Speculation and the U.S. Housing Boom

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Abstract

Between 1996 and 2006 the US has experienced an unprecedented boom in house prices. As it has proven to be difficult to explain the large price increases by observable fundamentals, many observers have emphasized the role of speculation, i.e. beliefs about future price developments. The argument is, however, often indirect: speculation is treated as deviation from a benchmark. The present paper aims to identify speculation directly and to compare its importance to other factors. To that purpose, we estimate a VAR model for the United States and use sign restrictions to identify speculation, supply, demand, and mortgage rate shocks. Overall, these shocks can account for more than 80 percent of the recent house price increase in the period preceding the 2008/09 crises. Speculation and interest rate shocks are the most important drivers and account each for about 1/3 of the increase during the boom period. The relatively large contribution of the speculation shock is historically exceptional: the average contribution is significantly smaller.

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1 Introduction

Between 1996 and 2006, the United States has experienced an unprecedented boom in house prices. There is no agreement on the ultimate cause for the boom. Explanations include a long period of low interest rates (Taylor, 2007), declining credit standards (Mian and Sufi, 2009; Kuttner, 2012), as well as shifts in housing supply and demand. Several studies have, however, pointed out that it is difficult to explain the entire size of the boom with these factors (Dokko et al., 2011; Glaeser et al., 2012) and have offered speculation or "unrealistic expectations about future prices" (Case and Shiller, 2003) as an alternative explanation. The argument for speculation is largely indirect: speculation is the residual that cannot be explained by the model and its observed fundamentals. The role of speculation may, however, be overestimated if the underlying model is misspecified or omits important features of the housing market. For example, Himmelberg et al. (2005) have argued that with proper adjustments to the benchmark models, house prices in 2004 were in line with observed fundamentals.

Instead of treating speculation as deviation from a benchmark, the present paper aims to identify speculation directly and compare its importance to other explanations. To that purpose, we estimate a structural VAR model for the United States and use sign restrictions to identify speculation shocks. We then compare their effect to other shocks, including shocks to interest rates and shocks to housing demand and supply. A positive speculation shock is defined as an exogenous increase in the expectations about future house prices. Our identification of speculation shocks relies on the theoretical literature on speculation and the literature on search and matching models in the housing market (Wheaton, 1990; Peterson, 2012; Leung and Tse, 2012). Specifically, we use the behavior of the vacancy rate as a discriminatory variable to identify the speculation shock. We argue that a speculation shock is associated with an increase of current house prices, housing construction, and the vacancy rate. As current demand for housing has remained unchanged, the combination of a larger supply and higher sales prices implies a higher vacancy rate.

Results indicate that about 1/3 of the recent U.S. housing price boom between 1996 to 2006 may be ascribed to speculation shocks. On average their contribution to fluctuations in housing prices in the U.S. has been smaller, explaining about 20% of the long run forecast error variance of housing prices. Regarding other shocks, interest rate shocks have a similar quantitative importance for housing prices during the boom, but are dominant in explaining housing investment fluctuations. Their contribution to fluctuations in housing investment is larger than all other identified shocks taken together. Demand and supply shocks play a subordinated role for fluctuations in housing prices and investment. Furthermore, we find that speculation shocks are generally followed by a delayed contraction in output, which would suggest that speculative shocks are typically disruptive and potentially based on irrational expectations.[1]

The previous empirical literature that explores the role of expectations and speculation in the housing market can be broadly divided into two groups. A first group treats speculation as a deviation from a model benchmark. Glaeser et al. (2012), for example, find that easy credit cannot explain the full extent of the housing boom and conclude that this leave the door open for a potentially important role of irrational expectations. Similarly, Dokko et al. (2011) using a VAR based analysis, conclude that actual monetary policy was well in line with the predicted monetary policy, while residential investment and housing prices were well above predicted levels, suggesting that monetary policy cannot have contributed to the boom.

[1] Igan and Loungani (2012) using a standard VAR framework for individual countries, find that the average impact of a 10 percent decline in housing prices is a 2 percent reduction in GDP growth. Claessens et al. (2012) find that recessions associated with housing busts are significantly more severe and longer than other recessions.

In the authors view, "the most logical conclusion is that expectations of future house price growth among borrowers, lenders, and investors played a key role in the housing bubble consistent with the views of Shiller (2007)" A weakness of such an indirect approach is that it is difficult to distinguish between a misspecifed model and irrational expectations. Himmelberg et al. (2005), for example, find that there is no evidence for a housing bubble by 2004, despite a strong increase in housing prices. The authors argue that price-rent ratio, price-income ratio or simply price growth are inadequate measures to assess misalignment of housing prices and compute instead the imputed rent based on user cost considerations.

The second group of papers relies on on survey data about house price expectations. The probably most prominent example of this literature is Case and Shiller (2003) who conduct a survey among home buyers about their buying motives and find that a high fraction of respondents emphasize the investment motive. They conclude that this motive is a "defining characterstic of a housing bubble". Quigley (2003) interprets the survey responses differently and argues that they do not necessarily point to a bubble. Lambertini et al. (2013) include consumer survey data about house price expectations in a structural VAR to identify shocks to house price expectations, using a recursive identification scheme with the expectations measure ordered first. Such an identification scheme implies that house price expectation do not respond contemporaneously to other shocks. If other shocks, however, have persistent effects on house prices, it seems plausible that house price expectations will respond contemporaneously to these shocks. Furthermore, a general weakness of house price expectations survey measures is that the sample of survey participants may not be representative for the housing market participants that are relevant for price determination (i.e. the marginal buyers). [Literature Review to be completed].

Section 2 provides a description of the empirical framework. The results of the estimations are discussed in section 3, followed by some robustness analysis in section 4. Finally, section 5 concludes.

2 Empirical Framework

This section presents the empirical framework of the study. It first presents model and data. It then details the identification approach and concludes with a discussion of inference and computational implementation.

2.1 Model

We estimate a Bayesian vector autoregressive (BVAR) model of the form:

$$\mathbf{y}_t = \sum_{i=1}^{p} \mathbf{A}_i \mathbf{y}_{t-i} + \mathbf{e}_t, \quad \text{with} \quad \mathbf{e}_t \sim \mathrm{N}(\mathbf{0}, \mathbf{\Sigma}) \quad \forall\ t = 1, ..., T \tag{1}$$

$\mathbf{y}_t$ is a vector of seven variables

$$\mathbf{y}_t = \begin{pmatrix} \triangle P_t & R_t & Inv_t & V_t & r_t & LTV_t & \triangle RGDP_t \end{pmatrix}^T$$

$\mathbf{e}_t$ is a reduced-form error term with variance-covariance matrix $\mathbf{\Sigma}$, p is the lag length and $\mathbf{A}_i$ and are coefficient matrices. Our sample comprises quarterly data that cover the period from 1973Q3-2013Q4. We chose a lag length of 2 and an uninformative prior.

2.2 Data

The growth in the housing price ($\triangle P_t$) is measured by the first difference of the log of the Shiller real house price index. The rent-to-price ratio (R_t) is computed as the log of the ratio between the housing CPI component from the BLS and the nominal Shiller house price index. Investment in the housing sector (Inv_t) is measured by the log ratio of private residential construction investment relative to GDP. The vacancy rate (V_t) is given by the overall ratio of vacant houses relative to the total housing stock excluding seasonal factors (Census Bureau).[2] The real mortgage rate (r_t) is proxied by the nominal contract rate on the purchases of existing single family homes provided by the Federal Housing Financing Agency (FHFA) less the 10-year-ahead forecast of the inflation rate (Federal Reserve Bank of Philadelphia's Survey of Professional Forecasters). The loan-to value ratio (LTV_t) is taken from the FHFA. Finally, US real GDP ($RGDP_t$) is taken from the Bureau of Economic Analysis. Figure 1 shows the evolution of the respective variables.

