Housing Cycles and Macroeconomic Fluctuations: A Global Perspective

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 U.S. 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. Moreover, the analysis of synchronized housing demand shocks speaks in favor of the recent evidence of increased resilience of emerging economies to shocks originating in advanced economies; and it also suggests that a close monitoring of housing cycles in advanced economies as well as in emerging economies should be of interest for policy-makers.

Keywords: Housing demand shocks, Great Recession, Identification of shocks, Emerging market economies, Global VAR, International business cycle.
JEL Codes: C32, E44, F44.

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.

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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 et al., 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 et al., 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. While much of the debate has focused on advanced economies, it is surprising that housing markets in emerging market economies and their links to the broader economy have not been systematically researched yet.

Figure 1(a) displays the behavior of a global house price index and three group–specific indices, for advanced economies, emerging Asia (excluding China), and eastern Europe, respectively. Both the global and the group–specific indices clearly show the pronounced boom–and–bust cycle of the last decade. However, the group–specific indices also display significant differences. While comoving closely from the beginning of the 2000s, house prices in each group display distinctive features during the whole 1990s. Figure 1(b) compares the global house price index with the country–specific indices for the U.S. and China. House prices in the U.S. are in free fall since the fourth quarter of 2006, excluding an up–tick in early 2009 (most likely propelled by the U.S. first–time home buyer credit provision of the American Recovery and Reinvestment Act of 2009). In contrast, house prices in China dropped for only two quarters, namely 2008:2 and 2008:3, and then started growing again.

[INSERT FIGURE 1 HERE]

Motivated by this evidence, many interesting questions arise. Are international house 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? Across these questions, which is the difference, if any, between advanced economies (AEs) and emerging economies (EMEs)?

This paper takes a global perspective and aims to provide an assessment of the linkages between the macroeconomy 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 et al. (2004), is used to investigate the international transmission of housing shocks. Specifically, three types of shocks are identified and investigated: i) housing demand shocks originating in the U.S.; ii) housing demand shocks simultaneously originating in all AEs; and iii) housing demand shocks simultaneously originating in all EMEs.

This paper aims to contribute 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, moreover, 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, U.S. housing demand shocks are quickly transmitted to the domestic economy, leading a short–term expansion of real GDP and consumer prices. Second, shocks originating in the U.S. housing market are also quickly transmitted to the global economy, even though the transmission is different across groups. While almost all AEs are affected by a U.S. housing demand shock in a significant fashion, EMEs response is heterogeneous. In particular, the effect of a U.S. 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, a synchronized housing demand shock originating in AEs positively affects AEs and EMEs GDP with an estimated elasticity of similar magnitude; and a synchronized housing demand shock originating in EMEs leads to a sharp increase in EMEs GDP, generating a pronounced regional cycle.

An interpretative key for these results is provided by recent evidence on the increasing resilience of EMEs to shocks originating in AEs and the emergence of "regional" business cycles (briefly surveyed below), which most likely played an important role in the unfolding of the recent global financial crisis and, most importantly, in the recovery. The findings of this paper, therefore, suggest that a close monitoring of housing cycles not only in AEs but also in EMEs should be of interest for policy-makers.

Literature. The analysis in this paper draws on two different strands of literature.[1] First, a broad empirical literature investigates the features of international housing cycles and the international transmission of house price shocks. Few studies provide a descriptive analysis of international housing cycles —and their relation with macro–financial aggregates— in groups of AEs (Renaud, 1995, Case et al., 2000), EMEs (Egert and Mihaljek, 2007, Beidas-Strom et al., 2009, Ciarlone, 2012) or both (Igan and Loungani, 2012). For AEs, IMF (2004) and Beltratti and Morana (2010) document the surprisingly high synchronization of real house price returns in AEs and investigate, in a FAVAR framework, which factors help to explain the comovement of house prices. Moreover, in a recent paper Hirata et al. (2012) show that house prices are internationally synchronized and that the degree of synchronization has increased over time. 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,

[1] A third strand of literature this paper is related to 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 *'a' la* Kiyotaki and Moore (1997) and the financial accelerator literature pioneered by Bernanke et al. (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 et al. (2010) and Iacoviello (2011).

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 and find that U.S. housing and stock prices have real effects in both AEs and EMEs.

Second, this paper loosely relates to the decoupling literature and, more specifically, to few recent studies on the relative importance of global, regional, and country–specific factors in explaining business cycle fluctuations. Few early papers document the importance of a global factor accounting for national business cycles (e.g., Kose et al., 2003). However, recent empirical evidence shows that —while the importance of the global factor has declined over time— regional factors explain an increasing share of business cycle fluctuations (Mumtaz et al., 2011, Kose et al., 2012, Hirata et al., 2013). According to this view, the emergence of regional business cycles helped some EMEs to become somewhat resilient to shocks originating in AEs (Kose and Prasad, 2010), as many EMEs may have shifted their loadings from the U.S. and the euro zone into other EMEs (Levy Yeyati and Williams, 2012, Cesa-Bianchi et al., 2012).

