Housing Cycles and Macroeconomic Fluctuations: A Global Perspective*

Ambrogio Cesa-Bianchi†

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Abstract

This paper investigates the international spillovers of housing demand shocks on real economic activity. The global economy is modeled using a Global VAR, with a novel house price data set for both advanced and emerging economies. The impulse responses to an identified US housing demand shock confirm the existence of strong international spillovers to advanced economies. In contrast, the response of some major emerging economies is not significantly different from zero. The paper also shows that synchronized housing demand shocks in advanced economies reinforce each other and have a deep and long-lasting impact on economic activity.

Keywords: Housing Cycles, Global VAR, Identification of shocks, Emerging Market Economies, Boom and Bust Cycles.
JEL code: C32, E44, F40.

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†Università Cattolica di Milano and Inter-American Development Bank. Correspondence to: Research Department, Inter-American Development Bank, 1300 New York Avenue, 20577 Washington DC, USA. Email: ambrogio.cesabianchi@gmail.com

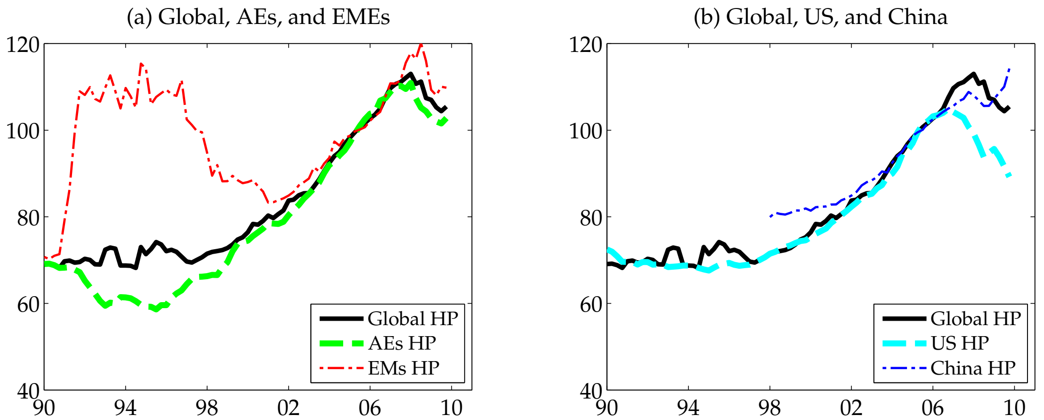
1 Introduction

The recent global financial crisis and ensuing recession led many to look at the housing market as a possible source of macroeconomic fluctuations. Moreover, the sluggish pace of the recovery among industrialized countries highlighted the crucial role played by emerging market economies as a source of world growth.

Many theoretical models stress the important linkage between the price of assets, such as stocks or house prices, and real economic activity (among many others, see Bernanke, Gertler, and Gilchrist, 1999, Iacoviello, 2005, Iacoviello and Neri, 2010). Also, many empirical studies show that house prices are subject to frequent boom–and–bust cycles and that housing busts can be very costly in terms of output loss (e.g., Bordo and Jeanne, 2002). Moreover, the surprisingly high synchronization of the housing downturn, as observed during the global financial, is likely to have exacerbated such episodes (e.g., Claessens, Kose, and Terrones, 2010).

The similarity of the house price pattern within the major advanced economies during the last two decades raised a number of questions concerning the existence of common international factors affecting house prices, perhaps due to global macroeconomic developments. While much of the debate has focused on advanced economies, it is surprising that housing markets in emerging market economies and their links with overall macroeconomic conditions, have not been systematically researched yet.

Figure 1 Real House Price Indices



Note. Real house price indices. The global index is computed as the median across all series in the dataset (described below); advanced economies (AEs) and emerging economies (EMEs) indices are computed as the median across all countries belonging to each group. The sample period is 1990:1–2009:4

Figure 1(a) displays the behavior of a global house price index and two group–specific indices, for advanced economies (AEs) and emerging market economies (EMEs), respectively. Both the global and the group–specific indices clearly show the pronounced boom–and–bust cycle of the last decade. However, AEs (dashed thick line) and EMEs (dashed thin line) also display significant differences. In fact, while the group–specific indices closely comove from the beginning of the 2000s, the cycle in EMEs is clearly disconnected from the cycle in AEs during the whole 1990s. Figure 1(b) compares the global house price index with the country–specific index for the US (dashed thick line) and China (dashed thin line). House prices in the US are in free fall since the fourth quarter of 2006, excluding an uptick in early 2009 propelled by the first-time home buyer credit provision. In contrast, house prices in China dropped for only two quarters, namely 2008:2 and 2008:3, and then started growing again, partly because of the massive fiscal stimulus adopted by the Chinese government in the aftermath of the financial crisis.

Motivated by this evidence, many interesting questions arise. Are international housing prices really correlated across countries? Is there a common factor driving a global housing cycle? How are house price shocks transmitted to the real economy? Do the coincidence of asset price movements across countries lead to magnified outcomes on the real economy? Across these questions, which is the difference, if any, between advanced economies and emerging economies?

This paper takes a global perspective and aims to provide a joint assessment of the linkages between general macroeconomic conditions and the housing market, as well as to investigate the effects of housing demand shocks onto real economic activity. Exploiting a novel multi-country data set of real and financial variables, a Global Vector AutoRegression (GVAR) model, originally proposed by Pesaran, Schuermann, and Weiner (2004), is used to investigate the international transmission of housing shocks. Specifically, three types of shocks are identified and investigated: 1) housing demand shocks originated in the US; 2) housing demand shocks simultaneously originated in all AEs; and 3) equity price shocks simultaneously originated in all AEs. The focus on the US housing demand shock reflects the interest in better understanding the recent US housing bust and how such a country-specific shock could propagate to the rest of the world, triggering of the global financial crisis. Instead, the focus on housing demand and equity price shock simultaneously originated in all AEs reflects the interest in understanding the impact of "common" shocks on international macroeconomic fluctuations.

The global financial crisis has highlighted the existence of an important knowledge gap. Reinhart and Rogoff (2009) show that financial crises are usually associated with deep recessions and house price declines stretched over long periods of time. Claessens, Kose, and Terrones (2010) find that globally synchronized asset price downturns tend to have large and long-lasting effects on real GDP. Despite the importance of these stylized facts, together with the evidence of the increasing synchronization of international housing cycles, it is surprising that very few studies analyzed the interaction between housing and business cycle fluctuations with a global perspective.

This paper aims to fill this gap, contributing to the existing literature along two dimensions. The main contribution lies in the investigation of the transmission of housing demand shocks with a global perspective, an issue whose scarce assessment is due to the technical challenges involved in dealing with high-dimension multi-country models and to the lack of a comprehensive house prices data set for EMEs. Secondly, this paper offers a methodological contribution to the GVAR literature by providing a methodology to identify country–specific and synchronized housing demand shocks. With few exceptions, the GVAR literature has so far relied on generalized impulse response functions to non-identified disturbances for the dynamic analysis of the transmission of shocks. I will demonstrate that, while this modelling choice can be justified for a class of applications, a meaningful analysis of the transmission of financial shocks requires a structural economic interpretation of the shocks under investigation.

The paper puts forth two sets of results, one stemming from the descriptive analysis of the novel house price data set and another from the structural GVAR analysis, respectively. Empirical evidence, based on simple dynamic correlations and principal component analysis, shows that real international house price returns can be highly correlated across countries and that such correlation varies significantly over time. The documented synchronization, however, is larger when considering AEs and EMEs separately.

Against this background, a GVAR model is estimated with data on 33 major AEs and EMEs covering more than 90 percent of world GDP. The data set is quarterly, from 1983:1 to 2009:4, thus including both the 2008–09 global recession and the first few quarters of the global recovery. In addition to house prices, the data set includes a set of macroeconomic and financial variables, namely real GDP, consumer price inflation, equity prices, exchange rates, short-term and long-term interest rates, and the price of oil. The results of the GVAR analysis are threefold. First, and consistently with the literature, US housing demand shocks are quickly transmitted to the domestic real economy, leading a short-term expansion of real GDP and consumer prices. Second, shocks originated in the US housing market are also quickly transmitted to foreign real activity, even though the transmission is different across groups. While almost all AEs are affected by a US housing demand shock in a significant fashion, EMEs response is heterogeneous. In particular, the effect of a US housing demand shock on the real GDP of four large EMEs (namely China, India, Brazil, and Turkey) is not significantly different from zero. Third, and finally, regional house price shocks, defined as a synchronized increase in house prices in all AEs, have larger impact on real GDP than synchronized equity price shocks.

These results speak in favor of the recent ”regionalization hypothesis” advanced by Hirata, Kose, and Otrok (2011), according to which, in the past two decades, while the relative importance of the global factor was declining, there has been some convergence of business cycle fluctuations within AEs and EMEs separately. Consistently with this view, some EMEs have also become somewhat resilient to shocks originated in AEs.

Literature. The analysis performed in this paper draws on a broad empirical literature on the international transmission of financial shocks and, more specifically, of house price shocks.[1] An early study by Renaud (1995) provides a comprehensive descriptive analysis of the international housing cycle in AEs between 1985 and 1994, concluding that such synchronized episode was a consequence of unique events following the widespread liberalization of financial markets in the late 1980s. Case, Goetzmann, and Rouwenhorst (2000) use 11 years of commercial property returns from both industrialized and emerging economies to show that the comovement between property price returns decrease noticeably after controlling for global GDP, concluding that real estate markets are largely correlated through common movements of economic activity.

Some recent papers add a more structural flavor to the analysis. IMF (2004) and Otrok and Terrones (2005) document the surprisingly high synchronization of real house price returns in AEs and show, in a FAVAR framework, how both global interest rates and global economic activity help

[1] Another relevant strand of literature for this paper concerns the role of housing within dynamic stochastic general equilibrium (DSGE) models. Nevertheless, such literature is vast and its exhaustive analysis is beyond the scope of the brief review presented in this section. It is important to notice, however, that this literature is closely related to the collateral constraints *á la* Kiyotaki and Moore (1997) and the financial accelerator literature pioneered by Bernanke, Gertler, and Gilchrist (1999). After the seminal work of Iacoviello (2005), many others augmented fairly standard New Keynesian frameworks with a housing sector (see, for example, Iacoviello and Neri, 2010). These models were then further developed by the introduction of frictions in the banking sector as in Gerali, Neri, Sessa, and Signoretti (2010) and Iacoviello (2011).

to explain the comovement of house prices. With a similar approach, Beltratti and Morana (2010) study the existence of a common factor driving international house prices for five large AEs and find that comovement of international house prices is due to both global and housing factors, mainly driven by the US. The analysis, however, does not take into account the EMEs. Vansteenkiste and Hiebert (2009) empirically assess the spillover effects of non–identified house price shocks within the euro area with a small scale GVAR model for ten countries of the monetary union. Finally, in a recent contribution, probably the closest to this paper, Bagliano and Morana (2012) investigate the transmission of different types of real and financial shocks in a large scale FAVAR framework and find that US housing and stock prices have real effects in both AEs and EMEs.

The implications of this paper are also related to a series of studies by Claessens, Kose, and Terrones (2009, 2010, 2011). Their descriptive analysis (based on a large data set on house prices, land price, credit, and equity prices) documents the long duration and deep impact of recessions associated with financial disruption episodes, notably house price busts. The authors also show that synchronized asset price downturns result in longer and deeper recessions relative to country-specific or asset-specific downturns. Notice, however, that these empirical regularities are based on an unconditional analysis: this paper is complementary to their work in that it corroborates some of their results within a structural multi–country framework.

The rest of the paper is organized as follows. Section 2, provides preliminary empirical evidence on the existence of global and group–specific housing cycles. Section 3 describes the GVAR model and discusses its estimation. Section 4 discusses the identification strategy. Section 5 reports the analysis of structural shocks and the main results of the paper. Section 6 concludes. Three appendices report the technical details of the identification strategy, a full set of estimation results for the GVAR model, and a description of the housing data set.

2 Are International House Prices Really Correlated? Some Stylized Facts

Given its location fixity and its heterogeneity, housing is considered the quintessential non-tradable asset, implying that housing cycles ought not to be very correlated across countries. However, a well known stylized fact is the similarity of the pattern of house prices for the major AEs. A common explanation for such stylized fact is that comovement in international house prices may arise in response to common movements in housing fundamentals, concurrent changes in housing-related borrowing conditions, and correlation of housing risk premia across borders.

Before analyzing the international comovement of house prices, it is worth to look at few interesting features of the house price data.[2] Table 1 reports the summary statistics of annual growth rates of house prices and real GDP computed as the average of all series within AEs and EMEs, over the common sample 1990:1–2009:4.

As evidenced by the average growth rate, the long–term trend in real house prices over the

[2]The house price data is described in Appendix C. Notice that house price series have very different starting dates. To fully take advantage of the information contained in the data set, I shall proceed as follows. First, in this section, I analyze house prices using the whole unbalanced panel, i.e. considering all available series in the data set. Then, I estimate a GVAR model augmented with house prices from 1983:1 to 2009:4, therefore considering only the series covering that sample.

Table 1 Summary Statistics: Real House Prices and Real GDP

	Real House Price		*Real GDP*	
Statistic	*AEs*	*EMEs*	*AEs*	*EMEs*
Mean	2.1%	2.0%	2.1%	4.1%
Median	2.5%	1.9%	2.5%	5.2%
Max	14.0%	28.3%	6.2%	11.8%
Min	–11.1%	–28.9%	–5.1%	–11.5%
St. Dev.	5.7%	12.1%	2.3%	4.8%
Autocorr.	0.92	0.85	0.85	0.83
Skew.	–0.10	–0.10	–1.08	–1.24
Kurt.	3.03	3.74	4.69	5.41

Note. Annual growth rates; the country–specific summary statistics are averaged across each group, namely advanced economies (AEs) and emerging economies (EMEs) and are computed across the common sample 1990:1–2009:4.

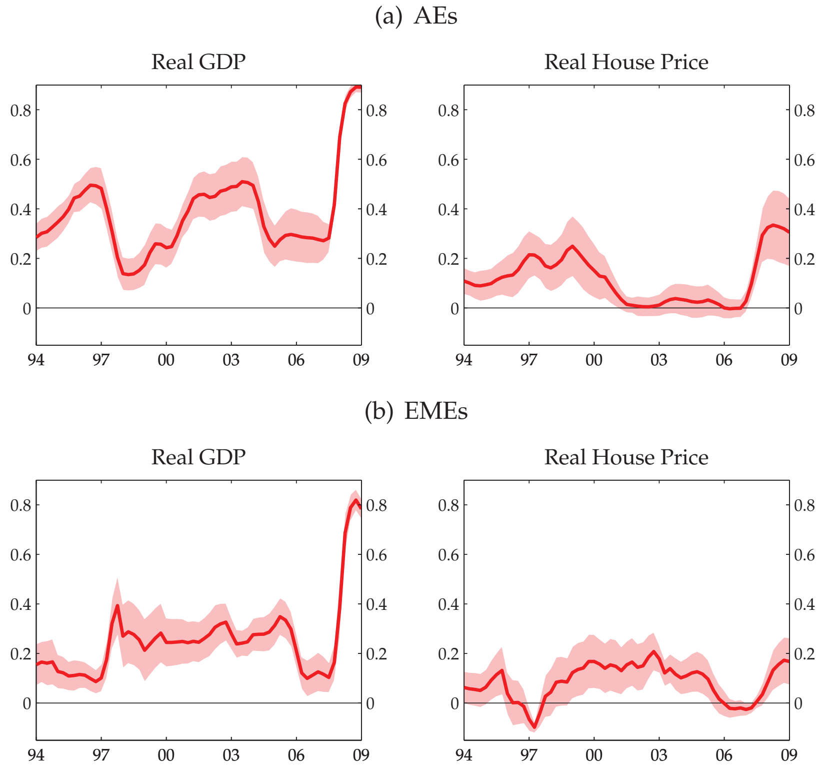
period under consideration is comparable across AEs and EMEs: real house prices have grown at an average rate of 2.1 and 2 percent per year in AEs and in EMs, respectively. Notice however that, while the average growth of house prices in AEs is broadly similar to the growth of real GDP, real GDP in EMEs has grown at much faster pace than house prices during the past 25 years. This fact underlies the exceptional buoyancy of the housing boom in industrialized countries, which experienced house price increases relative to GDP twice as big as in EMEs. Moreover, real house prices have fluctuated significantly over time. The standard deviation of real house price annual returns is very high and averages around 6 and 12 percent in advanced economies and emerging economies, respectively. Finally notice that the volatility of the annual growth rate of house prices is almost three times larger than the volatility of real GDP, both in AEs and in EMEs.

As a preliminary analysis of the degree of international comovement of housing markets, I compute the pair–wise cross country correlation of house prices and I compare it with the same statistic computed for real GDP. The pair–wise correlation for country i is the average correlation between country i and everybody else. To analyze the evolution over time of such synchronization measure, I compute a 5–years moving version of the pair–wise correlations over the sample 1990:1–2009:4. The results are then averaged across AEs and EMEs.[3].

Figure 2(a) displays the average moving pair–wise correlation of real GDP and house prices for AEs. The following stylized facts stand out. Consistent with the international business cycle literature, the average cross-country pair–wise correlation of real GDP is very high, averaging around 0.5 over the period under consideration and displaying a large spike corresponding to the 2008–09 global recession. In contrast, the average cross country pair–wise correlation of house prices is lower, averaging 0.25 over the period under consideration. Moreover, the synchronization of house prices varies markedly over time: it was positive and increasing in the late 1990s, decreased to zero in the 2000s, and spiked during the 2008–09 global recession, attaining a level twice as big as the average over the whole period. Notice also that the house price pair–wise correlation has very wide

[3] The sample standard deviation is adjusted to obtain consistent group mean estimate. Following Pesaran, Smith, and Im (1995), a consistent estimate of the true crosspair–wisesection variance can be obtained by taking the variance across countries and dividing it by $(N-1)$.

Figure 2 International Synchronization of Real GDP and Real House Prices



Note. Cross-country average of moving pair–wise correlation for real GDP and for real house prices with a 5-year rolling window (20 quarters) over the sample 1990:1 to 2009:4. The pair–wise correlation is computed as $\rho\rho_i = (\sum_{j=1}^{N} COR(x_i, x_j) - 1)/(N-1)$ where x is the annual growth rate of the variable of interest and N is equal to the number of countries in each group—21 for advanced economies (AEs) and 19 for emerging economies (EMEs).

error bands, pointing to the fact that there are marked differences across countries.[4] As a matter of fact, the UK, France, and Spain display an average pair–wise correlation of about 0.4 over the total sample, while Germany and Japan display an average pair–wise correlation of about –0.1.