With the exception of real GDP growth and the rent-to-price ratio, all other five variables in the VAR are required for identification. The inclusion of the rent-to-price ratio is motivated by the co-integrating relationship between rents and prices. Furthermore, both real GDP and the rent-to-price ratio are included to trace their responses to the identified shocks in order to assess the consistency of the responses with various arguments made in the literature.

2.3 Identification

Structural shocks are identified with sign restrictions (Canova and Nicolo, 2002; Uhlig, 2005). The main focus lies on the identification of the speculation shock. We compare the effects of the speculation shock to those of housing demand, housing supply and mortgage interest rate shocks and discuss how we can distinguish these shocks from speculation shocks. Table 2.3 summarizes the identification restrictions in the baseline specification. All shocks are normalized such that they imply an initially positive response of house prices. We constrain the sign restriction to hold for the first two quarters for all variables' responses.

To unambiguously distinguish between the four shocks, we rely on five key assumptions. First, the supply of housing is upward sloping. The upward sloping supply can be a result of various factors identified in the literature including zoning regulations, land limitations, and increasing construction costs (Glaeser et al., 2008; Huang and Tang, 2012). Furthermore, there are adjustment costs and large changes in housing supply are more costly than small changes, creating an incentive to spread adjustment over several periods. Second, the demand for housing is downward sloping. Hence, lower prices increase the demand for housing. Third, credit supply is not perfectly elastic (Adelino et al., 2012). If there is a strong demand for mortgage credit, mortgage rates rise. A potential shifter for mortgage credit demand is construction activity in the housing sector. Fourth, the housing market is characterized by search and matching frictions (Wheaton, 1990; Leung and Tse, 2012; Head et al., 2014). This implies that a certain fraction of the housing stock is vacant. The vacancy rate fluctuates as a result of fluctuations in housing supply and demand. Fifth, house prices are forward looking. The prospect of being able to sell the house in the future at a higher price, will lead to higher prices.[3]

[2] This value includes housing held off the market.

[3] This result is obtained for example if we consider the current house price p_t as the present discounted value of future rents r_{t+k}, discounted at rate i_{t+k}: $p_t = E[\Sigma_{k=1}^{T} \frac{r_{t+k}}{1+i_{t+k}} + \frac{p_{T+1}}{1+i_{T+1}}]$

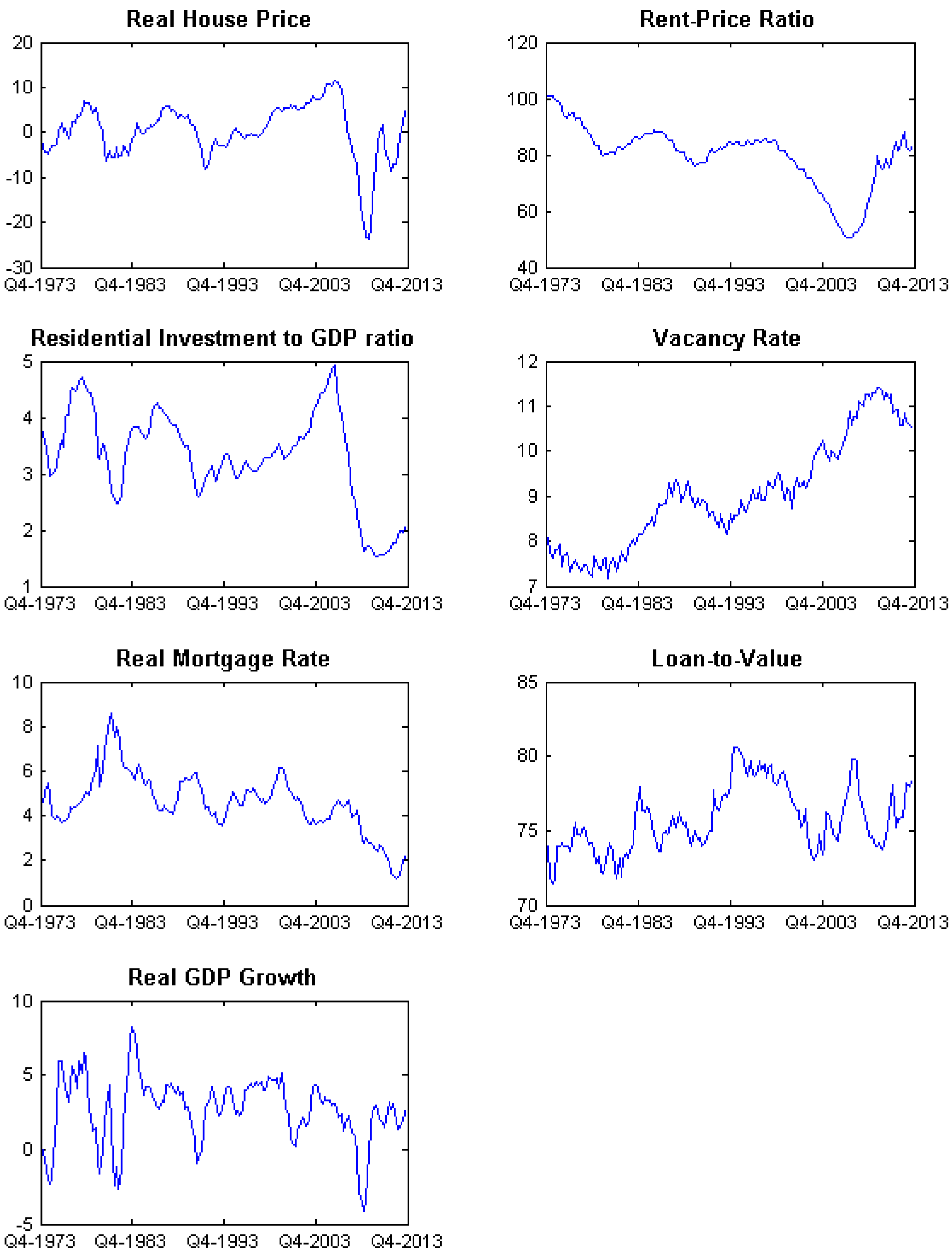


Figure 1: Evolution of variables over time

Speculation shocks A positive speculation shock leads to an increase in house prices, an increase in residential investment, an increase in vacancies, and an increase in the mortgage rate. A speculation shock is defined as a change in expectation about future house prices by homeowners and housing investors. The intuition behind the restriction on house prices is that the prospect of being able to sell the house at a higher price in the future leads to higher prices now. Under the assumption that it takes time to build a house, the prospect of higher future prices creates also the incentive to start building now, causing residential investment to increase. The increased housing construction and higher house prices lead to a higher demand for mortgage credit. Since mortgage credit supply is not perfectly elastic, the increased demand for loans associated with a higher demand for housing will lead to higher mortgage rates. The increase in vacancies relies on the assumption that markets do not clear fully, which occurs if search and matching frictions are present. As supply has increased and the current demand for housing is unchanged, the vacancy rate rises. Furthermore, Leung and Tse (2012) show in a search and matching model that the share of "flippers" (investors aiming to buy low and sell high) can cause a co-movement between high vacancy rates and high housing prices. This definition of a speculation shock leaves it open whether the increase in expectations is rational or not. It presumes, however, that people act rationally given their expectations about future house prices.