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. Two appendices report the technical details of the identification strategy and a description of the housing data set.

2. Are International House Prices Really Correlated? Some Stylized Facts

A well known stylized fact is the similarity of the pattern of house prices for the major AEs. This section investigates the international comovement of house prices taking into account EMEs, too.

Before analyzing the international comovement of house prices, however, it is worth to look at few 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 sample 1990:1–2009:4. As evidenced by the average growth rate, the long–term trend in real house prices over the 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 EMEs, respectively. Note however that, while the average growth rate of house prices in AEs is broadly similar to the growth rate 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 averages around 6 and 12 percent in advanced economies and emerging economies, respectively (almost three times larger than the volatility of real GDP both in AEs and in EMEs).

[INSERT TABLE 1 HERE]

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

[2] The house price data is described in Appendix B. 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.

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. Note also that the house price pair–wise correlation has very wide error bands, pointing to the fact that there are marked differences across countries. 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.

[INSERT FIGURE 2 HERE]

The evolution of pair–wise correlation of real GDP in EMEs is very similar to AEs (see Figure 2(b)). 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" im-

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

plication: 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 variability 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).

[INSERT FIGURE 3 HERE]

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. Moreover, these results are in line with the findings of Kose et al. (2012) and Hirata et al. (2013), who show that, while the global factor has become less important for macroeconomic fluctuations during the last decades, the importance of regional factors has markedly increased over time. The changes in the relative importance of global and regional factors in driving national business cycles may be relevant for the assessment of the spillover effects of domestic and regional 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 et al. (2004) and further developed by Dees et al. (2007), Dees et al. (2007), and Dees et al. (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.[4]

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 macroeco-

[4] There are few reasons why I chose the GVAR over the Factor Augmented VAR — FAVAR, pioneered by Bernanke et al. (2005) and Stock and Watson (2005)— approach for this paper. First, it is easier to assign an economic interpretation to the factors and to the loadings of country-specific variables on those factors. Second, the GVAR links the country-specific models in a global setting, generating a rich representation of the global economy allowing for regional and local spillover effects that are often absent from factor models. Third, and finally, the GVAR methodology is particularly suitable for evaluating the impact of shocks originating in a specific country onto another country (e.g., the effect of a housing demand shock originating in the U.S. on Chinese GDP).

nomic 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. Note 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 any more.

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:

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

with $t = 1, ..., T$. Note 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; $\mathbf{\Upsilon}_i(L, q_i) = \sum_{i=0}^{q_i} \mathbf{\Upsilon}_i L^i$ 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 $\sim i.i.d.(\mathbf{0}, \mathbf{\Sigma}_{u_i})$. Note also that for estimation purposes

$\mathbf{\Phi}_i(L, p_i)$, $\mathbf{\Upsilon}_i(L, q_i)$, 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 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 et al. (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 et al. (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 et al. (1998) and Pesaran et al. (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 $\mathbf{u}_t = (\mathbf{u}'_{0t}, \mathbf{u}'_{1t}, ..., \mathbf{u}'_{Nt})'$.

Note 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,

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

where $\mathbf{\Sigma}_{u_i}$ is the covariance matrix of the reduced form residuals of country i and $\mathbf{\Sigma}_{u_i u_j}$ 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.[5]

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

[5] 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.

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

[INSERT TABLE 2 HERE]

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 three–year average of trade weights in years from 2007 to 2009 is used. Note here that the choice of the weights affects the results of the GVAR along two dimensions. First, the weights enter in the specification of the star variables, therefore affecting the estimated coefficients of the country-specific VECMs. Second, the weights enter in the construction of the global model, therefore affecting the international transmission of shocks. While, the estimation of the country-specific VECMXs is quite robust to different choices of the weights (i.e., time–varying or equal weights), the transmission of shocks crucially depend on it. Therefore —and consistently with the motivation of the paper— the choice of using the average trade weights from 2007 to 2009 reflects the fact that, in those years, a U.S. house price shock has been transmitted to the global economy triggering a system-wide financial crisis.

Detailed empirical evidence on the estimation of the GVAR model for 33 countries is reported in an online appendix. 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 et al. (1996) and Pesaran and Shin (1998) to non–identified disturbances for the dynamic analysis of the international transmission of shocks.[6] 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

[6] Few exceptions are Dees et al. (2007), Chudik and Fidora (2011), Chudik and Fratzscher (2011), and Eickmeier and Ng (2011).