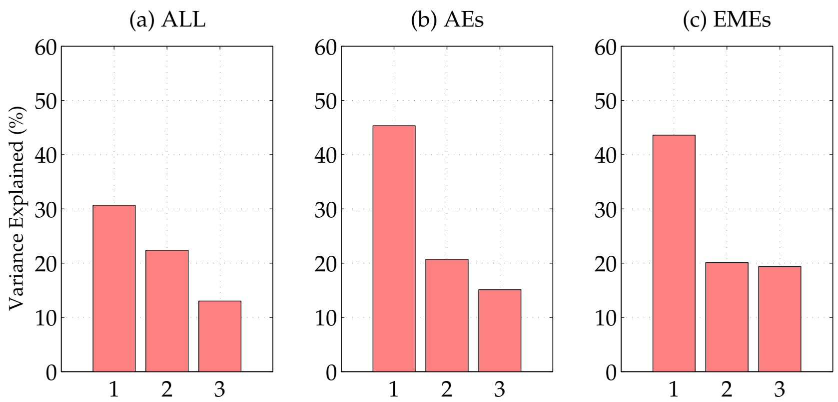
The evolution of pair–wise correlation of real GDP in EMEs is very similar to AEs (see Figure 2(b)), consistent with the evidence of a strong global factor driving world GDP growth, particularly in the last two decades (Kose, Otrok, and Whiteman, 2003). In contrast, the average real house price synchronization in EMEs is not as high as in AEs and, also, did not increase as sharply in 2008–09 . As we shall see later, this fact has an important ”labeling” implication: what has been referred to in the literature as a global housing bust should be better defined as a AEs housing bust. The fact that some EMEs, in the aftermath of the global financial crisis, recovered much faster than other countries has generated an upside pressure on house prices and a lower comovement relative to AEs.

As a second piece of evidence on the existence of international comovement of house prices, Figure 3 displays the results from a principal component analysis performed on the entire data set, on AEs only, and on EMEs only, respectively. Each bar of Figure 3 displays the share of total variabil-

[4]The country–specific results are not reported here for matter of space but are available from the author under request.

ity of house prices explained by the correspondent principal component. When considering AEs and EMEs together (left-hand panel of Figure 3), the first principal component explains a significant portion (around 30 percent) of the total variability of annual house price inflation. This is quite impressive, given the non-tradable nature of housing goods. But, even more interestingly, when considering AEs and EMEs separately, the share of variation explained by the first principal component increases to more than 45 percent for AEs and slightly more than 40 percent for EMEs (central and right-hand panel of Figure 3).

Figure 3 Principal Component Analysis on Real House Prices



Note. Explained variance of the first three principal components computed on real house price annual growth rates over the sample 1990:1 to 2009:4. The principal component analysis is performed on all countries in the dataset (ALL), on advanced economies only (AEs), and on emerging market economies only (EMEs).

This approach is clearly silent as to the reasons why such common factors are able to explain a substantial share of international house price variation. Much of the variance explained by first principal components, in fact, may be accounted for by common factors in global real GDP or global interest rates rather than common housing factors. It is possible that, once other variables or exogenous shocks are factored in, conditional correlations might be different. This will be the focus of next sections.

However, this novel empirical evidence hints to the existence of a multi-factor structure driving the behavior of house price in AEs and EMEs. These results are in line with the findings of Kose, Otrok, and Prasad (2012) and Hirata, Kose, and Otrok (2011), who show that, while the global factor has become less important for macroeconomic fluctuations during the last decades, the importance of regional factors has increased markedly. The changes in the relative importance of global and regional factors in driving national business cycles may be relevant for assessing the likely spillover effects of domestic shocks and, therefore, provides a natural motivation for the next sections of the paper.

3 The GVAR Model

The GVAR model is a multi-country framework which allows the investigation of interdependencies among countries and the analysis of the international propagation of shocks. It was first pioneered by Pesaran, Schuermann, and Weiner (2004) and further developed by Dees, di Mauro, Pesaran, and Smith (2007), Dees, Holly, Pesaran, and Smith (2007), and Dees, Pesaran, Smith, and Smith (2010), among others. The empirical evidence provided in the previous section suggests that international housing cycles might be correlated through the exposure to common driving forces. Thus, the GVAR model, with its implicit factor structure, looks like a well suited tool for the analysis of the spillover of housing demand shocks to the global economy.

The GVAR modelling strategy consists of two main steps. First, each country is modeled individually as a small open economy by estimating a country-specific vector error-correction model in which domestic macroeconomic variables ($\mathbf{x}_{it}$) are related to country-specific foreign variables ($\mathbf{x}_{it}^*$). Second, a restricted reduced-form global model is built stacking the estimated country-specific models and linking them by using a matrix of cross-country linkages. Consistent with previous GVAR modeling and the main purpose of the application in this paper, the country specific models are linked through trade linkages in the form of a matrix of fixed trade weights.[5]

3.1 First step: country-specific models

Consider $N+1$ countries in the global economy, indexed by $i = 0, 1, 2, ...N$. In the first step, each country i is represented by a vector autoregressive model for the vector $\mathbf{x}_{it}$ augmented by a set of weakly exogenous variables $\mathbf{x}_{it}^*$. Specifically a VARX*(p_i,q_i) model, in which the ($k_i \times 1$) country-specific domestic variables are related to the ($k_i^* \times 1$) foreign country-specific and ($m_d \times 1$) global variables, plus a constant and a deterministic time trend is set up for each country i:

$$\mathbf{\Phi}_i(L, p_i)\mathbf{x}_{it} = \mathbf{a}_{i0} + \mathbf{a}_{i1}t + \mathbf{Y}_i(L, q_i)\mathbf{d}_t + \mathbf{\Lambda}_i(L, q_i)\mathbf{x}_{it}^* + \mathbf{u}_{it}, \tag{1}$$

with $t = 1, ..., T$. Notice here that: $\mathbf{\Phi}_i(L, p_i) = I - \sum_{i=1}^{p_i} \mathbf{\Phi}_i L^i$ is the matrix lag polynomial of the coefficients associated to the $\mathbf{x}_{it}$; $\mathbf{a}_{i0}$ is a $k_i \times 1$ vector of fixed intercepts; $\mathbf{a}_{i1}$ is a $k_i \times 1$ vector of coefficients of the deterministic time trend; $\mathbf{Y}_i(L, q_i) = \sum_{i=0}^{q_i} \mathbf{Y}_i L^i$ is the matrix lag polynomial the coefficients associated with $\mathbf{d}_t$; $\mathbf{\Lambda}_i(L, q_i) = \sum_{i=0}^{q_i} \mathbf{\Lambda}_i L^i$ is the matrix lag polynomial of the coefficients associated to the $\mathbf{x}_{it}^*$; $\mathbf{u}_{it}$ is a $k_i \times 1$ vector of country-specific shocks, which we assume serially uncorrelated, with zero mean and a nonsingular covariance matrix, and $\sim i.i.d.(\mathbf{0}, \mathbf{\Sigma}_{u_i})$. Notice also that for estimation purposes $\mathbf{\Phi}_i(L, p_i)$, $\mathbf{Y}_i(L, q_i)$, and $\mathbf{\Lambda}_i(L, q_i)$ can be treated as unrestricted and differ across countries.

The vector of foreign country-specific variables, $\mathbf{x}_{it}^*$, plays a central role in the GVAR. At each time t, this vector is defined as the weighted average across section of all corresponding $\mathbf{x}_{it}$ in the model, with $i \neq j$, with fixed weights given by pre-determined (i.e., not estimated) linkages represented by the following matrix, $\mathbf{W}_{ij}$ of order $k_i^* \times k_j$:

$$\mathbf{x}_{it}^* = \sum_{j=0}^{N} \mathbf{W}_{ij}\mathbf{x}_{jt} = \mathbf{W}_i\mathbf{x}_t, \tag{2}$$

where $\mathbf{x}_t = (\mathbf{x}'_{0t}, \mathbf{x}'_{1t}, ..., \mathbf{x}'_{Nt})'$ is a $k \times 1$ vector of the endogenous variables ($k = \Sigma_{i=0}^{N} k_i$) and $\mathbf{W}_i = (\mathbf{W}_{i0}, \mathbf{W}_{i1}, ..., \mathbf{W}_{iN})$ is the $k_i^* \times k$ of weights with $\mathbf{W}_{ii} = 0$. In this application, I employ fixed trade

[5]Notice that, in principle, the weights could be based on bilateral trade, or capital flows, or others. However, Pesaran (2006) shows that when the number of countries, N, goes to infinite, the weighting scheme does not matter anymore.

weights corresponding to an average over three years. Therefore, equation (1) can be written as

$$\mathbf{x}_{it} = \mathbf{\Phi}_i \mathbf{x}_{i,t-1} + \mathbf{\Lambda}_{i0} \mathbf{W}_i \mathbf{x}_t + \mathbf{\Lambda}_{i1} \mathbf{W}_i \mathbf{x}_{t-1} + \mathbf{u}_{it}. \tag{3}$$

where, for sake of clarity and without any loss of generality, a VARX*(1,1) with no constant, trend, nor global variables has been considered.

As in Dees, di Mauro, Pesaran, and Smith (2007), equation (3) can be consistently estimated treating $\mathbf{x}_{it}^*$ as weakly exogenous with respect its long-run parameters. In practice, the weak exogeneity assumption permits considering each country as a small open economy with respect to the rest of the world and, therefore, allowing for country-by-country estimation. Note here that the number of countries does not need to be large for the GVAR to work. Nonetheless, when the number of countries is relatively small, the weak exogeneity assumption may not be satisfied for all countries. It is only when the number of countries tends to infinity, and all countries have comparable size, that we can have a fully symmetric treatment of all the models the GVAR. For this reason, as we shall see below, consistent with previous GVAR work, the united United States are treated differently in baseline GVAR specification.

Note also that, as shown in Dees, di Mauro, Pesaran, and Smith (2007), the country-specific VARX* models as in equation (3) can be written in error-correction form, allowing for the possibility of cointegration both within $\mathbf{x}_{it}$, and between $\mathbf{x}_{it}$ and $\mathbf{x}_{it}^*$, and consequently across $\mathbf{x}_{it}$ and $\mathbf{x}_{jt}$ for $i \neq j$. The estimation procedure for estimating error correcting models with $I(1)$ endogenous variables was first developed by Johansen (1992). Nonetheless, here the $\mathbf{x}_{it}$ are treated as $I(1)$ endogenous variables and the $\mathbf{x}_{it}^*$ are treated as exogenous $I(1)$ variables. Harbo, Johansen, Nielsen, and Rahbek (1998) and Pesaran, Shin, and Smith (2000) have developed appropriate methods for the estimation of such models, hereinafter VECMX models.

3.2 Second step: combining the country–specific models in a global model

The country–specific models can now be combined and solved to form the global model. First define a $k_i \times k$ selection matrix $\mathbf{S}_i$ such that

$$\mathbf{x}_{it} = \mathbf{S}_i \mathbf{x}_t.$$

Then rewrite equation (3) in terms of the vector $\mathbf{x}_t = (\mathbf{x}'_{0t}, \mathbf{x}'_{1t}, ..., \mathbf{x}'_{Nt})'$

$$\begin{aligned} \mathbf{S}_i \mathbf{x}_t &= \mathbf{\Phi}_i \mathbf{S}_i \mathbf{x}_{t-1} + \mathbf{\Lambda}_{i0} \mathbf{W}_i \mathbf{x}_t + \mathbf{\Lambda}_{i1} \mathbf{W}_i \mathbf{x}_{t-1} + \mathbf{u}_{it}, \\ \mathbf{G}_i \mathbf{x}_t &= \mathbf{H}_i \mathbf{x}_{t-1} + \mathbf{u}_{it}, \end{aligned} \tag{4}$$

where

$$\mathbf{G}_i = \mathbf{S}_i - \mathbf{\Lambda}_{i0} \mathbf{W}_i, \tag{5}$$

$$\mathbf{H}_i = \mathbf{\Phi}_i \mathbf{S}_i - \mathbf{\Lambda}_{i1} \mathbf{W}_i. \tag{6}$$

Finally, stacking (4) for $i = 0, 1, ..., N$ we get the global model,

$$\mathbf{G} \mathbf{x}_t = \mathbf{H} \mathbf{x}_{t-1} + \mathbf{u}_t, \tag{7}$$

where $\mathbf{G} = (\mathbf{G}_0', \mathbf{G}_1', ..., \mathbf{G}_N')'$, $\mathbf{H} = (\mathbf{H}_0', \mathbf{H}_1', ..., \mathbf{H}_N')'$, and $\mathbf{u}_t = (\mathbf{u}_{0t}', \mathbf{u}_{1t}', ..., \mathbf{u}_{Nt}')'$.

Notice that the error covariance matrix of the GVAR model can be computed as the sample moment matrix directly from $\mathbf{u}_t$, and will have the following representation,

$$\boldsymbol{\Sigma}_u = \begin{bmatrix} \boldsymbol{\Sigma}_{u_0} & \boldsymbol{\Sigma}_{u_0 u_1} & \cdots & \boldsymbol{\Sigma}_{u_0 u_N} \\ \boldsymbol{\Sigma}_{u_1 u_0} & \boldsymbol{\Sigma}_{u_1} & \cdots & \boldsymbol{\Sigma}_{u_1 u_N} \\ \vdots & \cdots & \ddots & \vdots \\ \boldsymbol{\Sigma}_{u_N u_0} & \boldsymbol{\Sigma}_{u_N u_1} & \cdots & \boldsymbol{\Sigma}_{u_N} \end{bmatrix},$$

where $\boldsymbol{\Sigma}_{u_i}$ is the covariance matrix of the reduced form residuals of country i and $\boldsymbol{\Sigma}_{u_i u_j}$ is the covariance matrix of the reduced form residuals of country i and country j.

3.3 Specification and estimation of a GVAR model with house prices

The GVAR model that I specify includes 33 country-specific VECMXs models, including all major AEs and EMEs in the world accounting for about 90 percent of world GDP. The models are estimated over the period 1983:1–2009:4, thus including both the 2008–09 global recession and the first few quarters of the global recovery.[6]

With the exception of the U.S. model, all country models include the same set of variables, when the required data are available. The variables included in each country model are real GDP, $y_{it} = ln(GDP_{it}/CPI_{it})$; the rate of inflation, $\pi_{it} = ln(CPI_{it}/CPI_{it-1})$; the real exchange rate, defined as $e_{it} - p_{it} = ln(E_{it}) - ln(CPI_{it})$; and, when available, real equity prices, $q_{it} = ln(EQ_{it}/CPI_{it})$; real house prices, $ln(HP_{it}/CPI_{it})$; a short rate of interest, $\rho_{it}^S = 0.25 \cdot ln(1 + R_{it}^S/100)$; and a long rate of interest, $\rho_{it}^L = 0.25 \cdot ln(1 + R_{it}^L/100)$. In turn, GDP_{it} is Nominal Gross Domestic Product of country i at time t, in domestic currency; CPI_{it} is the Consumer Price Index in country i at time t; EQ_{it} is a Nominal Equity Price Index; HP_{it} the nominal House Price Index; E_{it} is the nominal Exchange rate of country i at time t in terms of U.S. dollars; R_{it}^S is the Short rate of interest in percent per annum (typically a three-month rate); R_{it}^L is a Long rate of interest per annum, in per cent per year (typically a ten year rate). With the exception of the US model, all country models also include the log of nominal oil prices (p_t^o) as weakly exogenous variable.

In the case of the U.S. model, the oil price is included as an endogenous variable. In addition, given the importance of the U.S. financial variables in the global economy, the US-specific foreign financial variables, $q_{US,t}^*$, $\rho_{US,t}^{*S}$, and $\rho_{US,t}^{*L}$, are not included in the U.S. model as they are not likely to be long-run forcing for to the US domestic variables. On the contrary, foreign house prices ($hp_{US,t}^*$) turn out to satisfy the weak exogeneity assumption, thus, they are included in the US model. Finally, note also that the value of the US dollar, by construction, is determined outside the US model. The US-specific real exchange is implicitly defined as ($e_{US,t}^* - p_{US,t}^*$) and is included as a weakly exogenous variable in the U.S. model. Table 2 summarizes the specification for the country specific models.

While all the model variables have quarterly frequency, trade data for the construction of the fixed trade weights in the first stage of the analysis has annual frequency. In this application, a

[6]All series in the country-specific models need to have the same number of observations. Therefore, the choice of the starting date for the estimation, namely 1983:1, reflects a trade-off between series availability and precision of the estimation.

Table 2 Variables Specification of the Country-specific VARX* Models

Non–US Models		US Model	
Domestic	Foreign	Domestic	Foreign
y_i	y_i^*	y_{US}	y_{US}^*
π_i	π_i^*	π_{US}	π_{US}^*
q_i	q_i^*	q_{US}	–
hp_i	hp_i^*	hp_{US}	hp_{US}^*
ρ_i^S	ρ_i^{S*}	ρ_{US}^S	–
ρ_i^L	ρ_i^{L*}	ρ_{US}	–
$(e-p)_i$	–	–	$(e-p)_{US}^*$
–	p^o	p^o	–

Note. In the non–US models the inclusion of all the listed variables depends on data availability.

three-year average of trade weights in years from 2007 to 2009 is used.

Detailed empirical evidence on the estimation of the GVAR model for 33 countries is reported in Appendix B. This includes evidence on the degree of integration of all individual time series, the lag-length and the cointegration rank for all country models, test statistics on the weak exogeneity assumptions made, evidence on the stability of the GVAR model (persistence profiles and eigenvalues), as well as a full description of contemporaneous effects of foreign variables on their domestic counterparts.

4 Identification of Housing Demand Shocks in the GVAR

The GVAR literature largely relied on Generalized Impulse Response Functions (GIRF) of Koop, Pesaran, and Potter (1996) and Pesaran and Shin (1998) to non-identified disturbances for the dynamic analysis of the international transmission of shocks.[7] While this modelling choice can be justified for a class of GVAR applications, I will show how this is not suitable for the analysis of financial shocks and I will provide an alternative approach to identify housing demand shocks.

GIRFs consider shocks to individual errors and integrate out their effects using the observed distribution of all the shocks without any orthogonalization. Hence, and differently from more traditional orthogonalized impulse responses (Sims, 1980), GIRFs do not depend on the ordering of the variables. This is seen as a desirable feature in a multi-country framework like the GVAR, where a suitable ordering of the variables is unlikely to be derived from theoretical considerations. The fact that GIRFs are completely silent as to the structural nature of the shocks, however, is not necessary a problem, at least for a certain class of GVAR applications. If the researcher is not interested in the identification of the disturbances hitting the economy, GIRFs can in fact be used to quantify the dynamics of the transmission of shocks from one country to another one.

