The international transmission of house price shocks*

O. de Bandt,[†] K. Barhoumi,[‡] and C. Bruneau[§]

November 2009

Abstract

Using a sample of house prices in OECD countries, as well as a larger data base including different series to characterize the economic activity,

we extract common factors to summarize the comovements of the series, first from international house prices only, second, from the larger data base. These factors are then included in stationary FAVAR models.

We mainly focus a "pandemic" view of contagion where local shocks, originating from a country or a local housing market, spread out to other domestic housing markets. An interesting finding is that, even allowing for other channels of international transmission (through global interest rates, or activity), the US real house price, which appears to be exogeneous in the US dynamics, unidirectionally causes the international house price factor, which in turn causes the domestic real house price growth for each country. This tends to prove that a local shock originating from the US housing market can spread out to all other domestic housing markets through a direct transmission channel involving housing markets only.

Key words : housing, factor models, Vector Autoregressive models
JEL : G33, E32, D21, C41

*Many thanks to Jean Ludovic Audret for helping assemble the database. All errors remain ours. The opinions expressed are not necessarily those of the Banque de France or the Eurosystem.

[†]Banque de France, E-mail olivier.debandt@banque-france.fr

[‡]Banque de France, E-mail karim.barhoumi@banque-france.fr.

[§]Banque de France and University of Paris X, E-mail cbruneau@u-paris10.fr.

1 Introduction

The run-up of the housing bubble as well as the housing crisis that erupted in the USA in the summer of 2006, followed by the crisis in the UK and the sharp fall in house prices in Ireland and Spain, have raised questions of possible international transmission of shocks across countries (Terrones and Otrok, 2004). Arguably, price adjustments in housing markets are slower than in financial markets, given the existence of transaction costs and the absence of full comparability across units, which differ in terms of services they offer, notably location. As a consequence, housing markets are generally viewed as "local" markets, plagued with idiosyncracies, even if "local" economic fundamentals (city-based, regional, or national) may also be a key component of it (see, among others, Ortalo-Magne and Prat, 2009, for such a "spatial" asset pricing point of view). Nevertheless, the recent period provides, at face value, evidence in favour of correlation across markets.

Several dimensions are possible. In the long run, quality-corrected house prices should equalize, within a given economic area as a result of population movements. This may imply leads and lags of a few years between markets. Here, we rather focus on short or medium run links across markets.

Different explanations are possible of an international transmission of house price shocks. First of all, house prices maybe driven by fundamentals that are either real macroeconomic or financial variables (see Goodhart and Hoffman, 2004 for the role of credit variables). If the cycles of fundamentals are correlated, and house prices are driven by fundamentals, then house prices are likely to comove. Second, news on house prices in some countries may lead investors to revise their expectations on house prices in other countries. Third, in open economy, house prices may be directly affected by international fundamentals (world activity, global liquidity, world interest rates) that affect global investors arbitraging across domestic house markets (see e.g. Kiyotaki, Michaelides and Nikolov, 2008 for a model of domestic house prices determined by the world interest rate). A final possibility, is that the channel of transmission is time varying, leading to possible "contagion effects" in case of crisis, and notably global crisis : house price changes are more significant under some circumstances, e.g. when prices are decreasing, or during a crisis Another definition of contagion, closer to the previous explanation, is also, as in the case of a "pandemic", the occurence of a double interaction occur, i.e. when local prices in one region affect global prices, which in turn influence local prices in other regions.

We investigate the existence of such interactions across countries, notably the link between macroeconomic fundamentals and the dynamics of house prices and the relevance of international comovements, using factor analysis.

The plan of the paper is the following. Section 2 recalls the main principles of the econometric models we have selected to investigate the question of contagion, namely the FAVAR and the LSTAR models. In section 3, we present the data. The results are discussed in section 3, as well as the main steps of the empirical analysis.

2 Empirical methods

Based on the two definitions we have given above for contagion, we rely on two different tools. Favar models, as well as methods to assess non linearities in the reaction of house prices, in particular LSTAR models. We now present them successively.

2.1 Favar models for the analysis of the transmission of house prices

House prices in many industrial countries have increased unusually rapidly in recent years and in some cases these increases do not seem to be fully explained by economic fundamentals. The dynamics of house prices has indeed been mainly studied at the national level (Tatsanoris and Zhu, 2004), housing markets being viewed as "local" in nature. Goodhart and Hoffman (2004) stress the need to extend the set of fundamentals to money and credit variables. In that context, the transmission across markets is mainly national, between local and regional markets. However, Del Negro and Otrok (2007) conclude that the early 2000s in the US were different from before, with a much larger contribution of national as opposed to state level components.

In contrast, the analysis of international transmission of housing prices is less developed with the exception of Vansteekiste and Hiebert (2009) who use a Global VAR approach to study comovements of house prices in the euro area and conclude to limited spillovers across countries. Earlier, Terrones and Otrok (2004) had developed a systematic analysis of the dynamics of house prices across a larger number of industrial countries. They show that house prices are highly synchronized and that the house price boom that took place in the early 2000 was unusual in both its strength and duration. Innovative aspects of the analysis are the use of dynamic factor (DFA) models to determine the extent to which house price comovements are explained by global or countryspecific factors and of FAVAR models (for Factor Augmented Vector AutoRegressive models), that combine country-specific variables with factors in VAR-type frameworks.

Before developing the FAVAR-based analysis, the authors investigate the extent to which fundamentals explain the dynamics of house prices. They indeed find empirical evidence in favor of the dependence of house prices on economic fundamentals (real income growth, interest rates), besides a significant contribution of the autoregressive component: house prices appear to be highly persistent with a significant autocorrelation of order one.

The factor analysis consists in extracting factors from different variables (not only the growth rate of house price, but also real stock returns, per capita output, per capita consumption, per capita residential investment, and changes in the short- and long-term interest rates) for 13 industrial countries, over the period 1980-2004. The methods allows to identify complementary factors, namely, a global factor, which affects all variables in all countries, capturing the common shocks affecting these variables, a global housing factor, affecting all house prices in all countries, but not other variables, similarly, a global interest rate factor, capturing common shocks to global interest rates but not to other variables, and so on for each type of variable in the data base.

Moreover, country-specific factor are estimated, reflecting the common shocks to the country-specific variables.

The results are that a large share (about 40 percent on average) of house price movements appears to be due to global factors, which reflect global co-movements in interest rates, economic activity, and other macroeconomic variables, which in turn result from common underlying shocks. The overall global factor affecting all variables explains (on average) about 15 percent of movements in house prices, while the global housing factor—capturing global shocks to housing markets alone— explains —on average— 25 percent of house price movements, with a clear heterogeneity in the contribution of the common

Our aim is to estimate the same type of FAVAR models from our data base described hereafter. We use a slightly different database and extend the sample to include the burst of the housing bubble. We implement a more robust approach to assess the additional explanatory power of international house prices : we first estimate country-by-country models of real house prices based on domestic macroeconomic fundamentals, based on the usual view that housing market are "local" (i. e. respond to regional or national determinants); we then consider whether international house prices, derived from common factors, help provide better models.

In the following section we recall briefly how to build a FAVAR model, which may be of two types, and explain how we implement such a methodology in our case.

1. Model FAVAR in the lines of Stock and Watson (2005)

One considers a set of n vectors $X_{1t}, ..., X_{nt}$ with a factor dynamics. The matrix X_t may include in our case, house prices as well as other indicators (GDP, short and long interest rates, prices, housing investment, etc) for a large set of countries.

$$\begin{aligned} X_{it} &= \lambda_i(L) f_t + \varepsilon_{it} \\ \text{where } cov(f_t, \varepsilon_{it}) &= 0 \\ \text{and } cov(\varepsilon_{it}, \varepsilon_{jt}) &= 0 \text{ if } i \neq j \end{aligned}$$

The idiosyncratic components ε_{it} may be serially correlated, for example obeying an AR model of order p:

$$\forall i, \ \varepsilon_{it} = \delta_i(L)\varepsilon_{it-1} + v_{it}$$

Transforming the model as following:

$$\begin{aligned} (Id - \delta_i(L)L)X_{it} &= (Id - \delta_i(L)L)\lambda_i(L) f_t + v_{it} \\ &\Longleftrightarrow \widetilde{X_{it}} = \widetilde{\lambda}_i(L) f_t + v_{it} \\ &\Longleftrightarrow X_{it} = \widetilde{\lambda}_i(L) f_t + \delta_i(L) X_{it-1} + v_{it} \end{aligned}$$

allows to get white residuals.

