

House Prices, Interest Rates and Macroeconomic Fluctuations: International Evidence

Christopher Otrok*

Marco E. Terrones

University of Virginia

International Monetary Fund

First Version: February 2005

This version: May 2005

Preliminary

Abstract

This paper studies the dynamic properties of international house prices, stock prices, interest rates and macroeconomic aggregates in industrial countries. While the dynamics of stock market returns and interest rates have been studied previously, we use a new dataset to gain insight into both the comovement of house price across industrial countries and the relationship between the fluctuations of house price with the fluctuations of financial asset returns and macroeconomic aggregates. Despite the fact that housing is the quintessential nontradable asset, we find a large degree of synchronization or comovement in the growth rate of real house prices in industrialized countries. We then show that much of this comovement can be related to a common dynamic component in interest rates across these countries. While we confirm the existence of a great degree of comovement in macroeconomic aggregates (namely, real output, consumption, and residential investment), we find little evidence that these aggregates are important sources of house price fluctuations. Instead, we find that house prices have an effect on macroeconomic aggregates. Given the important role that interest rates play for asset prices and macroeconomic fluctuations in industrial countries, we examine the role of monetary policy shocks--both domestic and global--in driving movement in these variables using an identified VAR augmented with our latent factors. We find evidence of a strong but delayed impact of U.S. monetary shocks on housing price growth both in the U.S. and internationally. We also document differences in the response of the U.S. economy and the global economy to these shocks.

*Contact information: cmo3h@virginia.edu, mterrones@imf.org. We thank seminar participants at Indiana, Purdue and Emory for their comments. The views in this paper do not necessarily reflect the views of the International Monetary Fund.

I. Introduction

There is a large and growing literature documenting the nature and degree of cross-country comovement of macroeconomic variables¹ as well as a separate and equally large literature studying comovement in stock returns and interest rates. In this paper we contribute to the effort of bridging these two strands of literature and study the inter-relationships in the degree and nature of comovement across both macroeconomic aggregates and asset returns.² Included in our list of asset returns is the growth rate of real residential house prices.

Our interest in including house prices in our study is motivated by the large role that housing plays in an individual's wealth portfolio³ and the role they may play in explaining macroeconomic fluctuations.⁴ Housing activities account for a large fraction of GDP and households' expenditures in industrial countries. Moreover, housing is the main asset⁵ and mortgage debt the main liability held by households in these countries, and therefore large house price movements, by affecting households' net wealth and their capacity to borrow and spend may have important macroeconomic implications. From a global perspective, housing is the quintessential nontraded asset yet, as we document in this paper, there is a surprising degree of synchronization in the changes in the price of this asset across industrial countries. In fact, the degree of comovement is on par with the magnitude of comovement in both financial asset returns (essentially frictionless) and macroeconomic aggregates (slowed only by trade frictions).

¹ The papers by Gregory, Head and Raynauld (1998), Kose, Otrok and Whiteman (2003), Stock and Watson (2004) and Baxter and Kouporitsis (2005) and Canova et. al (2004) are a few examples.

² Recent work by Dees, Di Mauro Peseran and Smith (2005) also attempts to bridge these same literatures. A study of these issues using a smaller set of variables and countries is Canova and de Nicolo (2003) study the effects of the term structure of interest rates on G7 GDP and inflation cycles.

³ Campbell and Cocco(2004), Piazzesi et. al (2004), and Fugazza et. al. (2005) document the role of housing prices in portfolio choice problems.

⁴ See, for instance, Davis and Heathcote (2003).

⁵ Davis and Heathcote (2004) estimate that the market value of the US housing stock is \$24.2 trillion in 2004, or 1.7 times the market capitalization of the NYSE, Nasdaq and AMEX exchanges combined.

In this paper we provide empirical evidence on the nature and source of comovement in real house prices, real stock prices, real GDP, consumption, investment, and interest rates across 13 industrialized countries (see Appendix A). The novelty of this paper is that our econometric model explicitly allows us to study the system of variables simultaneously, identifying the international linkages between real variables and financial variables and providing evidence with implications for open economy real business cycle models, portfolio choice problems and the effects and transmission of monetary policy shocks.

To document the comovement properties of asset prices, interest rates, and macroeconomic variables we first estimate a dynamic factor model that contains a *global factor* capturing comovement in all variables, *country specific factors* that capture dynamics particular to a country, and *aggregate specific factors* that capture global movements specific to a variable type (e.g. global comovement in house prices not related to comovement across all variables in the system.). As already noted, an important feature of the econometric model is that all factors are estimated simultaneously, preventing confusion of the importance of each type of factor. That is, when estimating a country factor it is critical to control for comovement within the country that is caused by forces outside of the country to avoid overstating the importance of the country cycle.⁶ The second stage of our investigation uses the estimated factors in a VAR to first study lead-lag relationships in house prices across countries as well as to provide evidence on causal links between house prices, other financial variables and macroeconomic aggregates. Our results indicate a potential role for U.S. monetary policy shocks in explaining volatility in many of the variables, in particular house prices.

⁶ As demonstrated in Kose, Otrok and Whiteman (2003) the importance of a regional business cycle in macroeconomic aggregates for Europe depends critically on conditioning on the existence of a global business cycle in developed economies.

Related work by Chirinko et. al (2004) studies the interrelationship between stock prices, house prices, and real activity in a 13 country sample similar to ours.⁷ Their work estimates structural VARs country by country to develop systematic cross-country evidence on the importance of shocks to house prices, stock prices, real activity and monetary policy. Our work focuses on a different dimension of the data by using the dynamic factor structure to exploit commonalities across countries to better understand the sources and transmission of international shocks. In a similar spirit Dees, Di Mauro, Pesaran and Smith (2005) study the role of monetary, oil, real and equity shocks across countries in a global-VAR (GVAR) model that includes a factor structure to model linkages across countries. Econometrically, our model differs in that we estimate the factors as latent variables while Dees et. al. estimate the factors as weighted averages of observable variables. While our approach is computationally more burdensome it allows for a richer factor structure in the model as well as allowing the econometric procedure to dictate the implied ‘weights’ for each variable in constructing the unobservable factors. We also adopt different approaches to identifying shocks. While the procedures we adopt require fewer and weaker identifying assumptions, the downside is that we are unable to identify the full range of shocks that Dees et al do. Finally, our primary interest is in studying the role of house prices in the context of other macroeconomic and financial variables and hence our work emphasizes a different set of variables than in the Dees et. al. study.⁸

As mentioned above, while there is an existing literature on both macroeconomic aggregate and stock market return comovement there is little evidence on the comovement of house prices across countries. One exception from the finance literature is the work of Case, Goetzmann and Rouwenhorst (1999) who study the dynamics of international commercial real estate markets from 1987-1997. They conclude that the comovement among commercial real estate markets is through GDP linkages and that

⁷ The main difference in datasets is that we do not include France and Germany but do include Australia and New Zealand. Additionally, they end their dataset in 1998:4 (rather than our 2004:1) to deal with exchange rate issues associated with the ERM while we use this data to study the nature of the recent global housing boom.

⁸ Both our paper and the Dees et. al. study include GDP, equity prices and long and short term interest rates. We also include consumption, investment and house prices, while Dees et. al. use oil prices and exchange rates.

commercial real estate real estate is a bet on a countries production. Our work should be viewed as complimentary to Case et. al. by offering a broader assessment of the nature of comovement in house prices. However, in contrast to Case et. al., we study private real estate markets rather than commercial, focusing on fewer countries (13 versus 21) but over a longer period of time, 1980-2004 instead of 1987-1997, the last five years providing information on the recent housing boom. Furthermore, we examine a wider range of variables (financial and real) in our search for casual linkages. We confirm the Case et. al. finding of the importance of real GDP in coordinating house price comovement, however we assign an even larger role to interest rates in driving housing price comovement. Additionally, since our econometric model is explicitly dynamic we are able to document which housing markets lead and which follow the world housing cycle.

II. What explains financial and macroeconomic fluctuations and comovement?

To address this question we estimate a dynamic factor model (DFM) comprising seven variables—the growth rates of real house prices, real stock prices, per-capita output, per-capita consumption, per-capita residential investment, and differences of the short-and long-term interest rates—for 13 industrial countries during the 1980-Q1 to 2003-Q4 period. We then use the estimated factors to decompose the variance of each series attributable to the latent factors. In a later section we combine the factor model with a VAR to develop causal links.

II.1. A Dynamic Factor Model

Dynamic factor models are a generalization of the static factor models which are commonly used in finance (e.g the Arbitrage Pricing Theory) and psychology.⁹ The motivation underlying these models is that the covariance or comovement between a group of (observable) time series is the result of the relation

⁹ These models were originally introduced by Spearman, a century ago, to study the relationship between a set of (observable) test scores and underlying (unobservable) mental ability. Sargent and Sims (1977) developed the first dynamic factor model.

between these variables and a small number of unobservable variables, called factors. More precisely, the dynamic factor model used in this paper postulates that both the inter and intra-temporal comovement observed in the 91 time series (7 observable variables times 13 countries) can be decomposed into a small number of non-observable components. These components are classified into four categories: (i) a **global** component, common across all variables and countries, capturing the common shocks affecting these variables; (ii) a **variable-specific** component, common to a particular type of variable across all countries but not other variables, capturing the common shocks affecting only that variable, say, house prices, in all countries; (iii) a **country-specific** component, common to all variables in a given country (but not other countries); and (iv) an **idiosyncratic** (or “unexplained”) component, which only affects one variable in a given country.

Let $Y_t^{j,i}$ denote the j^{th} variable in country i at time t . The dynamic factor model decomposes each such variable into the following components:

$$(1) \quad Y_t^{j,i} = a + b_{j,i}^g f_t^g + b_{j,i}^j f_t^j + b_{j,i}^i f_t^i + \varepsilon_t^{j,i} \quad \text{for } j = 1 \dots 7, \quad i = 1 \dots 13 \text{ and } t = 1 \dots T,$$

where f_t^g is the global component common to all variables and $b_{j,i}^w$ is the sensitivity of variable j in country i to this global factor; $b_{j,i}^j$ is the sensitivity of the $Y_t^{j,i}$ variable to the factor common to this type of variable in each country; $b_{j,i}^i$ is the sensitivity of this same variable to the country specific factor. Finally, $\varepsilon_t^{j,i}$ is an idiosyncratic component measuring movements in the observable variables not captured by the common factors. We model the idiosyncratic components as independent autoregressive processes:

$$(2) \quad \varepsilon_t^{j,i} = \varphi_{j,i}(L)\varepsilon_t^{j,i} + \nu_t^{j,i}$$

where $\varphi_{j,i}(L)$ is lag polynomial operator and $\nu_t^{j,i}$ is distributed i.i.d. $N(0, \sigma_{i,j}^2)$.

Each factor evolves as an independent AR(p) process:

$$(3) \quad f_t^k = \varphi_k(L)f_t^k + \mu_{k,t} \quad \text{for } k = 1..21$$

(1 global factor, 7 variable-type-specific factors and 13 country factors), where $\phi_k(L)$ is a lag polynomial operator and $\mu_{k,t}$ is an i.i.d. $N(0,1)$ variable. We fix the variance of this innovation to unity as a normalization of the model. The second normalization of the model is the sign of the factor, which is not identified in the system (1)-(3). We normalize the sign of the factor by restricting the sign of one factor loading to be positive for each factor.¹⁰

To estimate the model we use the Bayesian procedure developed in Otrok, Silos and Whiteman (2003), which in turn builds on the approaches in Otrok and Whiteman (1998) and Kim and Nelson (1998). Alternative estimation procedures, such as the approximate factor models in Stock and Watson (1999, 2002) or Forni and Reichlin (1998), while computationally more efficient at dealing with very large datasets, are unable to capture the overlapping factor structure described in this model. The appendix contains details of the metropolis-in-Gibbs procedure used to simulate from the joint posterior of factors and parameters. Priors are uninformative except for the prior imposing stationarity on the lag polynomials for both factor and idiosyncratic dynamics.