However, the main focus of this paper is on the international transmission of identified "housing demand shocks". Economic theory suggests that asset prices are forward looking variables, meaning that investors determine stock prices and house prices in anticipation of future economic events. A change in the price of an asset should therefore reflect future changes in economic fundamentals,

[7] Few exceptions are Dees, di Mauro, Pesaran, and Smith (2007), Chudik and Fidora (2011), Chudik and Fratzscher (2011), and Eickmeier and Ng (2011).

such as changes in expected income, inflation, or interest rates. Consistently, the literature has defined a housing demand shock as an increase in the price of housing that leads to a rise in residential investment over time and is not associated with a fall in the nominal short-term interest rate, in order to rule out an expansionary monetary policy shock. Moreover, housing demand shocks are often assumed to have no contemporaneous effect on real GDP or consumption, so as to rule out a more fundamental type of shocks such as a positive technology shock (see Jarocinski and Smets (2008), Iacoviello and Neri (2010), and Musso, Neri, and Stracca (2011)).

Note here that, in a standard VAR framework, generalized and orthogonalized impulse responses are equivalent when the shocked variable is ordered first in the VAR. It is evident that, if GIRFs were to be used, the above assumptions would be violated, with house prices potentially having a contemporaneous impact on all other variables in the system. Non–orthogonalized innovations to forward–looking asset prices would most likely correspond the combination of many underlying economic shocks (such as productivity shocks, monetary shocks, credit shocks, risk shocks,...) which would be impossible to disentangle. For a meaningful analysis of the transmission of financial shocks in the GVAR framework, it is therefore necessary to achieve identification and provide some structural economic interpretation of the shocks under investigation.

This paper offers a methodological contribution to the GVAR literature, suggesting an approach to identify both country–specific and synchronized housing demand shocks. The procedure is general and can be applied to derive structural shocks in any country in the GVAR. However, for sake of clarity of exposition, let's consider a housing demand shock in the US, whose model is connoted by subscript $i = 0$.

Operationally, the identification is achieved with a Cholesky decomposition of the covariance matrix of the reduced form residuals in the US model.[8] In selecting the ordering of the variables I closely follow the literature. The vector of the country–specific endogenous variables is divided as

$$\mathbf{x}_{0t} = (\mathbf{x}_{0t}^{1\prime}, r_{0t}^{\prime}, \mathbf{x}_{0t}^{2\prime})^{\prime}, \tag{8}$$

where $\mathbf{x}_{0t}^{1}$ is a group of slow-moving macroeconomic variables predetermined when monetary policy decisions are taken, r_{0t} is a relevant monetary policy interest rate, and $\mathbf{x}_{0t}^{2}$ contains the variables contemporaneously affected by monetary policy decisions. As is customary in the VAR literature, the vector of slow-moving macroeconomic variables includes real GDP and inflation, $\mathbf{x}_{0t}^{1} = (y_{0t}^{\prime}, \pi_{0t}^{\prime})^{\prime}$; the monetary policy interest rate is the short term-interest rate, r_{0t}^{S}; and the vector of fast-moving variables include real house prices, the long-term interest rate, equity prices, and the oil price (in this order), $\mathbf{x}_{0t}^{2} = (hp_{0t}^{\prime}, r_{0t}^{L\prime}, q_{0t}^{\prime}, p^{oil\prime})^{\prime}$.

Note here that, on a theoretical basis, correlation between the residuals of the GVAR model may arise both *within countries* (among variables of a country–specific model), and *across countries* (among variables in different countries). While the within–country correlation is taken care through the Cholesky orthogonalization, the residuals associated with different countries may be contemporaneously correlated across countries, creating concerns about reverse spillover effects from one country

[8]Notice that, while it is relatively common to use a Cholesky decomposition to identify housing shocks (see Bagliano and Morana (2012), Aspachs-Bracons and Rabanal (2011), Musso, Neri, and Stracca (2011), Beltratti and Morana (2010)), alternative identification schemes have also been used in the literature, such as sign restrictions (see Andre, Gupta, and Kanda (2011), Buch, Eickmeier, and Prieto (2010), Cardarelli, Monacelli, Rebucci, and Sala (2010), Jarocinski and Smets (2008)) or a combination of zero contemporaneous and long-run restrictions (see Bjørnland and Jacobsen (2010)).

to another. This concern, however, is addressed by a particular strength of the GVAR model, namely the conditioning of domestic endogenous variables on foreign variables. Once $\mathbf{x}_{it}$ is conditioned on $\mathbf{x}_{it}^*$, the cross-country dependence of the residuals becomes null or of second-order importance, as supported by Tables B.7 and B.8 in Appendix B. Hence, the shocks can be safely considered country–specific (for a discussion see also Eickmeier and Ng (2011)).

The above assumptions can be summarized as follows. After ordering the variables as in equation (8), the GVAR model in equation (7) can be rewritten as

$$\mathbf{G}\mathbf{x}_t = \mathbf{H}\mathbf{x}_{t-1} + \mathbf{P}_0^G \mathbf{v}_t, \tag{9}$$

where

$$\mathbf{P}_0^G = \begin{bmatrix} \mathbf{P}_0 & 0 & \cdots & 0 \\ 0 & \mathbf{I}_{k_1} & 0 & 0 \\ \vdots & \cdots & \ddots & \vdots \\ 0 & 0 & \cdots & \mathbf{I}_{k_N} \end{bmatrix}, \qquad \mathbf{\Sigma}_v = \begin{bmatrix} \mathbf{\Sigma}_{v_0} & \mathbf{\Sigma}_{v_0 u_1} & \cdots & \mathbf{\Sigma}_{v_0 u_N} \\ \mathbf{\Sigma}_{u_1 v_0} & \mathbf{\Sigma}_{u_{1t}} & \cdots & \mathbf{\Sigma}_{u_1 u_N} \\ \vdots & \cdots & \ddots & \vdots \\ \mathbf{\Sigma}_{u_N v_0} & \mathbf{\Sigma}_{u_N u_1} & \cdots & \mathbf{\Sigma}_{u_{Nt}} \end{bmatrix},$$

$\mathbf{v}_t = \left(\mathbf{P}_0^G\right)^{-1} \mathbf{u}_t$ is the global vector of *semi*–structural residuals; $\mathbf{P}_0$ is the lower Cholesky factor of the covariance matrix of the US reduced form residuals; $\mathbf{\Sigma}_{v_0} = \mathbf{P}_0^{-\mathbf{1}} \mathbf{\Sigma}_{u_0} (\mathbf{P}_0^{-\mathbf{1}})' = \mathbf{I}$ and $\mathbf{\Sigma}_{v_0 u_j} = \mathbf{P}_0^{-\mathbf{1}} \mathbf{\Sigma}_{u_0 u_j}$. Finally, assuming then that $\mathbf{G}$ is non-singular we have

$$\mathbf{x}_t = \mathbf{F}\mathbf{x}_{t-1} + \mathbf{G}^{-1}\mathbf{P}_0^G \mathbf{v}_t, \tag{10}$$

where $\mathbf{F} = \mathbf{G}^{-1}\mathbf{H}$. The impact of unanticipated housing demand shocks can be evaluated directly from the GVAR in (10). In fact, once the structural residuals for country 0 are obtained through the Cholesky orthogonalization, equation (10) can be solved recursively and used for impulse response analysis in the usual manner. The technical details on the identification strategy and on the computation of the impulse responses are provided in Appendix A.

5 Analysis of Structural Shocks

5.1 A positive housing demand shock in the US

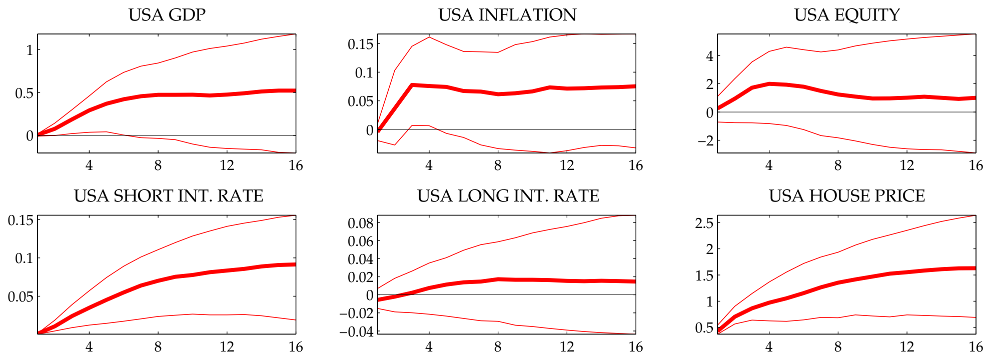
This section focuses on a US housing demand shock and analyzes its effects on both the US and the world economy. I look at a US house price shock because it is of particular interest to understand the recent global financial crisis; but also because it provides a natural benchmark against which to contrast the results for the synchronized shocks in the next sections. Since the main objective of this study is on the international transmission of house price shocks to real GDP at business cycle frequencies, I shall focus only on the first four years following the shock.

5.1.1 Transmission to the US economy

The US housing demand shock is equivalent to a 1 standard deviation increase in the house prices structural residuals, which corresponds to an increase of real house prices, on impact, of about 0.5

percent (see Figure 4). The shock builds up over time, generating an increase in the level of house prices of about 1.5 percent after 4 years.

Figure 4 US House Price Shock – Transmission to the US Economy



Note. Cumulative impulse responses to a one standard deviation increase in US house price residuals. Bootstrap median estimates with 90% error bands.

On a theoretical ground, house prices and economic activity are tightly linked through three main channels. First, according to the life-cycle model, changes in house prices may affect the real economy through wealth effects on consumption: a permanent increase in housing wealth leads, in fact, to an increase in spending and borrowing by homeowners, as they try to smooth consumption over their life cycle. A second channel of transmission can be expected through Tobin's Q effects on residential investment, a volatile component of GDP which can make a sizeable contribution to economic growth (see Leamer, 2007). A third, indirect, channel of transmission is represented by the credit market. In fact, house prices may influence credit conditions through both demand and supply factors. On the demand side, booming house prices lead to an increase in the value of collateral that households and firms can post, enhancing their borrowing ability (see Bernanke, Gertler, and Gilchrist, 1999, Kiyotaki and Moore, 1997); on the supply side, booming house prices lead to a strengthening of financial institutions' balance sheets, prompting lenders to loosen credit standards (see Adrian, Moench, and Shin, 2010). Financial accelerator and debt-deflation mechanisms may finally exacerbate the amplitude of boom–and–bust cycles and amplify the above effects, fuelling a feedback loop between house prices, balance sheets, and credit, with potentially deep consequences for real economic activity (see Fisher, 1933).

Consistently with these channels, the shock is quickly transmitted to the real economy, with GDP reacting with one lag and increasing over time in a significant fashion from the second quarter for one year and a half, according to the 90 percent error bands.[9] The maximum response of GDP is attained after the four years under consideration at a level of 0.5 percent, implying a long-run elasticity of real GDP with respect to house price changes of about 0.3. This value is broadly consistent with the values found in the literature: in a DSGE model with a housing sector, Iacoviello and Neri

[9]Notice that GIRFs error bands are obtained using the same bootstrap procedure used to test the model for parameter stability, which is described in detail in the Appendix of Dees, di Mauro, Pesaran, and Smith (2007).

(2010) estimate the response of US GDP to a 1 percent increase in house prices to be around 0.2 percent; using an identified Bayesian VAR, Jarocinski and Smets (2008) find that a housing demand shock which pushes house prices up by 1 percent, leads to an increase in real GDP of 0.13 percent after 4 quarters. Notice that, the elasticity of GDP to the housing demand shock implied by the impulse response is slightly higher relative to the values found in the literature. This difference most likely arises because of the global nature of the GVAR model and emphasizes the value added of the second step of the GVAR modeling strategy. In fact, both papers mentioned above consider the US as a closed economy, ignoring possible second round effects generated by the rest of world in response to the shock originated in the US.

Inflation displays an quick pick up in response to the housing demand shock, although with reduced statistical significance. After the first year and a half, inflation stabilizes at a level of about 0.75 percent. Equity prices also respond to the shock, with a very high elasticity of around 2 after one year which slowly decreases over time. The response of equity prices, however, is not significantly different from zero over the horizon considered for the impulse response. Finally, the short-term and long-term interest rates, display a gradual, significant increase of around 10 and 2 basis points, respectively.

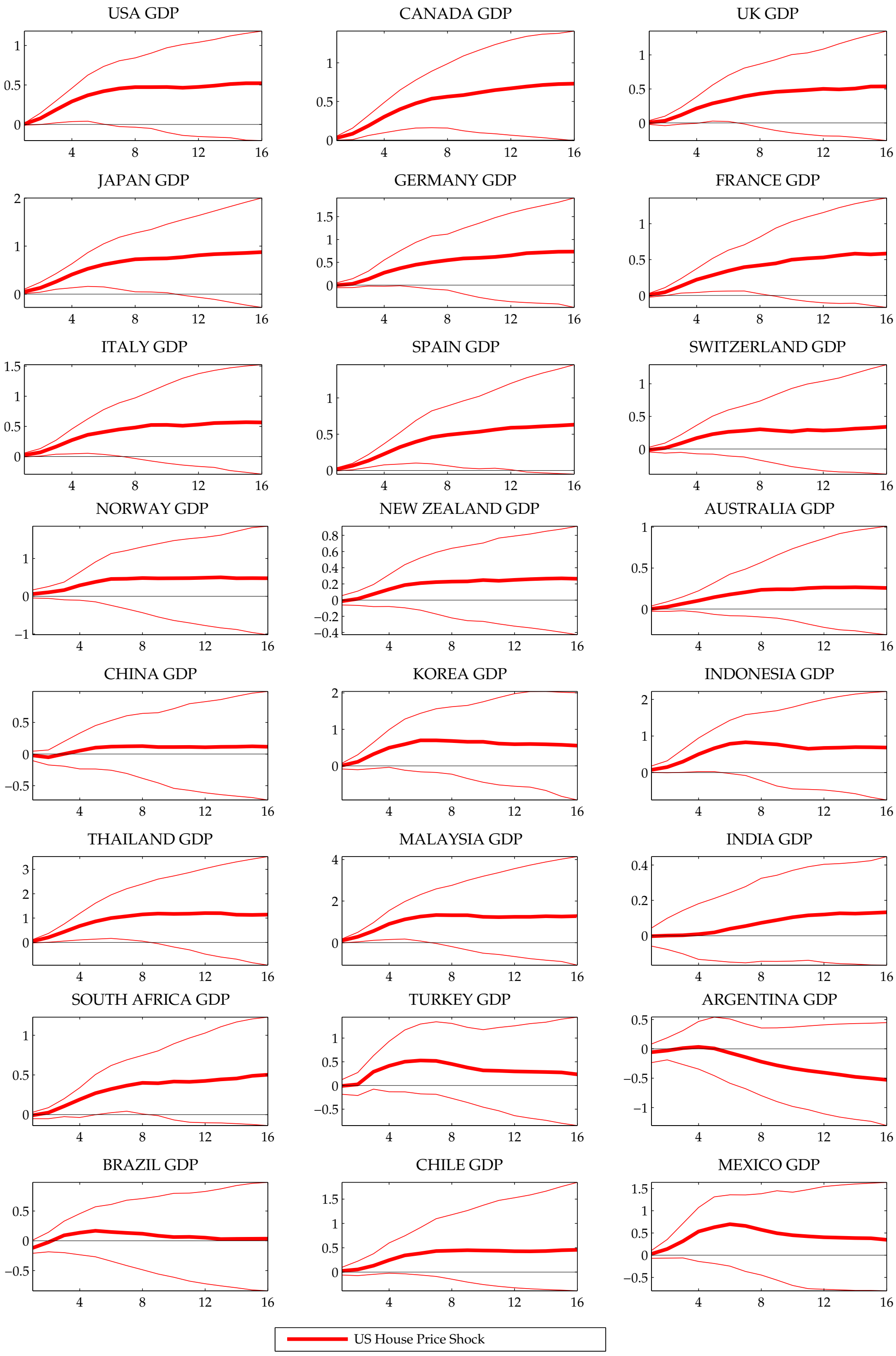
The overall pattern of impulse responses in Figure 4 suggests that the above estimated house price shock behaves as an identified housing demand shock: the increase in the real house price leads to a rise in GDP over time and is not associated with a fall in the nominal short-term interest rate, ruling out an expansionary monetary policy shock. On the contrary, the short–term interest rate displays a positive and significant response, consistent with an inflation targeting monetary authority which reacts to increasing output, consumer prices, and asset prices. Notice, moreover, that the identification assumptions made in the previous section allow us to disentangle the housing demand shock from an aggregate demand shock; given that GDP is not allowed to respond to house prices within a quarter, their relation should not be spuriously determined by a common unobserved shock driving both variables.

5.1.2 Transmission to the world economy

In theory, the transmission of house price shocks from one country to another one can happen through the following channels. First, house price shocks in a country may have important signaling effects in other countries' housing markets, as suggested by the strong cross-country linkages in business and consumer confidence often found to be relevant in the international business cycle literature. Second, residual movements in house prices not explained by standard housing demand fundamentals, such as income and interest rates, might reflect disturbances to the housing risk premia (a proxy for the desirability of this asset class) which, with tightly integrated capital markets, can rapidly propagate across borders (see IMF, 2007). Finally, given the positive impact of the US housing demand shock on US real GDP, spillover effects may be expected through international trade linkages. Trade linkages play an important role for the transmission of shocks across country borders and for international business cycle synchronization, as documented by Forbes and Chinn (2004), Imbs (2004), Baxter and Kouparitsas (2005) and Kose and Yi (2006).

The US housing demand shock is, in fact, quickly transmitted to the world economy, as showed by the responses in Figure 5. The following mechanism could be at work. First, the house price

Figure 5 US House Price Shock – Transmission to the world economy



Note. Cumulative impulse responses to a one standard deviation increase in US house price residuals. Bootstrap median estimates with 90% error bands.

shock originated in the US boosts domestic real GDP, as analyzed in Figure 4. Second, booming house prices and increasing activity in the US affect foreign housing markets and foreign GDP through the channels discussed above.[10] It is worth mentioning here that the US housing shock has no contemporaneous effect on foreign GDP nor on foreign house prices. This result not only suggests that the GVAR model does a good job in filtering the residuals' cross–sectional dependence; but it also corroborates the goodness of the identification assumptions, removing any concern over the reverse causality of the housing shock. Third, and finally, foreign GDP and foreign house prices generate second round effects on US GDP and US house prices, reinforcing the loop and fostering a world expansion. This is a key feature of the GVAR: in addition to the dynamics implied by the vector autoregression, foreign-specific variables can have a contemporaneous effects on their domestic counterparts, introducing a feedback between each country and the rest of the world.

As a matter of fact, the median response of GDP is, at least in the first few quarters, positive in all countries considered, with a dynamic which seems to lag by one or two quarters the response of US GDP. Also, the elasticity of foreign GDP four years after a US housing demand shock is, on average across both AEs and EMEs, of about 0.3 percentage points, confirming the existence of strong spillover effects. However, these long–run elasticities vary considerably across countries and they are somehow clustered across regions. In particular, Malaysia and Thailand display the highest elasticities, at a level of about 0.7; European and North American countries have elasticities ranging from 0.6 to 0.3; Indonesia, Korea, and Philippines from 0.4 to 0.2; Australia and New Zealand at 0.15; and finally the remaining EMEs (namely, Latin American countries, China, India, and Turkey) display the lowest elasticities, ranging from 0.15 to zero (or even negative values).