The R factors $f_t = (f_{1t}, ..., f_{Rt})'$ are dynamic factors obeying an AR model too:

$$f_t = \Gamma(L) f_{t-1} + \eta_t$$

Finally,

$$
\begin{aligned}
X_t &= \widetilde{\Lambda}(L) f_t + D(L) X_{t-1} + v_t \\
D(L) &= \begin{bmatrix} \delta_1(L) & 0 & 0 \\ 0 & . & 0 \\ 0 & 0 & \delta_n(L) \end{bmatrix} \\
\widetilde{\Lambda}(L) &= (\widetilde{\lambda}_1(L), .., \widetilde{\lambda}_n(L))' \\
v_t &= (v_{1t}, ..., v_{nt})' \\
f_t &= \Gamma(L) f_{t-1} + \eta_t \\
\eta_t &= (\eta_{1t}, ..., \eta_{Rt})' \\
\text{avec } \forall i, \forall r, \forall t, \forall s, E(v_{it}\eta_{rs}) &= 0
\end{aligned}
$$

If $\Gamma(L)$ is a polynomial matrix of order $q-1$, one can define the $\widetilde{R}$- dimensional factor F_t, $R \leq \widetilde{R} \leq Rq$ as:

$$F_t = (f_t', f_{t-1}', ..., f_{t-(q-1)}')'$$

such that:

$$
\begin{aligned}
X_t &= \Lambda F_t + D(L) X_{t-1} + v_t \\
F_t &= \Phi(L) F_{t-1} + G\eta_t
\end{aligned}
$$

or, equivalently, in a VAR-type framework:

$$
\begin{aligned}
\begin{bmatrix} F_t \\ X_t \end{bmatrix} &= \begin{bmatrix} \Phi(L) & 0 \\ \Lambda\Phi(L) & D(L) \end{bmatrix} \begin{bmatrix} F_{t-1} \\ X_{t-1} \end{bmatrix} + \begin{bmatrix} \xi_{Ft} \\ \xi_{Xt} \end{bmatrix} \\
\text{where } \begin{bmatrix} \xi_{Ft} \\ \xi_{Xt} \end{bmatrix} &= \begin{bmatrix} I \\ \Lambda \end{bmatrix} G\eta_t + \begin{bmatrix} 0 \\ v_t \end{bmatrix}
\end{aligned}
$$

It is worth emphasizing that the past values of the i^{th} component do not directly influence the dynamics of the j^{th} component ($j \neq i$) because the lag operator $D(L)$ is diagonal.

The influence of the i^{th} component on the j^{th} component ($j \neq i$), if it exists, is indirectly transmitted through the factors.

The previous FAVAR model appears to be a constrained VAR model. It is different from the FAVAR models estimated by Bernanke et al (2004), or Del Negro and Otrok (2005) who do not impose constraints on the autoregressive parameters.

2) The FAVAR model by Bernanke et al. (2004)

The idea underlying the FAVAR models estimated by Bernanke et al.(2004) is the following: if a small number of estimated factors effectively summarize large amounts of information about the economy, then a natural solution to the degrees-of-freedom problem in VAR analyses - which have to be of limited dimensions- is to augment standard VARs with estimated factors.

One considers a $M \times 1$ vector Y_t of observable economic variables of interest, namely in our case, domestic macro variables (GDP, housing prices, short and long interest rates, housing investment, etc) for a given country. One assumes that additional economic information, not fully captured by the Y series, may also be relevant to modeling the dynamics of these series. More preciseley, one assumes that this additional information can be summarized by an $K \times 1$ vector of unobserved factors, F , where K is "small".

The joint dynamics of (Y, F) is given by:

$$\begin{bmatrix} F_t \\ Y_t \end{bmatrix} = \Phi(L) \begin{bmatrix} F_{t-1} \\ Y_{t-1} \end{bmatrix} + v_t$$

with v_t denoting a white noise process.

The previous model provides a way of measuring the contribution of the additional information contained in the factors F_t. Besides, if the true system is a FAVAR, the estimation of a VAR model for Y , with the factors omitted, may lead to biased estimates of the VAR coefficients and the associated impulse response coefficients.

The FAVAR model cannot be estimated directly because the factors F_t are unobservable. However, as the factors represent forces that potentially affect many economic variables, one can suppose that it is possible to infer something about the factors from observations on a variety of economic "informational" time series, denoted by a $N \times 1$ vector X_t . This includes house prices in other countries which may affect domestic house prices. The number of informational time series N is "large" , generally assumed to be much greater than the number of factors ($K + M << N$) and the series X_t are related to the unobservable factors F_t and the observable factors Y_t by:

$$X_t' = \Lambda^f F_t' + \Lambda^y Y_t' + e_t'$$

where Λ^f is an $N \times K$ matrix of factor loadings, Λ^y is $N \times M$, and the $N \times 1$ vector of error terms e_t are mean zero and are assumed either weakly correlated or uncorrelated, depending on whether estimation is obtained by principal components or likelihood methods.

Indeed, the model can be estimated in a two-step principal components approach or a single-step Bayesian likelihood approach.

In the two-step procedure, (F_t, Y_t) is estimated using the first $K + M$ principal components of X_t .[1] .

In the second step, a FAVAR model is estimated by standard methods, with F_t replaced by $\widehat{F}_t$. However, to account for the uncertainty in the factor estimation, it is generally recommended to implement a bootstrap procedure, in order to obtain accurate confidence intervals on the impulse response functions deduced from the FAVAR, except if N is large enough relative to T.

[1] The estimation of the first step does not exploit the fact that Y_t is observed. However, as shown in Stock and Watson (2002), when N is large and the number of principal components C_t used is at least as large as the true number of factors, the principal components consistently recover the space spanned by both F_t and Y_t . $\widehat{F}_t$ is obtained as the part of the space covered by the components C_t that are not covered by Y_t, tanks to a specific identifying assumption used in the second step.

2.2 Non linear single equations : the STAR model and the LSTAR specification

In order to detect possible regime shifts that can be associated with contagion, we rely on non linear specifications.

2.2.1 The STAR model

Such a model is written as:

$$Y_t = (\phi_0^{(1)} + \phi^{(1)\prime} X_t)(1 - F(Z_t, \gamma, s) + (\phi_0^{(2)} + \phi^{(2)\prime} X_t)(F(Z_t, \gamma, s)) + \varepsilon_t \tag{1}$$

with $F(Z_t, \gamma, s) = [1 + \exp(-\gamma(Z_t - s))]^{-1}$

Y is the endogeneous variable, X denotes (jointly) the lagged endogeneous variable and an exogenous variable and Z the transition variable. In what follows, the exogenous variable is also the transition one

Equivalently, the model can be written as:

$$Y_t = \pi_{10} + \pi_1^{'} X_t + (\pi_{20} + \pi_2^{'} X_t)([1 + \exp(-\gamma(Z_t - s))]^{-1} - 1/2) + \varepsilon_t \tag{2}$$

with $\pi_{10} = \phi_0^{(1)}$, $\pi_1^{'} = \phi^{(1)\prime}$, $\pi_{20} = \phi_0^{(2)} - \phi_0^{(1)}$, $\pi_2^{'} = \phi^{(2)\prime} - \phi^{(1)\prime}$

$\{\gamma = 0\}$ indicates that Y_t is a linear process:

$$Y_t = \pi_{10} + \pi_1^{'} X_t + \varepsilon_t$$

Accordingly, Teräsvirta (1994) test the linear model against the non linear model by implementing the test: H_0:$\{\gamma = 0\}$ against H_1:$\{\gamma > 0\}$

He propose to implement a LM test, after solving out the identification problem due to the fact that the parameters π_{20}, π_2 and s are not identified under the null hypothesis.