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, 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 et al. (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 U.S., 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 U.S. model.[7] 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

[7] 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 et al. (2011), Beltratti and Morana (2010)), alternative identification schemes have also been used in the literature, such as sign restrictions (see Andre et al. (2011), Buch et al. (2010), Cardarelli et al. (2010), Jarocinski and Smets (2008)) or a combination of zero contemporaneous and long–run restrictions (see Bjørnland and Jacobsen (2010)).

slow–moving macroeconomic variables includes real GDP and inflation, $\mathbf{x}_{0t}^1 = (y'_{0t}, \pi'_{0t})'$; 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), $\mathbf{x}_{0t}^2 = (hp'_{0t}, r_{0t}^{L\prime}, q'_{0t}, p^{oil\prime})'$.

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 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 (see online appendix for details on the pair–wise correlation of the GVAR residuals). 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

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

$\mathbf{v}_t = \left(\mathbf{P}_0^G\right)^{-1} \mathbf{u}_t$ is the global vector of *semi*–structural residuals; $\mathbf{P}_0$ is the lower Cholesky factor of the covariance matrix of the U.S. reduced form residuals; $\mathbf{\Sigma}_{v_0} = \mathbf{P}_0^{-1}\mathbf{\Sigma}_{u_0}(\mathbf{P}_0^{-1})' = \mathbf{I}$ and $\mathbf{\Sigma}_{v_0 u_j} = \mathbf{P}_0^{-1}\mathbf{\Sigma}_{u_0 u_j}$. 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 U.S.

This section focuses on a U.S. housing demand shock and analyzes its effects on both the U.S. and the world economy. I look at a U.S. house price shock because it is of particular interest to understand the recent global financial crisis. Moreover, 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 U.S. economy

The U.S. housing demand shock is equivalent to a 1 standard deviation increase in the house prices structural residuals, which corresponds to an increase in 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.

[INSERT FIGURE 4 HERE]

From a theoretical standpoint, 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 home–owners, 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 et al., 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 et al., 2010). Financial accelerator and debt–deflation mechanisms may also 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.[8] 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 (2010) estimate the response of U.S. 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. Note 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 U.S. as a closed economy, ignoring possible second round effects generated by the rest of world in response to the shock originating in the U.S..

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

[8]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 et al. (2007).

a gradual, significant increase of around 10 and 2 basis points, respectively.

The overall pattern of impulse responses in Figure 4 suggests that, indeed, the 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 and consumer prices. Note, moreover, that the identification assumptions made in the previous section allow us to disentangle the housing demand shock from an aggregate demand shock; since GDP is not allowed to respond to the shock within a quarter, the relation between house prices and GDP 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). Third, given the positive impact of the U.S. housing demand shock on U.S. 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). Fourth and finally, given the documented importance of U.S. interest rates in determining EMEs' spreads (González-Rozada and Levy Yeyati, 2008), house price shocks originating in the U.S. may affect the real economy in EMEs through their impact on U.S. short-term and long-term interest rates (see Neumeyer and Perri (2005) for the theoretical link between spreads and real economy in EMEs).

The U.S. 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 shock originating in the U.S. boosts domestic real GDP, as analyzed in Figure 4. Second, booming house prices and increasing activity in the U.S. affect foreign housing markets and foreign GDP through the channels discussed above.[9] It is worth mentioning here that the U.S. 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 U.S. GDP and U.S. 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.

[INSERT FIGURE 5 HERE]

As a matter of fact, the median response of GDP is, at least in the first

[9] 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.

few quarters, positive in all countries considered, with a dynamic which seems to lag by one or two quarters the response of U.S. GDP. Also, the elasticity of foreign GDP four years after a U.S. 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 U.S. housing demand shock has a significant effect on the GDP of few countries, namely U.S., Canada, Japan, France, Italy, and Spain, while it has a borderline significant effect on the GDP of UK, Germany, and Australia. Concerning EMEs, however, there is mixed evidence on the spillover effects of the U.S. 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 U.S. housing demand shock is not significantly different from zero. In contrast, Malaysia, Mexico, and Indonesia are all significantly affected by the U.S. house price shock for the first two years.

How to interpret these results? The impulse responses presented in this section are consistent with recent evidence of the decreased importance of U.S. shocks in the global economy (Cesa-Bianchi et al., 2012); and with the fact that, rather than decoupling from the world economy, EMEs may have diversified away from the U.S. and the euro zone into emerging Asia and other EMEs (Levy Yeyati and Williams, 2012). Next section investigates further this issue, providing an interpretative key to the above results.

5.2. *A positive synchronized shock to house prices in AEs and in EMEs*

"When the developed world sneezes, emerging economies catch cold." This well known adage has been used extensively in the past decades to stress that when AEs are hit by a negative shock, that same shock would have much worse consequences on EMEs. However, the results in the previous section suggest that this may not be the case any more. To explore this issue further, this section considers the case that all AEs or EMEs simultaneously experience a housing demand shock.