Turning to the significance of the impulse responses, the error bands of AEs show that the US housing demand shock has a significant effect on GDP generally for the first 4 to 12 quarters. Concerning EMEs, however, there is mixed evidence on the spillover effects of the US house price shock on real activity. In particular, for four large EMEs, namely China, India, Brazil, and Turkey, the response of real GDP to a US housing demand shock is not significantly different from zero. In contrast, Malaysia, Mexico, and Indonesia are all significantly affected by the US house price shock for the first two years.

The intuition behind this set of results lies in the in the volume, direction, and nature of international trade and financial flows over the past decades. World trade has more than tripled as a share of world GDP since the 1960s and international financial flows have increased at even faster pace. Intuitively, this should generate both demand and supply-side spillovers across countries, thus making the impulse responses of Figure 5 puzzling at a first sight.[11]

However, as highlighted by the work of Hirata, Kose, and Otrok (2011) and Lane and Milesi-Ferretti (2011), intra–regional linkages contributed significantly to this unprecedented increase in the volume of trade and financial flows during the last 25 years (namely, the sample period considered in this paper). Instead of decoupling from the world economy, many EMEs shifted their loading from the US and the euro zone into other EMEs. This is consistent with recent evidence of the

[10] For reasons of space the impulse response to international house prices are not reported in the paper. A full set of impulse responses are available upon request.

[11] Note here that economic theory does not provide definitive guidance concerning the impact of increased trade and financial linkages on the degree of global business cycle synchronization. However it is a well known empirical regularity that countries with tight trade linkages experience higher business cycle comovement (see Frankel and Rose (1998), Calderon, Chong, and Stein (2007)).

decreased importance of US shocks in the global economy (Cesa-Bianchi, Pesaran, Rebucci, and Xu, 2012, Yeyati and Williams, 2012); and it also stresses how the resilience of some EMEs to shocks originated in AEs is likely to have played an important role in the unfolding of the recent global financial crisis and, most importantly, in the recovery.

5.2 A positive synchronized shock to AEs house and equity prices

This section evaluates the effects of house price and equity price shocks and their impact on real GDP in both AEs and EMEs in the case that all AEs simultaneously experience a housing or an equity boom. An important reason for focusing on this type of shocks that it is possible to investigate the effects and the dynamics of group–specific (*alias* ”regional”) shocks; to provide a comparison between different episodes of financial disruption, such as equity and house price busts; and, finally, to investigate whether there are mechanisms of amplification due to the cross-country synchronization of the shocks.

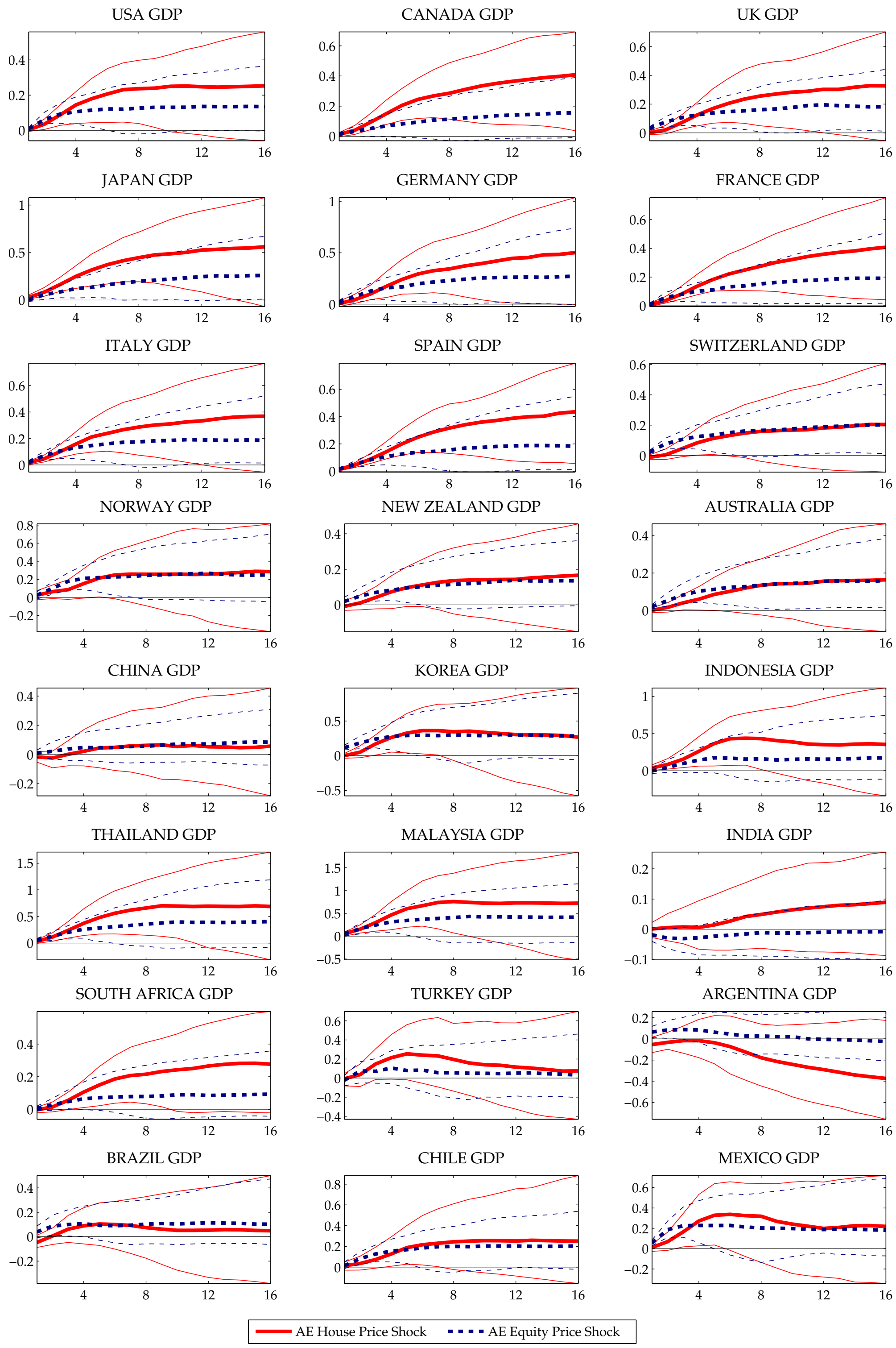
Such comparison is motivated by the recent findings of Claessens, Kose, and Terrones (2010, 2011), who provide a comprehensive empirical overview of boom–and–bust cycles in credit, house prices, and equity prices (i.e., ”financial cycles”) in terms of amplitude, duration, and synchronization. Their analysis sets forth that business cycles often display a high degree of *within–country* synchronization with financial cycles; and that recessions associated with house price busts tend to be longer and deeper than other recessions. Moreover, they study the implications of the coincidence of financial cycles *across countries* and showthat globally synchronized financial downturns result in longer and deeper recessions. This finding is especially true for credit and equity cycles and, to a smaller extent, for house prices.

The GVAR looks particularly suitable for the analysis of synchronized shocks to different asset classes and their implications for economic activity. The regional shock in AEs is defined as a simultaneous standard deviation shock to the structural residuals in the equations of the variables of interest, namely house prices and equity prices in all AEs (the identification procedure is described in Appendix A). Notice also that the regional shock is constructed as a weighted average of all shocks in AEs, meaning that each country–specific impulse is weighted by its corresponding PPP–GDP weight.

In AEs, the regional house price shock is equivalent, on average, to an increase of house prices of about 0.1 percent on impact and of 1 percent after four years; the regional equity price shock is instead equivalent to an average increase of equity prices of about 1.5 percent on impact, rapidly increasing to almost 2.5 percent after one year and then slowly decreasing to 1.6 percent after four years. Figure 6 displays the effects on GDP of both the regional house price shock (solid line) and the regional equity price shock (dashed line) with the bootstrapped 90 percent confidence bands.

Few interesting results stem from the analysis of these impulse responses. First, both the regional house price shock and the regional equity price shock have a significant impact on real GDP in AEs. However, and contrarily to the findings of Claessens, Kose, and Terrones (2010), the long-run effect of a synchronized house price boom has a larger effect on most AEs than a synchronized equity price boom: the regional house price shock builds up much quicker and for a longer horizon.

Figure 6 AEs House Price and Equity Price Shock – Transmission to the world economy



Note. Cumulative impulse responses to a one standard deviation increase in US house price residuals and equity price residuals in all AEs. The impulse is weighted by PPP–GDP weight of the correponding country. Bootstrap median estimates with 90% error bands.

For the countries analyzed in Figure 6, the long-run impacts of the regional house price shock on real GDP range from 1.5 to 2.5 times larger than the regional equity price shock. The countries with the highest elasticities (in relative terms with respect to the boom in equity prices) are the countries belonging to the euro area, in particular France, Germany, and Spain, and Canada. In contrast, the median responses of Switzerland, Norway, Australia, and New Zealand to a synchronized housing demand shock and equity price shock do not display substantial differences.

The effect of regional house and equity price shocks originated in AEs is, again, heterogeneous in EMEs. Let's consider first China, India, Brazil, and Turkey. Despite the large impact on AEs' real GDP, the AEs house price shock does not have any significant effect on these four large EMEs, as evidenced by the low median responses and by the wide error bands. To a certain extent, this finding is consistent with the observed behavior of those countries during the global financial crisis and recovery. Turning to the effects of the AEs equity price shock, notice that most of the bootstrapped distribution of the impulse response is positive in the case of Brazil and, to a lesser extent, in the case of China. while is clearly not significantly different from zero in the case of India and Turkey.

The remaining EMEs display significant and positive response to both shocks, the impact of the house price shock being generally larger than the equity price shock. In particular, the long-run impacts of regional house price shocks range from 1.5 to 3 times larger than the impacts of regional equity shocks. All together, these results stress the importance of the nexus between macroeconomy and the housing sector, whose dynamics are a key element in determining the severity and duration of booms and recessions.

5.3 Robustness issues

The impulse responses presented above hinge on two main assumptions: the ordering of the variables in the country–specific models and the weak cross–sectional dependence of the residuals across all countries in the GVAR. In order to assess the robustness of the main results to these assumptions, two alternative exercises are considered. While this section reports only the main insights from the robustness analysis, a full set of impulse responses under the alternative assumptions are reported in Appendix B.

First, the robustness to the within–country identification assumption is checked by estimating a housing demand shock with a different ordering of the variables in the US country–specific model. In particular, as in Iacoviello (2005) and Giuliodori (2005), the interest rate is ordered last, namely $x_{it} = (x_{it}^{1\prime}, x_{it}^{2\prime}, r_t')'$. This alternative ordering implies that the short–term interest rate is allowed to contemporaneously react to all shocks in the US model, whereas house prices are sluggish and do not respond contemporaneously to movements in the interest rate. As shown in Figure B.2, only minor differences arise between the two specifications, reassuring us on the robustness of the identification strategy.

The second robustness check concerns the assumptions made for the international transmission of shocks. As already mentioned, residuals in the GVAR may be correlated across countries, raising concerns about the origin of the shocks. For example, consider the case in which the residuals of the US house price equation are correlated with the residuals of the China GDP equation. If that would be the case, an increase in US house prices might arise because of a housing demand shock in the US, of a positive aggregate shock to the Chinese economy, or because of a mix of the two. To address the concern about the possible reverse causality of house price shocks, I follow Bagliano and Morana (2012) and assume cross–sectional orthogonality of the GVAR residuals. This can be achieved by imposing a block diagonal covariance in the reduced form GVAR matrix for the computation of the impulse responses. Such assumption can be interpreted as an additional contemporaneous restriction: a shock to US house prices cannot have contemporaneous spillover effects on any foreign variable. The impulse responses to a US housing demand shock obtained with the sample covariance matrix and the block–diagonal covariance matrix are compared in Figure B.3: the difference between the two approaches, if any, is not substantial and statistically not discernible.

6 Conclusions

Exploiting a novel multi–country house price data set, this paper investigates the international transmission of housing demand shocks and their spillover effects on real economic activity in both advanced and emerging economies.

Empirical evidence, based on unconditional dynamic correlations and principal component analysis, shows that real house price returns can be highly correlated across countries: such synchronization varies significantly over time and can be particularly high during the bust part of the cycle, as evidenced by the ongoing housing downturn. The documented synchronization, however, is larger when considering advanced and emerging economies separately, suggesting the existence of group–specific (*alias* regional) common factors.

A GVAR model is estimated with data for 33 major advanced and emerging economies, covering more than 90 percent of world GDP. The data set is quarterly, from 1983:1 to 2009:4, thus including both the 2008–09 global recession and the first few quarters of the global recovery. The focus of the analysis is on three different shocks, namely a country-specific housing demand shock in the US, and a ”regional” shock to house prices and equity prices simultaneously originated in all advanced economies.

The results of the GVAR analysis are threefold. First, and consistently with the literature, US housing demand shocks are quickly transmitted to the domestic real economy, leading a short-term expansion of real GDP and consumer prices. Second, shocks originated in the US housing market are also quickly transmitted to foreign real activity, even though the transmission is different across groups. While almost all advanced economies are affected by a US housing demand shock in a significant fashion, emerging market economies response is heterogeneous. In particular, the effect of a US housing demand shock on the real GDP of four large emerging economies (namely China, India, Brazil, and Turkey) is not significantly different from zero. Third, and finally, regional housing demand shocks, defined as a synchronized increase in house prices in all advanced economies, have larger impact on real GDP than synchronized equity price shocks.

These results speak in favor of the recent ”regionalization hypothesis” advanced by Hirata, Kose, and Otrok (2011), according to which, in the past two decades, there has been some convergence of business cycle fluctuations within advanced economies and emerging economies separately, while the relative importance of the global factor has declined. Consistently with this view, some emerging economies have also become somewhat resilient to shocks originated in advanced economies.

These findings have also important policy implications, in particular regarding the current policy debate on the need for and the design of macro-prudential approaches. Given the deep economic impact that shocks to the housing sector can have on the real economy, the results of this paper suggest that a close monitoring of housing cycles should be of interest for policymakers. Moreover, since both business and financial cycles are often synchronized internationally, it is important to consider the global nature of housing cycles.

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A Appendix. Identification in the GVAR

This appendix explains how to identify both country–specific and group–specific (i.e., synchronized) housing demand shocks using a standard recursive scheme within the GVAR framework (as suggested by Dees, di Mauro, Pesaran, and Smith (2007) and Smith and Galesi (2011)). The identification procedure consists of two steps. First, the structural shocks in the countries of interest are derived following Sims (1980); second, the identified shocks are coherently introduced in the GVAR model.

A.1 Step 1: within–country identification

Consider a reduced–form $VARX(1,1)$ for the generic country i,

$$\mathbf{x}_{it} = \mathbf{\Phi}_i \mathbf{x}_{i,t-1} + \mathbf{\Lambda}_{i0}\mathbf{x}^*_{it} + \mathbf{\Lambda}_{i1}\mathbf{x}^*_{i,t-1} + \mathbf{u}_{it}, \tag{A.1}$$

with $\mathbf{\Sigma}_{u_i} = \text{COV}(\mathbf{u}_{it})$ being the sample variance-covariance matrix of the reduced–form residuals. Let's assume that the structural form of the above is given by

$$\mathbf{P}_i^{-1}\mathbf{x}_{it} = \mathbf{P}_i^{-1}\mathbf{\Phi}_i\mathbf{x}_{i,t-1} + \mathbf{P}_i^{-1}\mathbf{\Lambda}_{i0}\mathbf{x}^*_{it} + \mathbf{P}_i^{-1}\mathbf{\Lambda}_{i1}\mathbf{x}^*_{i,t-1} + \mathbf{P}_i^{-1}\mathbf{u}_{it},$$

where $\mathbf{P}_i^{-1}$ is a $k_i \times k_i$ matrix of coefficients to be identified. Moreover, let $\mathbf{v}_{it}$ be the structural shocks given by

$$\mathbf{v}_{it} = \mathbf{P}_i^{-1}\mathbf{u}_{it}$$

The identification conditions using the triangular approach of Sims (1980) require $\mathbf{\Sigma}_{v_i} = \text{COV}(\mathbf{v}_{it})$ to be an identity matrix and $\mathbf{P}_i^{-1}$ to be lower triangular. Let $\mathbf{Q}_i$ to be the upper Cholesky factor of $\mathbf{\Sigma}_{u_i}$ so that $\mathbf{\Sigma}_{u_i} = \mathbf{Q}_i'\mathbf{Q}_i$. Given that

$$\mathbf{\Sigma}_{v_i} = \mathbf{P}_i^{-1}\mathbf{\Sigma}_{u_i}(\mathbf{P}_i^{-1})',$$

and imposing $\mathbf{\Sigma}_{v_{it}} = \mathbf{I}$, we get

$$\mathbf{\Sigma}_{u_i} = \mathbf{P}_i\mathbf{P}_i' = \mathbf{Q}_i'\mathbf{Q}_i,$$

which implies that $\mathbf{P}_i = \mathbf{Q}_i'$.

A.2 Step 2: GVAR identification

For sake of clarity of exposition, suppose we want to identify a structural shock in the first country–specific model of the GVAR (connoted by subscript $i = 0$). Notice, however, that the procedure is general and can be applied to derive structural shocks in any country.