There are two usual choices of the transition function which lead to the LSTAR and the ESTAR models.

2.2.2 The LSTAR specification

The transition function is the logistic one, defined as:

$$F(Z_t, \gamma, s) = [1 + \exp(-\gamma(Z_t - s))]^{-1} \tag{3}$$

•If $Z_t < s$ and $|Z_t$ - s| tends to infinity, the transition function tends to 0 and the process Y_t is characterized by:

$$Y_t = \phi_0^{(1)} + \phi^{(1)\prime} X_t + \varepsilon_t$$

which corresponds to the first regime.

• If $Z_t > s$ and $|Z_t$ - s| tends to infinity, the transition function tends to 0 and the process Y_t is characterized by:

$$Y_t = \phi_0^{(2)} + \phi^{(2)\prime} X_t + \varepsilon_t$$

which corresponds to the first regime.

Intermediate values of the transition variable implies a combination of both "regimes" in the dynamics of Y.

The transition speed depends on the parameter γ. If γ tends to infinity,one finds an AR specification with varying coefficients, depending on the impact of a dummy variable indicating a crisis event.

Note that there is another usual specification of the transition function: the exponential one coresponding to the definition:

$$F(Z_t, \gamma, s) = \left[1 - \exp(-\gamma(Z_t - s))^2\right] \tag{4}$$

Thus, if $|Z_t - s|$ is large, whatever the value of Z_t compared to s, F tends to 1 and the dynamics of Y_t is described by:

$$Y_t = \phi_0^{(2)} + \phi^{(2)\prime} X_t + \varepsilon_t$$

On the contrary, Z_t is near from the threshold s, la fonction F tends to 0 and the dynamics of Y_t obeys:

$$Y_t = \phi_0^{(1)} + \phi^{(1)\prime} X_t + \varepsilon_t$$

In what follows, we prefer to validate a LSTAR model, with two regimes - a normal one and a critical one- respectively associated with a low and an high value of the transition function compared to the threshold. Thus the LSTAR specification allows an easier intrepretations of the regimes from an economic point of view.

The statistic procedure is as follows. First, the maximal lag order of the AR model is chosen by using the AIC criteriom. Netx, linearity is tested against non linearity.

At a third step, one has to validate the LSTAR against the ESTAR specification. Finally, one estimates the parameters of the LSTAR model.

In the following sections, we build on the FAVAR literature by considering a slightly different set of house prices (for 15 OECD countries). We proceed in two steps. First, we extract common factors. We estimate these common factors from our database including house prices only. Following Stock and Watson (2005), we consider that the factors can be written in a VAR format. In a second step, we include our common factors into VAR systems for each country. These FAVAR models are estimated with real house prices in the country, as well as other domestic macroeconomic variables (interest rates, GDP, inflation, etc) and the common house price factors. We also test whether the relationship is non linear by estimating by estimating, extended AR-type model including dummies indicating crisis events or LSTAR model.

3 Data

As indicated before, the analysis concentrates on house prices, but we also used data for the real economy, using OECD quarterly national accounts (households' investment, consumption prices, 3-month and 10-year interest rates). We exclude non residential investment (i.e commercial real estate, like offices, warehouses, etc). For house prices, several database are available, either from the OECD or the BIS. In order to consider a larger (i. e. more recent) sample we rely therefore on national data on house price and checked whether are consistent with the data assembled by the OECD. We use data on Australia, Canada, Switzerland, Finland, France, Germany, Ireland, Italy, Japan, Netherlands, Norway, New Zealand, Spain, United Kingdom, United States, hence a total of 15 countries. It turned out that they are very close to the OECD for the period starting in 1980. We concentrate therefore on the period from 1980Q1 to 2008Q4, where the data are the most reliable. Series were seasonally adjusted. Based on the house price data for 15 countries, we constructed common factor using the Stock&Watson (1999)'s approach, after demeaning and standardising the quarterly growth rates on nominal prices. The common factors are called $fac_{1,t}$, $fac_{2,t}$, etc for the first two factors. We also computed two world indeces of nominal house prices, based on a geometric average of national house prices, the first one being unweighted, the second one weighted by the share of the country in world GDP. As indicated in Figure 1, the first factor is very close to the quarterly growth rate of the unweighted index.

[INSERT FIGURE 1 HERE]

4 Modelling approach and empirical results

To assess the likelihood of contagion effects, we have considered two different definitions as mentioned before. According to the first definition, contagion occurs when the transmission is different, in particular more pronounced, during crisis events. This implies to investigate whether the results are differently affected across subsamples. In the second approach, we investigate whether global shocks, initially originating at the local level, spread out to other domestic housing markets.

In both cases, the main objective is to investigate whether common factors have an effect on domestic real house prices. We consider both linear and non linear models and different information sets, depending whether we extract common factors from a database including housing prices only, or whether we use a more complete database, in order to uncover other channels of transmissions of housing shocks.

When we refer to the first definition of contagion, we estimate non linear single equations including dummies indicating crisis events or describing a smooth transition process according to a LSTAR specification. Thus, the factor which is included as the transition variable is extracted from the whole data set (excluding the house prices) or is one of the factor extracted from the house prices only.

For the second definition, we estimate FAVAR models for the different countries, with the factor extracted from the set of house prices only. In this case the transmission channel of contagion is exclusively based on the house prices.

We start the analysis by adopting a simple single equation approach, where we explain the real houseprice growth by lagged values of domestic fundamentals -nominal interest rate and inflation rate- and lagged values of factors extracted from international house prices only. The regressions are thus linear; then, we introduce non linearity in two ways:

first, by introducing dummies indicating crisis periods, second, by looking for regimes and smooth transition mechanims from a LSTAR specification.

4.1 Univariate linear models

We first estimate univariate models, using the General-to-Specific approach, as available in the Grocer software, by including factors extracted from the house prices only.

4.1.1 Linear single equations for each country

We first estimate, for each country, a model with the autoregressive component, as well as domestic fundamentals (inflation, GDP growth with an expected positive impact, interest rates with an expected negative impact). We then add the first two common house prices based factors ($fac_{1,t}$, $fac_{2,t}$)[2] and test whether the factors have additional explanatory power. Notice that all time series are stationary in growth rates (real house prices, consumption deflator), as clearly indicated from unit root tests. The only exception is for the US, which is a more borderline case since only KPSS tests do not reject I(0) for the growth rate of real house prices.

We have alternatively tested the factor lagged by one quarter or contemporaneously (but do not present the latter results to save space)[3].

The results are exhibited in Table 1 in Appendix. In all cases, it turns our that the best models, as selected by the General-to-Specific approach, include one-period lagged variables, for domestic fundamentals as well as for factors. All models end up including fundamentals (interest rate or inflation) , except for Australia and UK. A positive and significant coefficient associated with $fac_{1,t-1}$ means that increases in international house prices have a positive spillover on domestic prices.

Two groups of countries can be distinguished:

- Australia, Spain and the UK, where the first common factor has a significant effect (at the level of 10%);
- the other countries, namely USA, Germany, France and Ireland, where real house prices can be explained by domestic fundamentals only.

