. The impact of macroeconomic shocks

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

The source of comovement in nominal variables may possibly be associated with the disinflationary policies carried out by central banks over the 1980s, and the successful inflation control thereafter. Our hypothesis is that the monetary policy has shaped the trend behavior of the nominal variables, so that the latter may be better understood in terms of a deterministic rather than a stochastic process. For instance, the determination of the policy interest rate by the central bank renders the latter a step-wise deterministic process, inducing a non linear deterministic trend both in short and long-term interest rates series. Such forces are accounted for by the non linear deterministic trend previously described. 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.

The structural shock (ξ_n) is therefore estimated from factor dynamics around the deterministic trend. Following Gordon (2005), pointing to the important role of productivity growth on 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, which shows that a negative supply-side shock leads 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 1.4–3.4, for the UK and Canada).

The data show that a negative supply-side shock decreases housing and stock prices. Our estimates point to a non negligible impact of the supply-side/productivity shock on house prices, particularly in the medium-term. Such shock, in terms of forecast error variance decomposition, is dominating for the US (64%), and sizeable for Japan, Canada and the UK (34–42%), 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. An elastic response of house prices can in general be found for all countries in the medium-term, with a house price elasticity in the range 1.5–4.6 (Table 3). Overall, the evidence is then consistent with previous results of Otrok and Terrones (2005), as well as of Case et al. (1999), Goodhart and Hofmann (2008) and Jarocinski and Smets (2008), pointing to a direct linkage between expanding output (income) and housing demand and prices.

Our interpretation is that a negative productivity shock decreases dividends/rents to asset owners, at the same time increasing the discount factor because of the increase in inflation and interest rates. 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. An increase in inflation, and therefore in the nominal mortgage rate, can make liquidity constraints faced by agents more binding, lowering housing demand and prices (Alm and Follain, 1984). Moreover, money illusion may magnify the impact of inflation on asset prices (see Brunnermeier and Julliard, 2008, for an application to the house market). Yet, a positive correlation between housing prices and inflation can also be predicted, as an increase in inflation leads to a reduction in the real after-tax mortgage rate, and therefore in real homeowners' user costs, increasing housing demand (Poterba, 1984).

Finally, concerning stock prices, it should 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 (0.3–29%).

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 (8–14%), investment (6–16%) and consumption (2–17%) fluctuations at business cycle horizons, particularly for the US, the euro area and the UK (Table 2). 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 (0.3–2.7%), consistent with the role played by productivity advances on 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 countries, apart from the UK and Japan (not reported).

Interestingly, while this latter shock only plays a minor effect on house price fluctuations for all countries (apart from the UK), in the range 0–2.3%, the contribution to stock market fluctuations is sizeable, in the range 18–45%, 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.

Finally, oil price shocks explain a small proportion of returns variability for both stock (2–6%) and house prices (1–7%), 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 associated 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 0.10–0.40; 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.[13]

4.1.2. The impact of shocks to stock and housing prices

The global house market shock significantly affects output and consumption dynamics in all countries, apart from Japan (Figs. 1 and 2). GDP and consumption responses to house prices are inelastic, but larger than what is found for stock prices, and 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 3). For the euro area and Japan, on the other hand, only medium-term elasticities 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, despite the point impact being positive as for the other countries. 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 reasons to believe that the above results reflect true causality.

The impulse response analysis shows that global stock market shocks have a significant impact on output, consumption and investment dynamics for all countries, at least in the short-term (Figs. 3 and 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 3).

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 linkage 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 relation should not be spuriously determined by a common unobserved factor driving both series (for instance a factor reflecting future income prospects, to which, in addition to stock prices, also

[13] The more idiosyncratic findings obtained for Japan may possibly be related to the different macroeconomic framework experienced by this latter country since the beginning of the 1990s. Differently, for the remaining countries results are in general more homogeneous. For instance, stock price elasticities relative to the nominal (n) shock are not in general significant (apart from Canada). Moreover, stock price elasticities relative to the real (bc) shock are very similar across all the countries, particularly in the medium term. Finally, house price elasticities relative to the real (bc) shock are significant, and of similar magnitude, only for European countries, while elasticities relative to the nominal (n) shock are similar across countries, albeit higher for Canada and the UK. Due to the stronger real and financial connections with the US, finding a stronger response for the UK and Canada than for Euro Area is not surprising.

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.

Forecast error variance decomposition analysis (Table 2) shows the existence of some 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 (0–1.8%, 0.7% on average), while the latter has a more sizeable impact on stock prices in the cases of the US, Canada and especially Japan. The two markets do not seem to affect each other in the UK and in Europe. 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.

The findings could be interpreted in the light of a standard portfolio model where prices depend on net inflows. 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. We are not aware of previous evidence on the latter flight-to-safety feature in Europe. The result is in any case interesting from the point of view of portfolio diversification and suggests that, in the presence of home bias, European investors would be able to obtain better stabilization of wealth than US investors in the face of asset price shocks.