First, construct the following matrix

$$\mathbf{P}^G = \begin{bmatrix} \mathbf{P}_0 & 0 & \cdots & 0 \\ 0 & \mathbf{I}_{k_1} & \cdots & 0 \\ \vdots & \cdots & \ddots & \vdots \\ 0 & 0 & \cdots & \mathbf{I}_{k_N} \end{bmatrix}.$$

Then, pre–multiply the GVAR model in (7) by $\left(\mathbf{P}^G\right)^{-1}$ to get

$$\left(\mathbf{P}^G\right)^{-1}\mathbf{G}\mathbf{x}_t = \left(\mathbf{P}^G\right)^{-1}\mathbf{H}\mathbf{x}_{t-1} + \left(\mathbf{P}^G\right)^{-1}\mathbf{u}_t,$$

and, noticing that $\mathbf{v}_t = \left(\mathbf{P}^G\right)^{-1} \mathbf{u}_t = (\mathbf{v}'_{0t}, \mathbf{u}'_{1t}, ..., \mathbf{u}'_{Nt})'$,

$$\mathbf{G}\mathbf{x}_t = \mathbf{H}\mathbf{x}_{t-1} + \mathbf{P}^G\mathbf{v}_t. \tag{A.2}$$

The covariance matrix of the innovations in the structural GVAR is

$$\boldsymbol{\Sigma}_v = \mathsf{COV}(\mathbf{v}_t) = \begin{bmatrix} \boldsymbol{\Sigma}_{v_0} & \boldsymbol{\Sigma}_{v_0 u_1} & \cdots & \boldsymbol{\Sigma}_{v_0 u_N} \\ \boldsymbol{\Sigma}_{u_1 v_0} & \boldsymbol{\Sigma}_{u_{1t}} & \cdots & \boldsymbol{\Sigma}_{u_1 u_N} \\ \vdots & \cdots & \ddots & \vdots \\ \boldsymbol{\Sigma}_{u_N v_0} & \boldsymbol{\Sigma}_{u_N u_1} & \cdots & \boldsymbol{\Sigma}_{u_{Nt}} \end{bmatrix},$$

where $\boldsymbol{\Sigma}_{v_0} = \mathbf{P}_0^{-\mathbf{1}}\boldsymbol{\Sigma}_{u_0}(\mathbf{P}_0^{-\mathbf{1}})' = \mathbf{I}$ and $\boldsymbol{\Sigma}_{v_0 u_j} = \mathbf{P}_0^{-\mathbf{1}}\boldsymbol{\Sigma}_{u_0 u_j}$. It is clear in fact that the structural shock $\mathbf{v}_{\ell 0}$ (for variable ℓ in country 0) is uncorrelated with other shocks *within* country 0; but it may be correlated with shocks to other variables *across* countries. However, as displayed in Tables B.7 and B.8, after conditioning on foreign variables, the cross–country dependence of residuals is close to zero for most countries. This suggests that we shouldn't be concerned about reverse causality of shocks.

Finally, the structural reduced–form GVAR model in (A.2) can be written as

$$\mathbf{x}_t = \mathbf{F}\mathbf{x}_{t-1} + \mathbf{G}^{-1}\mathbf{P}^G\mathbf{v}_t,$$

and the impulse responses to the identified shock $\mathbf{v}_{\ell t}$ are given by

$$\begin{cases} \mathcal{IRF}_n = \mathbf{G}^{-\mathbf{1}}\mathbf{P}^G\boldsymbol{\Sigma}_v\mathfrak{e}_{\ell 0} & \text{for } n = 0 \\ \mathcal{IRF}_n = \mathbf{F}\cdot\mathcal{IRF}_{n-1} & \text{for } n \geq 1 \end{cases} \tag{A.3}$$

where $\mathfrak{e}_{\ell 0}$ is a $k \times 1$ selection impulse vector with unity as the ℓ^{th} variable in country 0 and n is the number of steps of the impulse response.

Finally, synchronized shocks can be identified by applying the first step to the countries of interest and by constructing accordingly the matrix $\mathbf{P}^G$. For example, a "global housing demand shock" can be identified by constructing the following matrix

$$\mathbf{P}^G = \begin{bmatrix} \mathbf{P}_0 & 0 & 0 & 0 \\ 0 & \mathbf{P}_1 & 0 & 0 \\ 0 & 0 & \ddots & 0 \\ 0 & 0 & 0 & \mathbf{P}_N \end{bmatrix},$$

where P_i is the lower Cholesky factor of the residuals' covariance matrix in country i. The impulse responses to the global shock can then be computed directly from equation (A.3), with the only difference that the selection vector, $\mathfrak{e}_t$, would have PPP–GDP weights that sum to one corresponding to the selected shocks of each of the $N + 1$ countries, and zeros elsewhere.

B Appendix. Specification of the GVAR Model

In this appendix, I present the details of the GVAR model specification used in the paper and describe technical details such as integration properties of the series, lag-length selection and cointegration rank, weak exogeneity of foreign variables, and stability of the GVAR. In addition, I provide some of the main estimation results, such as impact elasticities, the pair-wise cross-section correlation of all variables and associated residuals, and the robustness exercises.

Our GVAR model uses data for thirty-three countries. The core economies included in the model are China, Japan, the United Kingdom, and the United States; Latin American is composed by Argentina, Brazil, Chile, Peru, and Mexico; the euro area block is made up of the eight largest economies, namely Austria, Belgium, Finland, France, Germany, Italy, Netherlands, and Spain. Other developed and European economies in the model are Australia, Canada, New Zealand, Norway, Sweden and Switzerland. For emerging Asia, we have Indonesia, Korea, Malaysia, the Philippines, Singapore, and Thailand. Finally, the model also considers India, South Africa, South Arabia, and Turkey.

B.1 Unit root tests

The GVAR model can be specified in terms of either stationary or integrated variables. Following Dees, di Mauro, Pesaran, and Smith (2007), I assume that the variables included in the country-specific models are integrated of order one (or $I(1)$) and I distinguish between short run and long run relations. To examine the integration properties of both the domestic and foreign variables, given the recognized poor performance of ADF tests in small samples, I consider unit root t-statistics based on weighted symmetric estimation of ADF type regressions introduced by Fuller and Park (1995) (WS henceforth). The lag length employed in the WS unit root tests is selected by the Akaike Information Criterion (AIC) based on standard ADF regressions.

Results of the WS statistics for the level, first differences and second differences of the country-specific domestic and foreign variables are reported in Tables B.1 and B.2. This battery of tests generally support the unit root hypothesis with only a few exceptions, as evidenced in Cesa-Bianchi, Pesaran, Rebucci, and Xu (2012). For house prices, the unit root tests generally reject the null hypothesis of unit root for house price log-differences. There are three exceptions though: house price returns in France, Italy, and US are still $I(1)$ after first differencing. However, the values of the statistics imply that those are borderline cases.

B.2 Selecting lag-length and cointegration rank

We select the order of the individual country VARX*(p_i,q_i) models according to the Akaike information criterion under the constraints imposed by data limitations. Accordingly, the lag order of the foreign variables, q_i, is set equal to one in all countries; for the same reason, we constraint $p_i \leq 2$. Notice that, in preliminary analysis of the GIRFs, we observed very ragged responses for Argentina, Belgium, Brazil, Malaysia, Netherlands, New Zealand, Norway, Philippines, and Singapore. Therefore, and consistently with Cesa-Bianchi, Pesaran, Rebucci, and Xu (2012), we changed the orders of the VARX* models for these countries from VARX(2,1) to VARX(1,1).

We then proceed with the cointegration analysis. The rank of the cointegrating space for each country was tested using Johansen's trace and maximal eigenvalue statistics, as set out in Pesaran, Shin, and Smith (2000) for models with weakly exogenous $I(1)$ regressors, in the case where unrestricted constants and restricted trend coefficients are included in the individual country error correction models. Table B.3 reports the trace test statistics and the 95% critical values for all the country-specific VARX* models, respectively. The critical values are taken from MacKinnon (1991). We chose the trace test, because it has better small sample properties compared to the maximal eigenvalue test.

To address the issue of possible overstatement of the number of cointegration relationships based on asymptotic critical values, and to assure the stability of the global model, we reduced the number of cointegration relations. Specifically, the following *ad hoc* adjustments in the number of cointegration relations have been made from the results implied by the statistical tests: Argentina from 3 to 1, Australia from 4 to 1, Austria from 5 to 1, Belgium from 3 to 1, Brazil from 2 to 1, Canada from 5 to 1, China from 2 to 1, France from 4 to 1, Germany from 3 to 1, Indonesia from 3 to 1, Italy from 2 to 1, Japan from 3 to 1, Korea from 3 to 1, Malaysia from 2 to 1, Netherlands from 4 to 1, Norway from 4 to 1, New Zealand from 4 to 2, Peru from 3 to 1, Philippines from 2 to 1, South Africa from 2 to 1, Saudi Arabia from 2 to 1, Singapore from 3 to 1, Spain from 3 to 2, Sweden from 4 to 1, Switzerland from 4 to 1, Thailand from 2 to 1, United Kingdom from 2 to 1, and United States from 3 to 2.

Finally, the country-specific models were estimated subject to reduced rank restrictions (Johansen, 1992). The order of the VARX* models, as well as the number of cointegration relations, are presented in Table B.4.

B.3 Testing weak exogeneity

The weak exogeneity of foreign variables is the key assumption for the whole GVAR modeling approach. After having estimated each country VECMX model individually, it is necessary to verify the validity of the hypothesis of weak exogeneity for both the country-specific foreign variables and the oil price in each of these country specific models.

We employ the weak exogeneity test proposed by Johansen (1992) and Harbo, Johansen, Nielsen, and Rahbek (1998), that is a test on the joint significance of the estimated error correction terms in auxiliary equations for the country-specific foreign variables, x^*_{it}. In particular, for each l^{th} element of x_{it} the following regression is estimated:

$$\Delta x^*_{it,l} = \mu_{il} + \sum_{j=1}^{r_i} \gamma_{ij,l} ECM^j_{i,t-1} + \sum_{k=1}^{s_i} \varphi_{ik,l} \Delta x_{i,t-k} + \sum_{m=1}^{n_i} \vartheta_{im,l} \Delta \tilde{x}^*_{i,t-m} + \epsilon_{it,l}, \tag{B.1}$$

where $ECM^j_{i,t-1}$, $j = 1, 2, ..., r_i$ are the estimated error correction terms corresponding to the r_i cointegrating relations found for the i^{th} country model, and $\Delta\tilde{x}^*_{it} = [\Delta x'^*_{it}, \Delta(e^*_{it} - p^*_{it}), \Delta p^o_t]'$.[12] The test consists in verifying by means of an F test the joint hypothesis that $\gamma_{ij,l} = i$ for each $j = 1, 2, ..., r_i$.

Results in Table B.5 suggest that most of the weak exogeneity assumptions are not rejected by the data: only 14 out of the 264 exogeneity tests reject the weak exogeneity assumption made. Notice that, concerning house prices, the weak exogeneity assumption does not hold for Chile and Korea, but holds for the US.

B.4 Stability of the GVAR

The eigenvalues of the GVAR model are 386 in total. In fact, the GVAR contains 193 endogenous variables with a maximum lag order of 2, which give rise to a companion $VAR(1)$ model with 386 variables. From the individual country models and the theorem in Pesaran, Schuermann, and Weiner (2004) we do not expect the rank of the cointegrating matrix in the global model to exceed 52 (namely the number of cointegrating relations in all the individual country models). Hence, the global system should have at least 141 eigenvalues (i.e. 193 - 52), that fall on the unit circle. The GVAR satisfies these properties and, indeed, has 141 eigenvalues equal to unity, with the remaining 245 eigenvalues having moduli all less than unity. After the unit roots, the two largest eigenvalues (in *modulus*) are 0.931 and 0.847, implying a reasonable rate of convergence of the model after a shock to its long-run equilibrium. Given the unit eigenvalues of the system, some shocks will have permanent effects on the levels of the endogenous variables.

Moreover, the stability of the system is analyzed through the persistence profiles, i.e. the time profiles of the effects of system or variable specific shocks on the cointegration relations in the GVAR model. If the vector under consideration is a valid cointegrating vector, the persistence profiles should return to equilibrium at acceptable rate (normally less then 40 periods). Figure B.1 displays the persistence profiles of all cointegration relations in the GVAR model.

B.5 Contemporaneous effects of foreign variables on their domestic counterparts

The estimation of the cointegrating VECMX models permits to examine the impact of foreign-specific variables on their domestic counterparts. As explained in the main text, these estimates

[12] Note that in the case of the United States the term $\Delta(e^*_{it} - p^*_{it})$ is implicitly included in Δx^*_{it}.

are generally viewed as impact elasticities, which measure the contemporaneous variation of a domestic variable due to a 1 percent change in its corresponding foreign-specific counterpart.

Table B.6 reports these impact elasticities, for all countries and variables. Statistical significance is computed with the corresponding t-ratios based on the White's heteroscedasticity-consistent variance estimator. As in earlier exercises by Pesaran, Schuermann, and Weiner (2004) and Dees, di Mauro, Pesaran, and Smith (2007), there is substantial comovement between the major advanced economies' real GDP and their specific foreign counterparts. The same result holds -with larger magnitudes- for most of the East Asian countries in the sample. Inflation transmission in the above-mentioned economies is smaller but still positive and significant. Contemporaneous elasticity between real equity prices is remarkably close to unity in the case of the euro area countries and Canada, reflecting their high degree of financial integration.

For the house price series considered in the current GVAR specification, the impact elasticities between foreign and domestic variables are generally positive and significant. The cross-country average of the coefficients is equal to about 0.5, implying that a 1 percent change in foreign real house price leads to an average increase of 0.5 percent in domestic house prices. Nonetheless, these coefficients vary considerably across countries. Countries with very active and volatile housing markets, such as Spain and Sweden, have coefficients ranging above one. In contrast, impact elasticities can be very low (e.g., Germany and Japan) or even negative (e.g., Switzerland), underlying the different historical behavior of the housing sector in such countries relative to other industrialized economies.

Finally, the high and positive coefficients of impact elasticities between foreign and domestic real GDP imply strong comovement of output across countries, a standard result in the international business cycle literature as well as in the GVAR literature.

B.6 Pair-wise cross country correlation

One of the basic assumption underlying the GVAR model is that the cross-dependence of the variable-specific innovations must be sufficiently small, so that

$$\frac{\sum_{j=1}^{N} \sigma_{ij,ls}}{N} \to i \; as \; N \to \infty \; \forall i, l, s \tag{B.2}$$

where $\sigma_{ij,ls} = cov(u_{ilt}, u_{jst})$ is the covariance of the variable l in country i with the variable s in country j. This means that the country-specific shocks are cross-sectionally weakly correlated. We check this requirement by following Dees, Holly, Pesaran, and Smith (2007): we calculate the pair-wise cross-section correlations of all the variables in the GVAR, both in levels and in differences, and of all the corresponding residuals, obtained both from each country-VECM and from country-VECMX model estimation. The main rationale is that foreign variables could be considered as common global factors for each country considered in the GVAR model. Thus, the estimation of each country-specific model by conditioning on the foreign variables can "clean" the common component among countries, in order to obtain simultaneously weakly correlated residuals.

Tables B.7 and B.8 report the pair-wise cross section correlations for the domestic variables and the residuals of the VECMX models (column labeled ResX) and the auxiliary unrestricted VECM models (column labeled Res). Although, these results do not constitute a formal statistical test of the importance of the foreign variables in the GVAR model, they do provide an important indication of their usefulness in modeling global interdependencies. As illustrated by the differences between the two columns ResX and Res, the results show that once country-specific models are formulated conditional on foreign variables, the degree of correlations across the shocks from different countries is sharply reduced.

B.7 Robustness issues

As discussed in the main text of the paper, to check the validity of the identification strategy, two robustness exercises are considered. Figure B.2 displays the impulse responses to a US housing demand shock identified with the following ordering, $x_{it} = (x_{it}^{1\prime}, x_{it}^{2\prime}, r_t')'$, as in Iacoviello (2005) and Giuliodori (2005). Figure B.3 displays the impulse responses to a US housing demand shock computed assuming cross–sectional orthogonality of the GVAR residuals.

Table B.1 Unit Root t-Statistics (Weighted Symmetric Estimation of ADF) for Domestic Variables

	Arg.	Austr.	Austria	Bel.	Bra.	Can.	China	Chile	Finl.	France	Germ.	India	Indon.	Italy	Japan	Korea	Mal.
y	-2.60	-2.47	-1.48	-2.64	-1.81	-2.12	-1.83	-1.01	-2.56	-2.52	-0.31	-0.86	-1.61	0.55	-0.96	-0.14	-2.09
Δy	-4.78	-3.48	-7.40	-5.62	-5.20	-3.85	-3.36	-6.76	-3.85	-4.67	-4.87	-7.51	-5.87	-4.61	-3.72	-5.59	-4.94
$\Delta^2 y$	-6.56	-9.88	-9.20	-7.58	-7.98	-10.61	-10.77	-9.03	-9.25	-7.33	-6.90	-10.01	-7.71	-7.92	-13.41	-9.63	-6.91
π	-3.71	-4.55	-4.09	-4.17	-2.83	-6.58	-2.99	-4.28	-2.65	-2.53	-3.14	-5.22	-5.65	-2.19	-3.97	-3.61	-6.17
$\Delta\pi$	-11.62	-7.11	-6.41	-7.98	-5.91	-8.49	-6.40	-6.52	-6.38	-6.21	-12.41	-8.09	-6.75	-5.69	-7.40	-12.15	-9.00
$\Delta^2\pi$	-13.95	-9.11	-7.65	-8.21	-8.28	-9.61	-8.20	-8.83	-8.61	-8.46	-9.70	-8.80	-8.11	-10.30	-10.10	-7.71	-11.20
r^S	-2.07	-1.84	-1.57	-0.64	-2.55	-1.13	-1.39	-1.89	-1.41	-0.24	-1.72	-2.55	-3.83	0.13	-1.10	-1.51	-1.92
Δr^S	-15.00	-4.40	-5.23	-4.52	-8.61	-5.05	-5.74	-6.03	-4.39	-5.58	-4.76	-6.24	-6.07	-7.39	-4.03	-8.64	-6.53
$\Delta^2 r^S$	-12.23	-7.57	-10.97	-6.60	-10.60	-8.09	-7.38	-13.15	-7.46	-7.82	-9.59	-8.02	-11.00	-7.42	-9.56	-8.78	-8.00
hp	–	-1.89	–	-1.85	–	-1.54	–	–	-2.86	-2.41	-1.45	–	–	-3.67	-1.17	–	–
Δhp	–	-5.29	–	-2.67	–	-4.45	–	–	-3.96	-2.01	-3.68	–	–	-1.72	-2.55	–	–
$\Delta^2 hp$	–	-7.78	–	-9.12	–	-7.80	–	–	-6.41	-8.92	-7.23	–	–	-13.78	-8.43	–	–
r^L	–	-0.38	-0.63	0.02	–	0.19	–	–	–	0.84	-1.13	–	–	0.16	-0.36	-0.82	–
Δr^L	–	-6.24	-5.80	-5.15	–	-6.15	–	–	–	-6.08	-5.24	–	–	-4.28	-7.27	-7.09	–
$\Delta^2 r^L$	–	-8.87	-12.18	-6.88	–	-8.46	–	–	–	-7.78	-13.86	–	–	-8.47	-7.57	-9.59	–
$(e-p)$	-1.47	-0.19	-0.02	-0.05	-1.03	0.29	-1.21	-0.61	-0.33	-0.23	-0.16	-0.48	-2.29	-0.09	-0.22	-1.00	-1.62
$\Delta(e-p)$	-7.07	-7.48	-6.49	-6.48	-6.66	-7.11	-6.68	-7.03	-4.67	-6.33	-6.44	-6.27	-7.57	-6.85	-4.74	-7.29	-6.76
$\Delta^2(e-p)$	-8.43	-8.56	-9.27	-12.53	-9.48	-7.25	-10.15	-10.30	-13.06	-6.97	-9.48	-11.46	-8.14	-7.20	-10.20	-8.21	-7.29
q	-3.58	-3.30	-2.35	-1.68	–	-2.84	–	-1.29	-2.95	-1.90	-2.52	-3.44	–	-3.86	-1.98	-2.44	-2.83
Δq	-7.09	-7.25	-6.78	-6.19	–	-7.19	–	-5.50	-3.97	-6.30	-6.58	-6.82	–	-4.32	-4.69	-6.36	-7.14
$\Delta^2 q$	-8.44	-8.47	-9.75	-7.59	–	-7.16	–	-9.11	-12.87	-9.36	-12.17	-8.66	–	-9.58	-8.08	-12.22	-12.52