The GVAR looks particularly suitable for the analysis of synchronized shocks to different asset classes and their implications for economic activity (see other examples of synchronized shocks in Chudik and Fidora (2011) and Cerrato et al. (2012), for example). Specifically, a regional house price shock is defined as a simultaneous standard deviation shock to the structural residuals of the house price equations in all countries belonging to each group (AEs and EMEs, respectively). The identification procedure is very similar to the one used for the U.S. housing demand shock and it is described in Appendix A. Note also that the regional shock is constructed as a weighted average of all shocks in each group, meaning that each country–specific impulse is weighted by its corresponding PPP–GDP weight.

To make a meaningful comparison between house price shocks originating in AEs and EMEs it is crucial to consider the balanced panel of house price series, so that all country–specific VARXs can be specified with a house price equation. For this reason, in this section, a new GVAR specification is estimated on the reduced sample period 1998:1–2009:4.[10]

[10] Due to the limited number of observations, I also have to shrink the number of variables in the country-specific models. Specifically, the VARX models in this section are specified in first differences, with $p = 2$ and $q = 1$, and with the following variables: real GDP, short–term interest rates, real house prices, and real exchange rates. The model is stable and satisfies the usual GVAR assumptions. Moreover, the results in Figures 4 and 5 largely hold. A full set of results for this specification is available from the author upon request.

[INSERT FIGURE 6 HERE]

Let's analyze first the AEs housing demand shock, equivalent (on average) to an increase in AEs house prices of about 0.15 percent on impact and of 0.6 percent after four years. Figure 6(a) displays the effect of the AEs house price shock on both AEs and EMEs GDP. The solid lines display the mean response (point estimate) across each group, while the shaded areas display the cross–sectional two standard error confidence bands (computed as in Pesaran et al., 1995) in order to gauge the dispersion of these point estimates within each group. The shock affects AEs and EMEs GDP in a similar fashion, with a long–run elasticity of about 1.5. This result has an important implication: contrarily to the adage quoted at the beginning of the section, in fact, the impulse responses in Figure 6(a) suggest that when the developed world sneezes, emerging economies sneeze, too.

Let's turn now to the EMEs housing demand shock, equivalent to an average increase in EMEs house prices of about 0.3 percent on impact, rapidly increasing to almost 0.5 percent after one year and then slowly decreasing to 0.2 percent after four years. Figure 6(b) —displaying the effect of the EMEs house price shock on GDP of both AEs and EMEs— shows that the EMEs house price shock leads to an increase in EME's GDP, generating a pronounced regional cycle. The mean response of EMEs GDP to a synchronized one standard deviation shock to EMEs house prices achieves its maximum after 1.5 years, at about 0.4 percent, implying an elasticity of about 1. Note, moreover, that the EMEs house price shock has a positive effect on AEs GDP in the short–run (with an estimated elasticity larger than 0.5 after one year), while it fades away at the end of the four years under consideration.

To check the robustness of these results, I consider —instead of a synchronized housing demand shock originating in AEs and EMEs— a housing demand shock originating in China and I compare it with a shock originating in the U.S.. The impulse responses are very similar to those presented in Figure 6, suggesting that —as argued by Levy Yeyati and Williams (2012)— a Chinese housing demand shock is of high importance in the convergence of real business cycles within EMEs.

These results also speak in favor of the recent "regionalization hypothesis" put forth by Hirata et al. (2013) and Kose et al. (2012), according to which, in the past two decades, while the relative importance of the global factor declined, there has been some convergence of business cycle fluctuations within AEs and EMEs separately. Note that the majority of the papers arguing for the regionalization hypothesis present evidence on the increased importance of the regional factors by estimating dynamic factor models on two different samples (pre and post globalization, respectively). In this paper, such a strategy is not feasible because of the reduced coverage of the house price time series. However, the results in this section suggest that, instead of decoupling from the world economy, some EMEs may have shifted their loading from the U.S. and the euro zone into other EMEs and gained resilience to shocks originating in AEs. This, in turn, is likely to have played an important role in the unfolding of the recent global financial crisis and, most importantly, in the recovery.

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.[11]

First, the robustness to the within–country identification assumption is

[11] 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 the working paper version available at https://sites.google.com/site/ambropo/.

checked by estimating a housing demand shock with a different ordering of the variables in the U.S. country–specific model. In particular, as in Iacoviello (2005) and Giuliodori (2005), the interest rate is ordered last, namely $x_{it} = (x_{it}^{1\prime}, x_{it}^{2\prime}, r_t^{\prime})^{\prime}$. This alternative ordering implies that the short–term interest rate is allowed to contemporaneously react to all shocks in the U.S. model, whereas house prices are sluggish and do not respond contemporaneously to movements in the interest rate: 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 U.S. house price equation are correlated with the residuals of the China GDP equation. If that would be the case, an increase in U.S. house prices might arise because of a housing demand shock in the U.S., 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 U.S. house prices cannot have contemporaneous spillover effects on any foreign variable. The impulse responses to a U.S. housing demand shock obtained with the sample covariance matrix and the block–diagonal covariance matrix show that 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. 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 focus of the analysis is on three different shocks, namely a country–specific housing demand shock in the U.S., and a synchronized housing demand shock simultaneously originating in all advanced economies and emerging economies, respectively.