II.2. Quantitative Results on the Degree and Nature of Comovement

The estimated factors capture well the known shocks that have hit the world, sectors and countries in our study. Figure 1 plots the posterior means of the world factor and each aggregate-specific factor. Posterior coverage intervals, which are very tight for these factors, are omitted so that multiple factors can be plotted on one graph to conserve space.¹¹ The global component tracks well the major changes in global economic activity including the recession of the early 1980s, the boom of the mid-

¹⁰ These normalizations, which are standard in the factor literature, are necessary because the model can always be rescaled by increasing (decreasing) the variance of the factor while simultaneously decreasing (increasing) the factor loading. This type of changes results in identical values for the likelihood function.

¹¹ These charts are however available from the authors upon request.

1980s, the recession of the early 1990s, the long-boom of the 1990s, and the mild-recession of 2001.¹² Of particular interest is the house factor which reflects the main developments in global housing markets of the last 25 years remarkably well, including the housing price bust of the early 1980s, the house price boom of the late 1980s, the bust of the early 1990s, and the current house price boom --which shows an unprecedented strength in its duration. The global component and house component have typically moved in the same direction, with the exception of the most recent years, during which they have diverged, possibly reflecting a recent 'disconnect' between house prices and economic activity. The stock factor captures the well-known declines in the stock market, such as the 1987 crash and the most recent collapse in stock market prices, as well as the long boom of the 1990s.. The factor also shows that the cycles in the stock market prices appear to be of a higher frequency than in the real variables or the housing variables, indicating some lack of synchronization with these variables. The interest rate factors capture well-known swings in global interest rates (including the most recent period of loose monetary policy) while the real factor captures the recessions over this period. The similarities in the two interest rate factors and the two real factors suggest that it may be appropriate to consider only one factor for each of these two types of variables.

Figure 2 documents the role the factors play for each aggregate in the United States. These figures contain both the observable U.S. variable (e.g. output growth) along with scaled version of each factor. The scale factor is the estimated factor loading which allows us to visually decompose each aggregate at each date into the movements due to each factor. For output we can see the changing roles of the different types of factors. The first dip of early 1980s recessions is well captured by the country factor, while the second dip is largely global in nature. The early 1990s recessions is primarily country specific (in fact the actual output line and country factor lie on top of each other) while the mid 1990s recovery is largely global. For both interest rates, the two global factors seem to explain most of the movements in these variables. In a later section we will investigate whether or not this is due to the exporting of US

¹² Reassuringly, the global component is similar to the one estimated in other studies with alternative datasets and methodologies (Gregory, Head and Raynald 1998, Kose, Otrok and Whiteman 2004, Canova et. al. 2004).

monetary policy shocks. Finally, the housing market in the U.S. seems to be well explained by the aggregate housing factor, indicating that global conditions are a large part of U.S. housing price movements.

The world and country-specific components, however, play different roles in explaining the evolution of house prices across countries and over time (see Figure 3). For instance, in the cases of Australia, United States, and United Kingdom the movements in house prices have been strongly linked to the movements in the house factor and to lesser extent to movements in the global factor. The highly synchronized house price run-up of the past several years is mostly explained by developments in the housing market including the deepening of mortgage markets, which by easing borrowing constraints may have contributed to a synchronized pick up in house prices.¹³ The case of Ireland is also remarkable. The evolution of house prices in this country during the 1980s and early 1990s was mostly explained by the movements in the house factor and country-specific factor. Since then, the evolution of house prices have been mostly driven by country specific developments as Ireland's house prices and the house factor were moving in different directions.¹⁴

While the graphs in Figures 1-3 allow one to begin to dissect the nature of comovement in these variables, one would also like to both make summary statements about the importance of the factors as well as determining whether or not the structure of the factor model provides a good fit to the data. The degree to which the dynamic factor model is a good 'fit' for the data can be judged by the amount of the variation in the observable variables that is attributable to the latent factors. That is, do the factors explain the variability in the data or is the data mostly explained by the idiosyncratic term? If the former is true,

¹³ There is a positive correlation between the housing price factor with the mortgage-to-GDP ratio.

¹⁴ In this period, Ireland's economy was experiencing a strong boom and a strong flow of repatriates. To contain the rapid increase in house prices, the government introduced in 1999-2000 temporary measures to discourage the speculation in the housing market.

we have evidence that the factor structure is rich enough to capture the salient features of the data.¹⁵ This variance decomposition also provides information on the nature of comovement. Is comovement common across all variables? Or is it common across particular types of assets, or largely country specific? Furthermore, are there differences for countries in specific regions (Europe, North America, Oceania) in the answer to these questions? In particular, for each country, the fraction of the variance of an observable variable explained by each factor is computed as:

$$(4) \quad \frac{(b_{j,i}^i)^2 \text{var}(f_t^i)}{\text{var}(Y_t^{j,i})}$$

Complete results of the variance decompositions are contained in Table 1, which reports medians of the variance decompositions. Posterior quantiles for the variance decompositions, which are omitted to save space, indicate that the results are statistically significant as well. In terms of model fit, the factors explain on average 50% of the movements in GDP and interest rates, nearly 60% of the movements in stocks and 40% of the movements in house prices. Given the diverse set of countries in our sample these variance decompositions are quite high, indicating that we have factor model that explains a significant portion of the volatility in our data. Furthermore, if we consider a ‘core’ group of countries in our sample, these averages rise considerably.

The main conclusions we draw from this table are that: 1) World developments play an important role in driving fluctuations in individual countries’ real house prices, stock prices, macroeconomic aggregates (per-capita output, consumption, and residential investment), and interest rates. About 35% of the volatility of the 91 time series in the model can be attributed to world sources (the sum of the global component and variable-specific components) on average.¹⁶ 2) The global component seems to be closely related to real economic activity. It explains close to 20% of the volatility of output and to a lesser degree

¹⁵ This intuition is formalized into a formal test for the number of factors in large scale factor models by Bai and Ng (2002). Their test for the number of factors is based on minimizing the variance of the idiosyncratic term subject to a penalty for the number of factors.

¹⁶ This result is consistent with the findings of the existing literature focusing on the role of global factors in explaining fluctuations in the main macroeconomic variables (see, for instance, Kose, Otrok and Whiteman, 2003).

interest rates where it explains around 10% of the volatility of changes in the short- and long-term interest rates. For the United States the fraction of output/consumption variance explained by the world factor is closer to 52% and 22%. This finding is consistent with the notion the United States is an important source of volatility in the global economy. 3) International comovement in house prices is relatively high and explained mainly by developments in housing markets as captured by the housing factor rather than general global economic conditions. 4) On average, 24.6 % of the comovement in house price reflects developments in global housing markets and reflects developments in the global economic activity. 5) The long-term interest rate factor accounts for 43% and the short-term rate factor for 23% of the volatility of the corresponding rates. The aggregate stock factor accounts for 48% of the movement in stock prices. Its is not surprising that we find a great degree of comovement in a financial variables, such as interest rates or stock prices. What is perhaps the most surprising is that the degree of comovement in house prices is not that much smaller for most countries and is on par with the degree of comovement in real variables.

One important implication of these results is that developments in one country could have important repercussions in the others, in light of the high comovement of key economic variables across countries. For instance, an increase in interest rates in the United States, by affecting global economic activity and global interest rates, could have an effect on the house prices in the rest of the industrial countries. The next section augments a VAR with our dynamic factor model to further explore these linkages.

III. International linkages in Asset Prices, Interest Rates and Real Activity

To understand the nature of linkages across countries and across aggregates we estimate a sequence of VARs combining both country specific observable variables along with the relevant (relevance defined by quantitative importance) factors estimated from the dynamic factor model in equations (1)-(3). The first VAR we estimate includes both country specific variables and global factors. The results from this VAR shed light on the global linkages across asset prices, interest rates, and real

variables. The combination of a small number of domestic variables and global factors allows us to combine information from outside the domestic economy with local economic conditions without losing too many degrees of freedom.¹⁷ The factor-augmented-VAR for each country thus yields a parsimonious model that allows us to study global linkages and spillovers while explaining movements in important variables in each country. These models also help examine the issue of the transmission of monetary shocks across countries. For example, does U.S. monetary policy transmit to other economies via the common interest rate factor?

III.1 A Vector Autoregression

The reduced form VAR is given by:

$$(5) \quad Y_t = A(L)Y_{t-1} + u_t \quad E(u_t u_t') = \Sigma$$

where Y_t is a $(m \times 1)$ vector of observable data or latent factors and $A(L)$ is a matrix lag polynomial. Hamilton (1994) gives the formulas for impulse response functions given estimates of $A(L)$. Ideally, one would estimate the VAR coefficients as part of the MCMC algorithm to estimate the dynamic factor model to allow uncertainty in the estimates of the factors to be captured in the uncertainty in the VAR parameters and functions of the VAR parameters such as impulse response functions. However, since estimating the dynamic factor model itself is computationally costly, combining this with estimating and identifying the VAR at each step of the MCMC algorithm would be computationally infeasible.¹⁸ Given how tightly the latent factors are estimated, this is however a relatively minor issue.

¹⁷ Bernanke, Boivin and Elioz (2004) develop a factor augmented VAR to study the effect of monetary shocks in the U.S. They use the latent factors to bring more ‘information’ into the VAR from the 100s of time series available.

¹⁸ Our identification procedure, described below, is based on sign restrictions. This procedure requires many draws of potential impulse response functions and is also computationally intensive procedure. It is the combination of this procedure with the dynamic factor model that is infeasible.

III.2 Recursive Identification of Shocks

The identification of structural shocks (monetary, fiscal, technology etc.) in the VAR framework has generated both an enormous literature. To gather evidence on the effects of housing shocks we use a recursive structure, with housing ordered first since house prices are likely to be slow to respond to other shocks in the economy. Here we focus mostly on the results pertaining to response of other variables in the system to shocks to house prices. This provides cross-country evidence on the role of housing shocks in explaining variation in real variables as well as variation in stock returns. We do not consider other shocks (i.e. to the stock market) because the ordering of the remaining variables in the VAR such as ours is controversial. The one exception is that we do consider the effect of a ‘global’ interest rate shock on house prices, as a lead-in to the next section on the role of U.S. monetary shocks. Where we will use an alternative, more robust, procedure to identify monetary policy shocks.

Granger causality tests reveal that the U.S. housing cycle leads the housing cycle in other countries (in particular it leads the global housing factor). We use a VAR to quantify the extent and nature of this relationship. Our first VAR investigates whether or not the changes in the U.S. housing market have implications either for housing markets abroad or on real variables such a GDP growth. The first VAR we estimate contains U.S. house prices, GDP, short-term interest rates, as well as the global housing factor and the global interest rate factor. Figure 4 shows that a 1 standard deviation (positive) shock to house prices raises housing price growth to 0.8%, and this effect is fairly persistent. At the same time, this shock leads to a 0.2% change in GDP which also persists for some time. The implication is that a fall in house prices of say 1%, will lead to a persistent drag on GDP growth. Additionally, that same shock is exported to the rest of the world via the global housing factor. A shock to U.S. house prices leads to an initial small response in global house prices, but that response increases over time. Since changes in house prices in other countries affects output growth in those countries, a U.S. housing shock may eventually lead to a global slowdown in economic growth. Of course, the magnitude of these responses simply predicts a slowdown, not a crisis. To put some scale perspective on the IRF the IRF is scaled by the average factor loading. The response of a particular country depends on its factor loading on the global

factor. For example, we include the U.K. and see that the UK has a greater response than average. Of interest in these IRFs is the long delay in the response of other countries to the U.S. shock. In contrast, prices of financial assets respond much more rapidly to shocks in other countries, indicating that the housing asset may have some unique characteristics. The delay may be due to either some friction that delays the response of house prices in other countries, such as a less liquid housing market or greater transactions costs. Or, it may be that U.S. monetary policy is exported to the rest of the world with some delay.