	Mex.	Neth.	Norway	New Zeal.	Peru	Philip.	South Afr.	Saudi A.	Sing.	Spain	Swed.	Switz.	Thail.	Turk.	UK	US
y	-3.24	-1.41	-1.32	-1.96	-1.42	-1.88	-1.37	-0.70	-1.62	-2.69	-2.38	-2.04	-1.22	-2.54	-1.66	-1.10
Δy	-4.09	-3.55	-10.30	-2.84	-7.45	-2.87	-4.53	-3.15	-5.76	-3.05	-4.75	-5.42	-4.84	-7.34	-4.22	-3.98
$\Delta^2 y$	-9.59	-6.17	-9.25	-9.57	-8.76	-9.46	-7.96	-19.64	-8.02	-8.48	-7.45	-7.99	-8.79	-8.60	-7.51	-6.85
π	-3.76	-3.09	-5.88	-3.83	-3.33	-5.38	-4.60	-4.53	-4.94	-2.79	-3.31	-3.79	-5.46	-2.09	-4.55	-4.11
$\Delta\pi$	-4.82	-12.52	-10.52	-7.46	-8.92	-5.87	-7.70	-10.17	-6.73	-7.21	-11.43	-6.41	-7.93	-7.69	-8.61	-8.50
$\Delta^2\pi$	-13.82	-8.16	-9.42	-9.31	-9.47	-7.85	-8.42	-9.01	-8.68	-9.17	-7.62	-8.39	-9.48	-9.85	-9.96	-9.46
r^S	-1.20	-1.68	-1.58	-1.77	-3.00	-2.37	-2.97	–	-2.01	-0.48	-0.78	-2.27	-2.22	-1.76	-0.89	-2.10
Δr^S	-9.49	-5.18	-8.41	-5.83	-4.17	-7.44	-5.23	–	-7.46	-6.94	-5.17	-4.00	-5.98	-8.89	-5.13	-4.07
$\Delta^2 r^S$	-10.37	-10.44	-10.64	-8.76	-8.35	-9.13	-8.42	–	-9.56	-7.55	-8.07	-8.57	-6.90	-8.64	-9.66	-10.30
hp	–	-1.62	-1.99	-2.11	–	–	-1.02	–	-2.44	-2.58	-1.39	-1.92	–	–	-2.63	-1.77
Δhp	–	-2.57	-3.84	-3.45	–	–	-2.87	–	-5.27	-3.00	-3.32	-2.55	–	–	-3.31	-1.59
$\Delta^2 hp$	–	-12.35	-7.77	-7.73	–	–	-5.61	–	-9.89	-7.87	-6.88	-13.29	–	–	-6.52	-7.83
r^L	–	-1.17	-0.64	-1.04	–	–	-1.43	–	–	-0.70	-0.20	-1.71	–	–	-0.10	-0.45
Δr^L	–	-4.76	-6.90	-7.20	–	–	-7.83	–	–	-6.81	-6.94	-7.00	–	–	-5.48	-5.45
$\Delta^2 r^L$	–	-13.72	-7.29	-8.49	–	–	-8.04	–	–	-8.98	-7.52	-11.42	–	–	-8.09	-7.25
$(e-p)$	-0.53	-0.15	-0.03	-0.71	0.13	-0.78	-2.17	-0.75	0.40	0.24	-0.70	-0.04	-1.03	0.02	-0.07	–
$\Delta(e-p)$	-4.86	-6.42	-6.78	-6.09	-8.24	-5.45	-4.48	-2.60	-5.89	-5.93	-6.88	-6.57	-7.10	-6.14	-7.73	–
$\Delta^2(e-p)$	-14.47	-9.43	-7.78	-7.52	-8.16	-6.87	-14.89	-8.67	-8.13	-7.27	-7.88	-13.12	-8.48	-9.65	-8.32	–
q	–	-1.49	-3.39	-2.61	–	-1.59	-4.01	–	-3.86	-1.78	-2.91	-1.97	-1.54	–	-1.51	-1.51
Δq	–	-6.01	-7.22	-5.30	–	-5.78	-7.86	–	-7.03	-6.17	-6.42	-6.26	-7.08	–	-6.88	-5.94
$\Delta^2 q$	–	-6.96	-13.29	-6.74	–	-12.22	-10.00	–	-9.20	-10.17	-12.24	-11.53	-9.73	–	-10.33	-7.67

Note. The ADF statistics are based on univariate AR(p) models in the level of the endogenous variables with $p \leq 5$, and the statistics for the level, first differences, and second differences of the variables are all computed on the basis of the same sample period, namely 1983:1–2009:4. The ADF statistics for all the level variables are based on regressions including a linear trend, except for the interest variables, and an intercept term only in the case of the first and second differences. The 95% critical value of the WS statistics for regressions with trend is -3.24, and for regressions without trend -2.55.

Table B.2 Unit Root t-Statistics (Weighted Symmetric Estimation of ADF) for Foreign Variables

	Arg.	Austr.	Austria	Bel.	Bra.	Can.	China	Chile	Finl.	France	Germ.	India	Indon.	Italy	Japan	Korea	Mal.
y^*	-2.19	-1.70	-0.44	-1.02	-3.02	-1.22	-0.95	-2.57	-2.20	-1.23	-2.30	-2.00	-1.59	-1.71	-2.20	-2.49	-1.58
Δy^*	-6.20	-3.77	-5.53	-4.69	-4.21	-3.48	-5.04	-5.21	-5.12	-4.90	-5.06	-4.06	-5.39	-5.12	-3.94	-3.88	-5.38
$\Delta^2 y^*$	-7.61	-9.32	-6.74	-7.97	-7.39	-6.98	-6.95	-7.54	-7.02	-7.94	-8.23	-7.98	-7.90	-8.10	-7.59	-9.75	-8.22
π^*	-2.78	-2.51	-2.84	-2.87	-3.51	-2.71	-2.84	-2.76	-3.05	-2.73	-3.55	-3.04	-2.43	-3.14	-3.07	-2.88	-3.52
$\Delta\pi^*$	-5.83	-6.96	-11.15	-10.08	-11.51	-7.83	-8.27	-7.12	-9.26	-6.59	-9.58	-8.75	-6.70	-9.31	-7.05	-6.72	-7.12
$\Delta^2\pi^*$	-8.20	-8.77	-8.36	-8.06	-14.42	-8.50	-8.01	-10.20	-8.37	-8.10	-8.03	-8.59	-8.33	-8.23	-8.97	-8.70	-8.70
r^{S*}	-2.41	-0.78	-0.78	-0.94	-1.68	-0.99	-1.30	-2.11	-0.84	-0.87	-0.67	-1.16	-1.09	-0.93	-0.95	-1.07	-1.16
Δr^{S*}	-10.09	-5.41	-7.10	-8.65	-14.28	-4.78	-9.92	-5.96	-9.07	-8.88	-9.36	-9.73	-9.38	-9.24	-9.00	-9.57	-5.27
$\Delta^2 r^{S*}$	-10.57	-10.31	-9.82	-9.61	-11.88	-10.49	-10.10	-9.44	-9.75	-9.50	-9.78	-9.83	-9.34	-9.82	-8.94	-9.63	-15.46
hp^*	-3.04	-3.07	-3.79	-2.69	-2.83	-1.98	-2.87	-3.17	-2.08	-4.04	-3.18	-3.00	-2.45	-2.96	-2.03	-2.36	-2.70
Δhp^*	-2.32	-3.70	-2.67	-3.10	-2.74	-1.50	-3.33	-2.29	-3.42	-2.72	-3.06	-3.74	-5.05	-2.96	-3.85	-3.91	-5.17
$\Delta^2 hp^*$	-5.65	-7.91	-9.27	-5.03	-5.64	-7.56	-6.05	-6.20	-5.84	-8.79	-4.91	-8.17	-9.33	-4.90	-6.30	-9.38	-9.52
r^{L*}	0.15	0.03	-0.34	-0.03	0.16	-0.17	0.01	0.17	0.07	0.00	0.28	0.23	-0.08	-0.04	0.09	0.10	0.00
Δr^{L*}	-6.22	-6.04	-5.60	-5.88	-6.23	-5.96	-6.06	-6.15	-6.34	-5.69	-6.05	-6.36	-5.68	-6.01	-6.57	-5.97	-6.01
$\Delta^2 r^{L*}$	-7.70	-7.93	-7.52	-7.59	-7.64	-7.39	-7.67	-7.65	-7.75	-7.54	-7.61	-7.62	-7.68	-7.71	-7.77	-7.97	-7.63
$(e-p)^*$	-0.18	0.03	-0.03	-0.02	0.05	0.42	0.20	0.28	-0.05	0.09	0.08	0.05	0.31	0.06	-0.29	0.10	0.08
$\Delta(e-p)^*$	-6.03	-6.69	-6.54	-6.57	-7.20	-7.31	-6.32	-6.25	-6.65	-6.60	-6.65	-6.59	-6.52	-6.50	-6.27	-6.76	-6.34
$\Delta^2(e-p)^*$	-8.88	-8.18	-9.40	-9.33	-12.60	-7.71	-7.40	-7.25	-7.25	-9.32	-7.16	-7.70	-8.09	-9.24	-7.43	-8.13	-8.07
q^*	-1.71	-2.33	-2.28	-1.99	-2.81	-1.62	-2.23	-2.55	-2.31	-2.00	-1.88	-2.30	-2.69	-2.00	-2.20	-2.23	-2.58
Δq^*	-6.44	-6.67	-6.44	-6.42	-7.23	-6.12	-6.59	-6.84	-6.53	-6.38	-6.41	-6.76	-6.77	-6.48	-6.80	-6.74	-6.84
$\Delta^2 q^*$	-9.50	-11.47	-12.05	-9.25	-12.63	-7.54	-11.41	-12.17	-12.10	-9.31	-9.46	-9.13	-11.34	-9.24	-11.64	-9.14	-11.44

	Mex.	Neth.	Norway	New Zeal.	Peru	Philip.	South Afr.	Saudi A.	Sing.	Spain	Swed.	Switz.	Thail.	Turk.	UK	US
y^*	-0.83	-1.37	-1.76	-1.73	-2.18	-1.44	-1.96	-1.20	-1.63	-1.51	-1.85	-0.57	-1.66	-1.61	-1.94	-3.93
Δy^*	-3.28	-5.41	-4.67	-3.84	-3.97	-3.93	-5.19	-5.09	-4.38	-5.12	-5.01	-5.13	-4.07	-5.11	-4.83	-4.91
$\Delta^2 y^*$	-8.01	-6.80	-7.82	-8.04	-7.62	-7.60	-7.74	-6.61	-6.29	-8.31	-7.23	-6.72	-7.02	-7.77	-8.12	-7.81
π^*	-3.11	-3.34	-2.65	-4.26	-2.88	-3.23	-2.76	-3.16	-4.57	-3.04	-3.05	-2.78	-3.28	-3.31	-2.86	-2.74
$\Delta\pi^*$	-9.00	-9.36	-6.90	-7.44	-8.31	-6.65	-9.15	-6.97	-7.54	-9.02	-10.00	-10.44	-6.72	-9.47	-10.21	-5.70
$\Delta^2\pi^*$	-8.36	-8.35	-8.41	-8.64	-8.24	-8.53	-7.95	-8.32	-9.15	-7.72	-7.84	-8.00	-8.75	-8.40	-7.95	-10.20
r^{S*}	-1.40	-0.88	-0.86	-1.10	-1.75	-1.19	-1.51	-1.03	-1.20	-1.05	-0.56	-0.72	-0.94	-0.95	-0.59	-0.83
Δr^{S*}	-9.29	-9.23	-8.29	-4.70	-10.51	-4.98	-5.99	-9.99	-7.02	-9.81	-8.83	-9.43	-9.30	-9.00	-9.12	-11.23
$\Delta^2 r^{S*}$	-9.48	-9.81	-9.18	-13.98	-9.82	-17.22	-9.37	-10.09	-10.08	-9.60	-9.40	-10.09	-9.38	-9.24	-9.67	-10.08
hp^*	-1.98	-3.48	-2.06	-2.71	-2.79	-2.26	-3.01	-2.94	-3.35	-3.13	-2.63	-4.13	-2.33	-3.78	-2.60	-2.52
Δhp^*	-1.57	-3.03	-4.02	-4.75	-2.19	-4.71	-3.16	-3.34	-2.66	-2.15	-2.98	-2.35	-4.12	-2.67	-2.82	-4.15
$\Delta^2 hp^*$	-7.88	-5.26	-6.28	-7.21	-6.62	-9.62	-5.00	-5.83	-10.27	-8.12	-6.41	-9.64	-8.77	-8.21	-9.71	-6.92
r^{L*}	-0.18	0.11	0.10	0.16	0.15	-0.09	0.10	0.00	0.10	0.31	0.17	0.11	-0.05	0.17	0.16	0.19
Δr^{L*}	-5.95	-5.84	-5.94	-6.42	-6.18	-5.75	-5.99	-5.93	-6.26	-5.89	-6.22	-5.91	-5.70	-6.03	-6.26	-5.79
$\Delta^2 r^{L*}$	-7.35	-7.64	-7.74	-7.56	-7.62	-7.56	-7.75	-7.69	-7.66	-7.58	-7.67	-7.60	-7.73	-7.63	-7.72	-8.15
$(e-p)^*$	0.20	0.04	-0.03	-0.04	0.26	0.09	0.21	0.15	-0.70	0.05	0.05	0.05	0.10	0.05	0.07	0.65
$\Delta(e-p)^*$	-6.24	-6.67	-6.90	-6.69	-6.44	-6.60	-6.81	-6.55	-6.33	-6.68	-6.72	-6.56	-6.64	-6.67	-6.48	-7.35
$\Delta^2(e-p)^*$	-7.48	-7.14	-7.48	-7.88	-7.31	-8.26	-7.57	-7.63	-7.66	-7.08	-7.25	-9.42	-8.04	-7.19	-9.28	-7.14
q^*	-1.74	-2.04	-2.05	-2.45	-2.11	-2.48	-2.18	-2.21	-2.36	-2.09	-2.05	-2.16	-2.48	-2.13	-2.10	-2.88
Δq^*	-6.19	-6.51	-6.44	-6.84	-6.46	-6.78	-6.65	-6.57	-6.93	-6.40	-6.50	-6.51	-6.68	-6.48	-6.50	-6.91
$\Delta^2 q^*$	-7.61	-11.97	-9.29	-7.60	-11.33	-11.40	-11.82	-11.41	-11.75	-9.13	-12.24	-9.18	-11.34	-9.24	-9.17	-7.48

Note. The ADF statistics are based on univariate AR(p) models in the level of the endogenous variables with $p \leq 5$, and the statistics for the level, first differences, and second differences of the variables are all computed on the basis of the same sample period, namely 1983:1–2009:4. The ADF statistics for all the level variables are based on regressions including a linear trend, except for the interest variables, and an intercept term only in the case of the first and second differences. The 95% critical value of the WS statistics for regressions with trend is -3.24, and for regressions without trend -2.55.

Table B.3 Cointegration Rank Statistics (Trace Test)

	# End.	# For.	$r = 0$	$r = 1$	$r = 2$	$r = 3$	$r = 4$	$r = 5$	$r = 6$
ARGENTINA	5	7	289.66	108.28	63.25	24.89	20.72	–	–
AUSTRALIA	7	7	102.74	89.46	72.28	43.33	37.98	26.66	21.64
AUSTRIA	6	7	132.50	62.36	59.18	46.97	41.45	19.13	–
BELGIUM	7	7	83.70	67.42	62.95	40.92	29.58	19.06	17.47
BRAZIL	4	7	238.42	57.42	34.50	24.69	–	–	–
CANADA	7	7	123.83	76.79	58.91	50.21	44.10	32.30	19.62
CHINA	4	7	72.49	52.61	28.71	22.41	–	–	–
CHILE	5	7	106.64	54.06	37.57	20.50	18.19	–	–
FINLAND	6	7	87.92	73.99	46.88	31.80	26.77	19.20	–
FRANCE	7	7	95.18	85.29	80.43	51.85	34.94	30.11	22.93
GERMANY	7	7	90.51	73.21	58.12	52.95	40.00	20.21	14.14
INDIA	5	7	67.24	52.28	42.42	18.87	11.14	–	–
INDONESIA	4	7	66.15	55.29	40.04	20.24	–	–	–
ITALY	7	7	117.26	90.39	53.46	42.67	29.09	24.38	10.57
JAPAN	7	7	96.40	68.97	56.57	43.97	30.38	27.84	16.35
KOREA	6	7	98.00	77.10	51.37	40.12	30.94	17.16	–
MALAYSIA	5	7	71.85	53.43	41.71	22.96	16.04	–	–
MEXICO	4	7	97.94	49.28	40.75	17.70	–	–	–
NETHERLANDS	7	7	124.09	88.79	72.22	48.42	40.26	25.91	16.56
NORWAY	7	7	134.52	110.05	99.76	86.13	39.92	19.83	18.24
NEW ZEALAND	7	7	152.70	140.66	103.18	88.13	34.72	27.30	20.12
PERU	4	7	91.36	50.92	40.70	26.58	–	–	–
PHILIPPINES	5	7	119.62	64.43	47.86	24.66	12.02	–	–
SOUTH AFRICA	7	7	71.41	63.87	48.33	40.48	37.11	23.69	14.38
SAUDI ARABIA	3	7	68.79	50.87	29.33	–	–	–	–
SINGAPORE	6	7	110.10	82.89	68.77	40.39	26.52	15.92	–
SPAIN	7	7	120.79	100.00	57.71	51.13	31.91	29.40	14.65
SWEDEN	7	7	92.13	83.21	59.88	52.41	35.01	22.86	18.87
SWITZERLAND	7	7	119.34	95.55	83.40	61.43	36.38	30.73	17.47
THAILAND	5	7	70.79	56.63	29.68	26.78	19.06	–	–
TURKEY	4	7	52.86	48.52	28.89	10.53	–	–	–
UNITED KINGDOM	7	7	123.93	64.57	53.98	38.30	32.20	21.24	18.23
UNITED STATES	7	4	87.96	58.29	43.93	38.97	26.04	19.05	13.81

Note. Tests are conducted using the trace statistic at the 5% level of significance. The critical values for models including weakly exogenous variables are obtained from MacKinnon (1991); "# End." corresponds to the number of domestic variables in each model; "# For." corresponds to the number of foreign (star) variables; "r" is the number of cointergrating relation to be tested.