The results of the GVAR analysis are threefold. First, and consistently with the literature, U.S. housing demand shocks are quickly transmitted to the domestic real economy, leading a short–term expansion of real GDP and consumer prices. Second, shocks originating in the U.S. housing market are also quickly transmitted to the global economy, even though the transmission is different across groups. While many advanced economies are affected by a U.S. housing demand shock in a significant fashion, emerging market economies response is heterogeneous. In particular, the effect of a U.S. 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, a synchronized housing demand shock originating in advanced economies positively affects advanced economies and emerging economies GDP with an estimated elasticity of similar magnitude; and a synchronized housing demand shock originating in emerging economies leads to a sharp increase in emerging economies GDP, generating a pronounced regional cycle.

The results presented in this paper link with recent evidence on the increasing resilience of emerging economies to shocks originating in advanced economies, which is likely to have played an important role in the unfolding of the recent global financial crisis and, most importantly, in the recovery. 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 policy–makers. Moreover, given the increasing importance of emerging economies and the emergence of regional business cycles, it will be important to consider the global nature of housing cycles.

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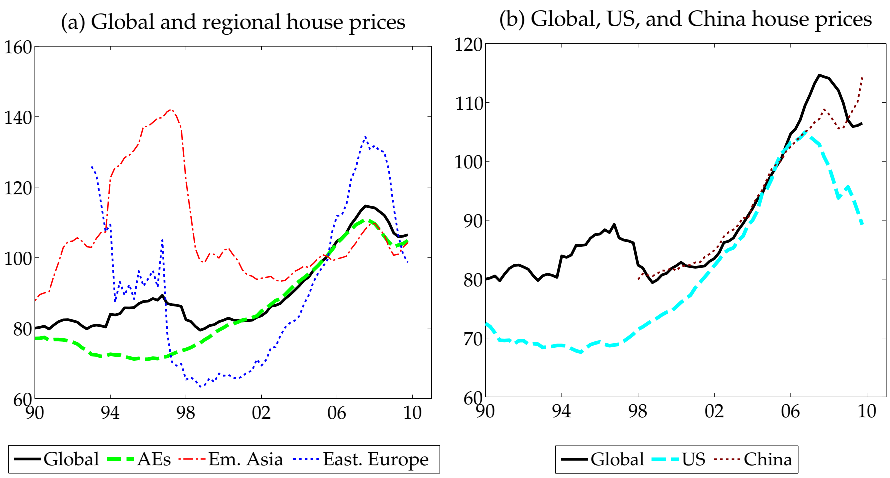
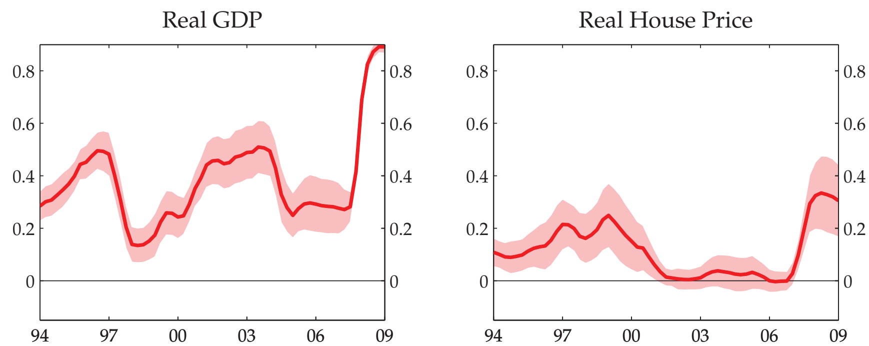
Figure 1: Real House Price Indices



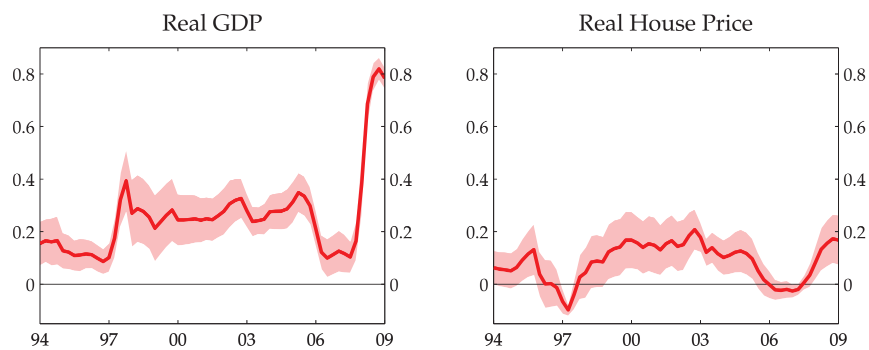
Note. Real house price indices (2005=100). The global index is computed as the average across all series in the dataset (described below); advanced economies (AEs), Emerging Asia excluding China (Em. Asia) and Estearn Europe (East. Europe) indices are computed as the mean across all countries belonging to each group. The sample period is 1990:1–2009:4