The evidence 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; Case et al., 2005), showing that a real estate shock has a larger impact on consumption than a stock market shock, also due to the larger proportion of wealth invested in the real estate market than in the stock market, particularly for European countries and Japan.[14] Similarly, Cecchetti (2006) finds that housing prices bubbles, contrary to stock price bubbles, affect both the level and volatility of the output gap, as well as "economic growth risk".

Also, Lettau and Ludvingson (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 (especially stock prices) are attributable to transitory innovations that have no association with consumption. Only permanent changes in wealth (largely determined by shocks to nonstock wealth) are associated with movements in consumption (about 5%). As house prices are less volatile than stock prices, stronger effects on real activity should then be expected from housing than stock prices. In addition to wealth effects, the findings would also point to significant Tobin's Q effects, working through residential investment, as an increase in house prices leads to an increase in house values over construction costs. Moreover, an increase in house price implies an increase in the value of the collateral firms may use to guarantee external financing for their investment plans. A positive credit effect may similarly be expected for consumption plans as well. Recent empirical evidence supporting the relevance of the credit channel can be found in Goodhart and Hofmann (2008), Guariglia and Mateut (2006), Backé and Wójcik (2008), Oikarinen (2009), Marcucci and Quagliarello (2009) and Grunert and Weber (2009).

Somewhat peculiar is the negative response of inflation to the (positive) global house market shock, albeit statistically significant in the short-term only. Differently, the response of inflation to the global stock market shock is positive already in the short-term, consistent with the expansionary impact of the shock on real activity.

Also peculiar is the positive correlation between nominal money balances and stock prices detected for the US: after a stock market crash, nominal balances would increase in the euro area but contract in the US. Yet, once the price effect is taken into account, an increase in real money balances can be found for both countries. The different degree of price sluggishness in the two countries (higher in the euro area than in the US) explains why for the US an increase in real money balances in the short-to medium-term can be achieved even through a decrease in nominal money balances, while for the euro area an increase in nominal money balances is required.

According to the forecast error variance decomposition, apart from the US, the real exchange rate is mostly determined by the idiosyncratic shocks, with little role for the global shocks. Some of our results (not reported for reasons of space) suggest that after a positive global house price shock the (point) real exchange rate appreciates for Japan, the UK and Canada but depreciatee for the US and the euro area. Differently, following a positive stock market shock only the real effective US rate appreciates. The finding may be possibly rationalized in terms of increased foreign investment in the US stock market (and increased demand for US$) following an expansionary global (yet mostly US) stock market shock.

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. 4–47% (22% on average) for house prices, and 16–30% (27% on average) for stock prices, pointing to non negligible real estate sources of comovement in house prices. Also, consistent with Jarocinski and Smets (2008), the latter factor may reflect over optimistic expectations in house price or general macroeconomic developments, fuelled by the (anti-deflationary) low interest rates policy followed by the Fed in 2002–2004 and depressed long-term interest rates thereafter.[15]

4.2. Implications for the sub-prime crisis

The findings of the paper have interesting implications concerning the real effects of the decline in asset prices occurring in 2008. According to the Case–Shiller index, US real house prices have contracted about 24% in 2008. Real S&P 500 stock prices have fallen about 45% over the same period. By considering the latter figures as the size of the global assets price shocks, it is possible to provide a first estimate of the likely costs of the crisis over the short-to medium-term.

Using the estimated median elasticities, the actual reductions in house and stock prices imply the following estimates for the rate of decrease of real activity for the US: −6% ($-24\% \times 0.24$) due to the real house price shock and −6% ($-45\% \times 0.13$) due to real stock

[14] For instance, 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).

[15] Again, somewhat peculiar results can be pointed out for Japan, while for the other countries the range of variation is mostly consistent with what found in the literature. For instance, real activity appears to be more sensitive to stock and house price shocks in the US, the UK and Canada than for Euro Area countries, consistent with the larger role for and stronger linkages of financial markets with real activity.

price negative shock, for a total of −12%. The figure is impressive, but not unreasonable in the light of what actually occurred during the Great Depression of the 1930s in the US. At that time, real house prices contracted about 30%, stock prices fell about 70% and real output contracted about 28% over 1929–1932. Obviously, our estimates are not considering the effects of the stabilization policy currently in progress in the US, and therefore should be taken only as a conditional (on the magnitude of the assets price shocks) worst case scenario.

Subject to the same caveat as for the US, for the euro area the figures are −3% ($-24\% \times 0.13$) from the house price shock and −1.5% ($-45\% \times 0.03$) from the stock price shock, for a total −4.5% real GDP contraction, while for the UK figures are −1.5% ($-24\% \times 0.06$) and −3.2% ($-45\% \times 0.07$) for the house and stock price shocks, respectively, and −4.7% in total. These results are in line with what occurred in Europe during the Great Depression: −6% for Italy, −11% for France, −16% for Germany, and −5.8% for the UK.