[to be added in a later version: summary of results from all countries]

One concern for global house prices is that rising global interest rates may provide a drag on global house prices, and hence provides a channel, perhaps through wealth effects, to provide a drag on global output growth. To quantify this relationship we estimate VAR using the global aggregate specific factors for house prices, short-term interest rates, GDP growth and the world factor. We order the global house factor first and the global interest rate factor last. A shock to interest rates of 50 basis points will lead to decline in global house prices (again, the IRF is scaled by the average factor loading, the response of each country will vary with the size of its factor loading). However, this decline is quite small, reaching a maximum response (again, after some delay) of only 0.2%. While a 0.2% decline in house prices that is persistent will have a nontrivial effect on the level of house prices, the results do not indicate that house prices will collapse in the face of rising interest rates worldwide. We now turn to a more formal identification of monetary policy shocks.

III.2 Identification of Monetary Shocks with Sign Restrictions

The identification of monetary shocks is controversial. For the application here we choose to identify only the monetary shock by using a sign restriction (on impulse response functions) approach introduced by Faust (1998) and further developed by Uhlig (2004).¹⁹ A recursive identification scheme

¹⁹ See also Uhlig (1998).

(e.g. Sims 1980) is questionable here to identify the monetary shock since we expect innovations to both asset prices and monetary policy to be contemporaneously related. A non-recursive structural VAR (e.g. Sims 1986 or Bernanke 1986) would require us to make assumptions about the innovations to the latent factors as well as the observable variables. While assumptions about innovations to observable variables can sometimes be justified from economic theory or intuition, the innovations to latent dynamic factors are not well suited to such a procedure. Since the dynamic factors themselves are indexes of common activity capturing any number of underlying shocks, any assumption about the innovations to these series would be difficult to defend in this context.

The procedure developed by Uhlig (2004) identifies only the response to one of the innovations in the system, here as in Uhlig's work, that innovation is to monetary policy. Identification is achieved by placing restrictions on the sign of the impulse response for some variables for some number of periods in the future. For example, after a contractionary monetary policy shock we restrict the impulse response function of reserves to be non-positive. Some variables in the system are restricted in this way while others, typically the variables we are most interested in studying, are left unrestricted. Due to space restrictions and the notion that U.S. monetary policy is a central part of global monetary changes we focus on identifying only the shock to U.S. monetary policy. To our data on U.S. short-term interest rates we add data on nonborrowed and total reserves to our VAR as well as either the global factors or other U.S. variables of interest, such as house prices. We then identify the (contractionary) monetary shock as the shock that results in a set of impulse response functions consistent with 1) a increase in interest rates that is not reversed for at least 4 quarters, 2) a non-positive change in growth of total reserves for 4 quarters, 2) a non-positive change in growth of nonborrowed reserves for 4 quarters. Technical details of the procedure are in Appendix B.

Our first VAR captures the effects of a U.S. monetary shock on the rest of the world. Our VAR has 6 variables, the 3 U.S. variables used to identify the shock as well as the global house, stock and long-term interest rate factors. Figure 7a displays the impulse responses associated with this shock. The U.S. shock leads to an immediate and large response of long-term interest rates to the shock. The effects of this

shock remain for 5-6 quarters. The response of the global housing factor is negative as expected and does not reach its peak until the 5th quarter. The median maximal response is around a 0.8% decline in house prices. The effect is also very long lived, and significant even 10 quarters into the future. The response of each individual country varies by its factor loading, however the average factor loading is close to 1 so this impulse response is indicative of the typical magnitude of the response. The response of the global stock factor is initially positive and turns negative by the 3rd quarter, though the negative response is only statistically significant in the 5th and 6th quarters. The initial positive response may indicate that U.S. monetary policy is responding to asset price shocks. We also estimated a separate VAR with the same variables as above except we used the global GDP factor instead of the stock factor (issues associated with degrees of freedom make estimating a 7 variable VAR problematic). The response of GDP is shown in Figure 7b, the responses of the other variables are the same as in Figure 7a so they are omitted. The results in this case are ambiguous, with some tendency for a decline in global GDP. This result is consistent with Uhlig's (2005) finding for the U.S. that the effects of monetary policy on GDP are uncertain. Taken together, these IRFs indicate that the effects of U.S. monetary shocks, which impact global interest rates rapidly, only affect global asset prices with a significant delay. Furthermore, the impact of U.S. monetary policy shocks on global wealth through changes in these asset prices is more concentrated in housing than in stocks. However, the effect of these shocks on real output is ambiguous, on average. In revision of this paper we will study this issue country-by-country to see if there are real output effects on at least a subsample of our countries, such as those in Europe.

Our second VAR focuses on the response of U.S. house prices to the U.S. monetary shock. This VAR contains the same 3 U.S. monetary variables as well as U.S. house prices, U.S. stock prices and long term U.S. interest rates. Figure 8 contains the impulse response functions for the latter 3 variables, the IRF for the first 3 variables are virtually the same as in Figure 7a so they are omitted. Figure 9 displays the median IRF from the U.S. and global VAR to facilitate comparison of the two. The response of U.S. house prices reaches its maximal effect much more rapidly (2nd quarter versus 5th quarter) than for global house prices. Consistent with this response, the recovery of U.S. house prices is much more rapid, though

the contractionary effect does still last for 6 periods. The response of the U.S. stock market is slightly more rapid than the global stock market, reaching its peak at 4 quarters instead of 5. The response also appears to be greater in magnitude. Finally, it appears that the response of long term interest rates in both the U.S. and globally is very similar. The finding that monetary shocks both manifest and dissipate more rapidly in the U.S. suggests that understanding the frictions that lead to these results may lead to a better understanding of the differential impact of U.S. monetary shocks on the U.S. and the rest of the world.

IV Conclusion

The paper first documented the degree and nature of the comovement across 4 types of variables: real, interest rates, stock returns and house prices. We find that the degree of comovement in house prices is quite high, on the same order of magnitude as real variables, and somewhat less than for financial variables. From a cyclical perspective, it appears that the global cycles in house prices, stock returns and real variables move with different periodicities, or cycle lengths. House prices have the longest cycle length, while stock returns have the shortest. We find that much of the comovement in house prices and stock returns are specific to those variables and not common with interest rates or real variables. On the other hand, we find a greater degree of comovement across real variables and interest rates.

A VAR analysis of house prices shocks show that a shock that originates in the U.S. will affect house prices in the rest of the world, but with a significant delay. Additionally, we find that a housing price shock of almost 1% will reduce GDP growth around 0.2%. This response is persistent, but not catastrophic for the economy. We then turned to the identification of monetary shock using a ‘robust’ identification procedure. We find both similarities and difference in the effects of a U.S. monetary shock on the U.S. and the rest of the world. For long-term interest rates, the responses are nearly identical. For house prices, the response in the U.S. reaches its peak more rapidly while the response globally takes significantly longer to reach full impact. For stock returns, the response in the U.S. is slightly quicker and more dramatic. In no case can we find a significant response of GDP to a contractionary monetary policy shock.

References

- Jusan Bai, and Serena Ng, 2002, "Determining the Number of factors in Approximate Factor Models," *Econometrica*, 70, 191-221.
- Baxter, Marianne and Michael Kouparitsas, 2004, "Determinants of Business Cycle Comovement: A Robust Analysis," Working paper, Boston University.
- Bernanke, Ben, Jean Boivin, and Piotr Elias, 2004, "Measuring the Effects of Monetary Policy: A Factor-Augmented Vector Autoregressive (FAVAR) Approach," Finance and Economics Discussion Series, 2004-3. Federal Reserve Board.
- Case, Bradford, William Goetzmann, and Geert Rouwenhorst, 1999, "Global Real Estate Markets: Cycles and Fundamentals," Yale International Center for Finance, WP No. 99-03.
- Chrinko, Robert S., Leo de Haan, and Elmer Sterken, 2004, "Asset Price Shocks, Real Expenditures, and Financial Structure: A Multi-Country Analysis", Working paper, Emory University.
- John Y. Campbell and Joao Cocco, 2004, "How Do House Prices Affect Consumption? Evidence from Micro data", Harvard working paper.
- Canova, Fabio and Gianni de Nicolò, 2003. "On the Sources of Business Cycles in the G-7," *Journal of International Economics*, vol 59:1, pp 77-100.
- Canova, Fabio, Eva Ortega and Matteo Ciccarelli, 2004, "Similarities and Convergence in G-7 Cycles," ECB working paper No 312.
- Davis, Morris and Jonathan Heathcote, 2003, "Housing and the Business Cycle," Working Paper No. , Federal Reserve Board.
- Davis, Morris and Jonathan Heathcote, 2004, "The Price and Quantity of Residential Land in the United States," Working Paper No. , Federal Reserve Board.
- Dees, Stephane, Filippo Di Mauro, M Hashem Pesaran and Vanessa Smith, 2005, "Exploring the International Linkages of the Euro Area: A Global VAR Analysis", CESifo working paper 1425.
- Faust, Jon, 1998, "The Robustness of identified VAR conclusions about money," Carnegie-Rochester Conference Series in Public Policy, 49:207-244.
- Forni, M., and L. Reichlin (1998), "Let's Get Real: A Factor Analytical Approach to Disaggregated Business Cycle Dynamics," *Review of Economic Studies* 65:453-73.
- Gregory, Allan W.; Allen C. Head and Jacques Raynaud. "Measuring World Business Cycles." *International Economic Review*, August 1997, 38(3), pp. 677-702.
- Kim, Chang-Jin, and Charles R. Nelson, (1998), "Business Cycle Turning Points, a New Coincident Index, and Tests for Duration Dependence Based on A Dynamic Factor Model with Regime Switching," *Review of Economic Statistics*, 80:188-201.

- Kose, Ayhan, Christopher Otrok, and Charles Whiteman, 2003, "International Business Cycles: World, Region, and Country-Specific Factors," *American Economic Review*, Vol. 93, No. 4.
- Piazzesi, Monika, and Martin Schneider and Selale Tuzel, 2004, "Housing, Consumption and Asset Pricing, Chicago GSB working paper.
- Quan, Daniel and Sheridan Titma, 1998, "Do Real Estate Prices and Stock Prices Move Together? An International Analysis," *Real Estate Economics*, Vol. 27, No.2
- Sargent, Thomas J. and Christopher A. Sims, 1977, "Business Cycle Modeling Without Pretending to Have Too Much A Priori Economic Theory," in Christopher A. Sims et al., eds., *New Methods in Business Cycle Research*. Minneapolis: Federal Reserve Bank of Minneapolis, pp. 45-108.
- Sims, Christopher, 1980, "Macroeconomics and Reality," *Econometrica*, 48:1-48.
- Spearman, Charles, 1904, "General Intelligence, Objectively Determined and Measured,": *American Journal of Psychology*, (15) pp. 201-93.
- Stock, J.H. and M.W. Watson (1999), "Forecasting Inflation" *Journal of Monetary Economics*, (44) 2, pp. 293-335.
- Stock, James and Mark Watson, 2002, "Macroeconomics Forecasting Using Diffusion Indexed," *Journal of Business and Statistics*, Pp. 147-162.
- Stock, James and Mark Watson, 2004, "Understanding Changes in International Business Cycles," NBER Working Paper.
- Uhlig, Harald, 1998, "The Robustness of identified VAR conclusions about money: A Comment" *Carnegie-Rochester Conference Series in Public Policy*, 49:245-263.
- Uhlig, Harald, 2005, "What Are the Effects of Monetary Policy on Output? Results from an Agnostic Identification Procedure," *Journal of Monetary Economics*, 52:381-419.