[2] Note that in order to avoid spurious correlations, when regressing a country house price on the common house price factor, we exclude the country's price from the database of international house prices. As a result, fac_1 should actually be written as fac_1^i for country i when considering the first common factor extracted from the database of all house prices excluding country i's house price. fac_1^i enters all regressions involving country i, for example, fac_1^{usa} in the particular case of the USA. Even if it turns out that such a difference is not very significant, as shown in Figure 2 in Appendix ($fac_1^i \simeq fac_1^j \simeq fac_1^{all}$ for all $i \neq j$, with fac_1^{all} the first common factor from the database of all house prices), using fac_1^i instead of fac_1^{all} provides more robust results.

[3] To avoid spurious correlations, the factors are computed for each country on a database of 14 countries, i.e. the 15 initial countries after exclusion of the country under study. As shown in Figure 2, the first common factors computed for the restricted database (ie with 15 instead of 14 countries) is quite close to the one computed from the whole database of 15 countries.

The level of the interest rate (i_{t-1}) is associated with a significantly negative coeffficient for France, Germany, Ireland. However, when measured in first difference (Δi_{t-1}), in order to account for its persistence, it is no longer significant .The coefficient of the (lagged) inflation rate is significant only in the case of Germany.

As annouced before, we introduce dummies to account for crisis periods and we examine the robustness of the previous results to crisis events.

4.1.2 Robustness to crisis events

In order to assess the robustness of the previous results to changes in the transmission mechanism of international house prices during specific events, notably crisis, we now test whether the sensitiveness is time varying. This is a measure of contagion of house prices, as we expect domestic prices to react more significantly to international house prices during crisis periods. Here we test therefore

$$\Delta Log(p_{h,t-1}) = \alpha_0 + \alpha_1(L)\Delta Log(p_{h,t-1}) + \alpha_2 fac_{1,t-1} + \alpha_3 du\_crise_{tt} fac_{1,t-1} + \epsilon_t$$

where du_crise_{tt} is a dummy variable that takes the value of 1, during a crisis and 0 otherwise. Under such a specification, α_3I measures the differential impact of the crisis on domestic house crisis. Testing for contagion implies rejecting the null hypothesis $H_0 : \alpha_3 = 0$ *vs* $H_1 : \alpha_3 > 0$.

We need therefore to define du_crise_{tt}. We use for that the definition of crisis in the World Economic Oulook, April 2009 (based on Rogoff and Reinhart, 2008), which provides the recession periods, associated with financial crisis. When at least one OECD country is in recession, the indicator is equal to one. An alternative index, would measure the proportion of countries in recession. We update such an index by introducing a recession period as from 2008Q2. The index appears in Figure 7 in Appendix.

It turns out that for 4 countries, namely Australia, Spain, Ireland and United Kingdom, (See Appendix, Table 2), α_2 is not statistically different from zero, while α_3 is significantly negative. This should be interpreted (given the normalisation of the housing factor) as a stronger positive elasticity of domestic house prices to international house prices during a financial crisis period.

Next, we extend the linear models by introducing factors extracted from a larger data base including prices, interest rates, GDP among other variables.

4.1.3 Transmission through other macroeconomic variables

We now use the full database described in the data section to compute common factors with a view to consider alternative transmission channels of house price changes. In order to do that, we adopt a three steps procedure. First, we extract 3 common factors from a larger database excluding the house prices. Secondly, we identify the factors ($Glob1\_price$, $Glob2\_price$ and $Glob3\_price$). Finally, we estimate for each country the appropriate model, by using one of these "global" factors or a factor extracted from the house prices only as in previous section.

It turns out that the factors that we estimate from that extended database have a direct economic interpretation. As shown in Figure 3 to 5, the first factor of the database excluding house prices, denoted $Glob1\_price_{t-1}$,is correlated with interest rates. the second factor, denoted $Glob2_price_{t-1}$is correlated with GDP growth. The third factor is an activity specific factor as it appears to be quite close to the world Output Gap.

In Table 3, we present the results from the estimation of the same type of univariate regressions as in Table 1. The first factor is never associated with a significant coefficient except in the case of Ireland. The second factor has now a negative impact in Australia but positive in Spain. The housing factor remains significant in Australia and the UK.

It now becomes significant in the case of France, as from the new set of candidate regressors, Grocer selects a model with international house factor $fac_{1,t}$.as the only regressor on top of the autoregressive component.

Now we examine whether the dynamics could have different features depending on different regimes, by estimating LSTAR models.

4.2 LSTAR models

When estimating the LSTAR models, we limit us to five countries at this step of the analysis, namely France, Germany, Spain, UK and USA. The investigation will be further extended to the other countries. We run through the different steps and find different transition variables, namely Glob1_prices for Spain and UK, Glob2_prices for France and Glob3_ prices for the USA. As indicated above, these factors can be interpreted, respectively, as a global interest rate, the growth rate of global GDP in OECD countries, the (inverted) lagged annual growth rate of GDP.

In the following table, we summarize the main results about the instantaneous impact (denoted correlation) of the global factor which is also the transition variable. We just focus on the contemporaneous impact of the global factor. Indeed, it has its own dynamics, which cannot be characherized from the single equation which describes the dynamics of the endogenous variable (the house price). The MA type specification obtained by inverting the AR type model including X (and Y) involves an infinite number of lags of the exogenous variable (that is the global factor). But contrary to standard impulse response analyses, one cannot consider any shock on the lagged values of the global factor as past innovations. The difference comes from the intertemporal correlations between the different lags of the global factor.

The results are summarized in Table 4 in the Appendix.

The first result is that non linearity is clearly validated only for two countries, Spain and UK. In both cases, the two regimes are defined by the level of world interest rates: high level of interest rates versus low level. One observes a negative correlation between the level of world interest rates and the first differences in log (real) house prices in these 2 countries. The negative coefficient is stronger when interest rates are low.

For France and the USA, house prices respond to the world GDP cycle, but the results may be seen as a bit suspicious, since non linearity is borderline (the log- likelihood of the model with two regimes is not very different from the model with one regime only). For the USA, we observe a positive correlation between the output gap and the first difference in log (real) house price with a higher correlation in expansion periods. House prices are therefore more sensitive to the world output gap when the latter is very positive, than when it is negative. For France, we find a positive (respectively negative) correlation between (contemporaneous) world GDP growth rate and the change in Log real house prices, in expansion periods (respectively recession) periods. For both countries, USA and France, house prices would therefore tend to respond more to activity in the upswing than in the downswing. One can conjecture that other factors than activity, notably financial variables, may explain the adjustment of prices in the downswing.

In any case, it is not easy to interpret one or the other regime as a crisis regime. For Spain and UK, one could claim that the low level of interest rate is explained by lower risk premia, and accordingly, the corresponding regime could be viewed as a "critical" state. Thus we could conclude that we have find evidence of contagion, according to our first definition for both countries. We may rather conclude that we have actually identified a more "speculative" behavior of housing markets in the second subperiods, with sharper reactions of house prices to interest rates.

To summarize, at this stage of the analysis, the LSTAR approach does not provide a clear conclusion in terms of contagion effects.

Moreover, the analysis we have proposed up to now should be considered as a simple investigation preceding the multivariate analysis. Indeed, we will observe that the linear specification of the equation describing the dynamics of the real house price growth rate is dramatically changed inside a FAVAR model, wich tends to prove that the regressors of the single equations are not exogeneous.

In what follows, we focus on the multivariate analysis involving all factors extracted previously (including the first factor extracted from international house prices only) except the first global factor, which we drop because of its high persistence. However, as it is stronthgly related to interest rates, we decide to systematically include a national long term interest rate in the FAVAR models, after differencing this variable to insure its stationarity.

4.3 FAVAR models and causality analysis

In this section, we present the results we have obtained for each country of the panel, by estimating a FAVAR model. It is worth emphasizing that we do not have any tool which allows us to choose the best FAVAR model. Our General-to-Specific approach, carried out through GROCER, in order to select the best specifications of the single equations for all countries, cannot be used in the VAR context.

The numerical results are detailed in Appendix. We postulate a special role for the USA and look whether the American housing market can trigger contagion channels to the rest of the world.