There are some similarities between vacancies in the housing market and inventories in the oil market. Knittel and Pindyck (2013) argue that speculative demand in the oil market should be associated with high oil prices and inventories, as traders store the oil for future sale. Kilian and Murphy (2010) use this insight to identify speculative demand shocks in the oil market. Housing vacancy may be considered as a sort of inventory that is available for future sale. But there are also important differences between the two markets: oil is a non durable good that can only be consumed once, whereas housing is a durable good and its service can be consumed every period. The reason for vacancies stems from the search and matching frictions and the limited amount of houses that can be constructed in a given period. There is an increase in supply, but people are reluctant to sell now, because they expect higher prices later.

Housing demand shocks A positive housing demand shock leads to an increase in house prices, an increase in residential investment, a decrease in housing vacancies, and higher mortgage rates. Possible reasons for higher housing demand are increases in population, higher personal incomes or shifts in tastes The restriction on house prices and residential investment are as in Jarocinski and Smets (2008): an upward shift of the demand curve leads, everything else fixed, to higher house prices and higher quantities (residential investment). Upward sloping mortgage credit supply will lead to higher interest rates, as loan demand increases with higher demand for housing. In standard search and matching models higher demand is associated with lower vacancies (Head et al., 2014). As it takes time for housing supply to adjust, demand growth temporarily exceeds the growth in supply, which reduces the vacancy rate. The restriction on vacancies is crucial to distinguish the housing demand from a speculation shock.

Housing supply shocks A negative housing supply shock is associated with a rise in house prices, a fall in residential investment, and an increase in the vacancy rate. Supply shocks at the aggregate level may arise from changes in the regulatory environment which reduce the provision of land (e.g zoning restrictions) or make it more costly to construct on existing land. It also includes cost increase in the construction sector. The restrictions on house prices and residential investment are as in Jarocinski and Smets (2008). Everything else fixed, an upward shift of the supply curve leads to higher prices and lower quantities. As there is now less housing supply for a given demand, the vacancy rate falls.

Mortgage interest rate shocks A negative mortgage interest rate shock is characterized by a fall in the real mortgage rate, an increase in house prices, and an increase in residential investment. There are several reasons for a surprise fall in mortgage rates: the fall can be a result of an expansionary monetary policy shock, as emphasized in Taylor (2007), lower term premia on risk-free long term bond (e.g. because there is higher demand for long term save assets due to savings glut as in Bernanke (2005) and Caballero et al. (2008), or because of a lower risk spread for mortgage rates (for example, because banks take more risk).[4] Our baseline approach does not attempt to disentangle the different causes. The user-cost approach to house prices implies that lower interest rates decrease the opportunity costs of buying a house. Higher demand for housing pushes up prices. The increased demand for houses is met by an increase in residential investment. The effects are amplified in models with collateral constraints (Iacoviello, 2005) or with a risk-taking channel (Borio and Zhu, 2012). The imposed restrictions have been both derived theoretically and confirmed empirically (see e.g. Calza et al. (2013)). Opposite movement of mortgage rates allow us to distinguish mortgage rate and speculation shocks (as well as demand shocks).

Table 1: Baseline Shock Identification

	Shock to:			
	Supply	Demand	Mortgage Rate	Speculation
House prices (∂P_t)	>0	>0	>0	>0
Investment (∂Inv_t)	<0	>0	>0	>0
Mortgage rate (∂r_t)		>0	<0	>0
Vacancy rate (∂V_t)	<0	<0		>0

2.4 Computational Implementation

We calculate Bayesian error bands. We sample the regression coefficients A_i and covariance matrix Σ from the posterior distribution, with an uninformative prior distribution.[5] Given the parameter draws, we implement the identification based on sign restrictions. We can think of the one step ahead prediction error e_t as a linear combination of orthonormal structural shocks $e_t = B \cdot v_t$, with $E(v_t' v_t) = I$ where the matrix B describes the contemporaneous response of the endogenous variables to structural shocks, $\Sigma = E(e_t e_t') = E(B v_t v_t' B') = BB'$. To sample candidate matrices B, we compute the Cholesky factorization V of the draws of the covariance matrix Σ. We then multiply V with a random orthonormal matrix Q ($B = VQ$). Q is sampled as in Rubio-Ramirez et al. (2010).[6] The Q matrices are orthonormal random matrices. Given the matrix Q and the impact matrix B, we compute candidate impulse responses. If the impulse response functions implied by B are consistent with the sign restrictions for all shocks, we keep the draw. We repeat the procedure 500000 times.

[4] Sá and Wieladek (2011) and Sá et al. (2014) compare the importance of monetary policy and capital inflows shocks for the US and a sample of OECD countries, respectively.

[5] Σ is drawn from an Inverted-Wishart Distribution $IW(\Sigma_{OLS}, T)$, and coefficient matrices A_i from a Normal Distribution $N(A^k_{OLS}, \Sigma_{OLS})$, where T is the number of observations and subscript OLS stands for the OLS estimates.

[6] We compute Q by drawing an independent standard normal matrix $\mathbf{X}$ and apply the QR decomposition $\mathbf{X} = QR$.

In contrast to exact identification schemes (e.g. zero restrictions) error bands for SVAR models based on sign restrictions reflect two types of uncertainty: parameter and identification uncertainty. Parameter uncertainty occurs both in models with exact restrictions and in models with sign restrictions: with a limited amount of data there is uncertainty about the true parameters of the model. Identification uncertainty is specific to models with sign restrictions. When applying sign restrictions there is a set of impulse response functions that satisfy the restriction for a given parameter draw. This bears the question which of the accepted impulse response functions should be reported.

In our main results, we report the pointwise mean of accepted impulse response functions for each variable. Much of the literature (see, for example, Uhlig (2005)) reports the pointwise median. Fry and Pagan (2011) criticize the practice of using the pointwise median, since the median at each horizon may be obtained from different accepted impulse response function, which leads to mixing different structural models. They suggest to report the single impulse response functions that minimize the distance to the pointwise median. However, Canova and Paustian (2011) have shown in simulation studies that in practice the pointwise median performs often better than the Fry-Pagan median in capturing the true dynamics of the model. Furthermore, Inoue and Kilian (2013) criticized the use of pointwise median as reference point in Fry and Pagan (2011), since the median is not a defined concept in multivariate distributions. They propose to use the posterior mode of the joint distribution of all admissible models to derive the most likely models. Unfortunately, the associated procedure is computationally very intensive, particularly in partially identified models. We report instead the mean of accepted impulse response functions, the mean being a defined concept in multivariate distributions. This procedure may, however, still mix different accepted models. Among the set of impulse response functions, we therefore also report the accepted impulse response function closest to the mean and second closest to the mean. As an established benchmark, we also report the point wise median. As error bands, we report the point wise 16^{th} and 86^{th} percentile. We proceed similarly for historical decomposition and variance forecast error decomposition. The closest to mean results correspond to the same model as those reported for the impulse response functions. As is standard in the literature, historical decompositions are constructed using point estimates, i.e. discarding parameter uncertainty. This facilitates the interpretation of results, as it ensures that the sum of the individual contributions adds up to the total.

3 Results

The following section discusses the impulse responses to the identified shocks, the variance forecast error decomposition and the historical decomposition for house prices and residential investment.