Appendix A: Sample Composition and Data Sources.

This appendix provides details on the sample composition and data sources. The sample used in this paper includes the following 13 countries: Australia, Canada, Denmark, Ireland, Italy, Japan, New Zealand, the Netherlands, New Zealand, Norway, Sweden, Switzerland, the United States, and the United Kingdom. The data is quarterly and covers the 1980:Q1 to 2004:Q4 period.

Data was taken from a variety of sources, including the European Central Bank (ECB), European Mortgage Foundation (EMF), Eurostat, Haver Analytics, IMF International Statistics, national authorities, the OECD Analytical Database, and the World Development Indicators from the World Bank.

Main financial and housing series:

- 1) Real asset prices. These are calculated as the ratio of the nominal house price (stock price) index to the consumer price index. The house price index is obtained from national sources while the stock price index and consumer price indexes are obtained from the IMF International Financial Statistics.
- 2) Interest rates. The short- and long-term interest rates series were obtained from OECD, Analytical Database and Haver Analytics. Short-term interest rates are the 3-month inter-bank rates while long-term rates are government bonds rates (typically 10-year bonds).

Main macroeconomic series.

The real GDP, private consumption, and private residential investment are from the OECD Analytical Database and the WEO Database.

Appendix B: MCMC Estimation of the Dynamic Factor Model

[to be added]

Appendix C: Identifying Monetary Shocks with Sign Restrictions

[to be added]

Table 1: Variance Decompositions

		House	Stock	D LR	D SR	Cons	GDP	Res Inv
U.S	World	0.92%	0.58%	30.56%	48.93%	15.66%	43.94%	42.65%
	Country	7.30%	0.61%	1.31%	1.23%	47.79%	32.63%	7.86%
	Aggregate	57.99%	73.95%	41.33%	11.56%	11.95%	8.63%	1.94%
U.K.	World	8.09%	0.28%	23.93%	15.22%	7.98%	11.28%	9.28%
	Country	0.17%	6.56%	15.83%	27.31%	0.76%	0.91%	2.18%
	Aggregate	69.35%	67.44%	45.17%	11.43%	34.34%	28.50%	0.88%
Denmark	World	5.89%	8.97%	0.74%	7.08%	2.22%	3.94%	0.94%
	Country	0.73%	0.45%	8.06%	10.18%	0.63%	0.96%	0.51%
	Aggregate	2.36%	34.74%	54.12%	29.51%	0.99%	16.57%	17.19%
Italy	World	0.60%	8.06%	0.89%	0.56%	3.24%	18.00%	9.83%
	Country	18.60%	0.20%	29.87%	60.14%	9.88%	5.85%	1.57%
	Aggregate	2.91%	33.69%	53.78%	23.33%	23.62%	20.15%	1.66%
Netherlands	World	2.07%	7.48%	20.15%	13.05%	0.98%	23.12%	2.10%
	Country	29.60%	2.71%	6.27%	8.21%	56.81%	52.85%	44.16%
	Aggregate	17.19%	69.83%	56.97%	33.94%	14.87%	13.47%	2.34%
Norway	World	3.94%	22.64%	0.50%	8.38%	0.46%	5.69%	7.00%
	Country	2.23%	4.13%	2.63%	1.31%	1.08%	2.25%	0.74%
	Aggregate	7.63%	42.78%	38.72%	21.17%	2.78%	4.32%	2.65%
Sweden	World	4.72%	5.07%	3.30%	0.71%	2.08%	19.17%	12.16%
	Country	0.80%	9.80%	16.52%	42.77%	0.54%	1.52%	12.85%
	Aggregate	44.68%	50.99%	50.18%	12.88%	50.97%	36.62%	2.03%
Switzerland	World	13.26%	3.58%	14.26%	17.80%	4.69%	26.34%	14.49%
	Country	4.92%	1.63%	12.08%	13.29%	3.34%	30.32%	51.80%
	Aggregate	34.83%	78.04%	35.94%	19.96%	52.01%	6.29%	11.19%
Canada	World	4.62%	4.84%	24.96%	35.09%	29.16%	44.57%	32.85%
	Country	0.37%	0.80%	0.36%	2.64%	1.68%	0.96%	0.39%
	Aggregate	40.33%	65.59%	53.94%	35.56%	18.47%	12.57%	1.63%
Japan	World	0.72%	10.49%	1.67%	0.96%	0.50%	3.27%	5.67%
	Country	41.13%	8.45%	3.28%	2.80%	67.62%	57.84%	24.81%
	Aggregate	4.37%	21.76%	28.54%	0.45%	1.31%	1.13%	0.44%
Ireland	World	2.91%	2.05%	0.42%	1.60%	18.74%	7.49%	10.16%
	Country	3.58%	0.33%	3.80%	1.29%	0.44%	0.89%	0.47%
	Aggregate	10.40%	19.18%	60.65%	36.01%	9.92%	14.59%	1.54%
Australia	World	17.16%	2.40%	6.80%	10.02%	15.40%	41.76%	24.01%
	Country	0.33%	2.24%	10.46%	4.73%	1.20%	0.43%	0.85%
	Aggregate	25.87%	47.40%	44.49%	10.71%	1.62%	4.00%	1.38%
New Zealand	World	9.67%	1.94%	0.49%	1.09%	23.74%	13.46%	15.10%
	Country	25.46%	8.45%	0.11%	0.73%	62.48%	32.32%	12.10%
	Aggregate	1.31%	24.37%	2.60%	5.96%	2.74%	0.74%	1.06%