For USA, we include three factors, fac_1, $Glob2\_price$ and $Glob3\_price$, on top of the domestic long term interest rate and house price growth rate. This allows to shed light on the maximum number of transmisson channels. Indeed, according to our "pandemic" view of contagion once a factor is influenced by one (or two) of the local variables, it can be associated with a contagion mechanism of a shock originating from the local house market or interest rate. Moreover, it is worth examining whether contagion effects involve the house markets only or more global activity channels.

For the other countries we limit the FAVAR model to four components, the interest rate, the real house price growth and two factors, the house price factor fac_1 and Glob2_price or Glob3_price, depending on the country.

Due to the limited number of observations, we aim at limiting the order of the FAVAR models. However, the persistence of the factors obviously increases the autoregressive order of the models. We test therefore different types of models, which mainly differ in terms of lags and estimation method and check the consistency of the results. We find indeed quite similar results.

More precisely, our strategy is the following:

First, as causal links can be measured equation by equation in a VAR model, we estimate FAVAR models with lower orders (see Tables 5 to 9 in Appendix), because it is easier to get white noise residuals from single equations taken separately and for which we test causality. To make sure that the results are not biased by persistence effects, we increase the order of the FAVAR models, when necessary, as proposed by Toda and Yamamoto (1995) and Dolado and Lütkepohl (1996) for implementing causal analyses in non-stationary VAR models, without preliminar cointegration analyses. But this latter step does not seem to be necessary, as proved by the features of the generalized impulse responses which returns to zero after a sufficient number of periods (about 36).

Second, for each country, we estimate a FAVAR model of high order (about 12) in order to obtain residuals which define a vectorial (weakly) white noise. Thus, we deduce from this FAVAR a system of equations, so as to limit the number of parameters to estimate: we just keep the regressors associated with significant coefficients, by still checking that the residuals are white noises. This system is reestimated with a SUR estimation method. Then causal links are measured through the system.

As mentioned before, both kinds of analyses provide rather close results about causal links. We decide to keep as "certain" the causal links jointly identified through both analyses.

It is worth emphasing that the domestic interest rates and house price growth rates are both exogeneous in the American model and in this model only. Moreover the house price factor (fac_1) is unidirectionnaly caused by these two variables. Accordingly, one can imagine "exogeneous" shocks impacting the American interest rates or the (real) house price growth rate and one can be sure that these shocks will affect the (world) house price factor fac_1. A second main result ,obtained from the FAVAR approach, is that the house price factor causes systematically the local house price growth for 5 of the 7 countries under review at the usual significance level of 5% (See Table 9 in Appendix, 7% for Australia). The other two countries are Ireland and Germany. In the case of Ireland, the growth rate of real house prices appears to be exogeneous in the FAVAR model of limited order estimated for that country (see Table 7 in Appendix). Moreover, it is worth noticing that, in the case of Germany, causality from the house price factor fac_1 to the domestic house price growth rate is indirectly transmitted by the global factor Glob3_price, for which one cannot reject a causal link from fac_1 (see Table 8 in Appendix). However when causality is investigated from systems of equations, we find strong evidence of causality from the house price factor to each domestic house price growth rate (See table 11 in Appendix) .Moreover in the second approach, exogenity of both domestic variables (house price growth and interest rates) is confirmed as well as causality from the domestic variables to the house price factor (See Table 10 in Appendix).

These results tend to prove that contagion may occur from the USA house price market to all other house markets. One can also imagine contagion mechanisms for shocks originating from the American interest rate, which is an interesting finding, if one refers to the recent supprime crisis, which was revealed after the increase in interest rates, which indeed took place in 2006. Accordingly, we could develop a stress test exercise replicating this increase in interest rate in order to examine its impact on all house markets and more generally on the global activity factors.

5 Conclusion

At this stage, we have investigated contagion effects in the movements of house prices across industrial countries by extracting factors and including these factors in linear multivariate models or non linear single equations, depending on the definition of contagion we have retained.

We have focused on two different definitions of contagion. According to the first definition, contagion occurs when the transmission is different during crisis events. In the second approach, contagion is viewed as a "pandemic" transmission mechanism where local shocks, originating from a country or a local housing market, spread out to other domestic housing markets.

In both cases, the main objective was to investigate whether common factors have an effect on domestic housing prices, inside non linear equations for the first definition and FAVAR models or systems of equations dervided from them, for the second one.

More precisely, referring to the first definition of contagion, we have estimated non linear single equations including dummies indicating crisis events or describing a smooth transition process according to a LSTAR specification. In the latter case, the factor included as the transition variable has been extracted from the large data set, which provides three factors, mainly correlated to interest rates and activity. We have thus observed non linearity in the dynamics of two countries (Spain and UK), but the results we obtain are not very conclusive at this stage, given the small sample size, the two regimes correspond to two subperiods of high, respectively low interest rates, with the break occuring in the mid-1990's. It is difficult to interpret them as a "normal" versus a "critical" regime. For France and the USA we provide evidence that the sensitiveness to the business cycle is more pronounced in the upswing than in the downswing, although non-linearity is less significant. Thus, results obtained from this approach should be considered as preliminiary and further completed.

According to the second definition, we have focused on multivarate dynamics.

Thus we have included factors, first extracted from international house prices only, second from a larger database, as components of a VAR model, on top of indicators of domestic economic fundamentals (namely, the growth of real house prices and the interest rates). When the factors are only derived from house prices specific, we provide evidence on the role of the common house price factor in the group made of the UK, Australia, Ireland and Spain, which means that contagion may occur, transmitted by a common component made of house prices.

In the broader approach, allowing many channels of global transmission of shocks, including house price specific as well as global factors, an interesting finding is that the US house price, which appears to be "independent" in the US dynamics, that is, not caused by any other variable, causes the international house price factor, which in turn causes the domestic house price of all other countries, inside the associated model. This tends to prove that a local shock originating from the US housing market can spread out to the other domestic housing markets and that the most direct transmission channel seems to involve house markets only.

References

[1] Ben S. Bernanke, Jean Boivin and Piotr Eliasz (2004), "Measuring the efffects of monetary policy:a factor augmented vector autoregressive (FAVAR) approach", *NBER Working Paper* 10220,http://www.nber.org/papers/w10220 and *Quarterly Journal of Economics*, February 2005.

[2] Dolado,J. J. and H. Lutkepohl. Making wald tests work

for cointegrated var systems. Econometric Reviews, 15 :369–386,

1996.

[3] Del Negro, M. and C. Otrok (2007) "99 Luftballons: Monetary Policy and the house price boom across US states" *Journal of Monetary Economics*, 54, 1962-1985.

[4] Goodhart, C. and B. Hofmann (2008) "House prices, money, credit and the macroeconomy", *Oxford Review of Economic Policy*, vol. 24(1), 180-205

[5] Kiyotaki, N., Michaelides, A. and Nikolov, K. (2008) "Winners and Losers in Housing Markets", mimeo.

[6] Kose, A., Otrok, C.and C. Whiteman (2003), "International Business Cycles: World, Region, and Country-Specific Factors," *American Economic Review*, Vol. 93 (September), pp.1216–39.

[7] Kose, A., Otrok, C.and C. Whiteman (1998),"Bayesian Leading Indicators: Measuring and Predicting Economic Conditions in Iowa", *International Economic Review*, Vol. 39, No. 4, pp. 997–1014.

[8] Ortalo-Magne, F. and Prat, A. (2009) "Spatial asset pricing : a first step", Mimeo.

[9] Stock, J.H. and M.W. Watson (2005), "Implications of dynamic factor models for VAR analysis", *NBER*, *Working Paper* n°11467, http://www.nber.org/papers/w11467.

[10] Tatsaronis, K. and H. Zhu (2004) "What drives housing price dynamics: cross-country evidence", *BIS Quarterly Review*, March, 65-78.