Figure 2: International Synchronization of Real GP and Real House Prices

(a) AEs

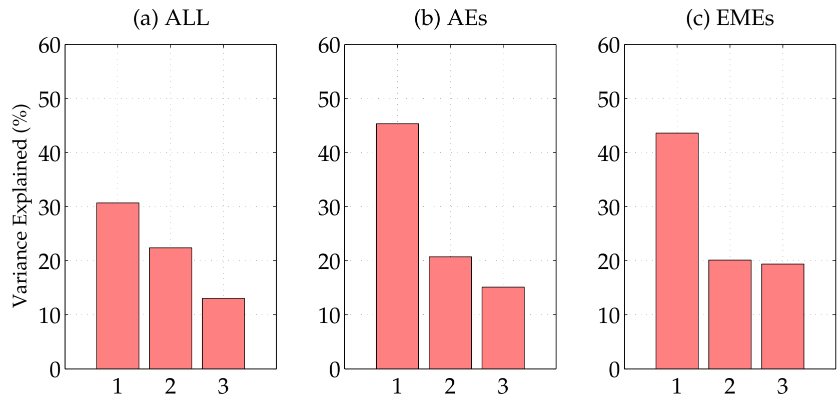


(b) EMEs



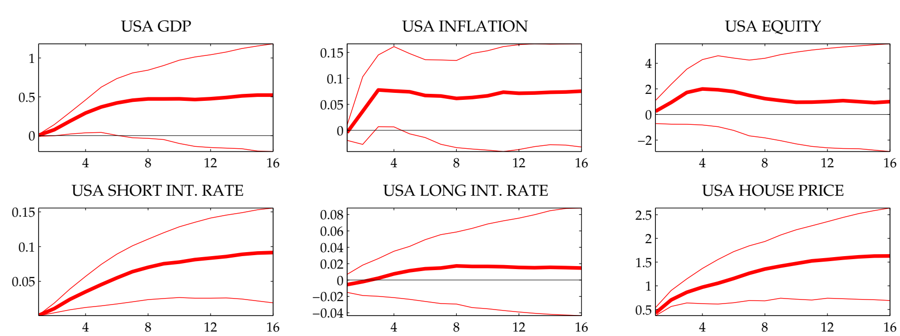
Note. Cross–country average of moving pair–wise correlation for real GDP and for real house prices with a 5–year rolling window (20 quarters) over the sample 1990:1 to 2009:4. The pair–wise correlation is computed as $\rho\rho_i = (\sum_{j=1}^{N} COR(x_i, x_j) - 1)/(N - -1)$ where x is the annual growth 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).