Table B.4 Lag Specification of the Country-specific VARX* Models and Number of Cointegrating Relations

	p_i	q_i	CV		p_i	q_i	CV
ARGENTINA	**1**	1	**1**	MEXICO	1	1	2
AUSTRALIA	2	1	**1**	NETHERLANDS	**1**	1	**1**
AUSTRIA	1	1	**1**	NORWAY	**1**	1	**1**
BELGIUM	**1**	1	**1**	NEW ZEALAND	**1**	1	**2**
BRAZIL	**1**	1	**1**	PERU	2	1	**1**
CANADA	1	1	**1**	PHILIPPINES	**1**	1	**1**
CHINA	1	1	**1**	SOUTH AFRICA	2	1	**1**
CHILE	2	1	2	SAUDI ARABIA	2	1	**1**
FINLAND	2	1	2	SINGAPORE	**1**	1	**1**
FRANCE	2	1	**1**	SPAIN	2	1	**2**
GERMANY	2	1	**1**	SWEDEN	2	1	**1**
INDIA	2	1	1	SWITZERLAND	2	1	**1**
INDONESIA	2	1	**1**	THAILAND	2	1	**1**
ITALY	2	1	**1**	TURKEY	2	1	1
JAPAN	2	1	**1**	UNITED KINGDOM	2	1	**1**
KOREA	2	1	**1**	UNITED STATES	2	1	**2**
MALAYSIA	**1**	1	**1**				

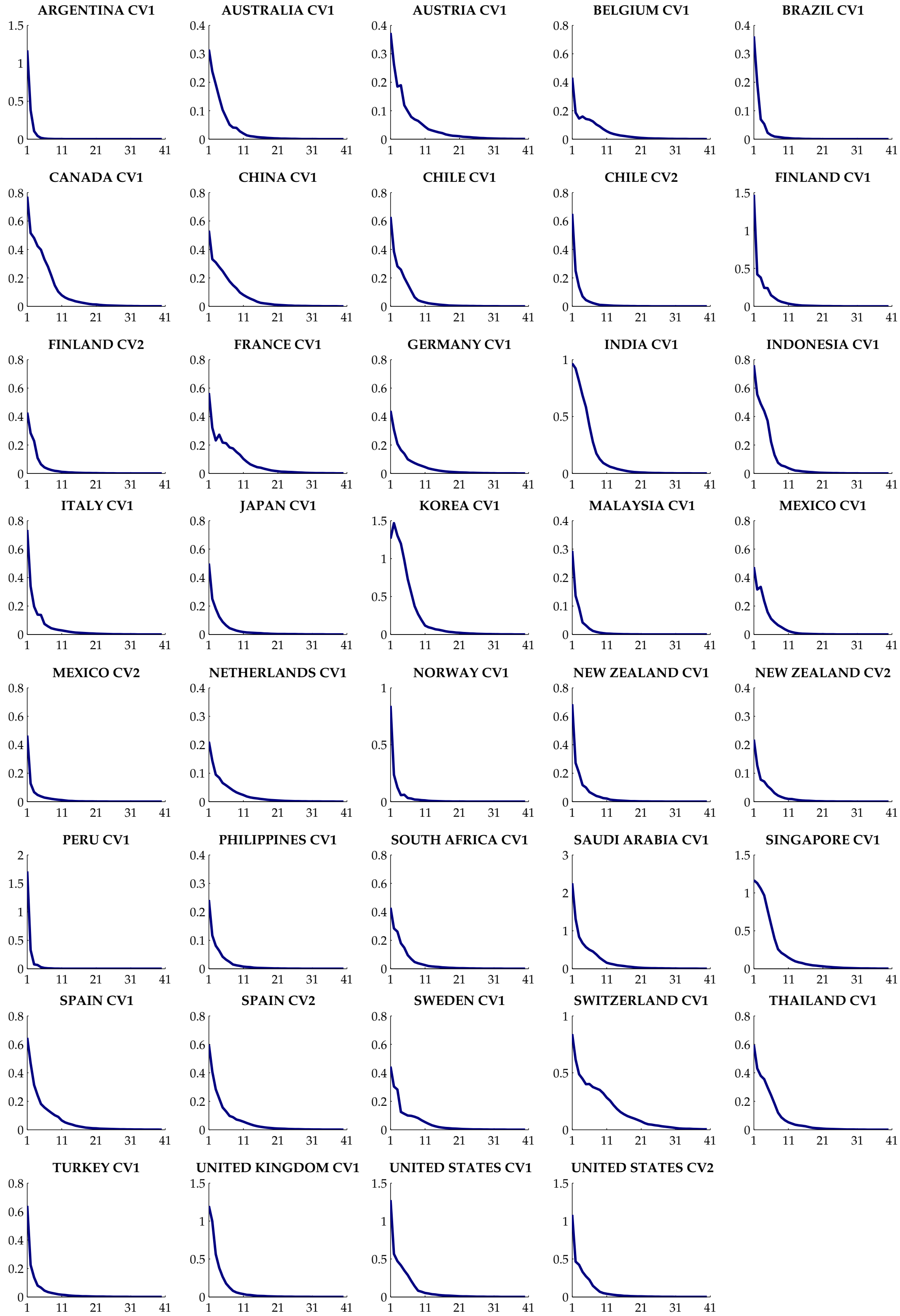
Note. The lag orders of the $VARX^*$ models are selected by AIC. Countries that showed very ragged responses in the GIRFs were changed from VARX(2,1) to VARX(1,1), as marked in bold. The number of cointegration relationships are based on trace statistics with MacKinnon's asymptotic critical values. To resolve the issues of potential overestimation of cointegration relationships with asymptotic critical values, the number of cointegration relationships for 29 countries are reduced, as marked in bold, to be consistent to economic theory and to maintain the stability in the global model.

Table B.5 F-Statistics for Testing the Weak Exogeneity of the Country-specific Foreign Variables and Oil Prices

		y^*	π^*	ρ^{S*}	hp^*	ρ^{L*}	$(e^* - p^*)$	q^*	p^o
ARGENTINA	F(1,82)	0.03	0.30	0.02	0.50	0.34	–	2.47	0.69
AUSTRALIA	F(1,73)	0.25	2.77	0.07	0.02	0.00	–	0.00	0.18
AUSTRIA	F(1,81)	0.35	1.86	0.00	2.54	0.73	–	2.39	1.12
BELGIUM	F(1,80)	0.37	0.03	0.17	5.49†	0.00	–	0.32	0.99
BRAZIL	F(1,83)	0.01	0.17	0.73	0.09	0.01	–	0.07	4.86†
CANADA	F(1,80)	0.40	0.15	0.91	0.17	2.29	–	0.00	0.49
CHINA	F(1,83)	1.37	0.03	0.00	0.09	2.68	–	0.00	2.35
CHILE	F(2,76)	0.80	1.02	0.74	3.18†	0.92	–	1.16	1.62
FINLAND	F(2,74)	0.47	0.67	3.20†	0.27	0.11	–	0.69	0.41
FRANCE	F(1,73)	0.31	0.52	0.03	3.61	1.62	–	1.63	4.37†
GERMANY	F(1,73)	1.28	0.73	0.00	0.00	0.34	–	0.03	0.63
INDIA	F(1,77)	0.41	0.50	0.77	0.02	0.47	–	0.58	0.10
INDONESIA	F(1,79)	1.57	0.02	0.04	0.31	0.04	–	0.12	0.56
ITALY	F(1,73)	2.73	2.56	1.05	0.68	0.27	–	7.24†	0.05
JAPAN	F(1,73)	0.03	0.42	8.26†	0.02	5.84†	–	0.11	4.89†
KOREA	F(1,75)	0.05	1.45	0.29	1.43	1.42	–	0.02	0.19
MALAYSIA	F(1,82)	0.79	0.86	0.19	0.70	0.29	–	1.82	0.69
MEXICO	F(2,82)	0.03	1.73	3.39†	0.87	0.82	–	1.73	0.30
NETHERLANDS	F(1,80)	1.41	0.12	0.01	2.21	0.00	–	0.01	0.07
NORWAY	F(1,80)	0.96	0.02	0.90	1.57	0.06	–	0.09	0.56
NEW ZEALAND	F(2,79)	1.49	2.51	1.49	1.07	1.25	–	0.78	0.05
PERU	F(1,79)	0.97	2.01	0.01	1.99	0.05	–	0.84	0.49
PHILIPPINES	F(1,82)	1.29	2.07	0.20	0.97	0.00	–	1.90	2.64
SOUTH AFRICA	F(1,73)	0.22	0.60	0.00	0.03	1.46	–	0.02	0.36
SAUDI ARABIA	F(1,81)	0.78	0.31	2.43	0.17	0.69	–	4.23†	2.77
SINGAPORE	F(1,81)	1.12	0.21	1.47	0.00	0.64	–	0.76	1.40
SPAIN	F(2,72)	0.51	0.51	0.82	2.89	0.83	–	1.29	0.88
SWEDEN	F(1,73)	0.68	1.20	0.00	0.48	1.19	–	6.38†	1.88
SWITZERLAND	F(1,73)	0.06	0.04	0.03	0.03	0.53	–	1.96	0.35
THAILAND	F(1,77)	0.01	0.29	0.00	0.30	0.08	–	0.60	0.59
TURKEY	F(1,79)	6.43†	2.85	3.31	7.98	5.47†	–	0.78	2.72
UNITED KINGDOM	F(1,73)	1.40	0.22	0.03	2.94	0.59	–	0.11	0.00
UNITED STATES	F(2,80)	0.09	0.04	–	0.02	–	0.18	–	–

Note. The F statistics test zero restrictions on the coefficients of the error correction terms in the error-correction regression for the country-specific foreign variables. † denotes statistical significance at the 5% level.

Figure B.1 Persistence Profiles of the GVAR Model



Note. Time profiles of the effects of system or variable specific shocks on the cointegration relations in the GVAR model. Note that the value of these profiles is unity on impact, while it should tend to zero as the horizon of the persistence profiles tends to infinity.

Table B.6 Contemporaneous Effect of Foreign Variables on Domestic Counterparts

	y^*	π^*	ρ^{S*}	hp^*	ρ^{L*}	q^*
ARGENTINA	$0.20^\dagger$	$0.58^\dagger$	$1.38^\dagger$	–	–	1.21
AUSTRALIA	0.36	0.60	0.29	$0.18^\dagger$	0.94	0.86
AUSTRIA	0.94	$0.14^\dagger$	0.44	–	0.88	1.01
BELGIUM	0.68	0.86	0.25	0.56	0.94	1.04
BRAZIL	$0.35^\dagger$	1.39	$0.51^\dagger$	–	–	–
CANADA	0.54	0.78	0.39	0.91	0.85	0.92
CHINA	0.65	$0.53^\dagger$	$0.00^\dagger$	–	–	–
CHILE	0.70	$-0.11^\dagger$	0.20	–	–	0.51
FINLAND	1.25	0.30	0.20	0.90	–	0.92
FRANCE	0.62	0.52	0.19	0.71	0.93	0.99
GERMANY	1.65	0.54	$0.03^\dagger$	$0.05^\dagger$	0.90	0.96
INDIA	$-0.15^\dagger$	0.69	$-0.07^\dagger$	–	–	0.67
INDONESIA	$0.58^\dagger$	$0.87^\dagger$	$0.24^\dagger$	–	–	–
ITALY	0.73	$0.17^\dagger$	0.16	0.59	1.00	0.91
JAPAN	0.68	$-0.08^\dagger$	$0.01^\dagger$	0.16	0.55	0.69
KOREA	$0.00^\dagger$	$0.29^\dagger$	$-0.14^\dagger$	–	0.56	0.93
MALAYSIA	1.30	0.87	$-0.02^\dagger$	–	–	1.00
MEXICO	0.69	$-0.27^\dagger$	$0.11^\dagger$	–	–	–
NETHERLANDS	0.67	0.36	0.14	$0.47^\dagger$	0.91	1.01
NORWAY	1.07	0.64	$0.12^\dagger$	$0.44^\dagger$	0.76	1.23
NEW ZEALAND	0.54	0.62	$0.27^\dagger$	$0.38^\dagger$	0.69	0.81
PERU	$0.28^\dagger$	$2.56^\dagger$	$0.80^\dagger$	–	–	–
PHILIPPINES	$-0.07^\dagger$	$-0.10^\dagger$	$0.60^\dagger$	–	–	1.18
SOUTH AFRICA	$0.16^\dagger$	0.42	0.07	0.34	$0.45^\dagger$	0.93
SAUDI ARABIA	$0.47^\dagger$	$0.16^\dagger$	–	–	–	–
SINGAPORE	1.22	$0.16^\dagger$	$0.04^\dagger$	0.95	–	1.23
SPAIN	$0.17^\dagger$	0.54	0.15	1.05	1.15	1.09
SWEDEN	1.22	1.00	0.47	1.05	1.15	1.09
SWITZERLAND	0.47	$0.23^\dagger$	$0.08^\dagger$	$-0.41^\dagger$	0.54	0.94
THAILAND	$0.68^\dagger$	$0.49^\dagger$	$0.08^\dagger$	–	–	1.08
TURKEY	2.16	$0.31^\dagger$	2.09	–	–	–
UNITED KINGDOM	0.54	0.52	0.19	$0.48^\dagger$	0.80	0.86
UNITED STATES	0.40	0.12	–	$0.08^\dagger$	–	–

Note. Contemporaneous effect of foreign variables on domestic counterparts can be interpreted as impact elasticities between domestic and foreign variables. T-ratios are computed using Newey-West's Adjusted standard errors. Non significant values are dentoed with †.

Table B.7 Average Pairwise Cross-section Correlations

	Real GDP				Inflation				Short-term Int. Rate				House Price			
	x_{it}	Δx_{it}	Res	ResX	x_{it}	Δx_{it}	Res	ResX	x_{it}	Δx_{it}	Res	ResX	x_{it}	Δx_{it}	Res	ResX
ARGENTINA	0.89	0.05	0.02	0.01	0.32	0.05	0.08	0.02	0.46	0.04	0.02	-0.04	–	–	–	–
AUSTRALIA	0.97	0.14	0.12	0.02	0.24	0.12	0.09	0.00	0.59	0.15	0.07	0.03	0.59	0.19	0.10	0.03
AUSTRIA	0.97	0.20	0.14	-0.02	0.33	0.16	0.11	0.01	0.66	0.29	0.18	0.10	–	–	–	–
BELGIUM	0.97	0.29	0.18	0.00	0.33	0.18	0.11	0.01	0.69	0.23	0.15	0.09	0.58	0.24	0.10	0.00
BRAZIL	0.95	0.15	0.09	0.01	0.29	0.02	-0.02	-0.04	0.49	0.04	0.02	-0.07	–	–	–	–
CANADA	0.97	0.23	0.09	0.02	0.32	0.18	0.10	0.02	0.70	0.20	0.14	0.07	0.58	0.20	0.16	0.03
CHINA	0.97	0.09	0.06	-0.07	0.17	0.09	0.06	-0.02	0.58	0.09	0.05	0.02	–	–	–	–
CHILE	0.97	0.15	0.09	0.00	0.39	0.04	-0.04	-0.03	0.67	0.05	-0.02	-0.07	–	–	–	–
FINLAND	0.94	0.28	0.15	0.03	0.40	0.14	0.08	0.02	0.70	0.21	0.05	0.02	0.47	0.26	0.06	-0.02
FRANCE	0.97	0.31	0.16	0.01	0.37	0.14	0.10	0.01	0.71	0.21	0.10	0.05	0.59	0.32	0.13	-0.03
GERMANY	0.95	0.26	0.14	-0.08	0.25	0.15	0.12	0.02	0.62	0.27	0.12	0.09	-0.63	-0.06	0.06	-0.01
INDIA	0.97	0.01	0.02	0.01	0.12	0.03	0.05	0.00	0.40	0.14	0.08	0.04	–	–	–	–
INDONESIA	0.96	0.09	0.01	-0.02	-0.02	0.06	0.08	0.02	0.13	0.08	0.08	0.06	–	–	–	–
ITALY	0.95	0.32	0.17	0.01	0.41	0.13	0.07	0.02	0.71	0.22	0.11	0.07	0.53	0.22	0.11	0.00
JAPAN	0.90	0.21	0.08	-0.03	0.33	0.08	0.06	0.01	0.69	0.12	0.01	0.00	-0.55	0.04	0.07	0.00
KOREA	0.96	0.19	0.12	0.02	0.21	0.05	0.05	0.02	0.61	0.08	0.06	0.05	–	–	–	–
MALAYSIA	0.96	0.22	0.15	0.01	0.16	0.13	0.12	-0.02	0.50	0.10	0.05	0.06	–	–	–	–
MEXICO	0.96	0.20	0.12	0.00	0.19	0.01	0.03	0.00	0.47	0.02	-0.02	-0.01	–	–	–	–
NETHERLANDS	0.97	0.25	0.15	-0.02	0.12	0.13	0.10	0.00	0.66	0.28	0.19	0.12	0.53	0.10	0.05	-0.05
NORWAY	0.97	0.13	0.13	0.01	0.23	0.10	0.07	0.01	0.61	0.08	0.05	0.05	0.50	0.07	0.12	0.04
NEW ZEALAND	0.95	0.17	0.10	0.04	0.19	0.08	0.03	0.00	0.52	0.07	0.03	0.00	0.56	0.16	0.12	0.00
PERU	0.86	0.05	0.05	0.01	0.30	-0.03	-0.01	-0.02	0.48	0.04	0.01	0.02	–	–	–	–
PHILIPPINES	0.96	0.09	0.04	0.01	0.25	0.03	0.05	0.02	0.65	0.12	0.09	0.07	–	–	–	–
SOUTH AFRICA	0.94	0.21	0.09	0.04	0.33	0.10	0.08	0.02	0.57	0.14	0.06	0.04	0.42	0.19	0.08	0.02
SAUDI ARABIA	0.96	-0.03	0.03	-0.01	-0.01	0.02	0.07	0.02	–	–	–	–	–	–	–	–
SINGAPORE	0.97	0.23	0.14	-0.02	0.22	0.07	0.04	0.00	0.61	0.06	0.02	0.01	0.30	0.06	0.09	-0.03
SPAIN	0.97	0.26	0.09	0.01	0.38	0.14	0.12	0.02	0.70	0.06	0.03	-0.01	0.59	0.26	0.10	-0.03
SWEDEN	0.96	0.28	0.20	0.01	0.42	0.13	0.12	0.01	0.73	0.20	0.12	0.02	0.59	0.30	0.14	-0.02
SWITZERLAND	0.96	0.24	0.15	0.02	0.39	0.14	0.10	0.05	0.61	0.18	0.05	0.03	-0.22	0.18	0.07	0.01
THAILAND	0.94	0.20	0.10	0.01	0.17	0.08	0.05	-0.02	0.58	0.10	0.06	0.04	–	–	–	–
TURKEY	0.97	0.15	0.12	0.01	0.13	-0.03	0.04	-0.02	0.30	0.04	0.04	-0.01	–	–	–	–
UNITED KINGDOM	0.97	0.30	0.17	0.01	0.38	0.14	0.13	0.02	0.70	0.24	0.14	0.08	0.60	0.30	0.08	-0.01
UNITED STATES	0.97	0.26	0.08	-0.05	0.35	0.22	0.17	0.03	0.61	0.16	0.05	0.05	0.58	0.17	0.05	0.01