[11] Terrones, M. and C. Otrok (2004), "The global house price boom", IMF, *World Economic Outlook*, September.

[12] Toda, H. Y. and T. Yamamoto. Statistical inference in vectorautoregressions with possibly integrated processes. Journal of Econometrics, 66 :225–250, 1995.

[13] Vansteenkiste, I. and P. Hiebert (2009) "Do house price developments spill over across euro area countries : evidence from a Global VAR", *European Central Bank*, *Working Paper*, 1026.

A Single equation approach

Table 1: Country Single Equations (1983:1-2008:4)

Country	$\Delta Log(p^r_{h,t-1})$	Δi_{t-1}	$\Delta Log(p_{c,t-1})$	$fac_{1,t-1}$
Australia	0.54 (5.16)			0.002 (1.86)
	R^2=0.37			
Germany	0.65(7.50)	0.001 (0.31)	0.40 (4.01)	
	R^2=0.36			
Spain	0.49 (2.71)		0.19 (0.75)	0.004 (1.88)
	R2=0.52			
France	0.50 (4.16)	0.001 (0.40)		0.001(1.47)
	R^2=0.30			
Ireland(*)	0.30 (4.09)	0.28 (2.96)		0.000(0.78)
	R2=0.25			
United Kingdom	0.53 (4.85)			0.004 (2.75)
	R2=0.57			
United States	0.90 (13.24)	-0.01 (-0.91)		0.001 (0.13)
	R2=0.80			

(*) we report here the lagged endogenous variable at t-2 and t-3.

Student t (exhibited in parenthesis) are based on Newey-West HAC standard errors

NB: $\Delta Log(p^h_{r,t})$ is the domestic real house price, i_t is the domestic short term nominal interest rate, $\Delta Log(p_{c,t})$ is the quarter-on-quarter domestic inflation rate computed with the consumption deflator. $fac_{1,t}$ is the first common factor from the international house price database.

Table 2: Country Single Equations (1983:1-2008:4)

Country	$\Delta Log(p^r_{h,t-1})$	$\Delta Log(p^r_{h,t-2})$	$\Delta Log(p^r_{h,t-3})$	du_crise$_t \times fac_{1,t-1}$	other
Australia	0.59 (5.26)			0.004 (2.64)	
	R2=0.44				
Spain	0.67 (5.12)			0.003(1.60)	0.22 (1.39)
	R2=0.49				$(\Delta Log(p_{c,t-1}))$
Ireland		0.32 (3.50)	0.21 (2.32)	0.006(1.88)	-0.003 (-0.82)
	R2=0.27				(Δi_{t-1})
UK	0.56 (6.55)			0.008 (4.64)	
	R2=0.57				

See Table 1 for details

Table 3 : Country Single Equations with global factors (1983:1-2008:4)

Country	$\Delta Log(p^r_{h,t-1})$	Glob1_price$_{t-1}$	Glob2_price$_{t-1}$	Glob3_price$_{t-1}$	fac$_{1,t-1}$
Australia	0.55 (4.92)		-0.002 (-2.54)		0.004 (2.84)
	R2=0.46				
Germany	0.35 (3.60)			-0.006 (-2.31)	
	R2=0.28				
Spain	0.53 (4.42)		0.0021 (2.42)		
	R2=0.48				
France	0.47 (3.60)				0.002 (1.94)
	R2=0.32				
Ireland	0.24 (1.57)	-0.001 (-2.11)			
	R2=0.13				
United Kingdom	0.50 (5.98)			0.001 (1.96)	0.004 (3.39)
	R2=0.58				
United States	0.94 (14.10)		-0.001 (-0.52)		
	R2=0.84				

Student t (exhibited in parenthesis) are based on Newey-West HAC standard errors

Table 4: Summary of the results obtained from LSTAR models

	regime 1		regime 2	
ES	Glob1 < -0.08	low interest rates (crisis)	Glob1 > -0.08	high interest rates
	-0.675	stronger <0 corr. with int. r.	-0.325	<0 corr. with int. r.
USA	Glob3 < 0.11	high Output GAP	Glob3> 0.11	low Output GAP (crisis)
	-0.38	stronger >0 corr. with GAP	-0.08	>0 corr. with GAP
FR	Glob2 < -0.058	low contemp. $\mathring{GDP}$	Glob2 > -0.58	high contemp. $\mathring{GDP}$
	-0.41	<0 correlation	0.29	>0 correlation
UK	Glob1 < 0.11	low interest rates (crisis)	Glob3> 0.11	high interest rates
	-0.60	stronger <0 correlation	-0.20	<0 correlation

where $\mathring{GDP}$ is quarterly GDP growth

B CAUSALITY in FAVAR models of reduced orders

The models include the real house price growth rate, the firs difference of the long term nominal interest rate and several common factors : fac1 and Glob2_price and Glob3_price. Order is chosen in order to get white noise residuals equation by equation. The number of lags of the Favar is given in parenthesis in column 1, row 1.

Table 5: USA

USA/FAVAR(7)	House price growth	D(interest rate)	Fac1 (house price)	Glob2_price
House price growth	* * *	0.4067	0.0186	0.0938
D(interest rate)	0.9345	* * *	0.0287	0.6848
Fac1(house price)	0.6717	0.9833	* * *	0.0232
Glob2_price	0.5180	0.5070	0.7633	* * *

Test of causality
from a variable from the first column to one variable of the first row
p-values of the chi-square test statistic

Comments: the house price growth and the first difference of the interest rate are exogeneous; and they unidirectionally cause the house price factor (fac1) and also the global factor Glob2, with a weaker causal link between the house price growth and the factor.

Table 6: France

FRANCE/FAVAR(5)	House price growth	D(interest rate	Fac1(house price)	Glob2_price
House price growth	* * *	0.5505	0.1569	0.9471
D(interest rate)	0.2623	* * *	0.1304	0.1978
Fac1(house price)	0.0042	0.0063	* * *	0.0014
Glob2_price	0.8803	0.0000	0.1843	* * *

Test of causality from a variable from the first column to one variable of the first row
p-values of the chi-square test statistic

Comments: The house price factor, fac1 is exogneous; it unidirectionally causes the other (global) factor Glob2; as well as the house price growth and the first difference of the interest rate. Moreover the global factor Glob2 unidirectionnaly causes the fisrt difference of the interest rate.

Table 7: Ireland

Ireland/FAVAR(5)	House price growth	D(interest rate	Fac1(house price)	Glob2_price
House price growth	* * *	0.1931	0.7275	0.0567
D(interest rate)	0.6136	* * *	0.0579	0.1801
Fac1(house price)	0.9709	0.1503	* * *	0.0023
Glob2_price	0.9676	0.1723	0.7865	* * *

Test of causality from a variable from the first column to one variable of the first row
p-values of the chi-square test statistic

Comments: In the case of Ireland, the house price growth rate is exogeneous.For all other countries, one observes causality from the house price factor to the domestic house price growth rate, directly for France, Spain, UK and Australia and, indirectly, in the case of Germany as shown in the next two tables.