3.1 Impulse response functions

Figure 2 depicts the response of the seven variables in the VAR to the four identified shocks. The responses of real house prices, real residential investment, and real GDP are displayed in annual growth rates. For each impulse response function, we report its pointwise mean and pointwise median, as well as the single responses closest and second closest to the mean (Fry and Pagan, 2011). Finally, we present pointwise 68 percent error bands.

The speculation shock leads to an initially positive response of the real price of housing, residential investment, the vacancy, and the mortgage rate. The rent-to-price ratio declines initially, as we would expect if expectations about future rent and sale prices increase. The rent-to-price ratio reaches its lowest level after about 3 years and starts to revert back. Output growth rises initially by about 0.2 percent. The relatively mild expansion is followed by a prolonged growth of output below the steady state growth starting around 2 years after the shock. This suggests that the speculation shocks are potentially disruptive to economic activity at longer horizons. Residential investment seems to have an important effect on the dynamics of output. Residential investment growth increases on impact by close to 1 percent and follows a hump-shaped pattern, peaking at about 2 percent. After 6 quarters investment growth starts to contract converging only slowly back to its steady state growth rate. Within the first year, the real mortgage rate increases by roughly 8 basis points, consistent with higher mortgage demand. As residential investment and output contract, the real mortgage rate starts to decline and even fall below its initial value. At the same time, the vacancy rate continues to increase well beyond the third year after the initial shock, reverting slowly only after about 6 years, suggesting that a persistent excess of supply follows the expansion in construction. The (unconstrained) loan-to-value ratio shows no significant response to the speculation shock.

The mortgage rate shock leads to qualitatively similar responses of prices, investment, vacancies and output as the speculation shock. Quantitatively, however, a mortgage rate shock is associated with a much stronger response of investment and output growth.[7] The response is about twice as large for both variables compared to the speculation shock, while the initial real housing price response is comparable. Output grows at about 0.4 percent in the first year. The vacancy rate remains unchanged on impact, but starts to increase after about 1 year reflecting spare capacity from the significant investment growth, similar to the speculation shock. Over the medium term, investment grows for several quarters below its steady-state level as both housing price and output growth fall, reversing some of the initial increase. Different to the speculation shock, the loan-to-value ratio increases significantly after about one year by 0.2 percentage points, implying a faster rise of loan volumes relative to housing prices in response to mortgage rate shocks reinforcing looser credit conditions.

Demand shocks are associated with an increase in investment, real housing prices, and a mild output expansion. Investment and output rise by about the same amount as in respone to the speculation shock, while house prices rise significantly less. In response to increased activity, the mortgage rate rises by about 10 basis points. After about 4 quarters, housing price growth and investment growth start to fall and revert back to their steady-state level. Different from the speculation shock, there is no sustained period where housing prices and output growth lie below their long term values. Consistent with this relatively quick return to equilibrium, the vacancy rate drops initially, but returns within less than 3 years back to to its steady state value: increased residential investment seems to close the gap between demand and supply.

Supply shocks are associated with an increase in house prices, a contraction of residential investment and output. The contraction in residential investment and output are of about the same order of magnitude as for demand or speculation shocks. They revert, however, faster back to the steady-state growth rates: the increase in housing prices is reversed after less than four quarters. The vacancy rate, by contrast, remains depressed for a prolonged period. Neither mortgage nor loan-to-value ratio react to the supply shock.

[7] The strong sensitivity of housing investment to interest rate conditions is confirmed by Erceg and Levin (2002) who find that housing investment is about 10 times as responsive as consumption to a monetary policy shock.

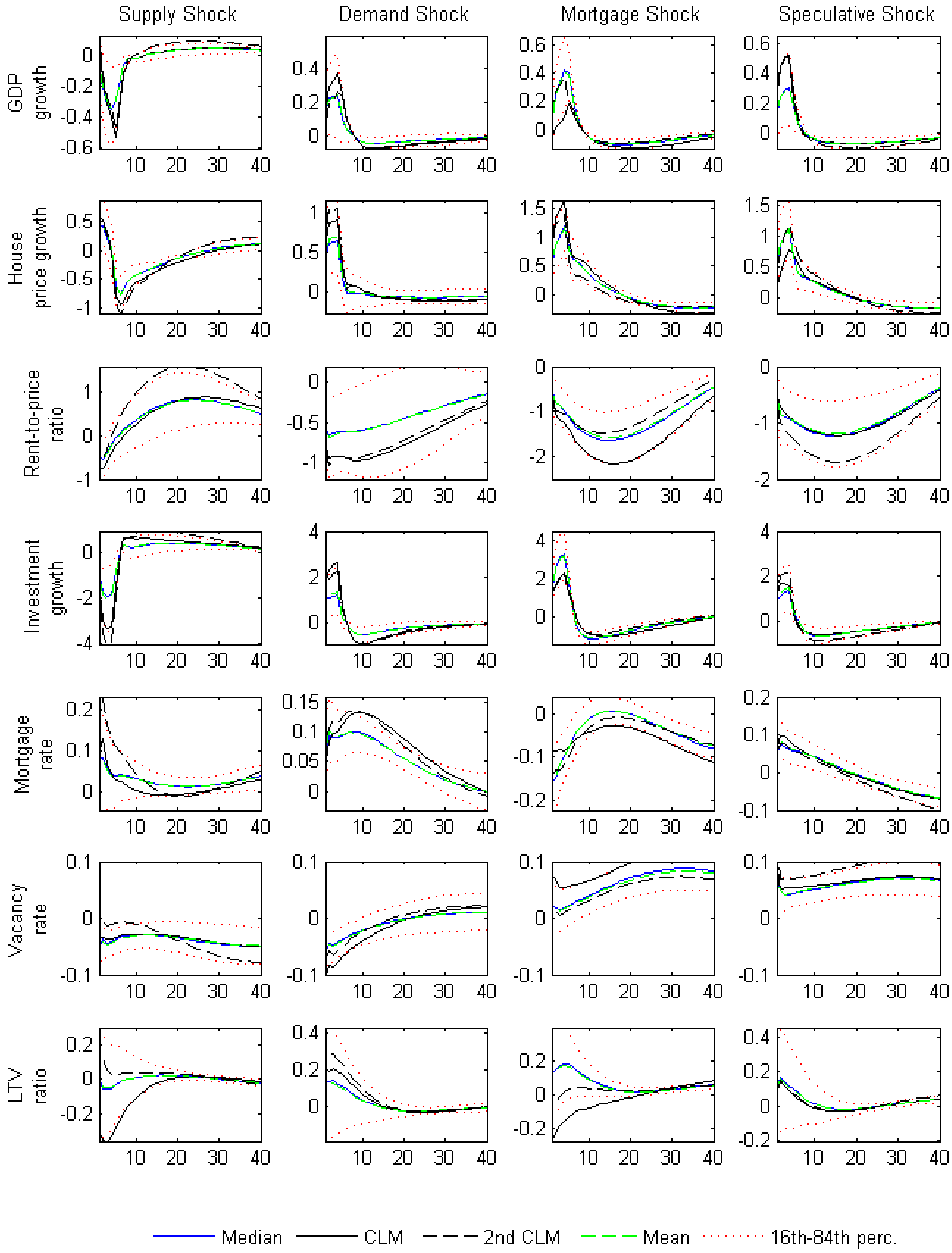


Figure 2: Baseline Model: Impulse Response Functions

3.2 Historical decomposition

Figure 3 displays the historical decomposition of real house prices and residential investment, using the pointwise mean. The solid line is the deviation of the observed house price from their level at the starting point of the boom period (1997Q4).