Figure 1

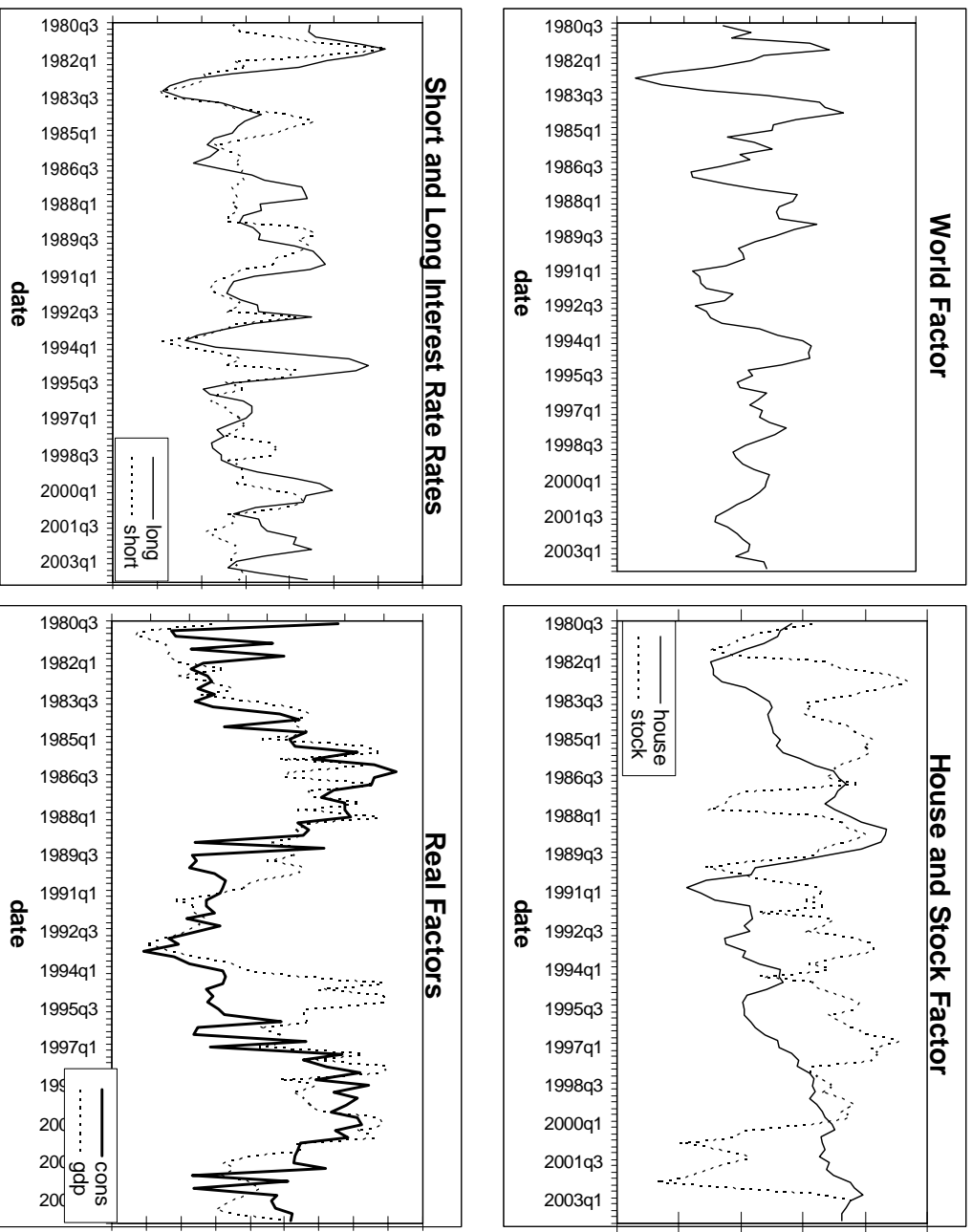
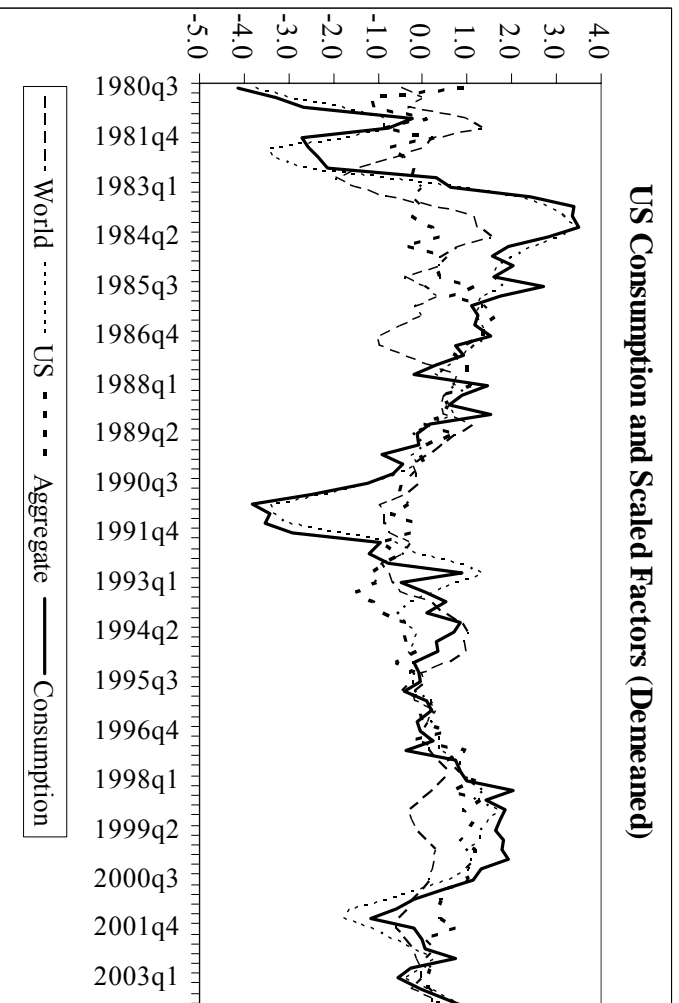
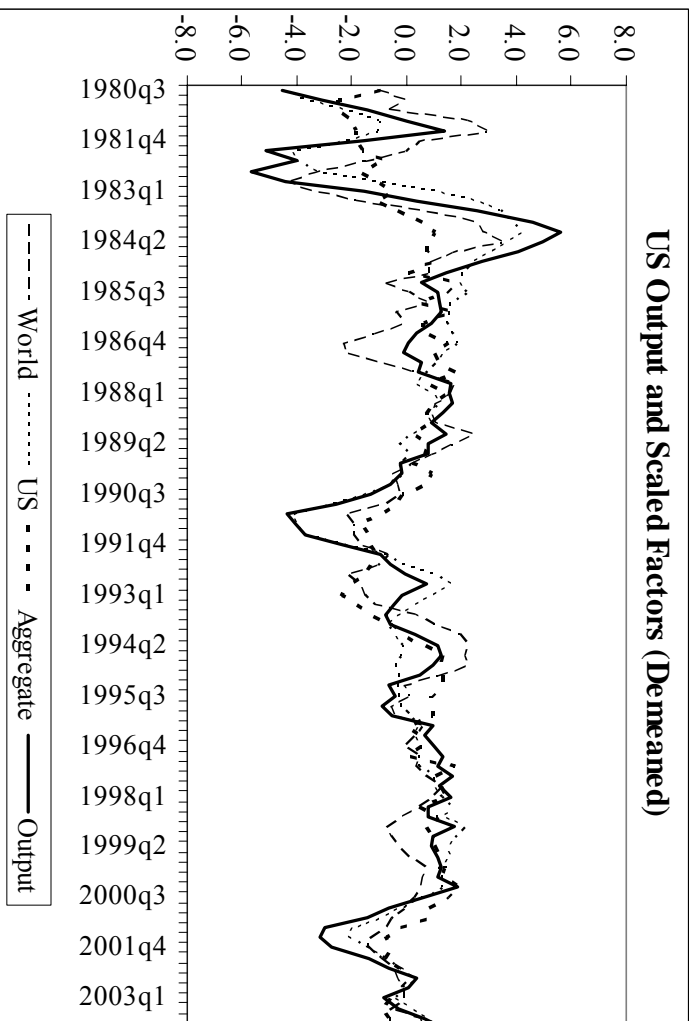
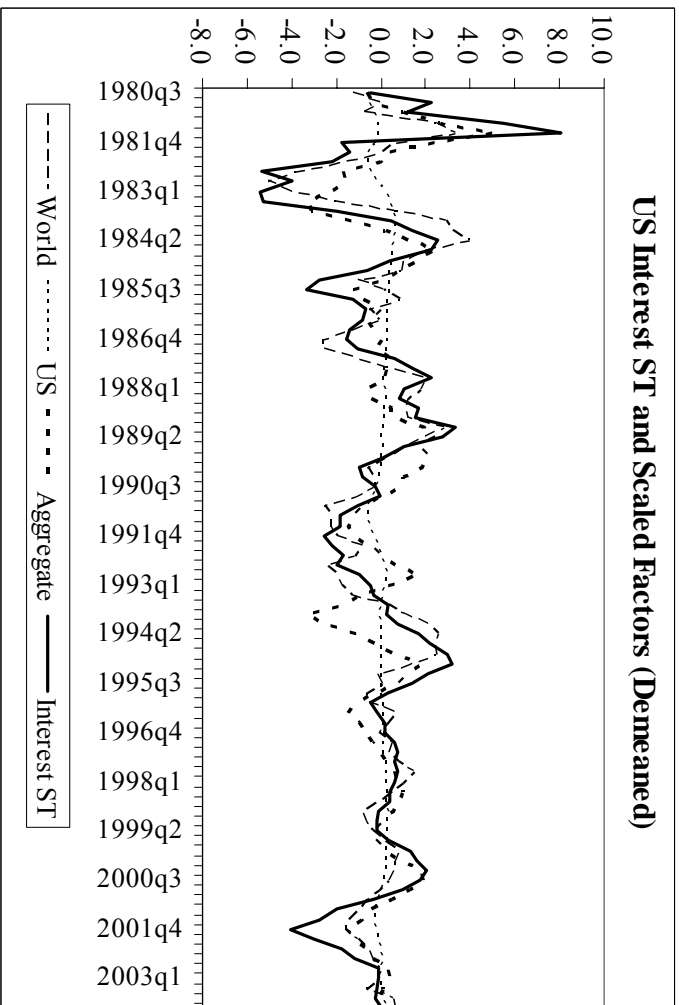
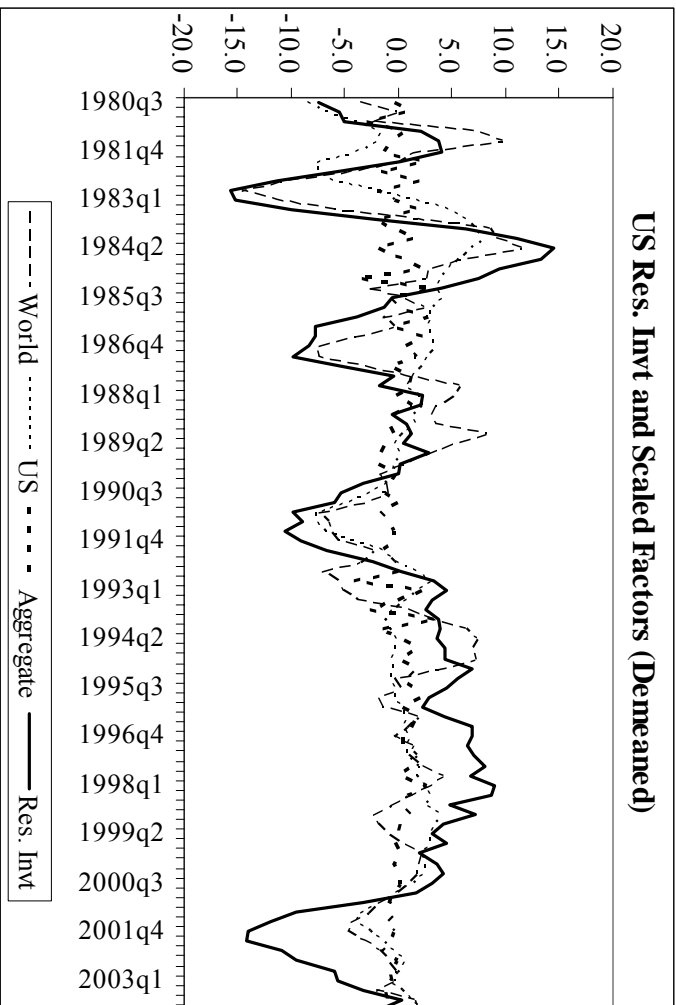
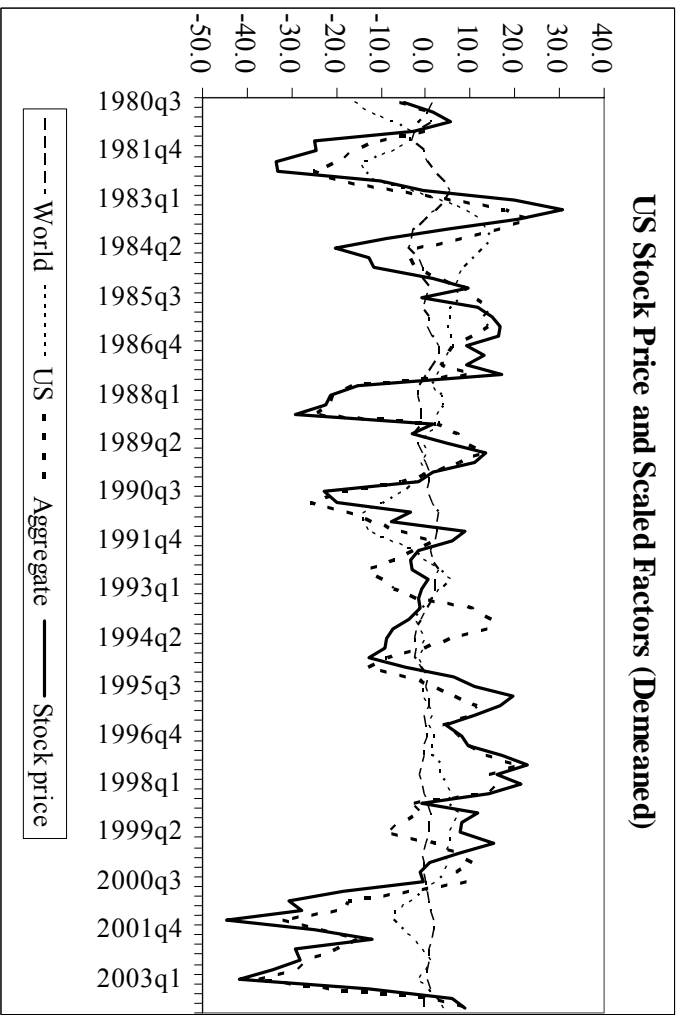
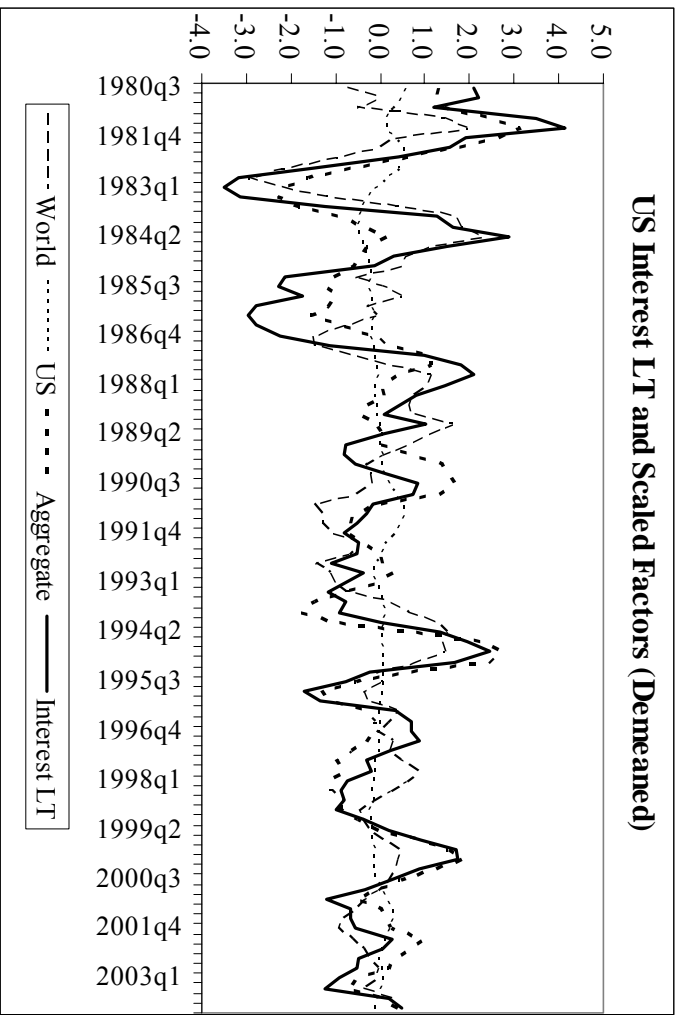