Table 8: Causality in FAVAR models in the case of Germany

Germany/FAVAR(4)	House price growth	D(interest rate	Fac1(house price)	Glob3_price
House price growth	$***$	?		?
D(interest rate)	0.0038	$***$		?
Fac1(house price)			$***$	0.0001
Glob3_price	?		?	$***$

Comments: The case of Germany: Evidence of indirect causality from the house price factor fac1 to the growth rate of the real house price through the global factor Glob3_price

p-values of the chi-square test statistic

Table 9: Summary Table of Causality from house price factor to real domestic house price in FAVAR models

Countries	France	Spain	UK	Australia	Ireland	Germany
Fac1(house price)	0.0042	0.0001	0.0010	0.0682	0.9709	NA

p-values of the chi-square test statistic used to test for causality of the house price factor fac1 to the domestic house price growth rate

C CAUSALITY tested from sytems of equations

The systems are derived fro FAVAR models of high order (12 or 13) including the growth rate of real house prices, the fisrt difference of the long term nominal interest rate and the factors fac1, Glob2 _price and/or Glob_3 price

Table 10: System of equations for USA

USA/system	equations
House price growth	0.000160+0.900258$^{(***)}$*USA_IMMO_REAL_GT(-1)
	Adjusted R-squared 0.792669
D(interest rate)	-0.090912$^{(***)}$+0.223769$^{(***)}$*DUSA_IRL(-1)-0.199008$^{(***)}$*DUSA_IRL(-7)
	Adjusted R-squared 0.108009
Fac1	-0.363979$^{(***)}$-0.418632$^{(***)}$* DUSA_IRL(-10)+29.76668$^{(***)}$*USA_IMMO_REAL_GT(-1)
	+0.497321$^{(***)}$*Fac1_USA(-1)+0.317634$^{(***)}$*Fac1_USA(-2)
	+0.240408$^{(***)}$*Fac1_USA(-10)-0.316671$^{(***)}$*Fac1_USA(-12)
	+0.189318$^{(***)}$*GLOB2_PRICE(-10)+0.272204$^{(***)}$* GLOB3_PRICE(-1)
	Adjusted R-squared 0.884742
Glob2_price	-0.286687+26.10069$^{(***)}$*USA_IMMO_REAL_GT(-4)+ 0.762789$^{(***)}$* GLOB2_PRICE(-1)
	+ 0.762789$^{(***)}$*GLOB3_PRICE(-7)-0.268343 $^{(***)}$*GLOB3_PRICE(-8)
	Adjusted R-squared 0.755615
Glob3_price	-0.155675-0.530828$^{(***)}$* DUSA_IRL(-1)-0.541460$^{(***)}$*DUSA_IRL(-3)
	-0.259325$^{(***)}$*DUSA_IRL(-6)-0.436491$^{(***)}$*DUSA_IRL(-11)
	-0.365732$^{(***)}$*GLOB2_PRICE(-1)+ 0.172*G970$^{(***)}$GLOB2_PRICE(-7)
	+0.698491$^{(***)}$* GLOB3_PRICE(-1)+ 0.358542$^{(***)}$*GLOB3_PRICE(-3)
	-19.34256$^{(***)}$*USA_IMMO_REAL_GT(-4)+17.01177$^{(***)}$*USA_IMMO_REAL_GT(-5)
	Adjusted R-squared .0.746031

USA_IMMO_REAL_GT is the growth rate of real house prices; DUSA_IRL is the first difference of the long term interest rate for the USA; Fac1_USA is the first common factor from the database of house prices excluding the USA.

The parameters are estimated by using the SUR estimation method, after whitening the residuals of the different equations.

$^{(***)}$indicates that the coefficients are statistically significant at a level of 5%.

Comments: The growth rate of real house prices rate and the first difference of the interest rate are both exogeneous. They unidirectionnally cause the house price factor (Fac1_USA) .The global factor Glob2_price is caused by the global factor Glob3_price and the growth rate of real house prices. The global factor Glob3_price is caused by the other three variables.

Table 11: Causality tested from systems of equations for the different countries

Countries	France	Spain	Germany	UK	Ireland	Australia
Fac1	0.0001	0.0029	0.0172	0.0002	0.0297	0.0008

Evidence of direct causality from the house price factor fac1

to the growth rate of the real house price for the different countries (in columns)
p-values of the chi-square test statistic derived from SUR estimation of the parameters

Appendix

Figure 1 : World indexes (quarterly change, %) and first common factor on housing prices

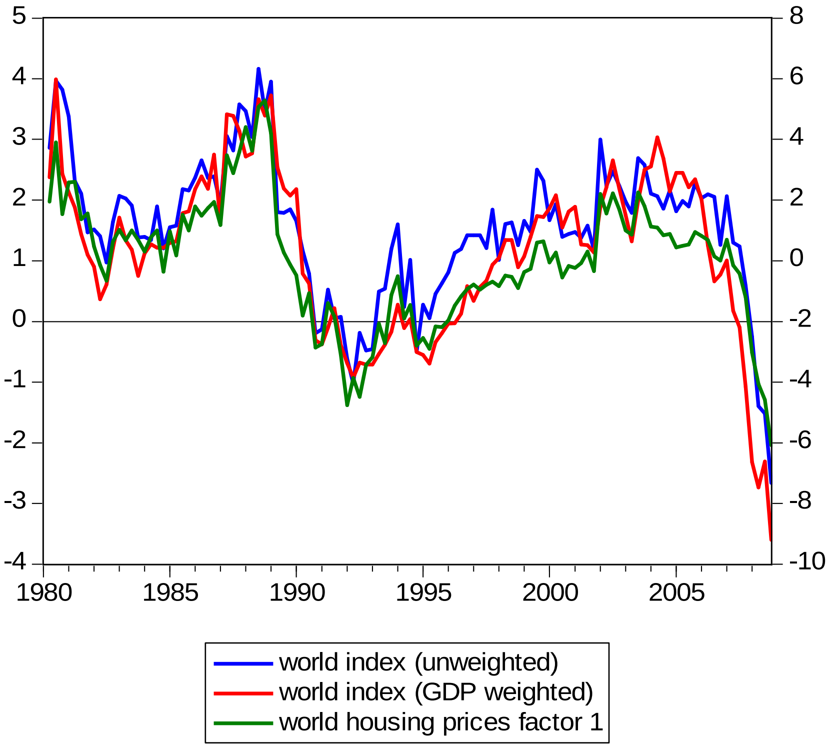


Figure 2: First common factor from complete database and excluding the country

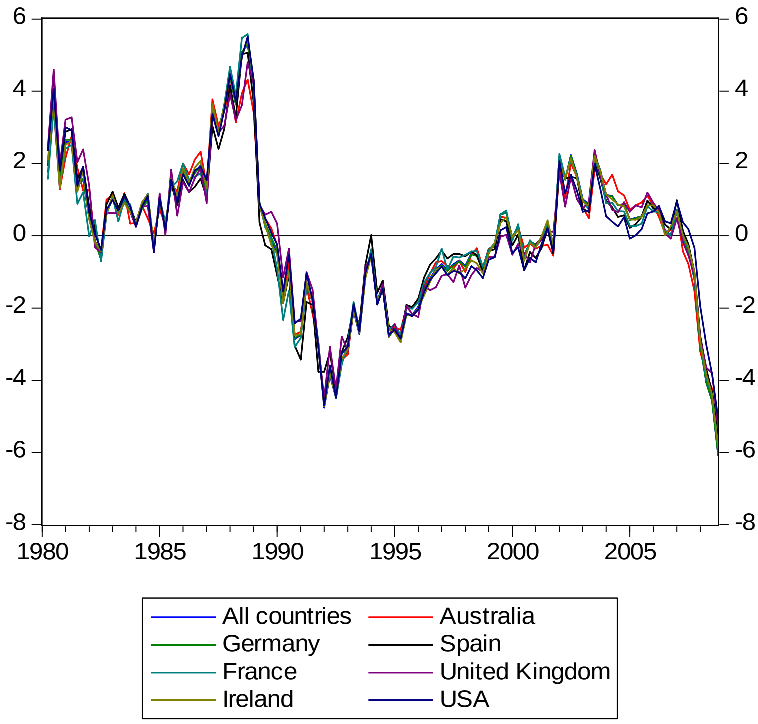


Figure 3 : GLOBAL1_w/o housing prices and world interest rates (%)