The four identified shocks explain a significant fraction of the rise in the housing price in the run up to the crisis. Close to 80 percent of the increase is explained by the four identified shocks, leaving about 20 percent for the three remaining, non identified, shocks. The largest contribution comes from speculation and mortgage rate shocks, each accounting for about one third of the rise.[8] The price path generated by these two shocks increases monotonically until the house price starts to collapse. The contribution from the mortgage rate shock gains in importance after the 2001 crisis, when monetary policy is widely perceived as accommodating. Demand and, in particular, supply shocks account only for a small fraction of the boom. Finally, as our model is only partially identified, there is an unexplained residual that remains sizeable. This suggests that fully ascribing the unexplained part of the housing boom to speculation, overestimates the its importance to the boom.

Turning now to the decline in the real housing price that started in 2006, our historical decomposition reveals that the decline was again mainly driven mortgage rate and speculation shocks. However, the path generated by the mortgage rate shock declines faster than the path generated by the speculation shock. Currently, the path generated by mortgage rate shock even lies below its 1997 level, when the boom started. The path generated by demand shocks displays a similar pattern, but of smaller magnitude. Speculation shocks, instead, still contribute positively, supporting a housing price level above the 1997 level.

The drivers of residential investment differ markedly from those of house prices. Growth in residential investment until 2006 was largely driven by mortgage rate shocks and, to a lesser extent demand shocks. Supply and speculation shocks have not played a major role. During the downturn this pattern changes: Speculation, mortgage, and demand shock accounted for broadly comparable fractions of the decline in growth of residential investment from 2006 to 2010. The recent recovery in residential is again mainly driven by mortgage rate shocks, with a smaller role for demand shocks.

3.3 Variance decomposition

The variance decomposition for real house prices and residential investment mirror to a certain degree the relative contribution of the four shocks in the recent boom period. The mortgage rate and speculation shocks are the two dominant shocks for the variation in housing prices. However, the two shocks each account for about 20 percent of the variation in the housing price, below the contribution in the boom period.[9] The demand and supply shocks account for about 15 percent of the variation in the housing price, in both cases higher than the contribution in the boom period. About 1/4 of the variation in the housing price remains unexplained by the four shocks.

The relative importance of the four shocks for the variation in residential investment is markedly different. Mortgage rate shocks account for more than 30 percent of the variation. This is higher than the combined

[8] As discussed in the identification section, mortgage rate shocks captures, in addition to monetary policy shocks also shocks to risk free long term rates as well as shocks to mortgage risk premia.

[9] To the extent that mortgage rate conditions and expectations are a national rather than a local phenomenon this is in line with evidence by Del Negro and Otrok (2007) who use a dynamic FAVAR model to extract the national housing factor component from the regional variables and find strong co-movement across regional prices only in the recent boom period.

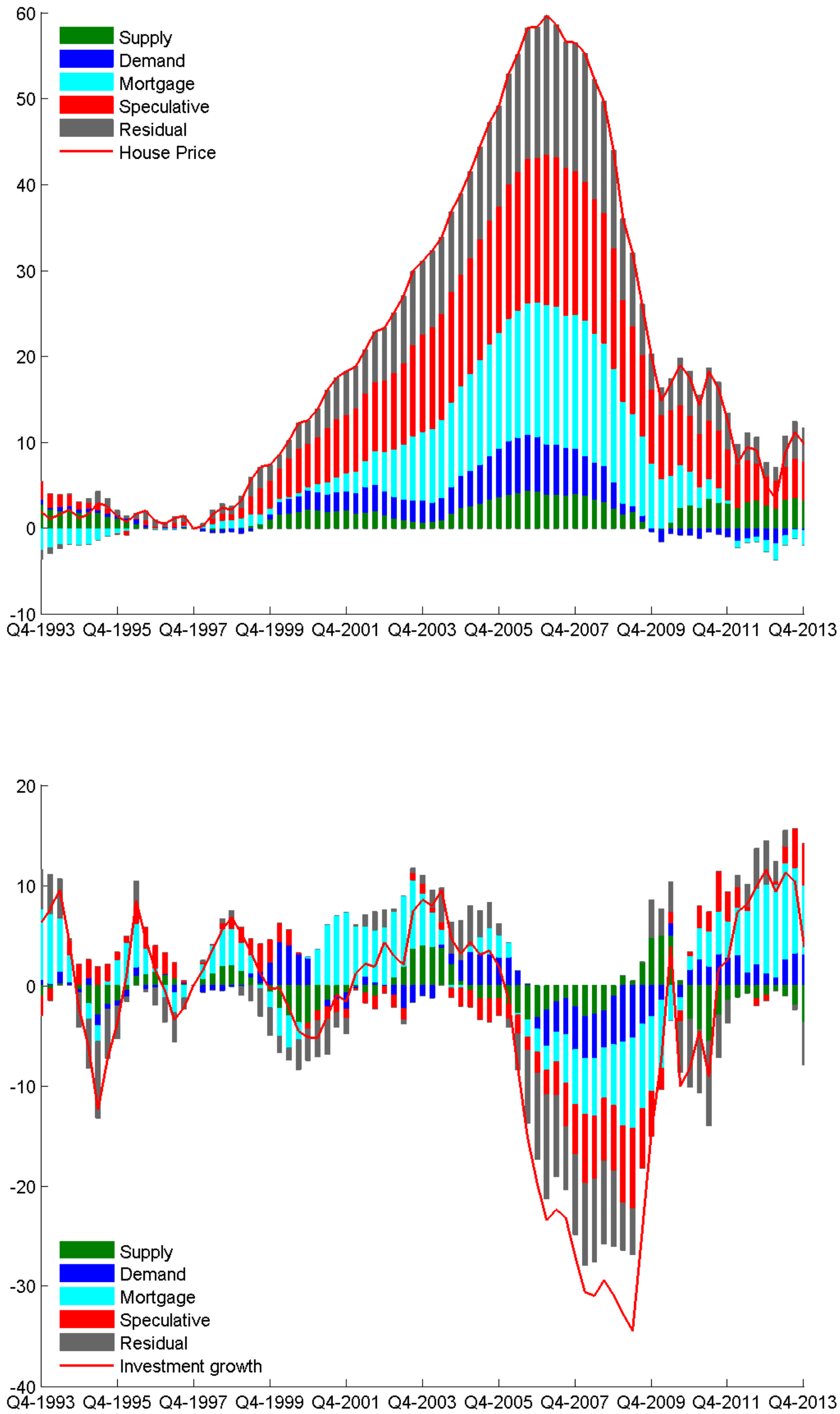


Figure 3: Historical contribution to investment and real house price developments (Baseline identification)