Figure 2







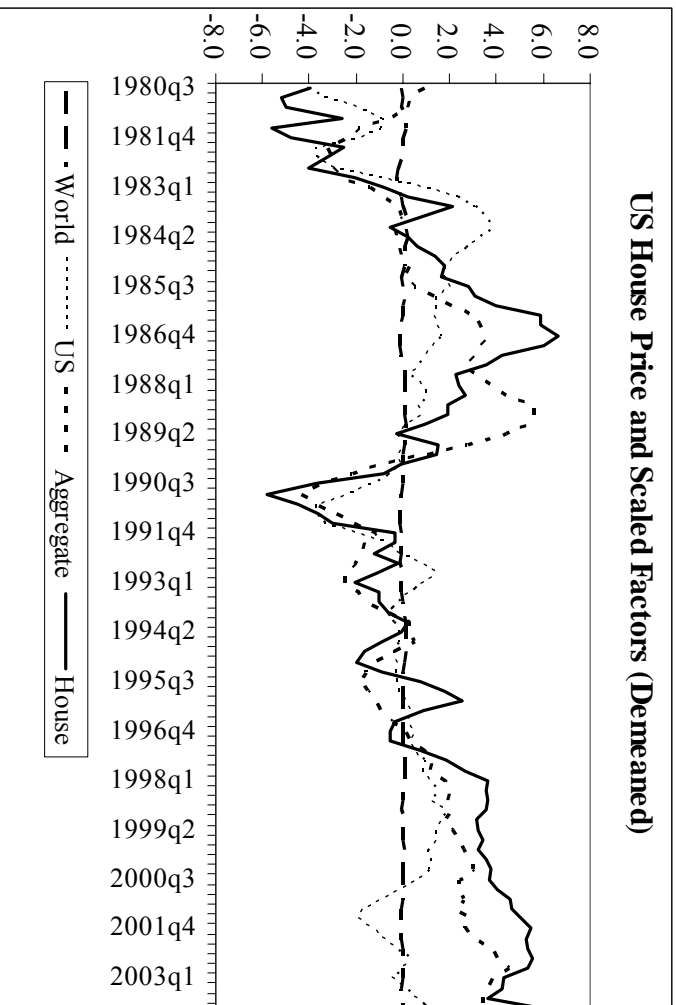
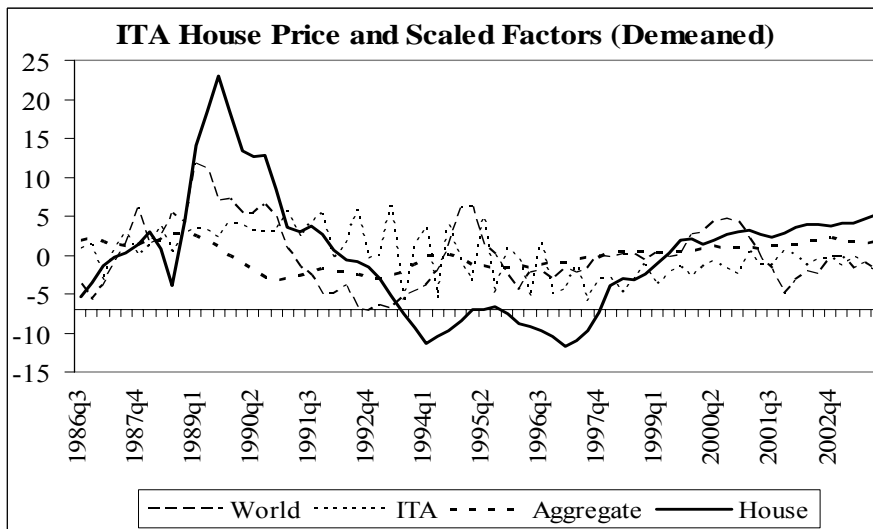
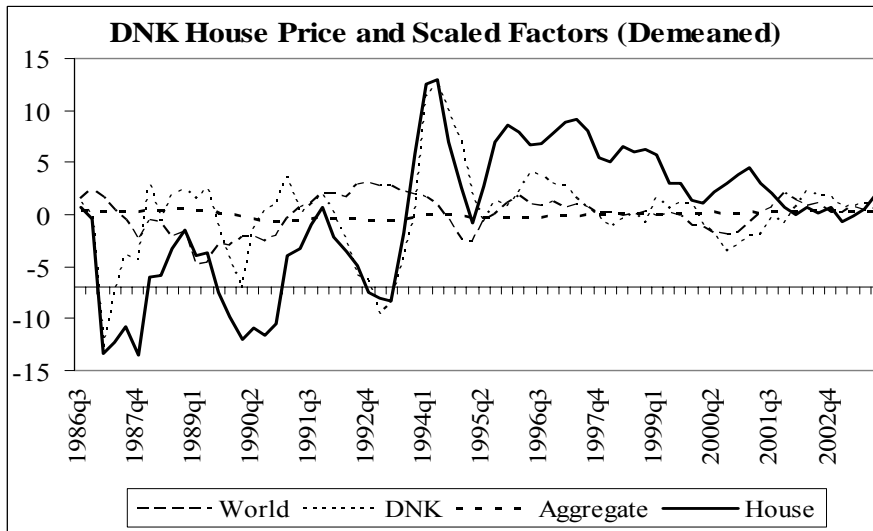
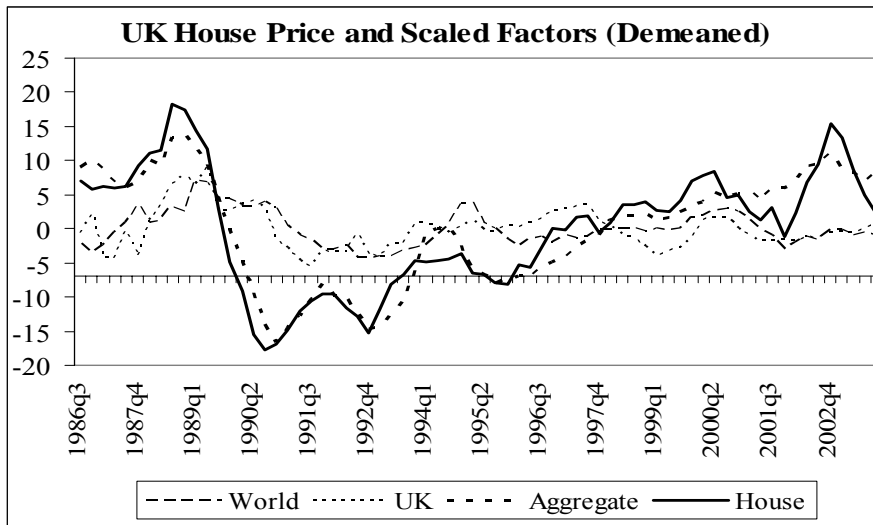
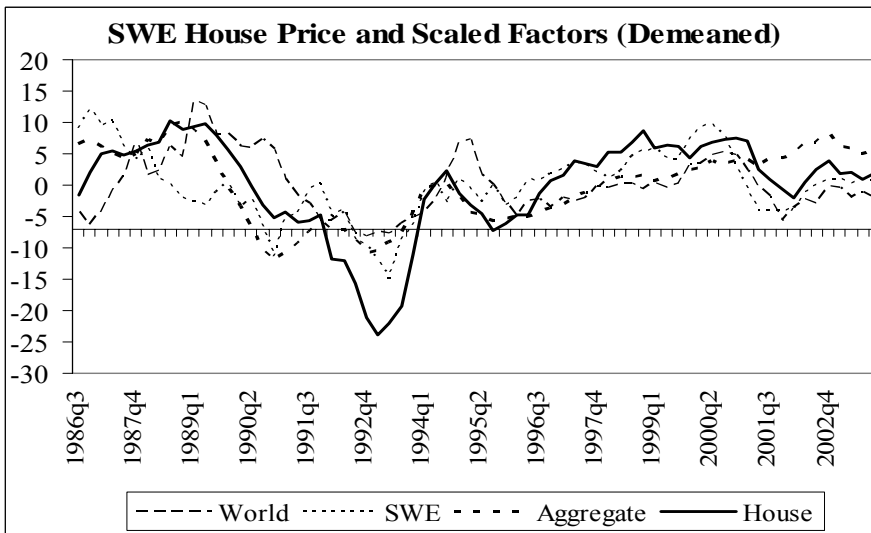
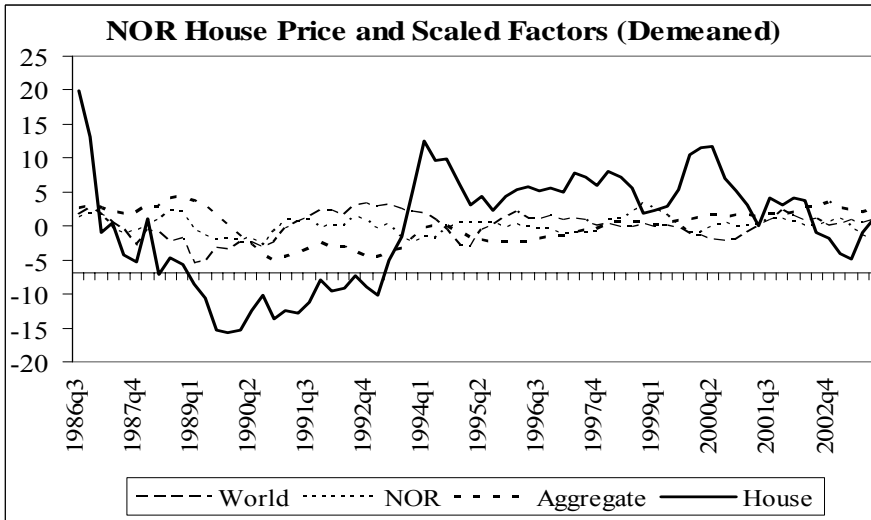
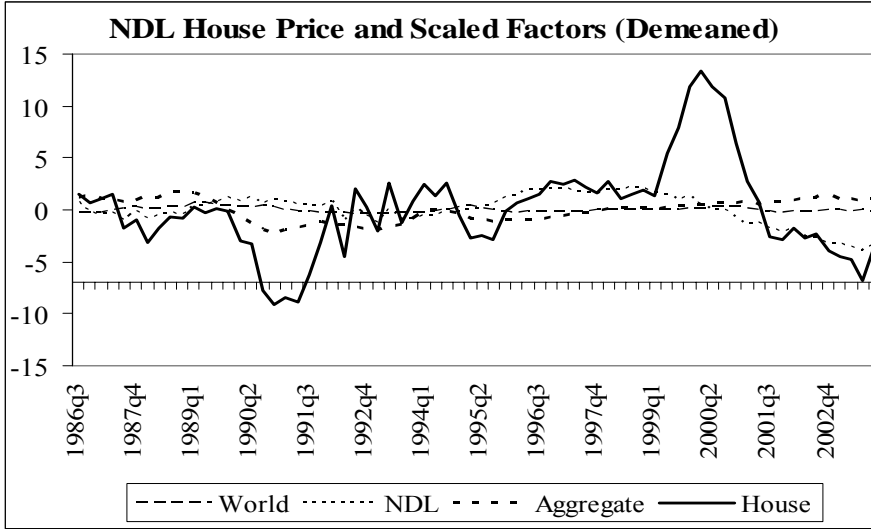
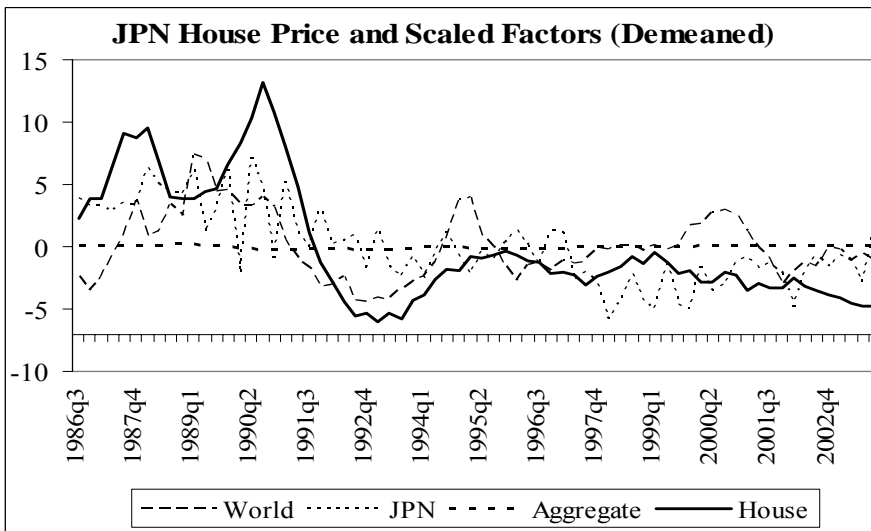
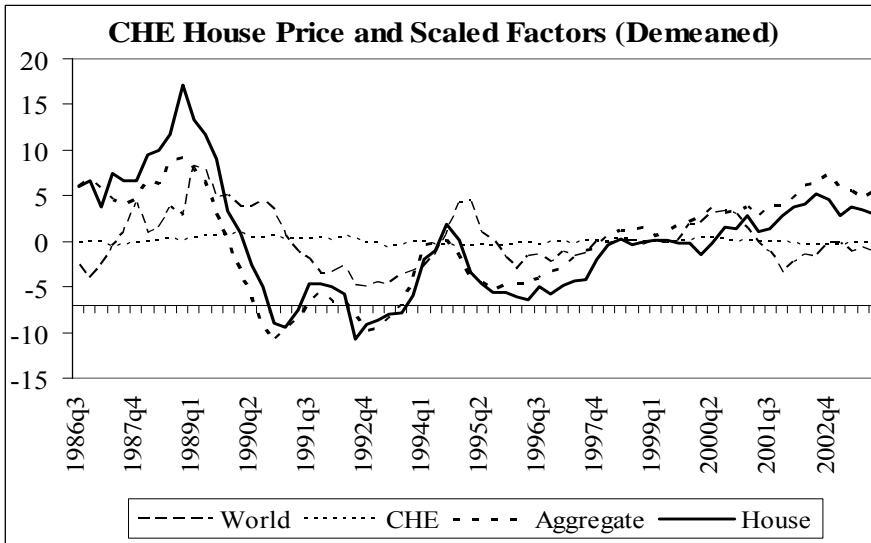
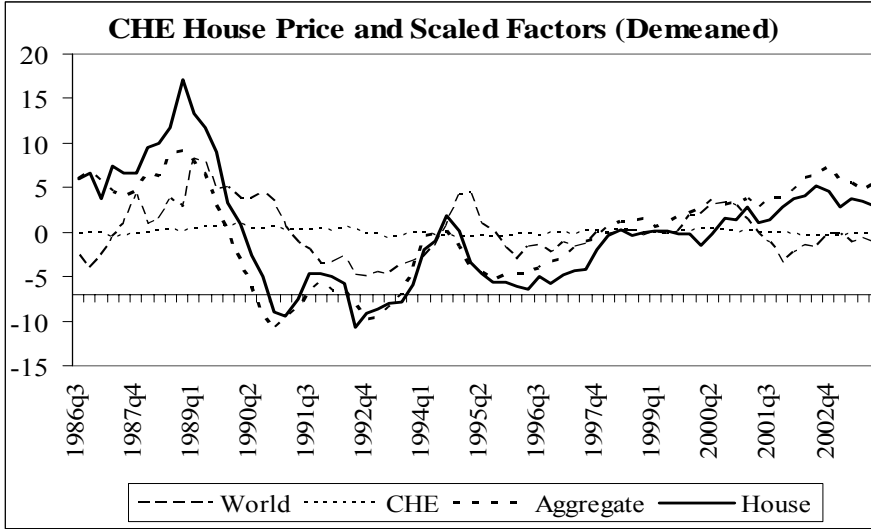


Figure 3







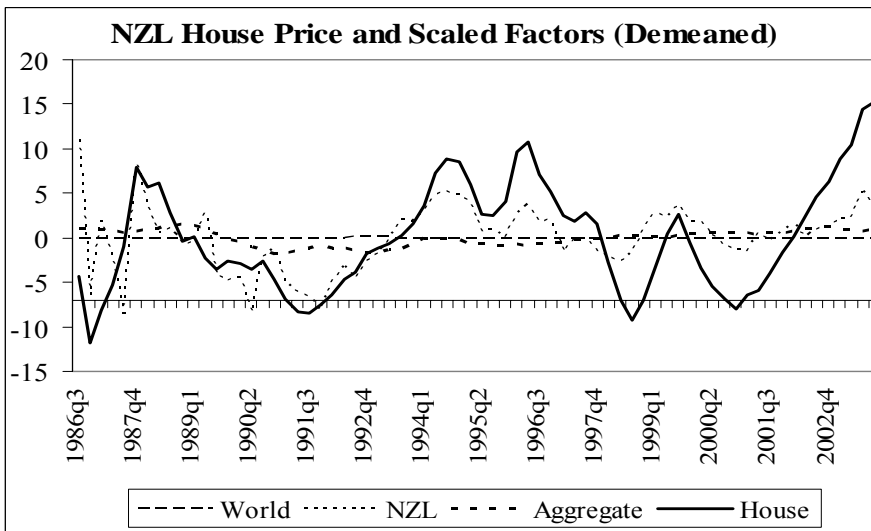
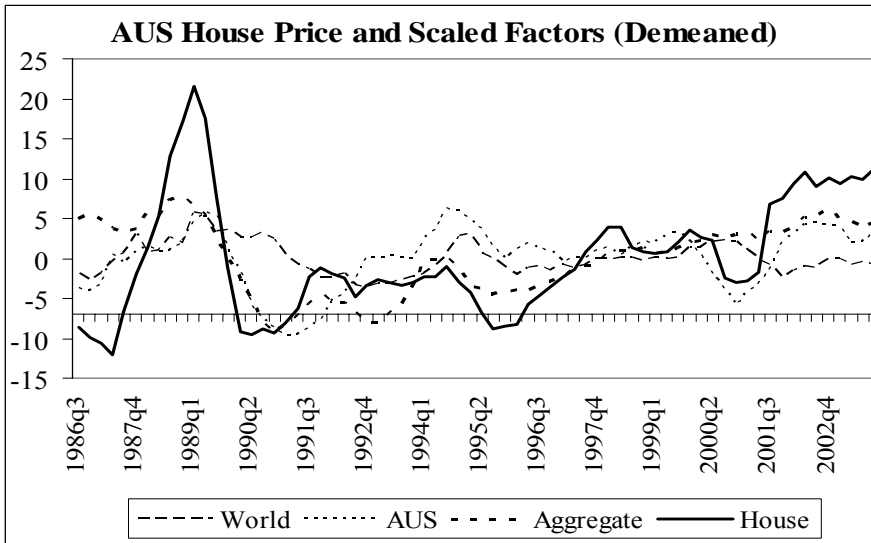
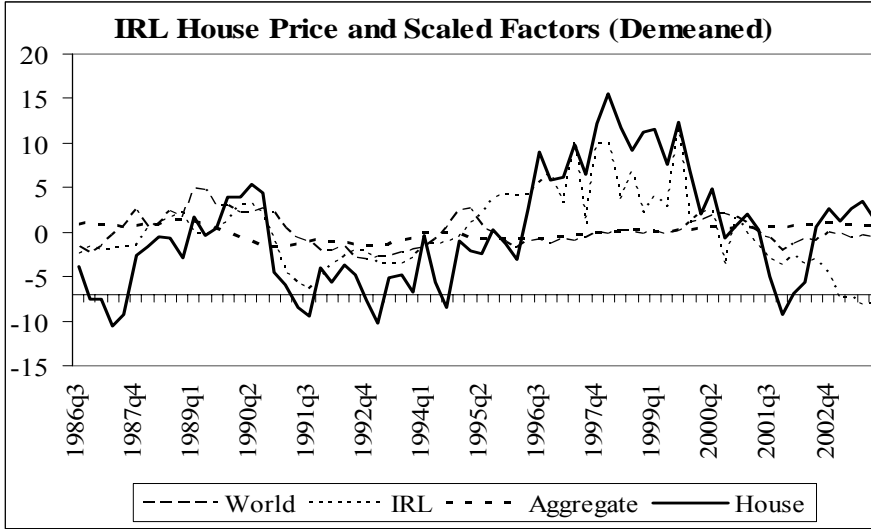


Figure 4: Impulse response: Shock to Housing in US VAR

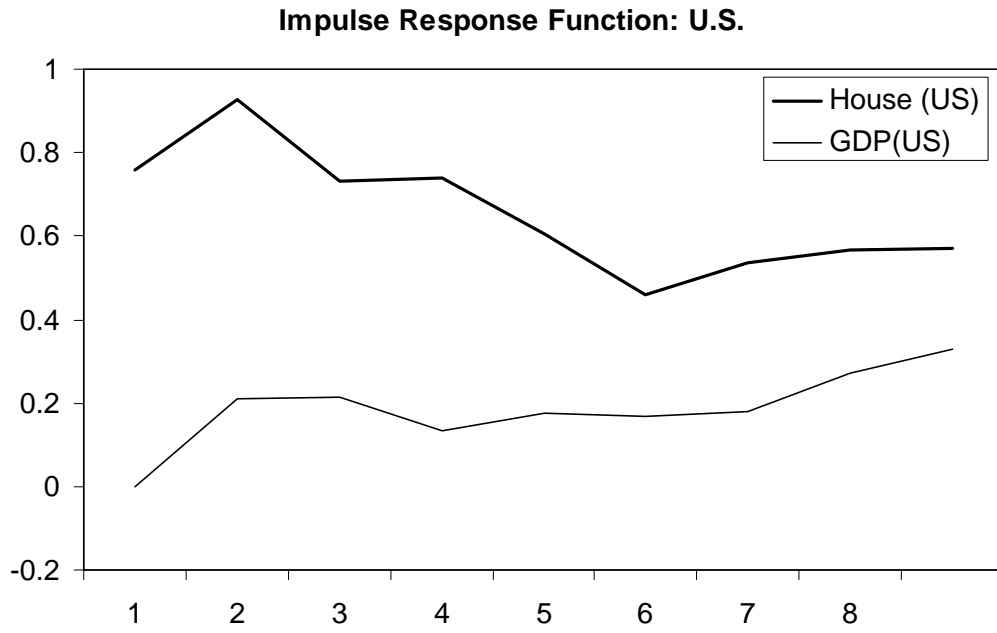


Figure 5: Response of the World to U.S. House Shock

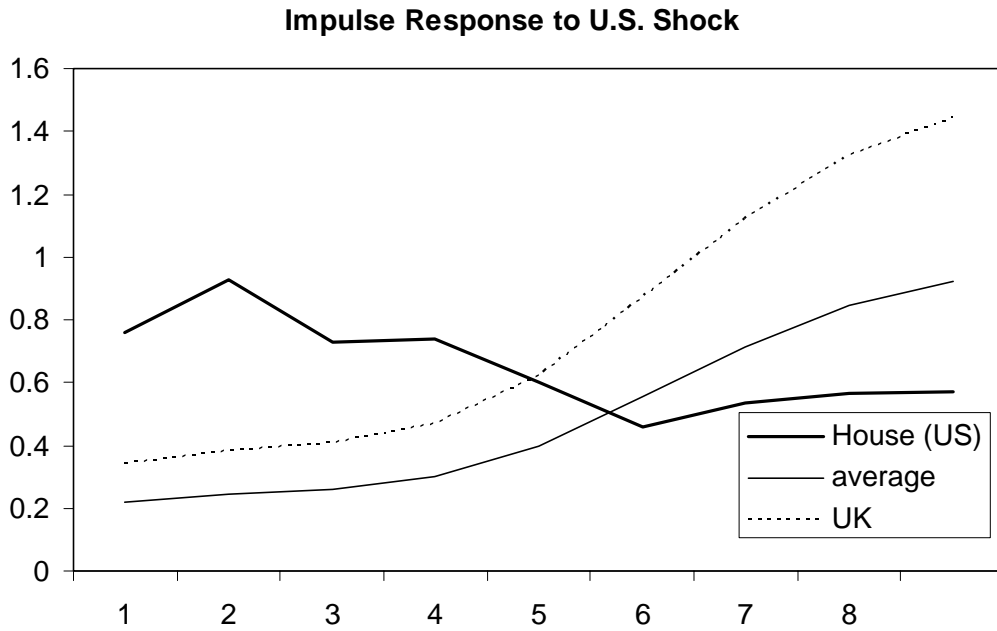


Figure 6: Shock to Global Interest Rates

Average Impulse Response Function

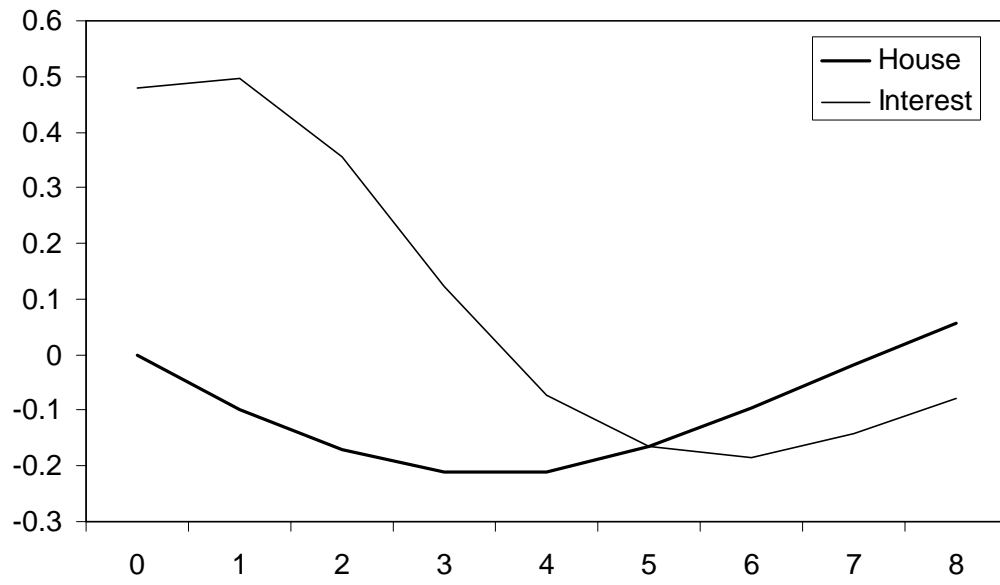


Figure 7a: Shock to U.S. Monetary Policy, Global VAR

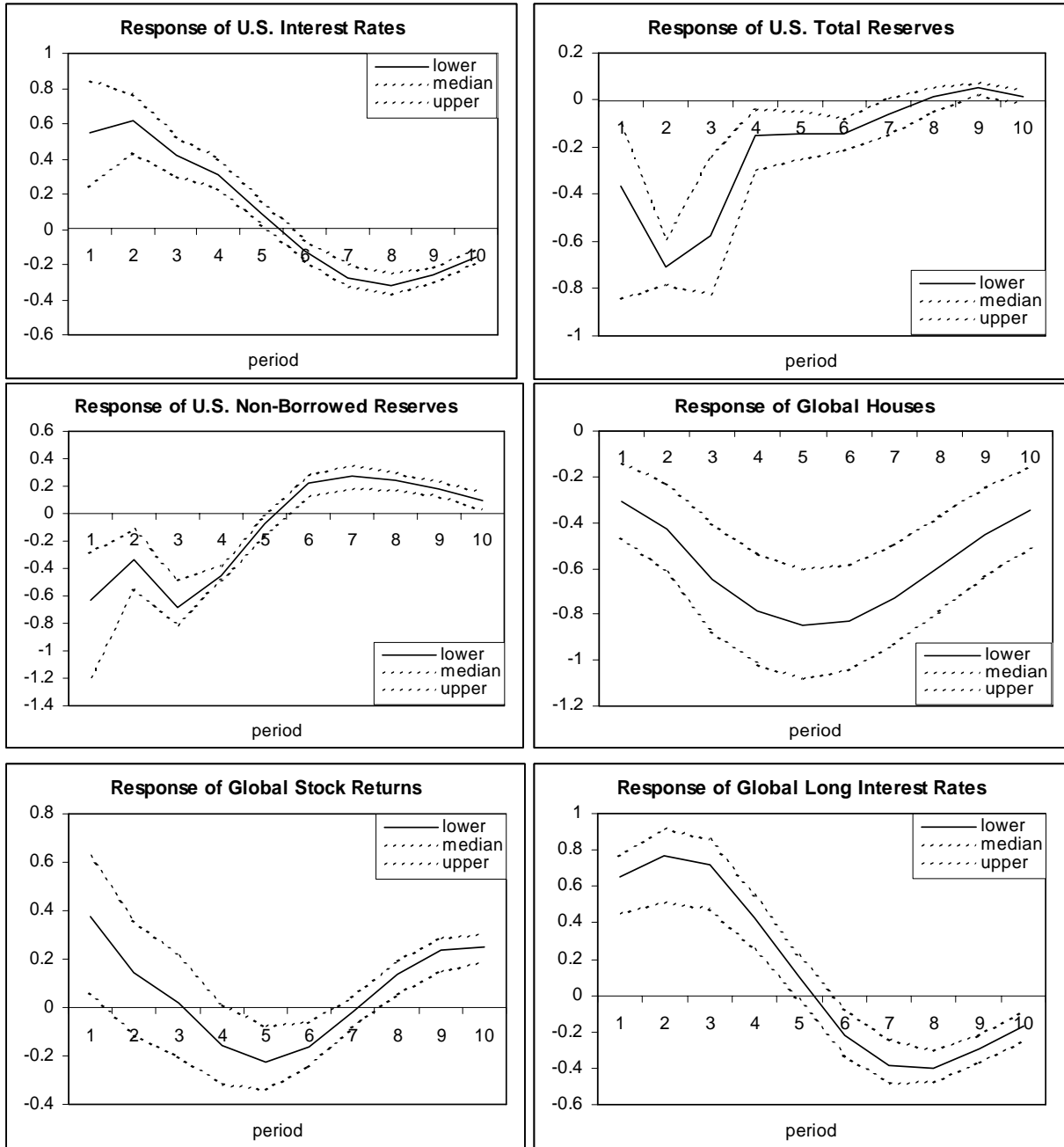


Figure 7b: Response to U.S. Monetary Shock, Global VAR 2

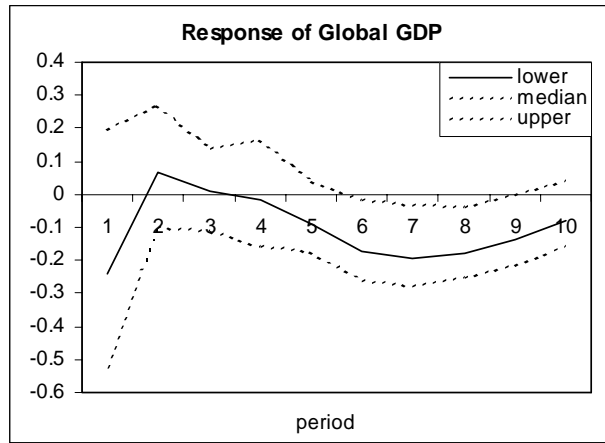


Figure 8: Response to U.S. Monetary Shock, U.S. VAR

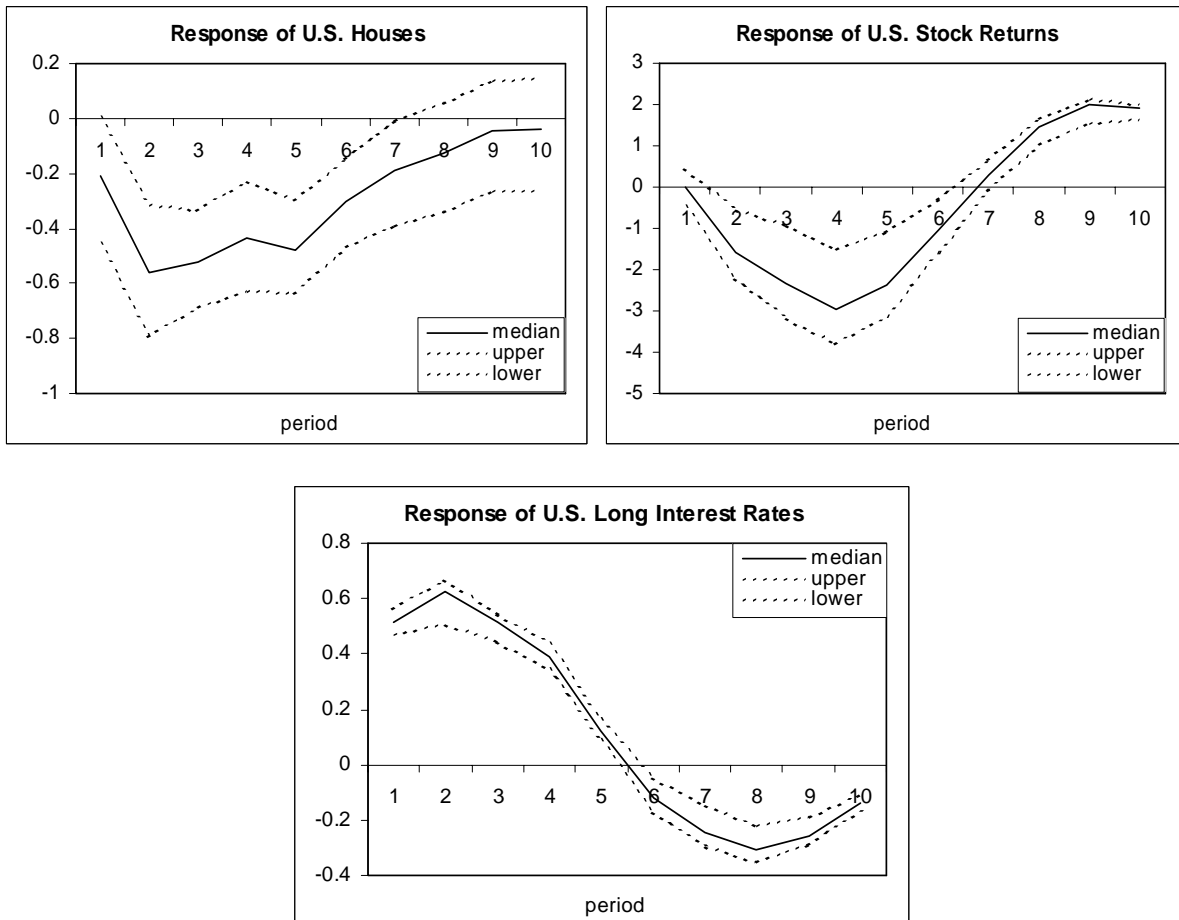


Figure 9: Comparison of Global and U.S. Responses