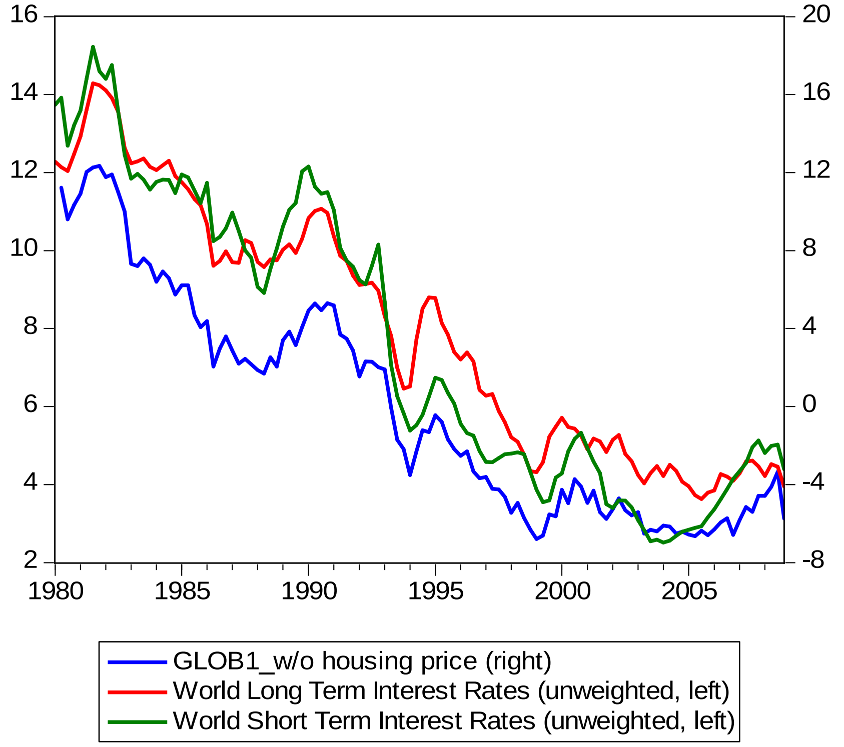


Figure 4: GLOBAL2_w/o housing prices and World GDP growth (quarterly, %)

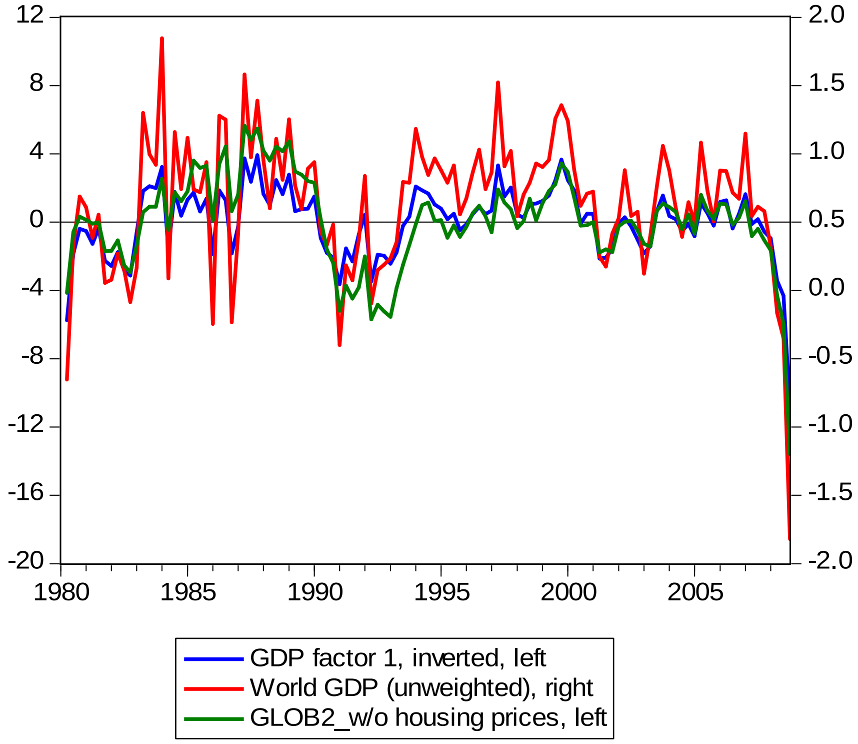


Figure 5 : GLOBAL3_w/o housing prices (inverted scale) and World Output Gap (%)

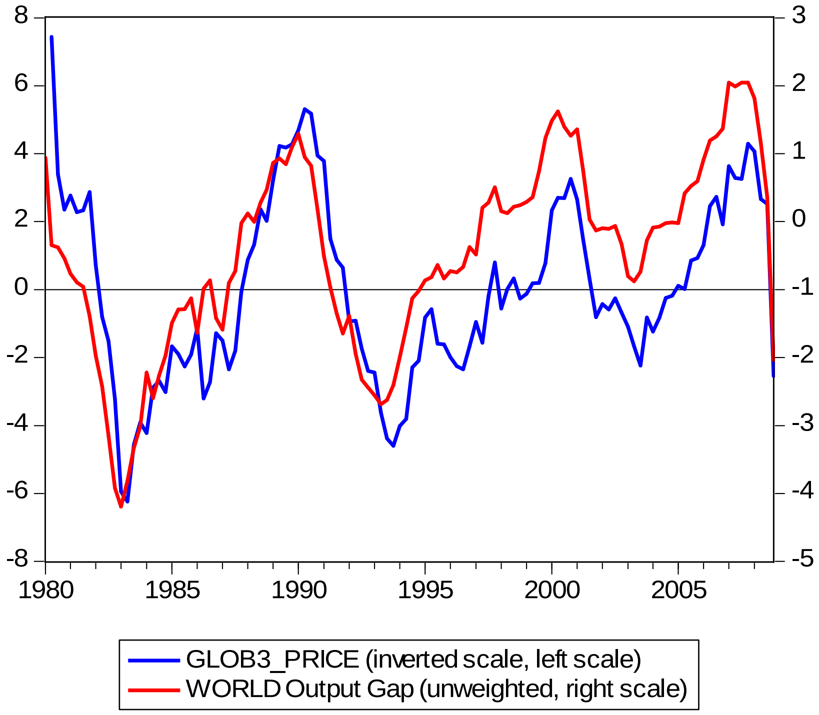
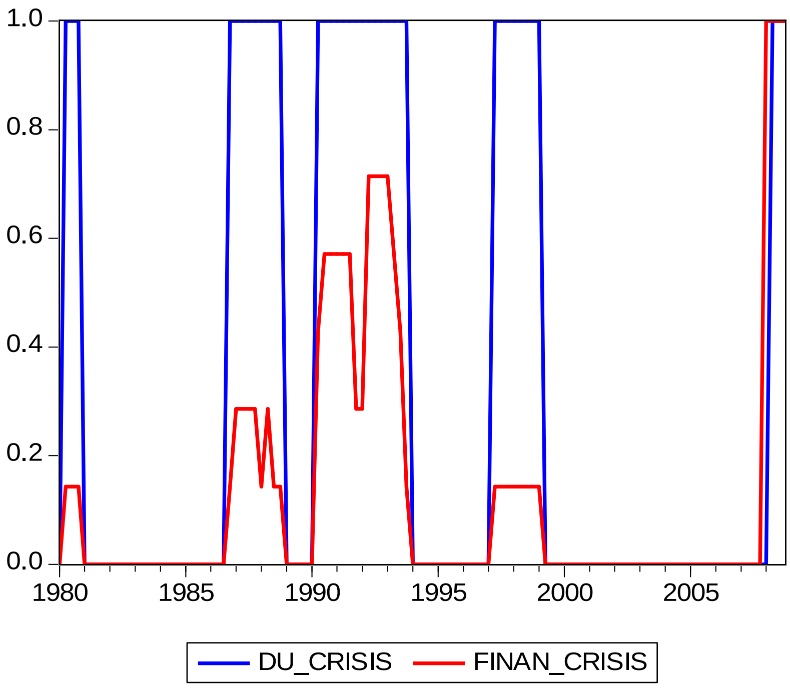


Figure 6 : Crisis periods



Du_crisis= 1 if at least one country is in recession
Finan_crisis = proportion of OECD countries in recession