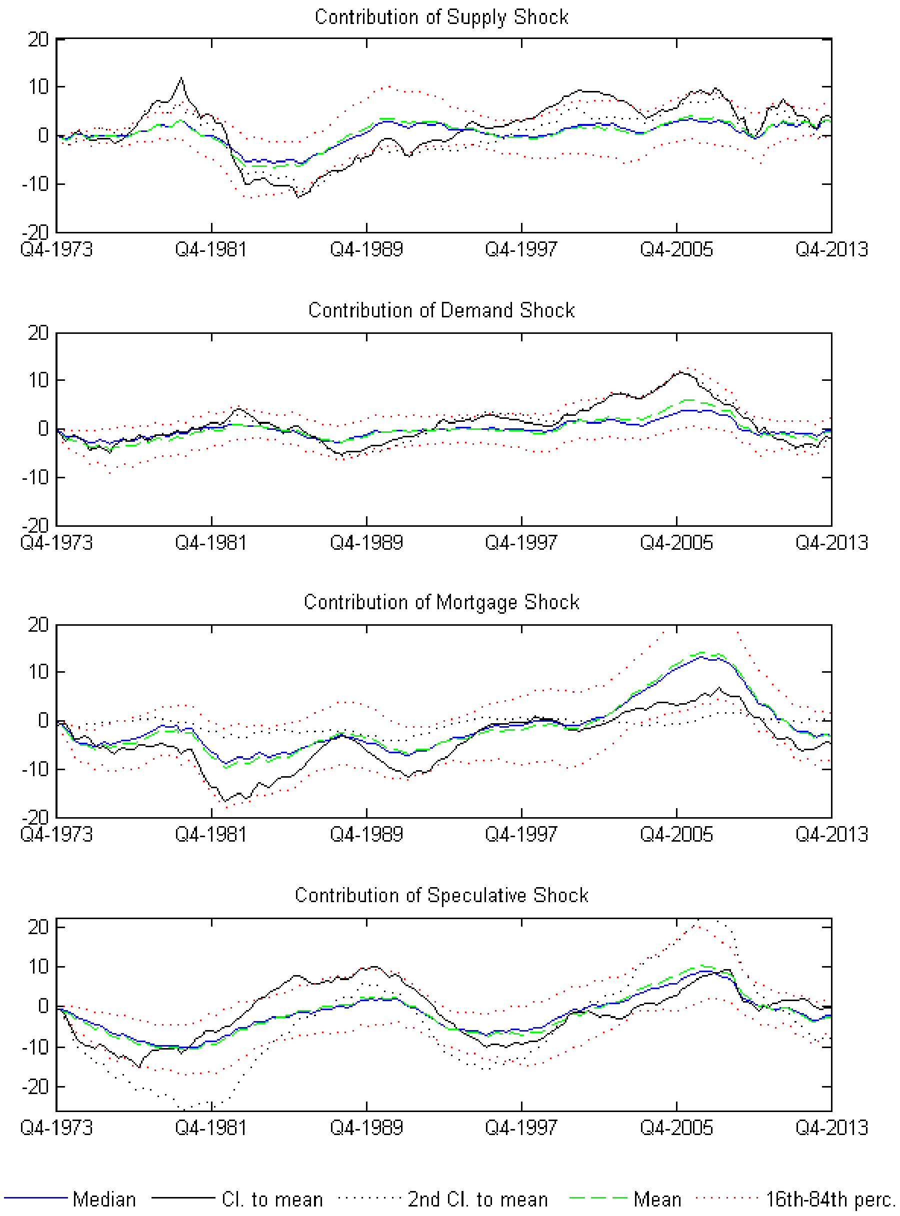


Figure 4: Baseline: Historical decomposition of house price developments for different models

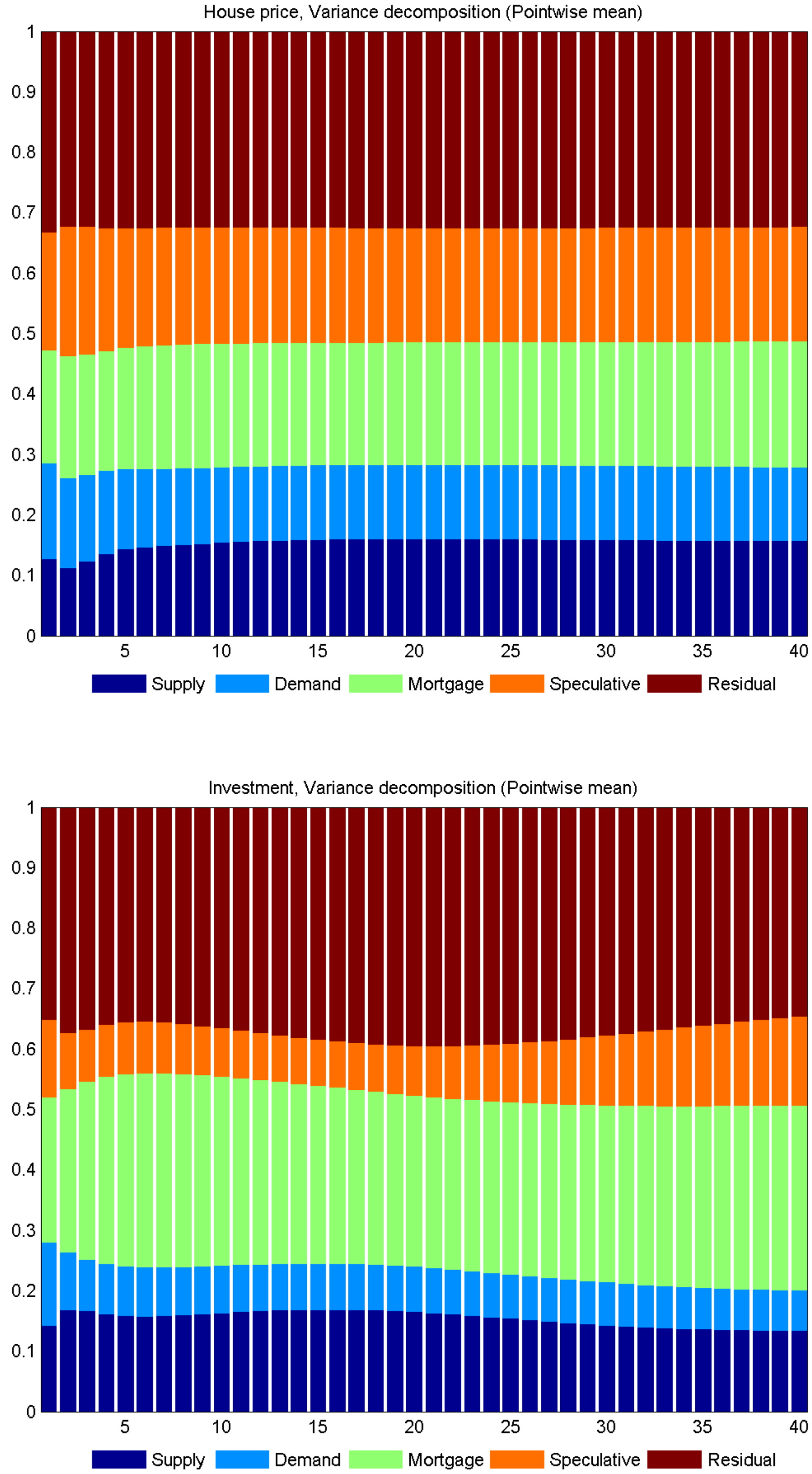


Figure 5: Variance decomposition for investment and real house price (Baseline identification)

contribution of supply, demand, and speculation shocks. The three shocks explain each close to 10 percent of the variation in residential investment, with supply shocks accounting for the smallest fraction. The four shocks explain jointly about 70 percent of the variation in residential investment.

4 Robustness

In this section, we briefly present alternative summary measures for the set of accepted impulse response functions and discuss the differences. Furthermore, we explore two changes to the baseline specification by identifying a shock to LTV criteria and by accounting for a possible trend in vacancy and mortgage rates.