Figure 3: Principal Component Analysis on Real House Prices



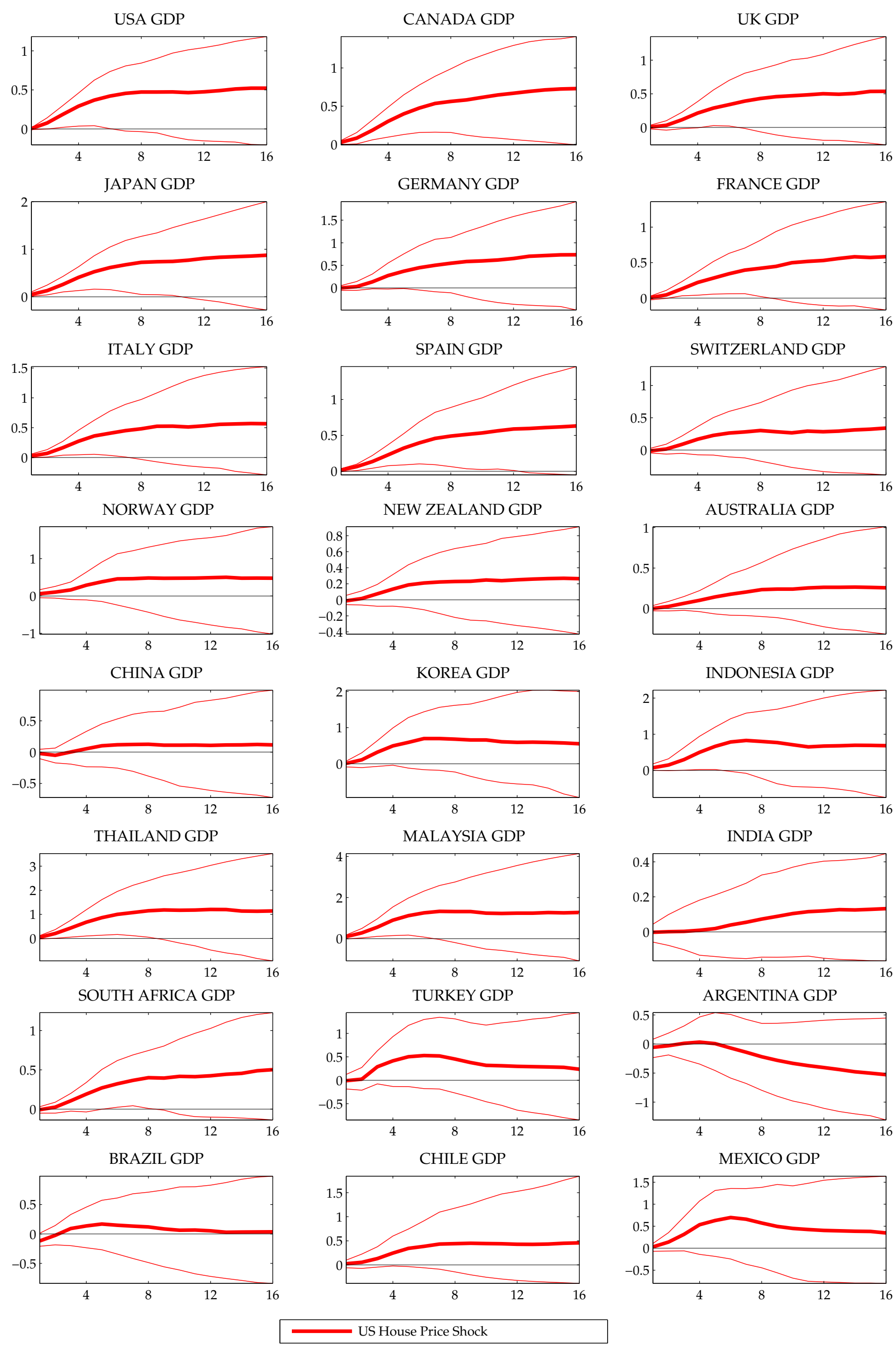
Note. Explained variance of the first three principal components computed on real house price annual growth rates over the sample 1990:1 to 2009:4. The principal component analysis is performed on all countries in the dataset (ALL), on advanced economies only (AEs), and on emerging market economies only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

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 structural residuals. Bootstrap median estimates with 90% error bands.

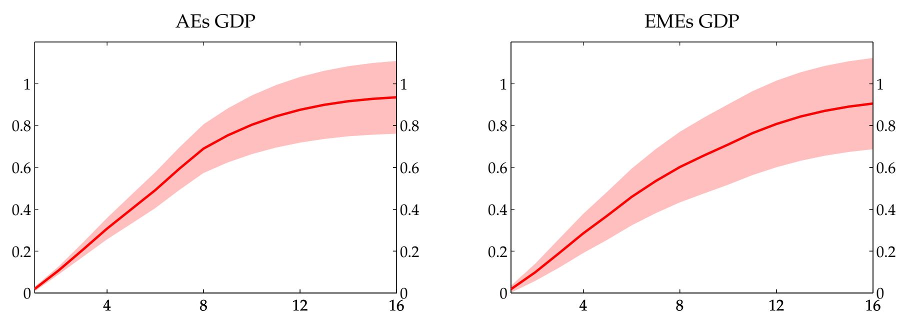
Figure 5: US House Price Shock – Transmission to the world economy



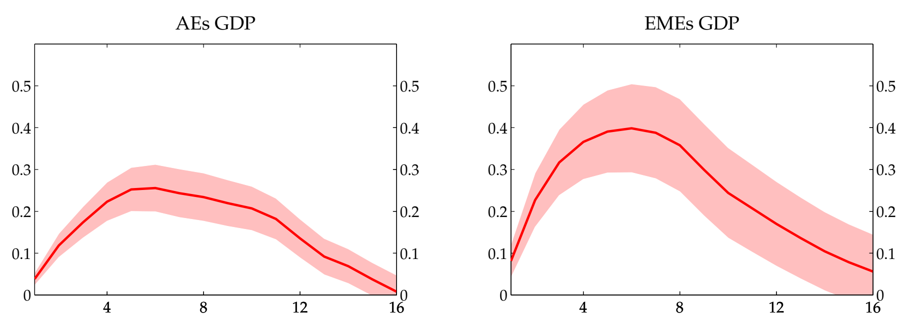
Note. Cumulative impulse responses to a one standard deviation increase in US house price structural residuals. Bootstrap median estimates with 90% error bands.

Figure 6: Real House Price Indices

(a) Synchronized Shock to AEs house prices



(b) Synchronized Shock to EMEs house prices



Note. Cumulative impulse responses to a one standard deviation increase in house price structural residuals in all AEs and EMEs, respectively. The solid line displays the average impulse response (point estimate) across all countries in each group; the shaded areas display the 2 standard deviations cross–sectional confidence bands.