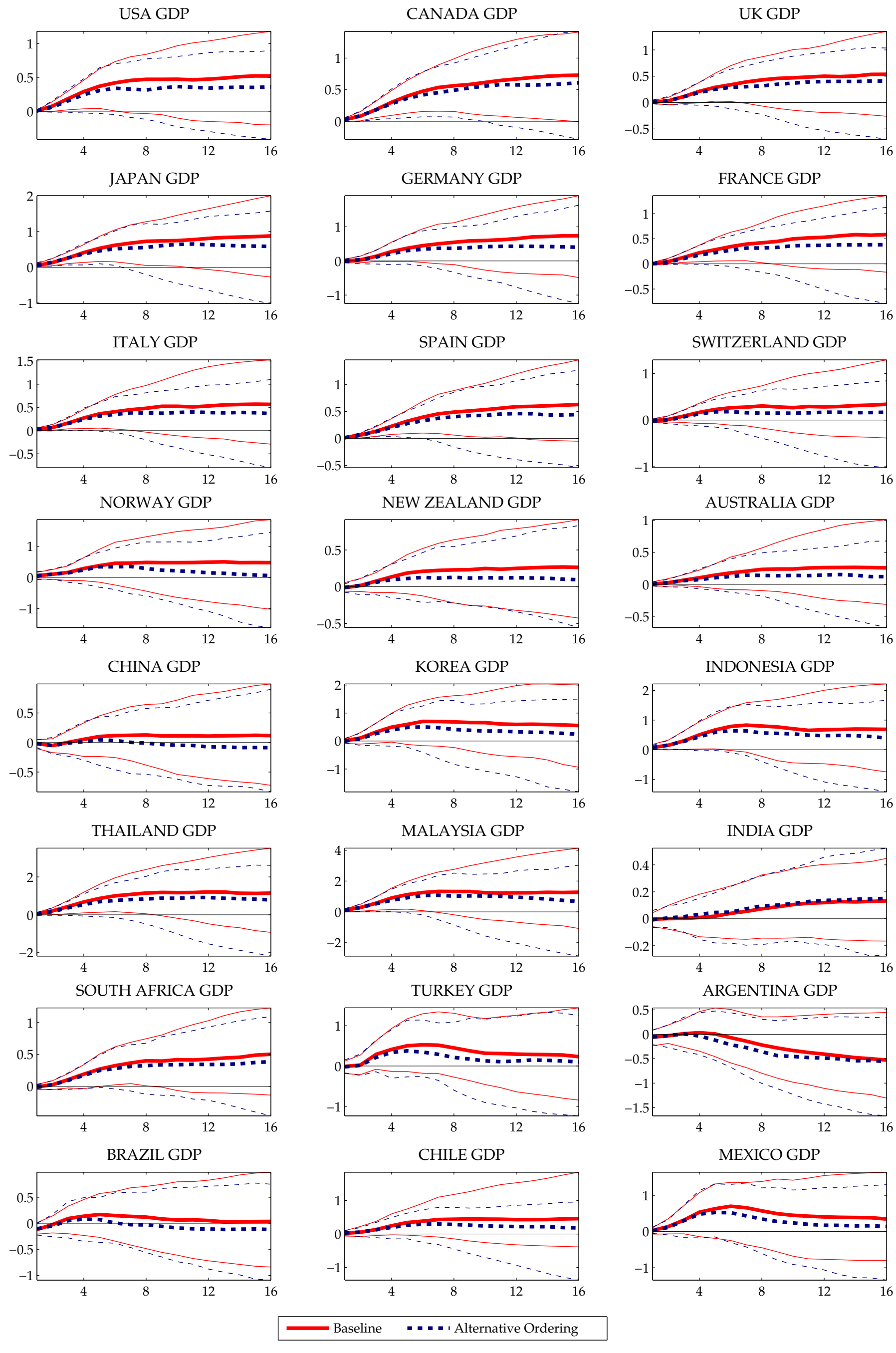
Note. x_{it} corresponds to the variables in log-levels; Δx_{it} corresponds to the variables in log-differences; Res corresponds to the auxiliary unrestricted VECM model's residuals (i.e.: without conditioning endogenous variables on the star variables) while ResX relates to the VECMX model's residuals.

Table B.8 Average Pairwise Cross-section Correlations

	Long-term Int. Rate				Exchange Rate				Equity Price			
	x_{it}	Δx_{it}	Res	ResX	x_{it}	Δx_{it}	Res	ResX	x_{it}	Δx_{it}	Res	ResX
ARGENTINA	–	–	–	–	0.44	0.08	0.07	0.07	0.51	0.22	0.19	-0.03
AUSTRALIA	0.87	0.38	0.32	0.01	0.81	0.37	0.30	0.23	0.77	0.58	0.55	0.01
AUSTRIA	0.90	0.50	0.39	0.00	0.83	0.50	0.44	0.44	0.70	0.46	0.44	-0.02
BELGIUM	0.91	0.53	0.42	-0.01	0.83	0.50	0.45	0.46	0.75	0.58	0.52	-0.02
BRAZIL	–	–	–	–	0.74	0.20	0.15	0.17	–	–	–	–
CANADA	0.91	0.42	0.35	-0.01	0.79	0.34	0.27	0.24	0.71	0.59	0.58	0.04
CHINA	–	–	–	–	0.48	0.05	0.00	0.00	–	–	–	–
CHILE	–	–	–	–	0.76	0.29	0.22	0.21	0.71	0.33	0.33	0.05
FINLAND	–	–	–	–	0.77	0.48	0.43	0.41	0.69	0.44	0.39	-0.03
FRANCE	0.90	0.55	0.40	-0.03	0.83	0.50	0.43	0.43	0.77	0.61	0.55	-0.03
GERMANY	0.87	0.56	0.42	-0.05	0.83	0.50	0.44	0.45	0.74	0.60	0.52	-0.06
INDIA	–	–	–	–	0.37	0.28	0.21	0.18	0.68	0.36	0.32	-0.02
INDONESIA	–	–	–	–	0.23	0.22	0.16	0.11	–	–	–	–
ITALY	0.87	0.34	0.26	-0.07	0.81	0.47	0.41	0.42	0.57	0.52	0.45	-0.06
JAPAN	0.87	0.34	0.26	-0.05	0.71	0.21	0.19	0.17	0.12	0.48	0.36	-0.07
KOREA	0.83	0.16	0.10	-0.03	0.79	0.27	0.22	0.17	0.58	0.39	0.35	-0.03
MALAYSIA	–	–	–	–	0.62	0.28	0.22	0.19	0.55	0.40	0.38	0.01
MEXICO	–	–	–	–	0.68	0.01	-0.04	-0.10	–	–	–	–
NETHERLANDS	0.88	0.57	0.47	-0.02	0.83	0.49	0.45	0.47	0.73	0.64	0.60	-0.03
NORWAY	0.84	0.33	0.24	-0.01	0.83	0.49	0.44	0.44	0.77	0.56	0.54	0.04
NEW ZEALAND	0.74	0.23	0.14	0.01	0.82	0.40	0.32	0.33	0.34	0.44	0.40	0.01
PERU	–	–	–	–	0.76	0.05	0.06	0.09	–	–	–	–
PHILIPPINES	–	–	–	–	0.77	0.16	0.16	0.14	0.62	0.39	0.37	0.00
SOUTH AFRICA	0.75	0.17	0.04	-0.02	0.69	0.35	0.28	0.26	0.74	0.53	0.48	0.05
SAUDI ARABIA	–	–	–	–	0.59	0.03	0.04	0.01	–	–	–	–
SINGAPORE	–	–	–	–	0.80	0.41	0.36	0.34	0.66	0.57	0.55	0.01
SPAIN	0.91	0.36	0.25	-0.06	0.82	0.48	0.43	0.44	0.77	0.59	0.56	0.00
SWEDEN	0.91	0.48	0.36	0.02	0.78	0.47	0.39	0.39	0.75	0.60	0.53	-0.01
SWITZERLAND	0.81	0.40	0.25	0.02	0.82	0.44	0.39	0.42	0.76	0.60	0.59	0.00
THAILAND	–	–	–	–	0.76	0.32	0.28	0.26	0.45	0.39	0.38	0.00
TURKEY	–	–	–	–	0.79	0.23	0.19	0.16	–	–	–	–
UNITED KINGDOM	0.91	0.46	0.36	-0.04	0.79	0.43	0.36	0.36	0.75	0.61	0.55	-0.02
UNITED STATES	0.85	0.44	0.32	-0.02	–	–	–	–	0.75	0.59	0.52	0.01

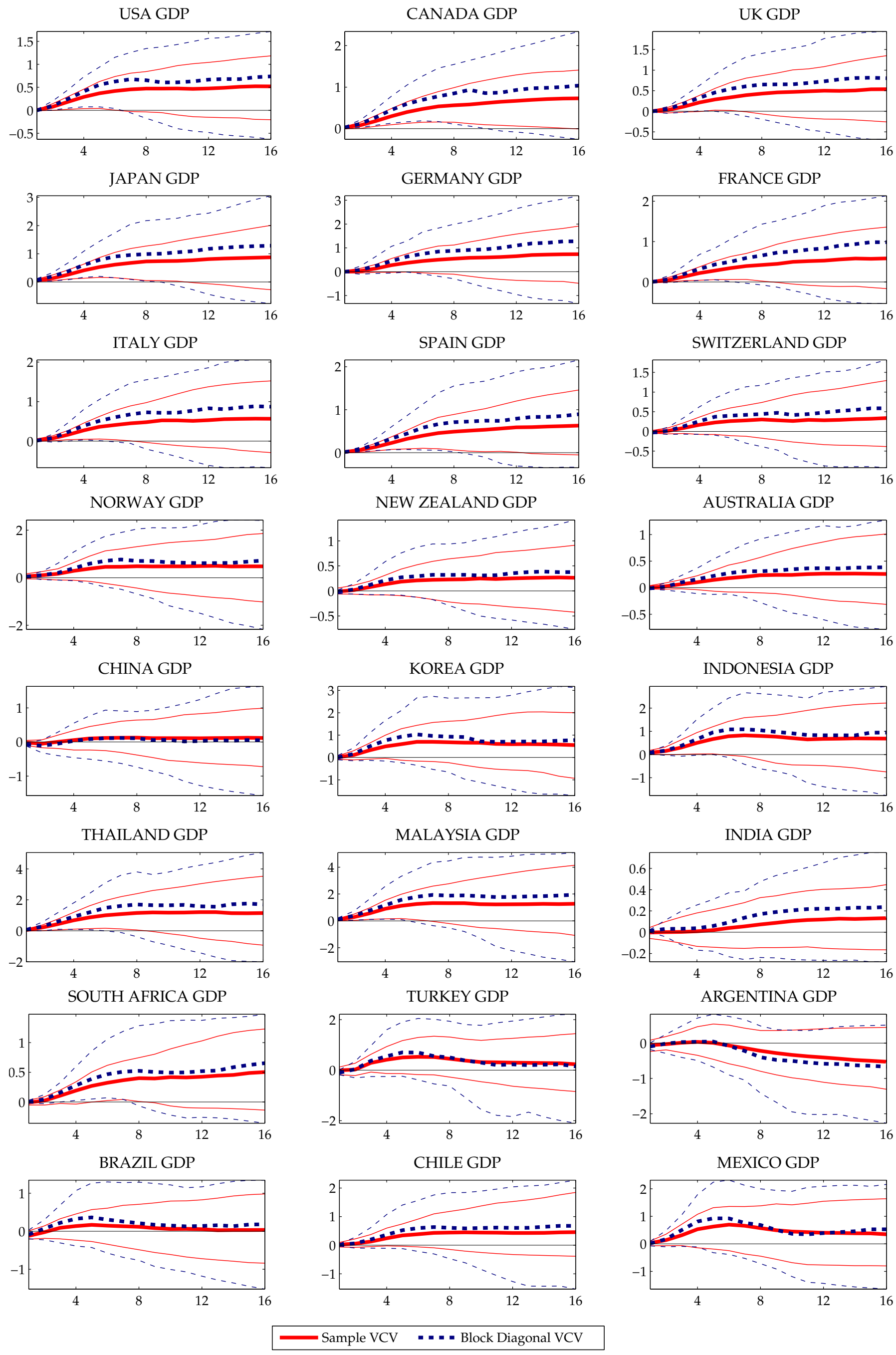
Note. x_{it} corresponds to the variables in log-levels; Δx_{it} corresponds to the variables in log-differences; Res corresponds to the auxiliary unrestricted VECM model's residuals (i.e.: without conditioning endogenous variables on the star variables) while ResX relates to the VECMX model's residuals.

Figure B.2 US House Price Shock - Alternative Orderings of US Variables



Note. Cumulative impulse responses to a one standard deviation increase in US house price residuals. The solid line is the baseline (as in the main text). The dashed line has been computed assuming a an alternative ordering for the variables in the US model, namely $\mathbf{x}_{0t} = (\mathbf{x}^{1\prime}_{0t}, \mathbf{x}^{2\prime}_{0t}, r^{\prime}_{0t})^{\prime}$. Bootstrap median estimates with 90% error bands.

Figure B.3 US House Price Shock - Sample VS Block Diagonal Covariance Matrix



Note. Cumulative impulse responses to a one standard deviation increase in US house price residuals. The solid line is computed as in the main text. The dashed line has been computed assuming a block diagonal covariance matrix for the reduced form residuals of the GVAR. Bootstrap median estimates with 90% error bands.

C Appendix. Data Source

The data used for the estimation of the GVAR model is the same as in Cesa-Bianchi, Pesaran, Rebucci, and Xu (2012) augmented with a novel data set which contains 40 house price series, 21 for advanced economies and 19 for emerging economies. AEs data is mostly from OECD Analytical Database, while EMs data is from central banks, national statistical institutes, or private entities. Even if in the aftermath of the US housing bust and the ensuing financial crisis house prices have gotten a lot of (deserved) attention by both policymakers and market participants, house price indices availability varies greatly across countries. In fact, the development of such indices is a complex issue, mostly because of the extreme heterogeneity of housing goods and the infrequency of sales.

All house price series, their start dates, and sources are described in Table C.1. The OECD Nominal House Price (Subject: HP.Index. Measure: Index) was collected for the following countries: Australia, Belgium, Canada, Denmark, Finland, France, Germany, Ireland, Italy, Japan, Korea, Netherlands, New Zealand, Norway, Spain, Sweden, Switzerland, United Kingdom, and United States. For the countries for which OECD data was not available, nominal House Price indices were collected from national sources.

Seasonal adjustments were applied to the house price series for the following countries: Austria, China, Colombia, Hungary, Lithuania, and Malaysia. Seasonal adjustment was performed using Eviews, applying the National Bureau's X12 program on the log difference of house prices using the additive option. The nominal seasonally adjusted indices were then deflated with the CPI, an exception being Peru, for which only a real index is available.

Table C.1 House Price Indices - Description and Sources

Country	Code	Unit	Source	Inception
Argentina	Ave. value of old apartments, Buenos Aires	USD / Sq. m.	Reporte Inmobiliario	1982-Q1
Australia	House price index, 8 capital cities	Index	OECD	1970-Q1
Austria	Real estate price index, Vienna	Index	OeNB	1986-Q3
Belgium	House Price Index	Index	OECD	1970-Q1
Bulgaria	Existing Flats (Big Cities)	Bulgarian Lev / Sq. m.	BIS	1993-Q1
Canada	House Price Index	Index	OECD	1970-Q1
China	Sales Price Indices of Buildings in 70 Medium-Large Sized Cities.	Index	National Bureau of Statistics of China	1998-Q1
Colombia	Used Housing Price Index (UHPI)	Index	Banco Central	1988-Q1
Croatia	Average prices of newly-built dwellings sold	HRKSq. m.	Croatian Bureau of Statistics	1996-Q2
Czech Republic	House Price Index	Index	Czech National Bank	1999-Q1
Denmark	House price index, One family houses	Index	OECD	1970-Q1
Estonia	Average Purchase-Sale Price of Dwellings 2-rooms and kitchen	Kroons / Sq. m.	Statistics Estonia	1997-Q1
Finland	House Price Index	Index	OECD	1970-Q1
France	House Price Index, Logements anciens	Index	OECD	1970-Q1
Germany	House Price Index, Total resales	Index	OECD	1970-Q1
Greece	Index of prices of dwellings, Other urban excluding Athens	Index	Bank of Greece	1993-Q4
Hong Kong	Private Domestic - 1979-2008 Price Indices by Class (Territory-wide)	Index	Rating and Valuation Department	1979-Q4
Hungary	FHB House Price Index	Index	Hungarian Mortgage Bank (FHB)	1998-Q1
Indonesia	Residential Property Price index, New Houses, Big Cities	Index	Bank Indonesia	1994-Q1
Ireland	House Price Index, Second hand houses	Index	OECD	1970-Q1
Italy	House Price Index, Average 13 Urban Areas	Index	OECD	1970-Q1
Japan	House Price Index	Index	OECD	1970-Q1
Korea	House Price Index, Nationwide House Price Index	Index	OECD	1986-Q1
Lithuania	House Price Index	Index	BIS	1998-Q4
Malaysia	House Price Indicators	Index	Bank Negara Malaysia	1989-Q1
Netherlands	House Price Index	Index	OECD	1970-Q1
NewZealand	House Price Index	Index	OECD	1970-Q1
Norway	House Price Index	Index	OECD	1970-Q1
Peru	House Price Index	Index	Peru Central Bank	1998-Q2
Philippines	Prime 3BR Condominium Price-Makati CBD	Peso / Sq. m.	Colliers International	1994-Q4
Portugal	Residential property prices, all dwellings	Index	BIS (Imometrica)	1988-Q1
Singapore	Property price index, private residential, Singapore	Index	URA	1975-Q1
Slovenia	The advertised price in Ljubljana	Euro / Sq. m.	www.SLONEP.net	1995-Q2
South Africa	ABSA House Price Index, All sizes, Purchase Price, Smoothed	Index	ABSA	1970-Q1
Spain	House Price Index	Index	OECD	1971-Q1
Sweden	House Price Index	Index	OECD	1970-Q1
Switzerland	House Price Index	Index	OECD	1970-Q1
Thailand	House Price index, Single Detached House, Thailand	Index	Bank of Thailand	1991-Q1
UK	House Price Index	Index	OECD	1970-Q1
US	House Price Index	Index	OECD	1970-Q1