Similarly, for Canada figures are −3.4% ($-24\% \times 0.14$) and −4.1% ($-45\% \times 0.09$), −7.5% in total, while a much larger impact can be detected for Japan, i.e. −17.5% ($-24\% \times 0.73$) from the house price shock and −2.7% ($-45\% \times 0.06$) from the stock price shock, for a −20.2% total. For the latter countries, figures during the Great Depression were −34.8% and −11%, respectively.

These results are in our opinion important also to evaluate the performance of the current model, which has been estimated with data to the second quarter of 2007. The sub-prime crisis represents a true out-of-sample test for the model. It is remarkable that the reactions implied by the model to shock to house prices and stock prices are so consistent with the actual reactions that started to unfold in 2008, where real GDP growth featured −1% for the US, −2.2% for the UK, −0.7% for Canada, −4.5% for Japan, and −1.3% for the euro area, and in 2009, where economic activity contracted on average 5%.

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. In particular, its main contribution lies in the investigation of global factors driving international house prices, an issue not thoroughly assessed in the literature so far. 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 (about 40%) in determining common house price fluctuations for the G-7. 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, the impact of house price shocks on stock price shocks is larger than the impact of stock price shocks on house price shocks.

Overall, the results show that housing 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 may reduce the usefulness of international diversification of residential investments. The results may also be of interest to policy-makers, who should not ignore the international business cycle and the forces associated with house prices in their macroeconomic risk assessments. House prices do play a powerful role and affect important macroeconomic variables.

According to the Case–Shiller index, US real house prices have contracted about 24% in 2008. Real S&P 500 stock prices have fallen about 45% over the same period. By considering the latter figures as the size of the global financial shocks, and neglecting the expected impact of the stabilization policies currently in progress, a conditional (on the magnitude of the assets price shocks) worst case scenario for the expected GDP costs of the sub-prime crisis has been computed. The downturn is predicted to be a "Great Recession" for all the G-7 countries, particularly for the US (−12%) and Japan (−20%), but still very deep for Canada (−7.5%), the UK and the euro area (−4.7% and −4.5%, respectively). The above figures are impressive, yet not unreasonable in the light of what actually occurred during the Great Depression of the 1930s, when similarly very large financial shocks (−30% and −70% for US real house and stock prices, respectively) occurred.

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 non-fundamental, 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. Also of interest would be the extension of the model to include additional variables, in order to explicitly measure the effects of interbank market instability and the credit crunch currently in progress.

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Appendix. Identification of structural disturbances

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

$$(\mathbf{X}_t - \boldsymbol{\mu}_t) = \mathbf{B}^*(L)\,\xi_t + \mathbf{C}^*(L)\,\boldsymbol{\psi}_t, \tag{7.1}$$

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 (ξ_t) and idiosyncratic ($\boldsymbol{\psi}_t$) shocks, respectively, with $\xi_t = \mathbf{H}\boldsymbol{\eta}_t, E[\xi_t\xi_t'] = \mathbf{H}\boldsymbol{\Sigma}_\eta\mathbf{H}' = \mathbf{I}_r$ and $\boldsymbol{\psi}_t = \boldsymbol{\Theta}\mathbf{v}_t, E[\boldsymbol{\psi}_t\boldsymbol{\psi}_t'] = \boldsymbol{\Theta}\boldsymbol{\Sigma}_\psi\boldsymbol{\Theta}' = \mathbf{I}_n$.

The elements of the $\mathbf{H}^{-1}$ matrix (with the $r(r-1)/2$ zero restrictions necessary for exact identification imposed) can then be estimated by the Choleski decomposition of the factor innovation variance matrix $\boldsymbol{\Sigma}_\eta, \widehat{\mathbf{H}}^{-1} = \text{chol}\,(\hat{\boldsymbol{\Sigma}}_\eta)$. The lower triangular structure of the $\mathbf{H}^{-1}$ matrix implies a precise "ordering" of the common factors in $\mathbf{F}_t$. Hence, an ordering based on plausible assumptions on the relative speed of adjustment to shocks can be chosen, starting with the factor showing the slowest speed of adjustment.

Similarly, the elements of $\mathbf{\Theta}^{-1}$ can be identified by imposing a block diagonal structure for each block of country variables:

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

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):

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

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 (2.3) is regressed on $\hat{\xi}_t$ 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 $\mathbf{\Theta}^{-1}$.[16]

The suggested approach implicitly assumes that cross-country interactions between the $\hat{\mathbf{v}}_t$ innovations are null, i.e. $\mathbf{\Sigma}_{v_{ij}} = 0, i \neq j$. 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, $\hat{\mathbf{v}}_t^{-m}$ $(\hat{\mathbf{v}}_t^{-m} = [\hat{\mathbf{v}}_t^{1\prime}\hat{\mathbf{v}}_t^{2\prime} \cdots \hat{\mathbf{v}}_t^{m-1\prime}]')$. 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 $\left(\hat{\mathbf{v}}_t^{-(m-1)} = [\hat{\mathbf{v}}_t^{1\prime} \cdots \hat{\mathbf{v}}_t^{m-2\prime}]'\right)$. Then, the procedure is repeated for the remaining countries.

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[16] 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.