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 and emerging economies, and are computed over the common sample 1990:1–2009:4.

Table 2: Summary Statistics: Real House Prices and Real GDP

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.

Appendix A. Identification in the GVAR

This appendix shows 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 et al. (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.

Appendix 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 $\mathbf{\Sigma}_{u_i} = \mathsf{COV}(\mathbf{u}_{it})$ 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 $\mathbf{\Sigma}_{v_i} = \mathsf{COV}(\mathbf{v}_{it})$ 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 $\mathbf{P}_i = \mathbf{Q}_i'$.

Appendix 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 $i = 0$). Note, 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

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

where $\mathbf{\Sigma}_{v_0} = \mathbf{P}_0^{-1}\mathbf{\Sigma}_{u_0}(\mathbf{P}_0^{-1})' = \mathbf{I}$ and $\mathbf{\Sigma}_{v_0 u_j} = \mathbf{P}_0^{-1}\mathbf{\Sigma}_{u_0 u_j}$. 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, after conditioning on foreign variables, the cross–country dependence of residuals is close to zero for most countries (see online appendix for details on the pair–wise correlation of the GVAR residuals). This suggests that we should not 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

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

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.

Appendix B. Data Source

The data used for the estimation of the GVAR model is the same as in Cesa-Bianchi et al. (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 EMEs data is from central banks, national statistical institutes, or private entities. Even if in the aftermath of the U.S. housing bust and the ensuing financial crisis house prices have gotten a lot of (deserved) attention by both policy–makers 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 heterogeneity of housing goods and the infrequency of sales.

All house price series, their start dates, and sources are described in Table B.3. 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 B.3: House Price Indices – Description and Sources

Country	Code	Source	Start Date
Argentina	Ave. value of old apartments, Buenos Aires	Reporte Inmobiliario	2000-Q1
Australia	House price index, 8 capital cities	OECD	1970-Q1
Austria	Real estate price index, Vienna	OeNB	1986-Q3
Belgium	House Price Index	OECD	1970-Q1
Bulgaria	Existing Flats (Big Cities)	BIS	1993-Q1
Canada	House Price Index	OECD	1970-Q1
China	Sales Price Indices of Buildings in 70 Medium-Large Sized Cities.	National Bureau of Statistics of China	1998-Q1
Colombia	Used Housing Price Index (UHPI)	Colombian Central Bank	1988-Q1
Croatia	Average prices of newly-built dwellings sold	Croatian Bureau of Statistics	1996-Q2
Chzec Republic	House Price Index	Czech National Bank	1999-Q1
Denmark	House price index, One family houses	OECD	1970-Q1
Estonia	Average Purchase-Sale Price of Dwellings 2-rooms and kitchen	Statistics Estonia	1997-Q1
Finland	House Price Index	OECD	1970-Q1
France	House Price Index, Logements anciens	OECD	1970-Q1
Germany	House Price Index, Total resales	OECD	1970-Q1
Greece	Index of prices of dwellings, Other urban excluding Athens	Bank of Greece	1993-Q4
Hong Kong	Private Domestic - 1979-2008 Price Indices by Class (Territory-wide)	Rating and Valuation Department	1979-Q4
Hungary	FHB House Price Index	Hungarian Mortgage Bank (FHB)	1998-Q1
Indonesia	Residential Property Price index, New Houses, Big Cities	Bank Indonesia	1994-Q1
Ireland	House Price Index, Second hand houses	OECD	1970-Q1
Italy	House Price Index, Average 13 Urban Areas	OECD	1970-Q1
Japan	House Price Index	OECD	1970-Q1
Korea	House Price Index, Nationwide House Price Index	OECD	1986-Q1
Lithuania	House Price Index	BIS	1998-Q4
Malaysia	House Price Indicators	Bank Negara Malaysia	1989-Q1
Netherlands	House Price Index	OECD	1970-Q1
NewZealand	House Price Index	OECD	1970-Q1
Norway	House Price Index	OECD	1970-Q1
Peru	House Price Index	Peru Central Bank	1998-Q2
Philippines	Prime 3BR Condominium Price-Makati CBD	Colliers International	1994-Q4
Portugal	Residential property prices, all dwellings	BIS	1988-Q1
Singapore	Property price index, private residential, Singapore	URA	1975-Q1
Slovenia	The advertised price in Ljubljana	Slonep	1995-Q2
South Africa	ABSA House Price Index, All sizes, Purchase Price, Smoothed	ABSA	1970-Q1
Spain	House Price Index	OECD	1971-Q1
Sweden	House Price Index	OECD	1970-Q1
Switzerland	House Price Index	OECD	1970-Q1
Thailand	House Price index, Single Detached House, Thailand	Bank of Thailand	1991-Q1
UK	House Price Index	OECD	1970-Q1
USA	House Price Index	OECD	1970-Q1