4.1 Alternative summary measures of accepted impulse response functions

In this subsection we compare the pointwise mean of accepted impulse responses to the other measures discussed in Section 2. We start by discussing impulse response functions and then turn to the historical decomposition. The pointwise median of accepted impulse response functions is always very close to the pointwise mean and almost indistinguishable, suggesting a symmetric distribution of the impulse response functions. The single impulse response function that is closest to the pointwise mean is in most cases within the 68 percentile range. In some cases, there are, however, important deviation from the pointwise mean and pointwise median, as emphasized by Fry and Pagan (2011). There are also sometimes large differences between the model that is closest and second closest to the mean. This puts some doubt on the robustness of this measure. In particular, the difference in the distance between the two impulse response functions is minor (see figure 7 in the appendix). This result suggests that, despite some theoretical appeal, the closest-to-median and closest-to-mean measures are relatively sensitive and supports our main focus on the pointwise mean, which appears to be more robust.

Regarding the historical decomposition, Figure 4 compares the path of the structural shocks to the closest and second closest to mean models and displays the 16 and 84 pointwise error bands. Using the closest-to-mean instead of the pointwise mean leads to qualitatively similar results. There are, however, important quantitative differences: The model closest to the mean tracks the historical contribution of the mean fairly well. However, it suggests a lower contribution of the mortgage rate shock to the house price increase in the recent boom. The model closest to the mean suggests stronger support for rising housing prices from positive demand shocks. Overall, the model closest to the mean confirms the relative limited contribution to the housing price from the demand shocks. At least as striking as the relatively similar pattern of closest to mean and mean is the difference between the model that is closest to the mean and the model that is second closest to the mean: Different to the closest to mean, the model second closest to the mean suggests a larger contribution from the speculation shock to the boom.

4.2 Identification of loan-to-value shocks

In a first robustness exercise, we assess whether accounting for relaxation in lending standards has an impact on the estimate for the contribution of the speculation shock to the rise in U.S. housing prices. We define a relaxation in lending standards as an exogenous increase in the loan-to-value (LTV) ratio.[10] Similar to

[10]Lending standards are a broader concept than LTV and include for example debtor screening standards. Thus, LTV cannot fully capture all dimensions of lower lending standards. It is not evident which measure best to use to reflect the overall ease

a reduction in the mortgage rate, this shock makes housing more affordable. Thus, housing prices should rise in response to easier lending standards (and the price-to-rent ratio should fall). Investment in housing should increase in response to the higher prices, as is the case for the mortgage rate, speculation, and demand shocks.

The LTV shock can be distinguished from the mortgage rate shock, because the LTV shock is associated with a rise in the mortgage rate because of higher demand for loans.[11] The LTV shock can also be distinguished from the speculation shock, imposing that speculation does not go along with an increase in the LTV ratio. The reason is that the rise in prices leads to a decline in the LTV ratio for existing mortgages. While it is possible, that a strong extension of credit overturns this result, we argue that in this case credit standard by banks must have been loosened and such shocks are more appropriately classified as LTV shocks. In that sense, our approach provides a lower bound for the contribution of the speculation shock. The discussed sign restrictions are summarized in table 2.

Table 2: Shock Identification including LTV Shock

	Shock to:				
	Supply	Demand	Mortgage Rate	Speculation	LTV
House prices (∂P_t)	>0	>0	>0	>0	>0
Investment (∂Inv_t)	<0	>0	>0	>0	>0
Mortgage rate (∂r_t)		>0	<0	>0	>0
Vacancy rate (∂V_t)	<0	<0		>0	
Loan-to-Value (∂LTV_t)		<0		<0	>0

The findings are summarized in figure 6a contrasting the historical contribution of the various shocks to the real housing price increase around the boom period analogous to figure 3 for the baseline identification.[12] The contribution of the four previously identified shocks, supply, demand, mortgage rate, and speculation shock are essentially unaffected. The LTV shock contributes to the rise in the housing price during the boom year. However, the contribution is generally low and never exceeds 5 percentage points over the period from 1997 to 2006. While the small contribution is somewhat surprising it is in line with earlier findings in the literature (Glaeser et al., 2012). One reason for the low contribution of the LTV shock could be that the mortgage rate shock reflects generally easier financing conditions including higher LTV ratios. This is consistent with the fact that there is a tendency for LTV ratios to rise in response to mortgage rate shocks.[13] Hence, the observed easier LTV requirements in the crisis may partly be a response to lower interest rates, rather than a separate shock independent of the low interest rate environment.

4.3 First difference of vacancy and real mortgage rate

In a second robustness check, we address potential stationarity concerns related to the mildly declining trend in the mortgage rate and the increasing trend in the vacancy rate over the time period considered in

of lending standards and a full treatment of the issues is beyond the scope of this paper. For a careful discussion of the role of lending standards see for instance Mian and Sufi (2009) or Ariccia et al. (2012), who use micro-level data.

[11] We place no restriction on the LTV response to an interest rate shock.

[12] Figure 8a in the appendix provides additionally the mean contribution for the entire estimation period.

[13] The variance decomposition ascribes about 20 percent of the variation in the LTV ratio to mortgage rate shocks and about 30 percent to own shocks. The other shocks account for less than 10 percent each.

our analysis (see figure 1). To account for the possibility that these two variables may be non-stationary, we re-estimate the baseline model with the LTV shock, but take the first difference of the two variables.

Again we contrast the historical contribution of the various shocks to the real housing price increase around the boom period in figure 6. Similar to the inclusion of the LTV shock, detrending mortgage and vacancy rate leaves the contributions of the four initial shocks relatively unaffected. The path generated by the speculation shock still peaks end-2006 at about 15 percent. The mortgage rate shock contribution increases slightly. Most notably the demand shock contribution increases from a maximum of about 5 percent in the baseline to slightly more than 10 percent. Different to mortgage and speculation shock, the demand shock contribution starts declining before house prices peaked in 2006. The LTV shock does not contribute to the rise in the housing price during the boom year in this specification. Instead, results suggest that the tightening in LTV ratios contributed to the acceleration of the decline in housing prices in 2009. However, the contribution of the LTV shock is again very limitedwith about 5 percent.

5 Conclusion

Asset market corrections have followed housing bubbles, with often severe repercussions for the overall economy. However, there is no agreement on the ultimate cause for the boom-bust cycles. Several authors have argued that residential investment and housing prices in the U.S. were well above forecasted level, suggesting that expectations of future house price growth among borrowers, lenders, and investors must have played a key role. Such arguments have been largely indirect.

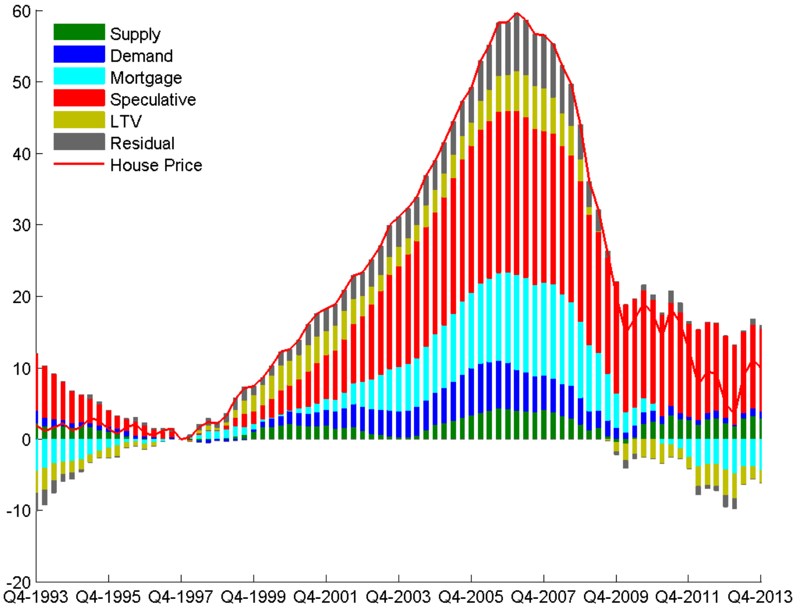
We suggest a framework based on VAR and sign restriction, which allows quantifying directly the contribution of speculation shocks to the developments in housing prices. Results suggest that about 1/3 of the recent U.S. housing price boom may be ascribed to speculation. Furthermore, we find that speculation shocks are followed by a delayed contraction in output, suggesting that speculation shocks are disruptive and potentially based on irrational expectations. While speculation shocks are essential to explain the recent boom, their contribution to past fluctuations in housing prices in the U.S. has been relatively limited. Mortgage rate shocks have accounted for a comparable fraction of the the price increase in the recent boom and are the dominant shocks in explaining the variation of residential investment.

References

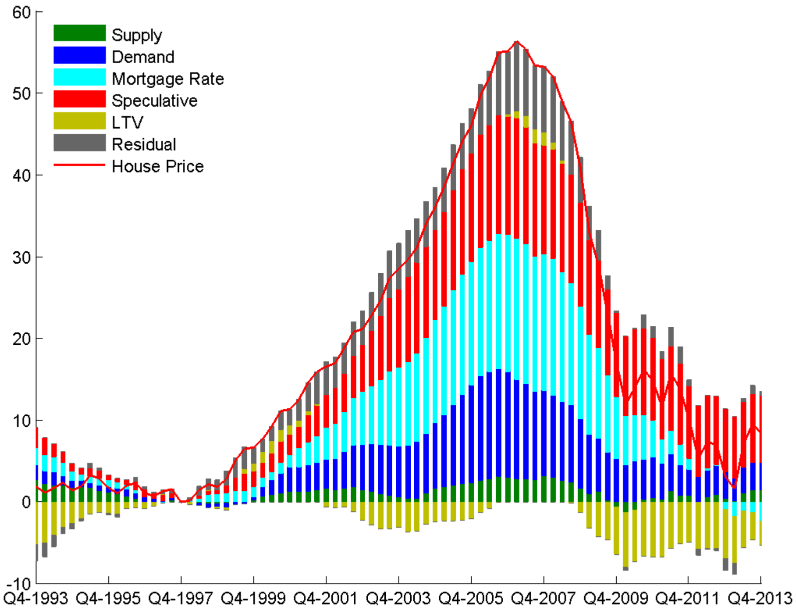
Adelino, Manuel, Antoinette Schoar, and Felipe Severino (2012) 'Credit Supply and House Prices: Evidence from Mortgage Market Segmentation.' NBER Working Papers 17832, National Bureau of Economic Research, Inc, February

Ariccia, Giovanni Dell, Deniz Igan, and Luc Laeven (2012) 'Credit Booms and Lending Standards: Evidence from the Subprime Mortgage Market.' *Journal of Money, Credit and Banking* 44, 367–384

Bernanke, Ben S. (2005) 'The global saving glut and the U.S. current account deficit.' Speech 77, Board of Governors of the Federal Reserve System (U.S.)



(a) Baseline including LTV



(b) Model (a) using detrended rates

Figure 6: Robustness: Alternative specifications

Borio, Claudio, and Haibin Zhu (2012) 'Capital regulation, risk-taking and monetary policy: A missing link in the transmission mechanism?' *Journal of Financial Stability* 8(4), 236–251

Caballero, Ricardo J., Emmanuel Farhi, and Pierre-Olivier Gourinchas (2008) 'An Equilibrium Model of "Global Imbalances" and Low Interest Rates.' *American Economic Review* 98(1), 358–93

Calza, Alessandro, Tommaso Monacelli, and Livio Stracca (2013) 'Housing Finance And Monetary Policy.' *Journal of the European Economic Association* 11, 101–122

Canova, Fabio, and Gianni De Nicolo (2002) 'Monetary disturbances matter for business fluctuations in the G-7.' *Journal of Monetary Economics* 49(6), 1131–1159

Canova, Fabio, and Matthias Paustian (2011) 'Business cycle measurement with some theory.' *Journal of Monetary Economics* 58(4), 345–361

Case, Karl E., and Robert J. Shiller (2003) 'Is there a bubble in the housing market?' *Brookings Papers on Economic Activity* 34(2), 299–342

Claessens, Stijn, Ayhan Kose, and Marco E. Terrones (2012) 'How do business and financial cycles interact?' *Journal of International Economics* pp. 178–190

Del Negro, Marco, and Christopher Otrok (2007) '99 luftballons: Monetary policy and the house price boom across u.s. states.' *Journal of Monetary Economics* 54(7), 1962–1985

Dokko, Jane, Brian M. Doyle, Michael T. Kiley, Jinill Kim, Shane Sherlund, Jae Sim, and Skander Van Den Heuvel (2011) 'Monetary policy and the global housing bubble.' *Economic Policy* 26(66), 233–283

Erceg, Christopher J., and Andrew T. Levin (2002) 'Optimal monetary policy with durable and non-durable goods.' International Finance Discussion Papers 748, Board of Governors of the Federal Reserve System (U.S.)

Fry, Rene, and Adrian Pagan (2011) 'Sign Restrictions in Structural Vector Autoregressions: A Critical Review.' *Journal of Economic Literature* 49(4), 938–60

Glaeser, Edward L., Joseph Gyourko, and Albert Saiz (2008) 'Housing supply and housing bubbles.' *Journal of Urban Economics* 64(2), 198–217

Glaeser, Edward L., Joshua D. Gottlieb, and Joseph Gyourko (2012) 'Can cheap credit explain the housing boom?' In 'Housing and the Financial Crisis' NBER Chapters (National Bureau of Economic Research, Inc) pp. 301–359

Head, Allen, Huw Lloyd-Ellis, , and Hongfei Sun (2014) 'Search, liquidity, and the dynamics of house prices and construction.' *American Economic Review* 104(4), 1172–1210

Himmelberg, Charles, Christopher Mayer, and Todd Sinai (2005) 'Assessing high house prices: Bubbles, fundamentals, and misperceptions.' NBER Working Papers 11643, National Bureau of Economic Research, Inc, September

Huang, Haifang, and Yao Tang (2012) 'Residential land use regulation and the us housing price cycle between 2000 and 2009.' *Journal of Urban Economics* 71(1), 93–99

Iacoviello, Matteo (2005) 'House prices, borrowing constraints, and monetary policy in the business cycle.' *American Economic Review* 95(3), 739–764

Igan, Deniz, and Prakash Loungani (2012) 'Global housing cycles.' IMF Working Papers 12/217, International Monetary Fund, August

Inoue, Atsushi, and Lutz Kilian (2013) 'Inference on impulse response functions in structural VAR models.' *Journal of Econometrics* 177(1), 1–13

Jarocinski, Marek, and Frank R. Smets (2008) 'House prices and the stance of monetary policy.' *Review* pp. 339–366

Kilian, Lutz, and Dan Murphy (2010) 'The role of inventories and speculative trading in the global market for crude oil.' CEPR Discussion Papers 7753, C.E.P.R. Discussion Papers, Mar

Knittel, Christopher R., and Robert S. Pindyck (2013) 'The Simple Economics of Commodity Price Speculation.' NBER Working Papers 18951, National Bureau of Economic Research, