Capital Inflows and the US Housing Boom*

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Abstract

We estimate an open-economy VAR model to study the effect of capital-inflow shocks on the US housing market. We look at different external shocks which generate capital inflows to the US, in particular 'savings glut' shocks and foreign monetary policy expansions. The shocks are identified with theoretically-robust sign restrictions derived from a standard Dynamic Stochastic General Equilibrium model. Our results suggest that capital-inflow shocks driven by 'savings glut' shocks have a positive and persistent effect on real house prices and real residential investment.

Key words: house prices, capital inflows
JEL Classification: F3, F4

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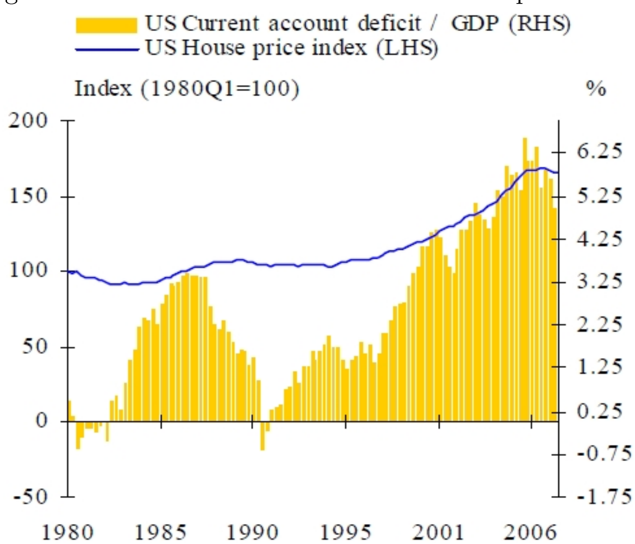
1 Introduction

One of the major sources of the financial and economic problems in the United States during the 2007-2009 financial crisis was the collapse of the housing boom that had been developing since the mid-1990s. This build up in house prices happened at the same time as the widening in the US current account deficit (Figure 1).

Figure 1. Current account balance and house prices



Sources: OECD Economic Outlook, Federal Housing Finance Agency (FHFA).

Several recent papers argue that the causality behind this correlation goes from real house prices to the current account. Laibson and Mollerstrom (2010) focus on domestic asset price bubbles as an explanation for current account deficits. Their model predicts a consumption, but not investment, boom and a current account deficit as a result of a domestic asset price bubble. Similarly, Gete (2010) shows that increases in housing demand may generate trade deficits via consumption smoothing across tradable and nontradable goods. Housing is a durable good that must be locally produced. If the desire to smooth consumption across goods is sufficiently strong, countries import tradable goods during periods when more domestic labor is devoted to the production of nontradables. Through this channel, housing booms cause current account deficits. Empirically, Fratzscher, Juvenal and Sarno (2010) find that real equity and house price movements in the US can explain up to 32% of the US trade balance, giving support to this stream of theoretical work.

By contrast, policy makers argue that the causality behind this correlation goes from the current account to real house prices. According to this view, the housing boom was caused by the increase in capital inflows to the US that has been occurring since the mid-1990s. During that period, the US current account deficit widened while other countries, especially oil exporters and Asian economies, have been building surpluses. The flow of capital from EMEs to the US generated an increase in liquidity in the US financial system and drove down long-term real interest rates. Low interest rates reduced the cost of borrowing and encouraged a credit boom and an increase in house prices.

Low risk-free rates led portfolio investors to allocate a larger part of their wealth to higher-yielding (and riskier) assets, including US sub-prime residential mortgage-backed securities and leveraged corporate loans. This hypothesis is advanced in King (2009), who suggests that "the origins of the crisis lie in the imbalances in the world economy which built up over a decade or more". Similarly, Bernanke (2010) shows that "countries in which current accounts worsened and capital inflows rose had greater house price appreciation" in the period from 2001Q4 to 2006Q3. He concludes that capital inflows seem to be a promising avenue for explaining cross-country differences in real house price growth.

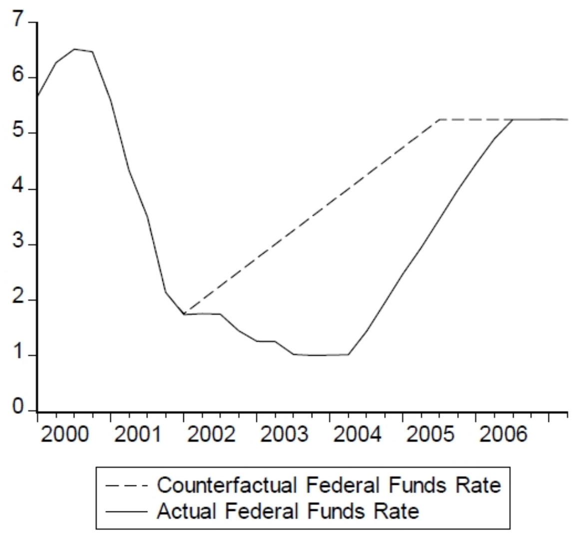
In an influential speech, Bernanke (2005) suggests that a satisfying explanation for the increase in the US current account deficit requires a global perspective that takes into account events outside the United States. In particular, Bernanke (2005) suggests that a combination of diverse forces has created a significant increase in the global supply of savings – a 'global savings glut' – which helps to explain both the increase in the US current account deficit and the relatively low level of long-term real interest rates in the US and the rest of the world in the early 2000s. He suggests that the rapid increase in the US current account deficit "was fueled to a significant extent both by increased global saving and the greater interest on the part of foreigners in investing in the United States".

The second channel mentioned by Bernanke — the increase in the preference of foreign investors for US assets — is studied in Caballero et al (2008) and Mendoza et al (2009). These papers propose models where the US has more developed financial markets than the rest of the world. In Caballero et al (2008) higher financial development in the US is modelled as a greater capacity to generate financial assets from real investments. In Mendoza et al (2009) it is modelled as a greater capacity of the US legal system to enforce financial contracts among its residents which can be used to insure against idiosyncratic risks. In both models, greater financial development in the US leads to capital inflows from abroad, a current account deficit and a decline in long-term interest rates. More recently, Acharya and Schnabl (2010) and Shin (2011) qualify this hypothesis and argue that a 'global banking glut' describes capital flows before the 2007-2009 financial crisis better than a 'global savings glut', since global banks outside the US were investing a large amount of funds in long-term US assets.

To our knowledge, no previous empirical work has studied the direct effect of these external factors on the US housing market. In this paper we aim to fill this gap. We estimate an open-economy vector autoregressive (VAR) model with US and foreign variables and identify two types of external shocks with sign restrictions. The first type of shock is a 'savings glut' shock, which can be interpreted as a shock that makes foreign investors more patient or a shock that increases their preference for US assets. The second type of shock is a monetary expansion abroad, which reduces foreign interest rates and increases the relative attractiveness of US assets, leading to capital inflows into the US. In addition to these external shocks, we also identify two types of domestic shocks: a US monetary expansion and a shock that captures both a domestic financial deregulation shock, which we model as an increase in the loan-to-value ratio, and an increase in the preference for housing in the US, as in Gete (2010) and Iacoviello and Neri (2010).

The role of US monetary policy in explaining the increase in house prices in the US is studied in Taylor (2007). Taylor (2007) argues that the US housing boom can be explained by the fact that the Federal Reserve kept nominal interest rates too low for too long after the 2001 recession. Figure 2 — reproduced from Taylor (2007) — compares the actual Federal Funds Rate with the nominal interest rate predicted by a standard Taylor rule with coefficients of 1.5 and 0.5 on inflation and real GDP, respectively, and smoothed to have 25 basis point increment adjustments in the interest rate. This figure shows clearly that monetary policy in the US was excessively expansionary between 2001 and 2005 compared with what an interest rate rule that fitted the data well in the previous two decades would suggest. In this paper, we compare the contribution of US monetary-policy shocks to the housing boom with that of external shocks and other domestic shocks.

Figure 2. Actual and counterfactual Federal Funds Rate



Source: Taylor (2007).

The sign restrictions used for identification are derived from a two-country dynamic stochastic general equilibrium (DSGE) model similar to the one in Ferrero (2012) and are robust across a range of parameter values. The model has tradable consumption goods and housing and introduces an endogenous borrowing constraint for households, as in Kiyotaki and Moore (1997). In the empirical analysis, the variables of interest — real house prices and real residential investment — are left unrestricted and their responses to the identified shocks are determined by the data.

Previous empirical work on this issue focused mostly on the effect of capital flows on US interest rates. Warnock and Warnock (2009) estimate that, if there had been no foreign official flows into US government bonds over the course of a year, long-term interest rates would be almost 100 basis points higher. Focusing on the spread between the yields on long-maturity corporate bonds and Treasury bonds, Krishnamurthy and Vissing-Jorgensen (2012) find that, if governmental holders (foreign central banks, US Federal Reserve banks, state and local governments) were to sell their holdings of US Treasuries and exit the market, the yield on US Treasuries would rise by the same amount as the yield on corporate bonds. Caballero and Krishnamurthy (2009) develop a model to show how capital flows to the US triggered a sharp rise in asset prices and a decrease in risk premia and interest rates. All these studies point to a link between low US long-term interest rates and the demand for US assets by foreign savers.

There is also a theoretical literature on the effect of capital inflows on the US housing market. Favikulis, Ludvigson and Van Nieuwerburgh (2010) use a small open economy model with endogenous interest rates and exogenous capital flows to show that the inflow of foreign money into domestic bond markets plays only a small role in driving up house prices, despite its large depressing influence on interest rates. By contrast, Adam, Kuang and Marcet (2011) use a small-open-economy model with adaptive learning about house price behavior to show that a decline in the world real interest rate can lead to a substantial increase in real house prices and a current account deficit. Quantitatively, their model can replicate the evolution of the current account and real house prices observed in US in the 2000s.

A related body of work looks at the role of financial innovation in the US as a driver of the correlation between real house prices and the current account. Boz and Mendoza (2012) develop a model with a collateral constraint in which agents learn over time the true riskiness of new financial assets. Agents form their beliefs by observing past realizations of the leverage ratio. Early realizations of states with high ability to leverage assets into debt turn agents overly optimistic about the persistence of a high-leverage regime. This leads to overborrowing and a boom in house prices. Their model predicts a large increase in household debt and in residential land prices between 1997 and 2006, followed by a sharp collapse in 2007. Another recent study suggesting that financial deregulation plays an important role in accounting for house price booms and current account deficits is Ferrero (2012). Using a calibrated two-country framework with tradable consumption goods and housing, this study shows that lower collateral requirements lead to an increase in borrowing from the rest of the world and an increase in house prices.

The study that is closest to ours is Bracke and Fidora (2008), which explains the evolution of the US current account balance and asset prices by three types of shocks: monetary-policy shocks, preference shocks (capturing changes in the savings rate), and investment shocks. The authors estimate two separate structural VARs, for the US and emerging Asia. For the US, they look at a monetary-policy expansion, a reduction in the savings rate and an increase in investment. For emerging Asia, they define these shocks with the opposite signs (monetary-policy contraction, increase in the savings rate and reduction in investment). The shocks are identified by imposing sign restrictions on the impulse responses. However, their VAR model does not include US housing market variables, the sign restrictions are not formally derived from a DSGE model and the model is expressed in cross-country differences. This last point implies that the model can only be used to identify relative shocks, but the origin of these shocks cannot be determined. As a result, the model cannot be used to study the effect of capital-inflow shocks driven by external factors on US macroeconomic variables.

Consistent with the evidence in Bernanke (2010), our results suggest that 'savings glut' shocks have a significant and positive effect on real residential investment and real house prices. One way of comparing the effects of different types of shocks is by computing the fraction of the variation in real residential investment and real house prices explained by each type of shock. We find that, at a three-year forecast horizon, 'savings glut' shocks explain about 13.2% and 10.8% of the variation in real residential investment and real house prices, respectively. Domestic financial deregulation and housing preference shocks also explain a large fraction of the variation in real house prices at longer horizons, but are less important in explaining real residential investment. Domestic and foreign monetary shocks have a statistically-insignificant effect on these housing variables and explain a much smaller fraction of their variance.

This article proceeds as follows. A two-country DSGE model with tradable goods and housing — similar to the model in Ferrero (2012) — is discussed in Section 2 and used to derive the sign restrictions used to identify the structural VAR. The econometric framework is described in Section 3. The baseline empirical results and robustness checks are presented in Section 4, and the conclusions are discussed in Section 5.

2 Identification

This section presents the model from which the sign restrictions used in the empirical exercise are derived. This model follows closely the one used in Ferrero (2012) to study the effect of financial deregulation and monetary policy on house prices and the current account. It extends that model by adding external shocks.

There are two countries: the US and the rest of the world (ROW). Each country has one representative household that consumes tradable goods and housing services. Tradable goods can be produced at home or abroad. For simplicity, there are no capital goods. Households face an endogenous collateral constraint which limits the amount of private credit that they can obtain as a fraction of the expected value of housing.

In order to study current account dynamics, we assume imperfect international capital markets. In particular, there is a single bond that is traded internationally and is denominated in units of home currency. In addition, investors in ROW may hold a bond denominated in units of foreign currency which is not traded internationally.

2.1 Model

2.1.1 Households

The representative household consists of a continuum of measure one of workers who consume and supply differentiated labor inputs.

Household preferences in the home country are given by:

$$U_t \equiv E_t\{\sum_{s=0}^{\infty} \beta^s [\frac{X_{t+s}^{1-\sigma}}{1-\sigma} - \frac{1}{1+\nu} \int_0^1 L_{t+s}(i)^{1+\nu} di]\} \quad (1)$$

where β is the discount factor, $\sigma > 0$ is the coefficient of relative risk aversion, $\nu > 0$ is the inverse Frisch elasticity of labor supply, X_t is the consumption index and $L_t(i)$ is the number of hours worked by each member of the representative household.

The consumption index is a composite of consumption of goods (C_t) and housing services (H_t) with constant elasticity of substitution $\epsilon > 0$ and a share of tradable goods in total consumption equal to η :

$$X_t \equiv [\eta C_t^{\frac{\epsilon-1}{\epsilon}} + (1-\eta)e^{\omega_t} H_t^{\frac{\epsilon-1}{\epsilon}}]^{\frac{\epsilon}{\epsilon-1}} \tag{2}$$

The variable ω_t is a shock to housing preferences as in Gete (2010) and Iacoviello and Neri (2010) and follows:

$$\omega_t = \rho_\omega \omega_{t-1} + u_{\omega_t}, \quad u_{\omega_t} \;\tilde{}\; i.i.d.N(0, \sigma_\omega^2)$$

Tradable consumption goods are a composite of home (C_{Ht}) and foreign (C_{Ft}) tradables with constant elasticity of substitution $\gamma > 0$ and a share of domestic tradable goods equal to α:

$$C_t \equiv [\alpha^{\frac{1}{\gamma}} C_{Ht}^{\frac{\gamma-1}{\gamma}} + (1-\alpha)^{\frac{1}{\gamma}} C_{Ft}^{\frac{\gamma-1}{\gamma}}]^{\frac{\gamma}{\gamma-1}} \tag{3}$$

The household's budget constraint is given by:

$$P_{Ht}C_{Ht} + P_{Ft}C_{Ft} + Q_t H_t - B_t = \int_0^1 W_t(i)L_t(i)di + \widetilde{P}_t + Q_t H_{t-1} + T_t - (1+i_{t-1})B_{t-1} \tag{4}$$

where B_t denotes nominal holdings at the beginning of period $t+1$ of an internationally traded one-period risk-free bond denominated in home currency which pays a net nominal interest rate i_t. The home prices of home and foreign tradables are given by P_{Ht} and P_{Ft}, Q_t is the price of housing, $W_t(i)$ is the wage of the labor input supplied by the i^{th} household member, $\widetilde{P}_t$ are profits from the ownership of intermediate-goods firms and T_t are lump-sum transfers.

The representative household can smooth consumption intertemporally by borrowing and lending internationally, subject to the following collateral constraint:

$$(1+i_t)B_t \leq \theta z_t^\theta E_t(Q_{t+1}H_t) \tag{5}$$

The amount of borrowing is limited by the expected value of housing, as in Kiyotaki and Moore (1997), and it is assumed that foreign lenders can only recover a fraction θ of the value of collateral in case of default. The variable z_t^θ captures a financial deregulation shock and follows:

$$\ln z_t^\theta = \rho_\theta \ln z_{t-1}^\theta + u_{\theta_t}, \quad u_{\theta_t} \;\tilde{}\; i.i.d.N(0, \sigma_\theta^2)$$

The price of the aggregate consumption bundle P_t can be derived from the household's expenditure minimization problem given the consumption composite (3). It is given by the following function of the price of home tradables (P_{Ht}) and the price of foreign tradables expressed in home currency (P_{Ft}):

$$P_t \equiv [\alpha P_{Ht}^{1-\gamma} + (1-\alpha) P_{Ft}^{1-\gamma}]^{\frac{1}{1-\gamma}}$$

The law of one price holds for tradables, i.e.:

$$\begin{aligned} P_{Ht} &= \frac{1}{\varepsilon_t} P_{Ht}^* \\ P_{Ft} &= \frac{1}{\varepsilon_t} P_{Ft}^* \end{aligned}$$

where ε_t is the nominal exchange rate defined such that an increase represents an appreciation of the home currency. Foreign-currency prices are denoted with a star.

The solution to the household's expenditure minimization problem also determines he allocation of consumption between home and foreign tradables:

$$\begin{aligned} C_{Ht} &= \alpha(\frac{P_{Ht}}{P_t})^{-\gamma} C_t \\ C_{Ht} &= (1-\alpha)(\frac{P_{Ft}}{P_t})^{-\gamma} C_t \end{aligned}$$

Foreign households solve the same problem as domestic households, but also face a preference shock that makes them more patient. Their preferences are given by:

$$U_t^* \equiv E_t\{\sum_{s=0}^{\infty} \beta^{*s} z_{t+s}^{\beta^*} [\frac{X_{t+s}^{*1-\sigma}}{1-\sigma} - \frac{1}{1+\nu} \int_0^1 L_{t+s}^*(i)^{1+\nu} di]\} \tag{6}$$

The preference shock follows the stochastic process:

$$\ln z_t^{\beta^*} = \rho_{\beta^*} \ln z_{t-1}^{\beta^*} + u_{\beta_t^*}, \quad u_{\beta_t^*} \,\tilde{}\, i.i.d. N(0, \sigma_{\beta^*}^2)$$

As is common in models with borrowers and savers — see, for example, Iacoviello (2005), Iacoviello and Neri (2010) and Ferrero (2012) — the borrowing constraint (5) is assumed to always bind in equilibrium in the home country because the home country representative household is more impatient than the foreign household: $\beta < \beta^*$.

2.1.2 Labor Agencies

Labor agencies are perfectly competitive and hire differentiated labor inputs from household members. The composite labor input is given by:

$$L_t = [\int_0^1 L_t(i)^{\frac{\phi_w - 1}{\phi_w}} di]^{\frac{\phi_w}{\phi_w - 1}}$$

where $\phi_w > 1$ is the elasticity of substitution between labor inputs.

Profit maximization gives the demand for the i^{th} labor input:

$$L_t(i) = [\frac{W_t(i)}{W_t}]^{-\phi_w} L_t \tag{7}$$

where the aggregate wage implied by the zero profit condition for labor agencies is given by:

$$W_t = [\int_0^1 W_t(i)^{1-\phi_w} di]^{\frac{1}{1-\phi_w}}$$

To introduce a role for monetary policy, the model includes nominal wage and price rigidities. In particular, each period a fraction ς_w of households do not adjust wages. The fraction $1-\varsigma_w$ that change wages set them to maximize the utility function:

$$\max_{\overline{W}_t(i)} E_t\{\sum_{s=0}^{\infty}(\beta\varsigma_w)^s[\lambda_{t+s}\overline{W}_t(i)L_{t+s}(i) - \frac{1}{1+\nu}L_{t+s}(i)^{1+\nu}]\}$$

subject to (7), where λ_t is the marginal utility of consumption.

The solution to this problem gives the following wage Phillips curve[1]:

$$(\frac{1-\varsigma_w\Pi_{wt}^{\phi_w-1}}{1-\varsigma_w})^{\frac{1+\phi_w\nu}{1-\phi_w}} = \frac{K_{wt}}{F_{wt}}$$

where $\Pi_{wt} \equiv W_t/W_{t-1}$ is wage inflation, K_{wt} is the present discounted value of the marginal disutility of labour and F_{wt} is the present discounted value of the real wage in units of marginal utility of consumption. These two terms are given by:

$$K_{wt} = \frac{\phi_w}{\phi_w-1}L_t^{1+\nu} + \beta\varsigma_w E_t[(\Pi_{wt+1})^{\phi_w(1+\nu)}K_{wt+1}]$$

and

$$F_{wt} = \eta X_t^{\frac{1}{\epsilon}-\sigma}C_t^{-\frac{1}{\epsilon}}\frac{W_t L_t}{P_t} + \beta\varsigma_w E_t[(\Pi_{wt+1})^{\phi_w-1}F_{wt+1}]$$

2.1.3 Production

Final-Goods Sector Firms in the final-goods sector are perfectly competitive and combine intermediate goods to produce output using a CES production function:

$$Y_{Ht} \equiv [\int_0^1 Y_t(h)^{\frac{\phi_p-1}{\phi_p}} dh]^{\frac{\phi_p}{\phi_p-1}}$$

The elasticity of substitution between intermediate goods is given by $\phi_p > 1$.

From profit maximization we get the demands for intermediate goods:

[1] More details on the derivation of the wage and price Phillips curves are provided in the appendix in Ferrero (2012).

$$Y_t(h) = [\frac{P_t(h)}{P_{Ht}}]^{-\phi_p} Y_{Ht} \tag{8}$$

The price index is an aggregation of the prices of intermediate goods:

$$P_{Ht} = [\int_0^1 P_t(h)^{1-\phi_p} dh]^{\frac{1}{1-\phi_p}}$$

Intermediate-Goods Sector Firms in the intermediate-goods sector produce output using only labor according to a linear production function:

$$Y_t(h) = AL_t \tag{9}$$

where A is constant labor productivity.

Intermediate-goods producers set prices on a staggered basis. In particular, each period a fraction ς_p of intermediate-goods firms do not adjust prices. The fraction $1 - \varsigma_p$ that change prices set them to maximize the present discounted value of profits:

$$\max_{\overline{P}_t(h)} E_t\{\sum_{s=0}^{\infty} (\beta\varsigma_p)^s \lambda_{t+s} [\overline{P}_t(h) Y_{t+s}(h) - W_{t+s} L_{t+s}]\}$$

subject to the demand for intermediate goods (8) and the production function (9).

The solution to this problem gives the price Phillips curve:

$$(\frac{1 - \varsigma_p \Pi_{ht}^{\phi_p - 1}}{1 - \varsigma_p})^{\frac{1}{1-\phi_p}} = \frac{K_{pt}}{F_{pt}}$$

where $\Pi_{Ht} \equiv P_{Ht}/P_{Ht-1}$ is inflation in the domestic tradable goods sector, K_{pt} is the present discounted value of real marginal costs and F_{pt} is the present discounted value of real marginal revenues. These two terms are given by:

$$K_{pt} = \frac{\phi_p}{\phi_p - 1} X_t^{\frac{1}{\epsilon} - \sigma} C_t^{-\frac{1}{\epsilon}} \frac{W_t Y_{Ht}}{A P_t} + \beta\varsigma_p E_t[(\Pi_{Ht+1})^{\phi_p} K_{pt+1}]$$

and

$$F_{pt} = X_t^{\frac{1}{\epsilon} - \sigma} C_t^{-\frac{1}{\epsilon}} \frac{P_{Ht} Y_{Ht}}{P_t} + \beta\varsigma_p E_t[(\Pi_{Ht+1})^{\phi_p - 1} F_{pt+1}]$$

Housing As in Ferrero (2012), housing supply is assumed to be fixed:

$$H_t = \overline{H}$$

In reality, the housing boom experienced in the US and other countries was characterized by a large increase in residential investment. However, this assumption simplifies the structure of the model and captures the idea that there may be restrictions to the construction of new housing, dictated by limited availability of land or planning regulations.

2.1.4 Monetary Policy

Home monetary policy follows a simple interest-rate rule with partial adjustment:

$$(1+i_t) = (1+i_{t-1})^{\rho}(\Pi_t^{\varphi_\pi} Y_{Ht}^{\varphi_y})^{1-\rho} z_t^i \tag{10}$$

where $\Pi_t \equiv \frac{P_t}{P_{t-1}}$ is the inflation rate for goods and z_t^i is a monetary-policy shock which follows the process:

$$\ln z_t^i = \rho_i \ln z_{t-1}^i + u_{i_t}, \quad u_{i_t} \ \tilde{} i.i.d.N(0, \sigma_i^2)$$

Foreign monetary policy follows a similar interest rate rule, but with a non-zero weight on the depreciation of the nominal exchange rate:

$$(1+i_t^*) = (1+i_{t-1}^*)^{\rho}(\Pi_t^{\varphi_\pi} Y_{Ft}^{\varphi_y})^{1-\rho}(\frac{\varepsilon_t}{\varepsilon_{t-1}})^{\varphi_\varepsilon} z_t^{i*} \tag{11}$$

The case when $\varphi_\varepsilon = 0$ corresponds to flexible exchange rates. Values of $\varphi_\varepsilon > 0$ indicate that the foreign county is partially pegging its nominal exchange rate to the dollar. It is important to consider this case because many emerging economies that financed the US current account deficit in the last decade (mostly China and oil producers) were pegging their exchange rates to the dollar in order to avoid appreciation and stimulate exports.

2.1.5 Uncovered Interest Parity Condition

The foreign country has a similar structure to the home country, but ROW investors can hold a foreign bond in addition to the internationally-traded bond. For them to be indifferent between holding these two types of bonds, the uncovered interest parity condition must hold:

$$E_t\{(1+i_t)\frac{\varepsilon_{t+1}}{\varepsilon_t}\frac{1}{\Pi_{t+1}^*}(\frac{C_{t+1}^*}{C_t^*})^{-\frac{1}{\epsilon}}(\frac{X_{t+1}^*}{X_t^*})^{\frac{1}{\epsilon}-\sigma}\} = E_t\{(1+i_t^*)\frac{1}{\Pi_{t+1}^*}(\frac{C_{t+1}^*}{C_t^*})^{-\frac{1}{\epsilon}}(\frac{X_{t+1}^*}{X_t^*})^{\frac{1}{\epsilon}-\sigma}\kappa_t\} \tag{12}$$

where κ_t is a risk-premium shock, which follows:

$$\ln \kappa_t = \rho_\kappa \ln \kappa_{t-1} + u_{\kappa_t}, \quad u_{\kappa_t} \tilde{} i.i.d.N(0, \sigma_\kappa^2)$$

An increase in κ_t raises the return required by foreign investors to invest in the internationally-traded bond.

2.1.6 Optimality Conditions for Households

Home households maximize utility (1) subject to the budget constraint (4), the borrowing constraint (5), and the demand for their labour input (7). The solution to the utility maximization problem gives the following two conditions:

$$(1+i_t)\Xi_t = 1-\beta(1+i_t)E_t[(\frac{X_{t+1}}{X_t})^{\frac{1}{\epsilon}-\sigma}(\frac{C_{t+1}}{C_t})^{-\frac{1}{\epsilon}}\frac{1}{\Pi_{t+1}}] \tag{13}$$

$$\frac{Q_t}{P_t} = \frac{1-\eta}{\eta}e^{\omega_t}(\frac{H_t}{C_t})^{-\frac{1}{\epsilon}} + \beta E_t[(\frac{X_{t+1}}{X_t})^{\frac{1}{\epsilon}-\sigma}(\frac{C_{t+1}}{C_t})^{-\frac{1}{\epsilon}}\frac{Q_{t+1}}{P_{t+1}}] + \Xi_t\theta_t E_t(\Pi_{t+1}\frac{Q_{t+1}}{P_{t+1}}) \tag{14}$$

Equation (13) is a modified version of the typical Euler equation, where Ξ_t is the shadow price of the borrowing constraint, and equation (14) determines the evolution of real house prices.

The borrowing constraint is never binding for the foreign household. Therefore, $\Xi_t^* = 0$ and the foreign household faces the typical Euler equation with the addition of the preference shock:

$$1 = \beta^*(1+i_t^*)E_t[(\frac{X_{t+1}^*}{X_t^*})^{\frac{1}{\epsilon}-\sigma}(\frac{C_{t+1}^*}{C_t^*})^{-\frac{1}{\epsilon}}\frac{1}{\Pi_{t+1}^*}(\frac{z_{t+1}^{\beta^*}}{z_t^{\beta^*}})] \tag{15}$$

2.1.7 Market Clearing

For the home final goods sector, production must equal the sum of the demands by home and foreign consumers:

$$Y_{Ht} = C_{Ht} + C_{Ht}^*$$

The housing stock is assumed to be fixed in both countries:

$$\begin{aligned} H_t &= H \\ H_t^* &= H^* \end{aligned}$$

Because domestic bonds are in zero net supply, the sum of nominal holdings of the domestic bond by home and foreign investors must equal zero:

$$B_t + B_t^* = 0$$

If these conditions are satisfied, Walras' Law ensures clearing in the foreign tradable sector.

The equilibrium conditions linearized around the steady state are listed in the Appendix.

2.2 Robust Sign Restrictions

2.2.1 Shocks

We calibrate the model to study the effects of capital-inflow shocks. Capital inflows into the US could be driven by different factors. For example, they could result from an increase in savings abroad, which pushes down long-term world interest rates and leads to an inflow of capital into the US, a deterioration of the US current account and an appreciation of the dollar. Alternatively, a greater interest on the part of foreigners in investing in the US would lead them to allocate a larger share of their wealth to US assets, providing another source of capital inflows. These two shocks capture the 'savings glut' hypothesis suggested in Bernanke (2005). Finally, a monetary-policy expansion abroad would reduce foreign interest rates and increase the relative attractiveness of US assets, also leading to capital inflows into the US. These three types of shocks point to external factors as explanations for the US current account deficit. Our analysis distinguishes between these different sources of capital inflows.

To ensure that we isolate capital inflows which are driven by external shocks, we also identify US monetary-policy shocks, housing preference shocks and financial deregulation shocks separately.

To summarize, we calibrate the theoretical model and derive impulse responses to six types of shocks:

1. *Reduction in aggregate demand in ROW*. This can be seen as an increase in $z_t^{\beta^*}$ in equation (6), which increases the discount factor and makes ROW households more patient.

2. *Expansionary monetary-policy shock in ROW*. This is a decrease in z_t^{i*} in the Taylor rule in ROW (equation (11)).

3. *Risk-premium shock*. This is a shock that increases the preference of foreign investors for US assets. It can be seen as a reduction in κ_t in equation (12), i.e., a reduction in the rate of return that investors require in order to invest in the US.

4. *Increase in the preference for housing in the US*. This can be seen as an increase in ω_t in equation (2).

5. Financial deregulation shock in the US. This corresponds to an increase in z_t^{θ} in the borrowing constraint (5).

6. *Expansionary monetary-policy shock in the US*. This is a decrease in z_t^i in the US Taylor rule (equation (10)).

2.2.2 Parameter Ranges

To derive robust implications from the theoretical model for each of these shocks that are not sensitive to variations in the structural parameters, we follow the approach in Peersman and Straub (2009), Pappa (2009) and Enders, Müller and Scholl (2011) and define a range for each of the structural parameters based on the empirical literature. The intervals for all parameter values are reported in Table 1.

Most intervals are uncontroversial and contain the values used in the calibration in Ferrero (2012). The intervals for the probability that the price and the wage do not adjust (ς_p and ς_w) contain the value 0.75, which is the mode of the prior distribution used by Smets and Wouters (2003) for the Euro area. The interval for the response to the CPI in the Taylor rule (φ_π) is the same as in Peersman and Straub (2009) and contains the value 1.5, which is the mode of the prior distribution in Smets and Wouters (2007). We assume preference shocks, risk-premium shocks and financial deregulation shocks to be quite persistent, as they represent structural preference parameters and are likely to persist over time. We assume a smaller degree of persistence for monetary-policy shocks. As in Ferrero (2012), we assume $\beta = 0.98$, $\beta^* = 0.99$ (in steady state), and we set the steady-state share of tradable goods in total consumption (η) to a value that implies a consumption share of total expenditure of about 80% in the Cobb-Douglas case (i.e., when $\epsilon = 1$). The steady-state borrowing constraint parameter θ is set to 85% as in Iacoviello and Neri (2010). The model is calibrated to match quarterly dynamics.

Table 1. Parameter ranges

Parameter	Description	Range
α	Preference share for home goods	$0.6 - 0.8$
γ	Elasticity of substitution between home and foreign tradables	$1.5 - 2.5$
ϵ	Elasticity of substitution between consumption and housing	$0.15 - 1.5$
σ	Coefficient of relative risk aversion	$1.5 - 2.5$
ν	Inverse of Frisch elasticity of labour supply	$1.5 - 2.5$
ϕ_p	Elasticity of substitution between intermediate goods	$3 - 11$
ϕ_w	Elasticity of substitution between labor inputs	$3 - 11$
ς_p	Probability that the price does not adjust	$0.6 - 0.9$
ς_w	Probability that the wage does not adjust	$0.6 - 0.9$
ρ	Smoothing coefficient in Taylor rule	$0.5 - 0.9$
φ_π	Response to CPI in Taylor rule	$1 - 3$
φ_y	Response to output in Taylor rule	$0.3 - 0.7$
φ_ε	Response to nominal exchange rate depreciation in foreign Taylor rule	$0 - 3$
ρ_η	Persistence of preference for housing shock	$0.95 - 0.99$
ρ_θ	Persistence of financial deregulation shock	$0.95 - 0.99$
ρ_κ	Persistence of risk-premium shock	$0.95 - 0.99$
ρ_i	Persistence of monetary policy shock	$0.4 - 0.7$
ρ_{β^*}	Persistence of foreign preference shock	$0.95 - 0.99$

We model the US and ROW as being symmetric in size. In reality, US output is only about one quarter of ROW output. The model could be extended to allow for differences in country size. However, to simplify the notation we adopt the simpler symmetric setup at the cost of some quantitative realism.

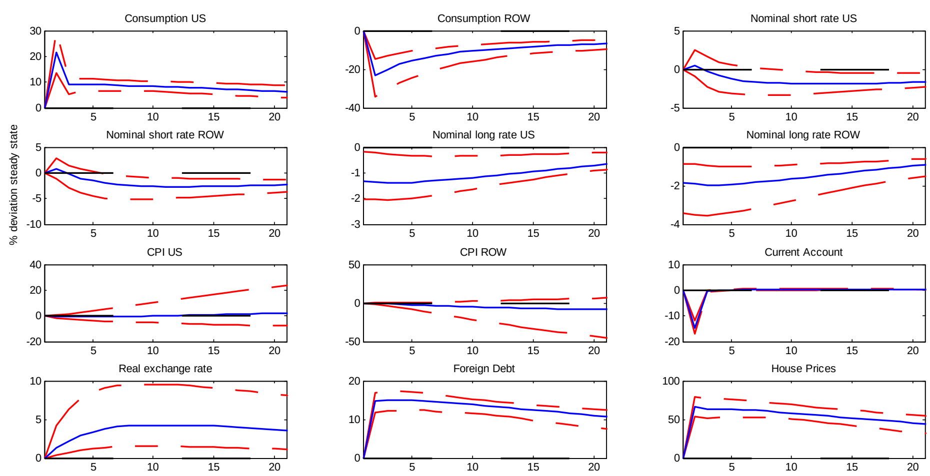
2.2.3 Dynamics

Having defined a sensible range of parameter values, we use the model to produce impulse responses for each shock. We assume that the parameters are uniformly distributed over the selected parameter range. We then draw a random value for each parameter from that range and calculate the impulse-response functions. As Peersman and Straub (2009) and Pappa (2009), we draw a total of $10,000$ realizations of the parameter vector. We report the median and the 5^{th} and 95^{th} percentiles of the impulse responses[2]. Long-term interest rates are constructed as the average of future short-term interest rates at a ten-year horizon.

The shocks are calibrated to generate a current account deficit of about 15% of tradable output. This is equivalent to a deficit of about 4% of GDP, which broadly matches the situation in mid-2009. The horizontal axis measures time in quarters and the vertical axis measures the percent deviation from steady state.

First we discuss the identification restrictions for all three types of capital-inflow shocks. Figure 3 (a) reports theoretical impulse responses following a negative shock to aggregate demand in ROW. The increase in the degree of patience of foreign households leads to a reduction in consumption and an increase in savings in ROW. The extra savings are partly allocated to US assets, generating an increase in consumption in the US, a current account deficit and an appreciation of the dollar. Long-term interest rates decrease both in the US and in ROW in response to the increase in global savings.

Figure 3 (a). Reduction in aggregate demand in ROW



Another interpretation of the 'savings glut' shock is that it results from a greater interest by foreign investors in investing in US assets. We are not explicit about what causes investors to change their preference for US assets. This could happen, for example, because other economies

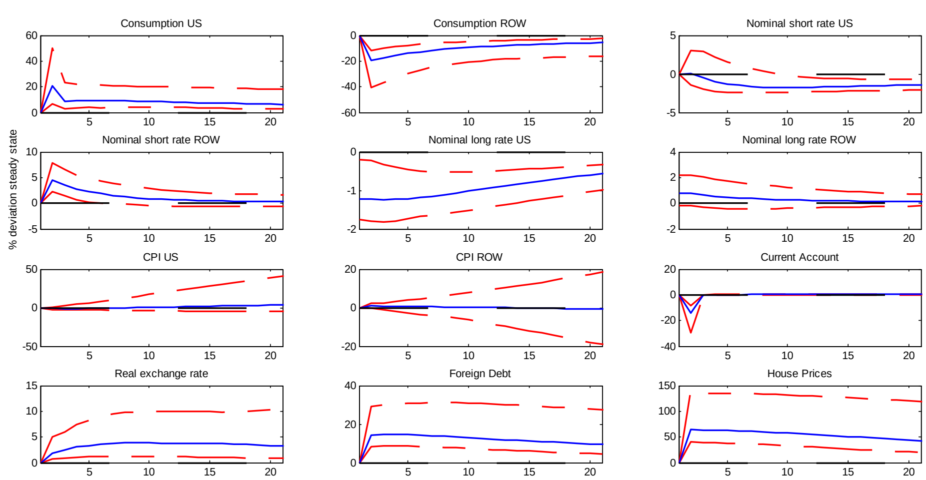
[2] In the empirical analysis we plot the 16^{th} and 84^{th} percentiles of the posterior distribution of impulse responses. Following Enders, Müller and Scholl (2011), we use a larger fraction of theoretical impulse responses. Computing the impulse responses for a large number of realizations of the parameter vector ensures the robustness of our sign restrictions.

are perceived as more risky than the US, as a result of the great moderation or improvements in the US monetary-policy framework. This is the argument made in Fogli and Perri (2008) who document a positive correlation between changes in output volatility and changes in the net foreign asset position in OECD countries. It could also be due to a greater degree of financial development in the US, as in Caballero et al (2008) and Mendoza et at (2009). We capture these different arguments in a reduced-form way by studying a risk-premium shock, which reduces the rate of return required by foreign investors to invest in US assets.

Figure 3 (b) reports theoretical impulse responses following this type of shock. The increase in the perceived safety of US assets encourages foreign investors to move part of their savings from domestic assets into US assets. This redistributes resources away from ROW into the US, leading to a reduction in consumption in ROW and an increase in consumption in the US. The increase in capital inflows in the US generates a current account deficit and an appreciation of the dollar. Interest rates decrease in the US reflecting the increase in demand for US assets. Similar qualitative predictions are obtained in Sá and Viani (2013), who use a general equilibrium model to simulate the implications of a reduction in the preference of foreign investors for US assets, i.e. a reduction in capital inflows. Their model shows that, if foreign investors invest a smaller share of their wealth in dollar assets, the dollar would depreciate in the short run and the current account would improve. The price of US assets would fall and the return would increase. These predictions are identical to the ones we obtain but with opposite signs, since we study the effect of an increase rather than a reduction in capital inflows to the US.

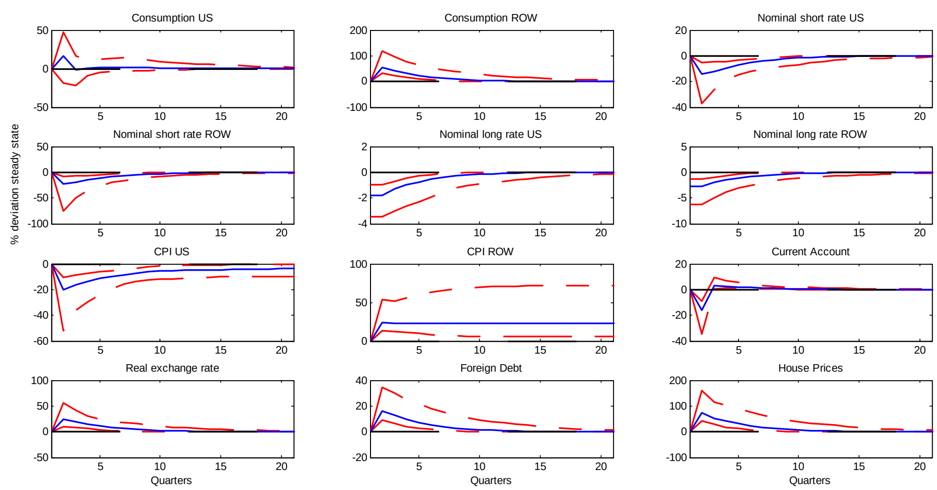
The risk premium shock generates similar qualitative responses to a reduction in aggregate demand in ROW. The only significant difference is that foreign long-term interest rates tend to increase following a risk premium shock, although this result is not robust across different parameter values. Since the two shocks are observationally equivalent and capture the same idea of a 'savings glut', we identify them together in the empirical analysis as a single 'savings glut' shock.

Figure 3 (b). Risk-premium shock



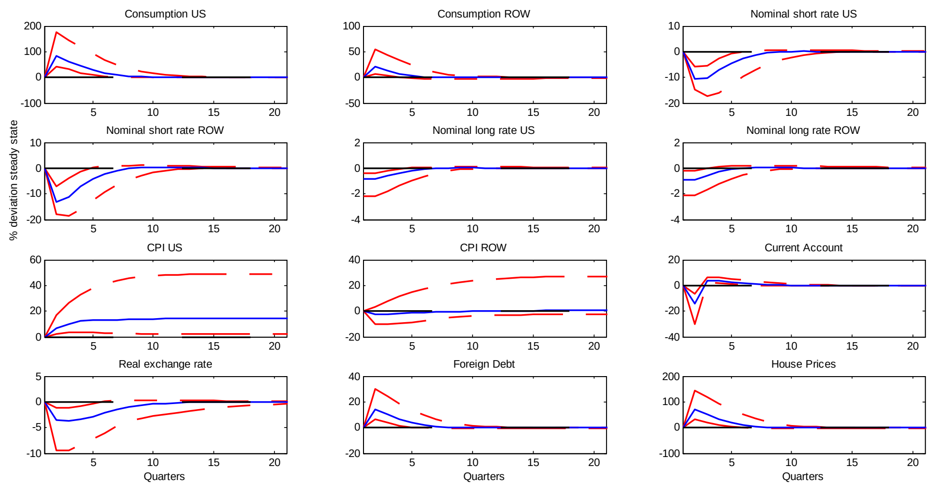
Another external factor which could explain an increase in capital inflows to the US would be a monetary-policy expansion in ROW. The impulse responses, shown in Figure 3 (c), are in line with well-known results in the literature. In particular, we find that a reduction in nominal short-term interest rates in ROW increases consumption and prices in ROW. This is consistent with the findings in Canova and de Nicoló (2002) who show that, under a variety of different models, output and prices rise following an expansionary monetary-policy shock. We choose to focus on consumption and not output in order to separate the effect on domestic absorption and on net exports (which is captured by the current account). The reduction in ROW interest rates increases the attractiveness of investment in US assets, leading to capital inflows to the US. As a result, the US current account deficit increases and the dollar appreciates. The effect of the shock on consumption in the US depends on parameter values, and is particularly sensitive to the elasticity of substitution between home and foreign tradables (γ) and the degree of home bias in goods consumption (α). With a lower degree of home bias, foreign consumers are more likely to consume more of both ROW and US-produced goods and the shock is more likely to increase US consumption. The same is true of there is a higher degree of complementarity between ROW and US-produced goods.

Figure 3 (c). ROW monetary-policy expansion



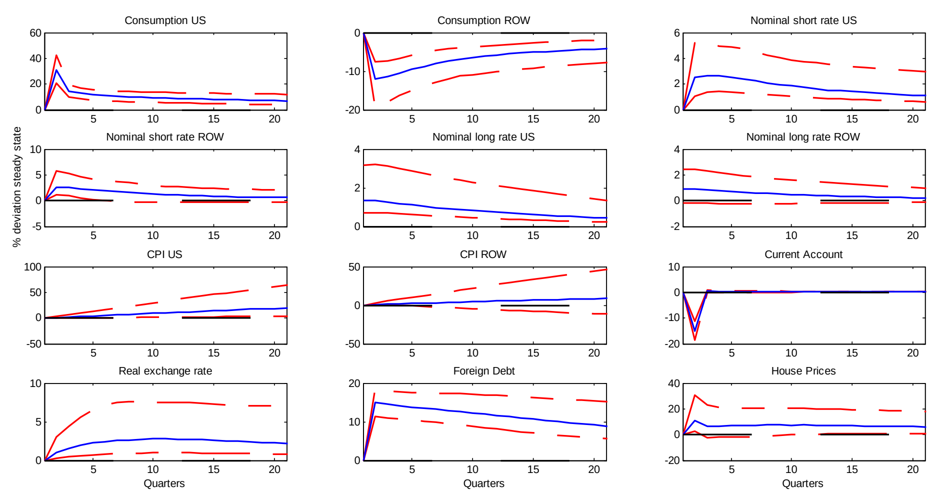
To ensure that we isolate capital-inflow shocks which are determined by external factors, we also identify three domestic shocks. The first domestic shock is a US monetary-policy expansion. This could provide an explanation for the low level of interest rates in the US and the rest of the world and for the housing boom, as suggested in Taylor (2007). Figure 3 (d) reports theoretical impulse responses. The reduction in nominal short-term interest rates in the US increases consumption and prices. US consumers increase their consumption of both US and foreign tradables, which leads to a deterioration of the current account and an increase in foreign consumption. Because we allow for some degree of pegging of the foreign nominal exchange rate to the dollar, low interest rates in the US spread to ROW as well, generating a reduction in foreign short and long-term interest rates. The exchange rate depreciates in response to the monetary expansion as a result of the uncovered exchange rate parity condition. The response of the exchange rate is consistent with the findings of a large body of empirical work — see, for example, Eichenbaum and Evans (1995) and Zettelmeyer (2004).

Figure 3 (d). US monetary-policy expansion



The second US shock that we identify is a financial deregulation shock, captured by an increase in the expected value of housing that can be pledged as collateral. Figure 3 (e) reports theoretical impulse responses. The relaxation of the borrowing constraint increases borrowing from abroad, generating an increase in foreign debt and a current account deficit. This allows US households to spend more on consumption of goods and housing. Interest rates increase in the US in response to the consumption boom. The transfer of resources from ROW to the US reduces consumption in ROW and generates an appreciation of the dollar.

Figure 3 (e). Financial deregulation in the US



Finally, we identify a positive shock to housing preferences in the US. The impulse responses — shown in figure 3 (f) — are qualitatively similar to the responses to a financial deregulation shock. US households consume more housing, which generates an increase in house prices. Because housing is used as collateral, the increase in the value of housing allows households to consume more goods as well. Interest rates increase in the US in response to the consumption boom. Consumption in ROW falls as foreign households postpone consumption and invest more in US assets. As US households borrow more from abroad, the current account deteriorates and the dollar appreciates[3].

Figure 3 (f). Positive shock to housing preferences in the US

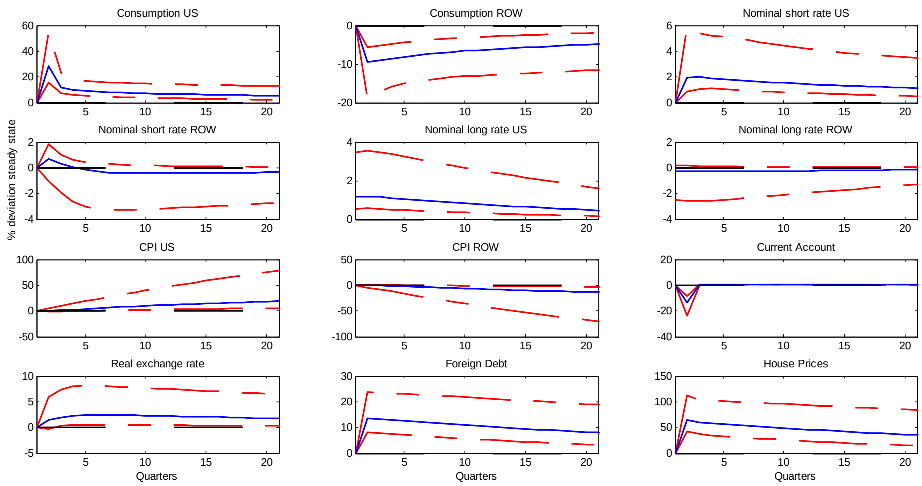


Table 2 summarizes the sign restrictions that will be used in the empirical model to identify the shocks. The predictions of the model are sufficient to distinguish between the shocks that we are considering, since there is at least one common and one different sign restriction for each pair of shocks. We allow for a possible zero impact of the shocks by imposing the restrictions as $\leq$ or $\geq$. The restrictions are imposed on impact for the current account and on impact plus two quarters after the shock for all other variables.

Table 2. Sign restrictions

Variables/shock	Savings glut	ROW monetary expansion	US monetary expansion	US financial deregulation/housing preference
US consump	≥ 0		≥ 0	≥ 0
ROW consump	≤ 0	≥ 0	≥ 0	≤ 0
US short rate			≤ 0	
ROW short rate		≤ 0		
US long rate	≤ 0		≤ 0	≥ 0
ROW long rate		≤ 0		
US CPI			≥ 0	
ROW CPI		≥ 0		
Current account	≤ 0	≤ 0	≤ 0	≤ 0
Exchange rate	≥ 0	≥ 0	≤ 0	≥ 0

[3]Another domestic shock which would lead to capital inflows to the US would be an increase in productivity. In standard models, a permanent increase in total factor productivity in the US would lead to a current account deficit. The shock increases the marginal productivity of capital, making investment in the US more attractive. There is a net capital inflow into the US and the dollar appreciates. A permanent increase in productivity leads, however, to an increase in the long-term interest rate because the marginal productivity of capital increases. Hence, the response of the long-term interest rate allows us to distinguish this shock from a 'savings-glut' shock.

3 Econometric Framework

3.1 Reduced Form Model and Data

We estimate the following open-economy vector autoregressive (VAR) model:

$$Y_t = c + \sum_{k=1}^{L} A_k Y_{t-k} + u_t \quad t = 1, ...T \quad u_t \sim N(0, \Sigma) \tag{16}$$

where c is a constant term, L is the lag length, Y_t is a vector of endogenous variables, A_k is a matrix of coefficients and u_t is the error term. The vector Y_t contains twelve endogenous variables. Ten of these variables are used to identify the shocks: short-term and long-term nominal interest rates in the US and ROW, real household consumption expenditure and the CPI in the US and ROW (in logs), the ratio of the US current account balance to GDP, and the dollar real trade-weighted exchange rate (in logs). The other two variables are used to capture developments in the housing market: real residential investment (in logs), and an index of real house prices (in logs) deflated by the GDP deflator. The model is estimated with two lags on quarterly data from 1979 Q1 to 2006 Q4.

Table 3 lists the variables and data sources. Data on interest rates and the CPI are from the dataset constructed in Pesaran, Schuermann and Smith — PSS (2009)[4]. Data on real household consumption expenditure are constructed using the share of (nominal) household consumption expenditure to GDP from the IMF International Financial Statistics (IFS), multiplied by the level of real GDP from PSS (2009). ROW variables are constructed as a trade-weighted average of the 32 countries (excluding the US) in the PSS (2009) dataset[5]. Private residential investment is obtained from the Federal Reserve Economic Data (FRED) and house prices are measured by the national house price index constructed by the Federal Housing Finance Agency (FHFA). Both variables are deflated by the GDP deflator. The FHFA house price index is a repeated-sales index, measuring average price changes in repeated sales or refinancings on the same properties. The use of repeated transactions helps to control for differences in the quality of the properties included in the sample. For this reason, the index is described as a "constant quality" house price index. It includes single-family properties whose mortgages have been purchased or securitized by Fannie Mae or Freddie Mac since January 1975. The evolution of this index is plotted in Figure 1, which shows that house prices have substantially increased since the late 1990s.

[4] These data can be downloaded from
http://www.econ.cam.ac.uk/emeritus/pesaran/fp09/Data_and_Codes_For_PSS_Rejoinder.zip.

[5] We have also estimated the model using GDP weights to construct the ROW variables and the results are qualitatively robust. We use three sets of weights: an average over the period from 1980Q1 to 1982Q4, to be used at the start of the sample (from 1979Q1 to 1986Q4); an average over the period from 1991Q1 to 1993Q4, to be used at the middle of the sample (from 1987Q1 to 1997Q4); and an average over the period from 2002Q1 to 2004Q4, to be used at the end of the sample (from 1998Q1 to 2006Q4). This combines the simplicity of fixed weights with the up-to-date nature of time-varying weights. As discussed in Dees et al (2007), trade weights that vary continuously could mask the underling movements of the macroeconomic variables that go into the construction of the ROW variables.

Table 3. Variables and data sources

Variable	Source
Short-term interest rate (3 month) US	PSS (2009)
	Treasury Bill rate from IFS series 60Czf
Short-term interest rate (3 month) ROW	PSS (2009)
Long-term interest rate (10 year) US	PSS (2009)
	Government bond yield from IFS series 61Czf
Long-term interest rate (10 year) ROW	PSS (2009)
Real household consumption expenditure US	PSS (2009) and IMF IFS
Real household consumption expenditure ROW	PSS (2009) and IMF IFS
CPI US	PSS (2009)
CPI ROW	PSS (2009)
Ratio of US current account balance to nominal GDP	OECD Economic Outlook
Dollar real effective exchange rate	IFS
Real residential investment	FRED, code PRFI, deflated by GDP deflator
Real house price index	FHFA index, deflated by GDP deflator

Open-economy VAR models typically have a large number of coefficients to be estimated. Previous work deals with the large dimensionality problem by specifying the model in differences between home and foreign variables — for example, Farrant and Peersman (2006) and Corsetti, Dedola and Leduc (2009). This implicitly assumes symmetry across regions and creates a problem with the interpretation of the shocks. For example, if we observe a shock which reduces relative short-term interest rates, increases relative consumption and prices and leads to a relative depreciation, we would not be able to distinguish whether this is an expansionary monetary-policy shock at home or a contractionary monetary-policy shock abroad. Another way of dealing with the large dimension of the model is to identify the shocks individually, without requiring them to all be present in the data and be orthogonal to each other, as in Corsetti, Dedola and Leduc (2009). This approach is problematic because the impulse responses for one of the shocks could be capturing the effect of some other shock.

To get around these issues, we use an explicit Bayesian prior to deal with the dimensionality problem. In particular, we use the prior suggested in Litterman (1986), often referred to as the Minnesota prior. Banbura, Gianonne and Reichlin (2010) provide an intuitive explanation for this type of prior and show that its application to large Bayesian VARs results in good forecasting performance.

The basic principle behind the Minnesota prior is that the variables in the VAR are 'centered' around a random walk with a drift so that the prior mean can be associated with the following representation for Y_t :

$$Y_t = c + Y_{t-1} + u_t$$

This corresponds to shrinking the diagonal elements of A_1 in model (16) towards one and shrinking the off-diagonal coefficients as well as the coefficients in $A_2, ..., A_L$ towards zero[6]. This prior is appropriate for variables that show a high degree of persistence, but is not appropriate for variables believed to be characterized by substantial mean reversion. Therefore, for short- and long-term interest rates and the exchange rate we impose the prior of white noise by setting the prior mean equal to zero.

3.2 Identification of the Shocks

The common identification problem in VAR models is that some restrictions need to be imposed on the covariance matrix in order to identify the structural shocks. Model (16) is the reduced form version of the structural model, where innovations are given by the vector v, with $E(vv') = I$. What is needed is to find a matrix B such that $u_t = Bv_t$, where the j^{th} column of B represents the immediate impact on all variables of the j^{th} structural shock, one standard error in size. The only restriction on B comes from the variance-covariance matrices of the reduced and structural form shocks:

$$\Sigma = E(u_t u_t') = E(B v_t v_t' B') = BB' \tag{17}$$

This leaves many degrees of freedom in specifying B and hence further restrictions are necessary to achieve identification. The usual methodology is to impose a certain ordering on the sequencing of shocks — Cholesky decomposition. This corresponds to imposing zero restrictions on the contemporaneous interactions between variables, for example assuming that output does not respond contemporaneously to changes in interest rates. But theory does not always provide guidance on what the ordering should be. For example, most DSGE models do not provide a sufficient number of zero restrictions in their reduced form to allow identification of the shocks.

Many studies have appealed to the reasonableness of the impulse responses as an 'informal' identification criterion and choose an ordering which delivers results consistent with conventional wisdom. In our particular case, however, it is unclear what the conventional wisdom regarding the three types of capital-inflow shocks is. It is therefore preferable to be explicit about the identifying restrictions. This can be achieved with the method developed by Canova and de Nicoló (2002), Faust and Rogers (2003) and Uhlig (2005) of imposing sign restrictions on the impulse responses. The idea is to rely on economic theory to derive 'reasonable' signs for the impulse responses. We use the sign restrictions derived from the theoretical model and reported in Table 2. We choose different matrices B which satisfy condition (17) and, for each choice of B, generate the implied impulse-response functions. Finally, we check whether the sign restrictions are satisfied and keep the impulse responses which satisfy the sign restrictions[7].

[6] To set the shrinkage parameter, we follow the approach in Banbura, Gianonne and Reichlin (2010) and choose it such that the in-sample fit of the model is the same found with a 'smaller' VAR. We estimate two smaller VARs: one with short term and long term interest rates and another with the short term interest rate and the ratio of the US current account balance to GDP. Both give a shrinkage parameter of about 0.09. We have also estimated the model with a looser prior, using a shrinkage parameter of 0.12, and the results are qualitatively robust.

[7] We have repeated the algortithm until we keep 100 impulse responses for each of the shocks. The results with

To strike a balance between relying on theory to select impulse responses that look 'reasonable' and allowing the data to speak for itself, we impose a parsimonious set of sign restrictions. In particular, we do not impose any restrictions on the responses of real residential investment and real house prices, which are the variables we chose to capture developments in the housing market. Instead, we leave them unrestricted and rely on the other variables for identification.

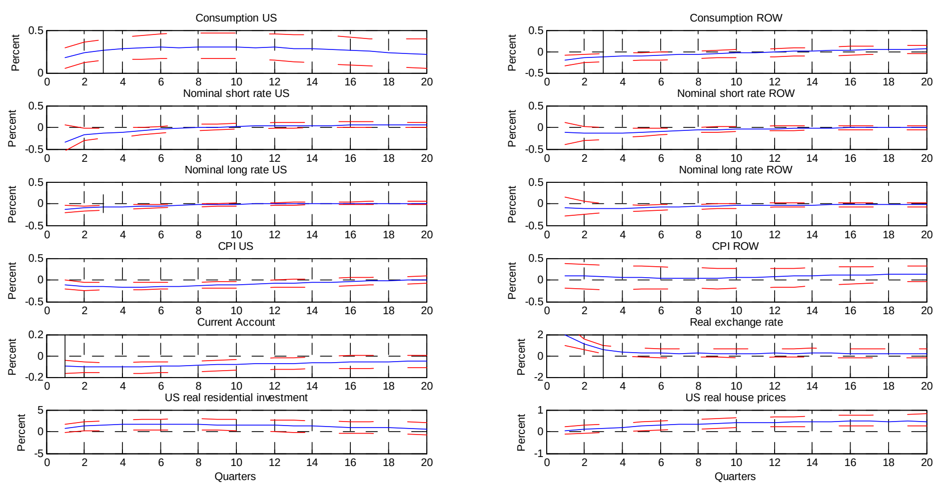
4 Empirical Evidence

4.1 Baseline Results

Figure 4 shows the impulse responses over five years obtained from estimating model (16) using the sign restrictions in Table 2. The solid vertical lines indicate the responses for which sign restrictions were imposed. We plot the median and the 16^{th} and 84^{th} percentiles of the posterior distribution of impulse responses. If the distribution was normal, these percentiles would correspond to a one-standard-deviation band.

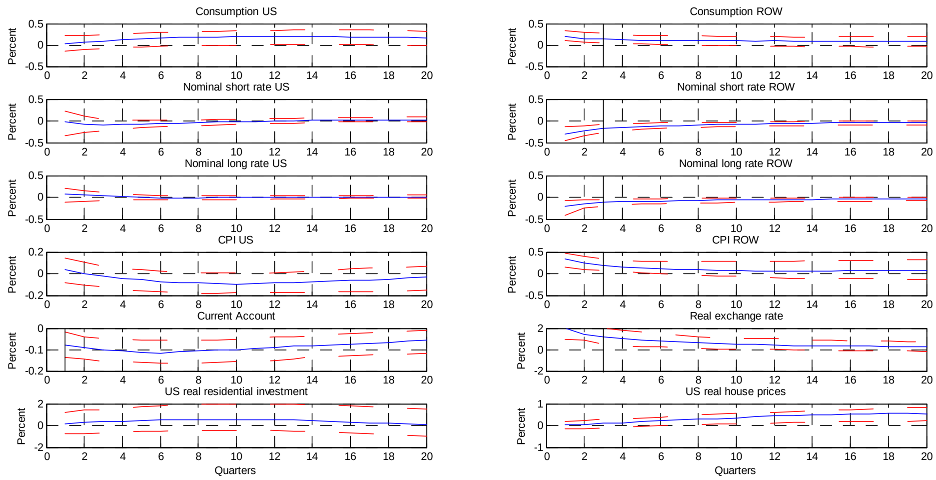
Figure 4. Empirical impulse responses

'Savings glut' shock

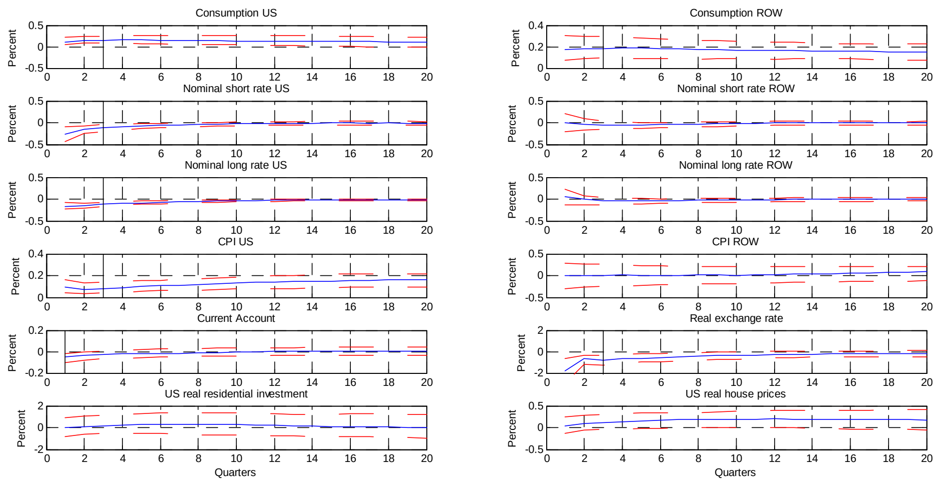


an acceptance threshold of 1000 are similar.

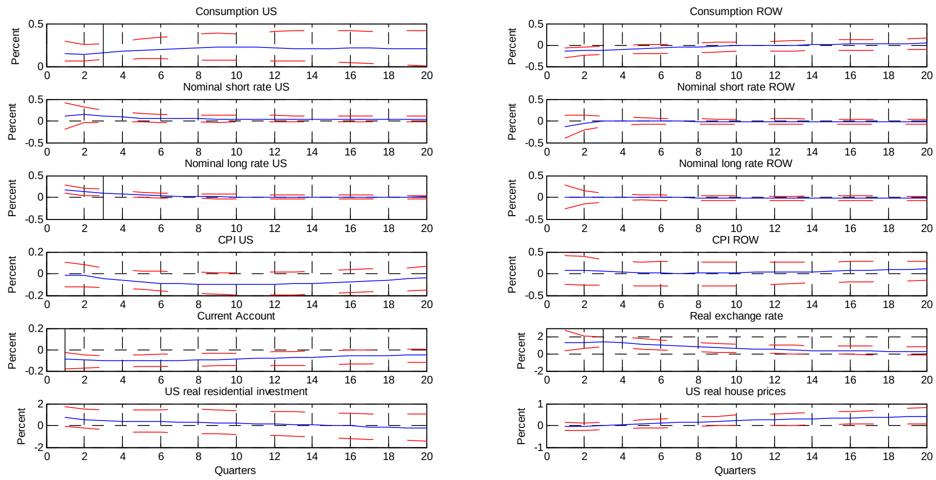
ROW monetary-policy expansion



US monetary-policy expansion



Financial deregulation/housing preference shock in the US



'Savings glut' shocks lead to a significant increase in real residential investment and real house prices. The increase in real residential investment peaks at about 2% six quarters after the shock and is quite persistent. The increase in real house prices is also very persistent and is equal to about 0.5% five years after the shock. A monetary expansion in ROW has a positive effect on real house prices at long horizons, but has an insignificant effect on real residential investment. Financial deregulation and housing preference shocks in the US have a positive initial effect on residential investment and a positive and significant effect on real house prices at longer horizons. These domestic shocks produce the counterfactual prediction of an increase in long-term interest rates and so play a smaller role in explaining the housing boom in the data than 'savings glut' shocks. Finally, US monetary-policy shocks do not seem to have a significant effect on real residential investment or real house prices, with zero lying within the posterior coverage intervals[8]. These results suggest that, compared to the other identified shocks, the 'savings glut' shock has the most significant impact on the housing variables.

Another way of assessing the relative importance of these various shocks on the US housing market is by comparing their relative contributions through variance decompositions. We ask what fraction of the variance of the k-step ahead forecast revision $E_t(Y_{t+k}) - E_{t-1}(Y_{t+k})$ in, for example, real house prices, is accounted for by the different types of shocks.

Table 4 reports the variance decompositions at different forecast horizons. 'Savings glut' shocks explain a larger fraction of the variation in real residential investment and real house prices than other types of shocks at all forecast horizons. For example, at a three-year forecast horizon, savings glut shocks explain about 13.2% of the variation in real residential investment and 10.8% of the

[8] This result appears inconsistent with previous studies which found a significant effect of monetary policy on house prices — for example, Iacoviello (2005) and Jarociński and Smets (2008). However, it should be noted that most of these studies rely on zero restrictions for identification of monetary-policy shocks, whereas our identification relies only on sign restrictions. Using a framework more comparable to ours, Del Negro and Otrok (2007) find a significant but small effect of monetary-policy shocks on residential investment and house prices using a VAR in first differences. Their model estimated in levels delivers even smaller effects.

variation in real house prices. Financial deregulation and housing preference shocks in the US also explain a sizeable fraction of the variation in real house prices at longer horizons. The variance decompositions confirm the limited role of US monetary policy shocks in explaining the housing boom[9].

Table 4. Variance decompositions

	Real residential investment			Real house prices		
	1 Year	3 Years	5 Years	1 Year	3 Years	5 Years
Savings glut	6.7%	13.2%	10.9%	5.9%	10.8%	12.2%
Monetary expansion ROW	3.9%	3.4%	3.7%	4.1%	5.1%	7.1%
Monetary expansion US	2.1%	2%	2.4%	4%	3.7%	3.1%
LTV/housing preference US	4.3%	3.4%	4.2%	4.5%	9.1%	11.2%

4.2 Robustness

As discussed in Section 3, sign restrictions allow identification of the structural shocks v from the reduced form errors $u_t = Bv_t$. Because the structural shocks satisfy the condition $E(vv') = I$, the matrix B needs to satisfy the restriction:

$$\Sigma = E(u_t u_t') = E(Bv_t v_t' B') = BB'$$

This leaves many degrees of freedom in specifying B. The sign-restrictions methodology consists of choosing different matrices B which satisfy this condition. For each choice of B, the implied impulse-response functions are generated and the impulse responses which satisfy the sign restrictions are kept.

One problem with this approach, as noted in Fry and Pagan (2011), is that each choice of B produces a new model, constituting a new set of structural equations and shocks. Consequently, the sign-restrictions approach does not identify a unique model. To summarize the information from multiple models, we present the median and the 16^{th} and 84^{th} percentiles of the impulse responses. We order the impulse responses in ascending order for each variable and each shock and compute these percentiles. The problem is that the sign-restrictions procedure averages impulse responses over several models. The model that produces the median impulse responses for, say, house prices in the 'savings-glut' shock my not be the same as the model that produces the median impulse responses for house prices in the ROW monetary-policy shock. This comment also applies to other percentiles.

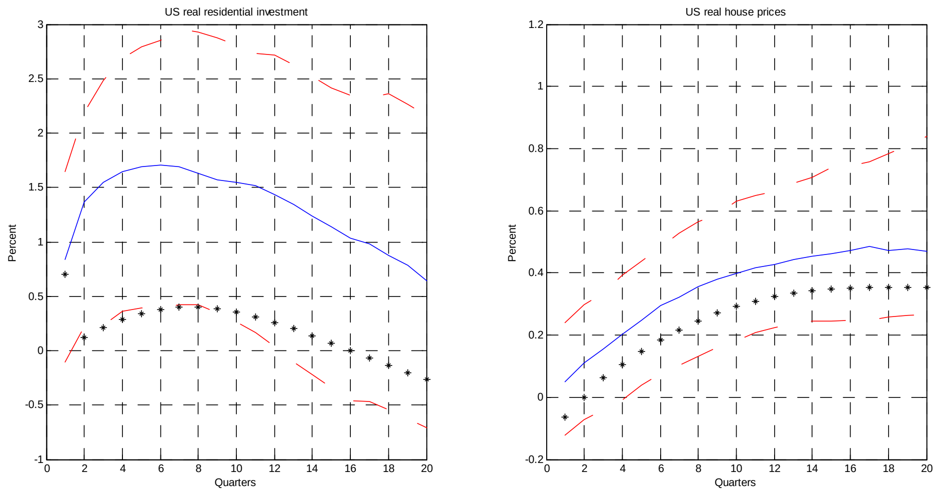
Fry and Pagan (2005) suggest an approach for dealing with this problem. It consists of selecting a single model whose impulse responses are as close to the median responses as possible. This is called the Median Target (MT) method. Figure 5 shows the median and the MT impulse responses for the housing variables. The median and the MT impulse responses are similar for all shocks.

[9] All shocks have quite persistent effects. This is consistent with the findings in Uhlig (2005), where monetary shocks explain a significant fraction of the variation in the variables in the model even five years after the shock.

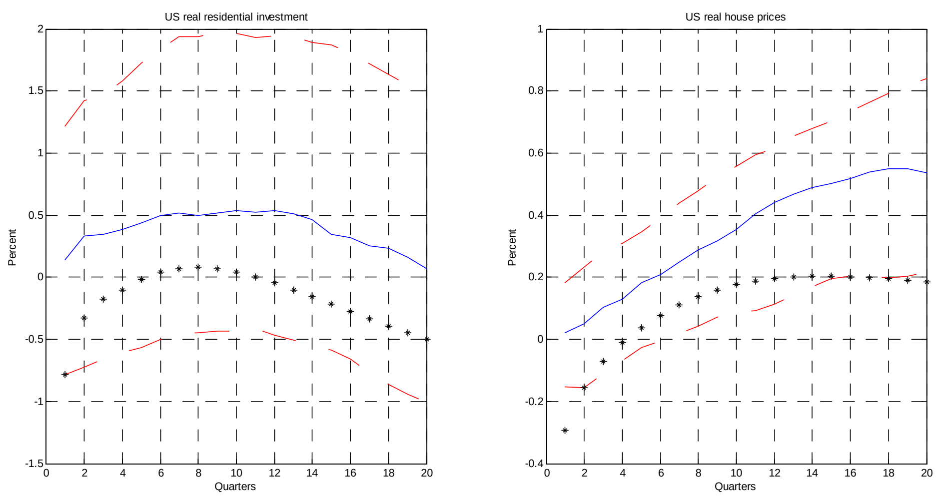
Other studies that compare median and MT impulse responses, for example Fry and Pagan (2011) and Canova and Paustian (2011), also do not find large differences between them. It is reassuring that our results remain valid when we impose the restriction that the impulse responses come from the same model.

Figure 5. Empirical impulse responses: median, MT and 16^{th} and 84^{th} percentiles

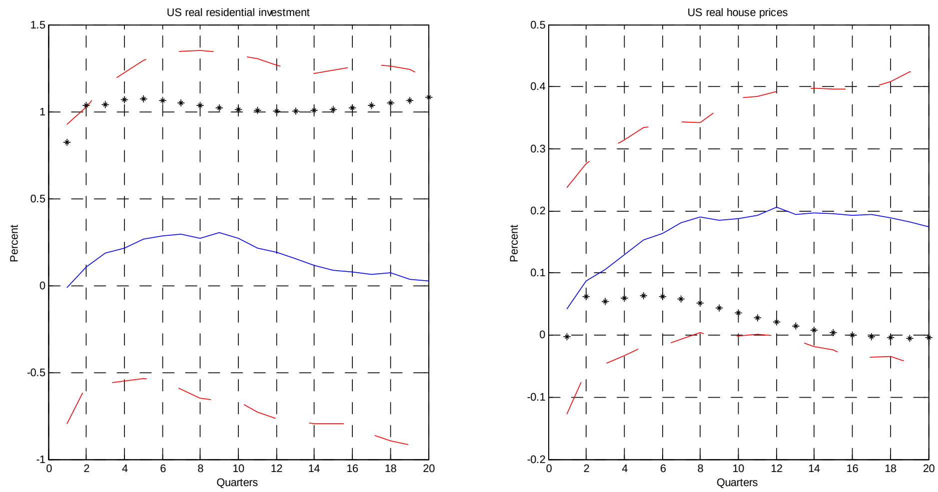
'Savings glut' shock



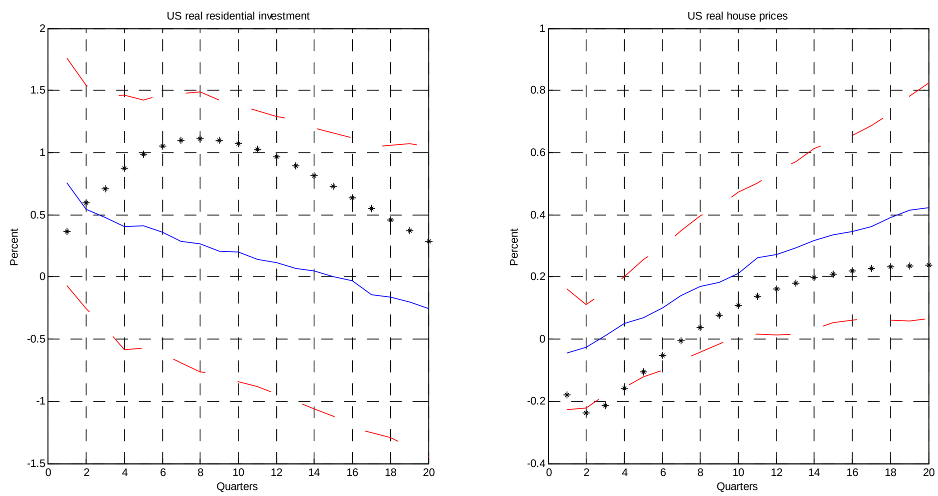
ROW monetary-policy expansion



US monetary-policy expansion



Financial deregulation/housing preference shock in the US



5 Conclusions

Prior to the 2007-2009 financial crisis, academics and commentators worried about the sustainability of the US current account deficit and discussed the magnitude of the dollar depreciation that would be required to balance the current account. In this article we look at imbalances from a different perspective, focusing on their role in driving down long-term real interest rates and encouraging a house price boom. We study the effect of four types of shocks on the US housing market. We look at two types of external shocks — a 'savings glut' shock and a monetary-policy expansion abroad — and two types of domestic shocks — a domestic monetary-policy expansion, and a shock that captures both financial deregulation and an increase in housing preferences. We estimate a large two-country Bayesian VAR model and identify these shocks with sign restrictions derived from a two-country DSGE model.

Our results suggest that 'savings-glut' shocks have a statistically significant and positive effect on real house prices and residential investment. This effect is substantially weaker for all other types of shocks that we identify. Results from variance decompositions suggest that, at a three-year forecast horizon, 'savings glut' shocks explain 13.2% and 10.8% of the variation in real residential investment and real house prices, respectively. These results suggest that 'savings glut' shocks are an important driver of developments in the US housing market. One avenue for future research would be to examine what actions policy makers can take to ameliorate the effects of these external shocks on the housing market and prevent the build up of asset price bubbles.

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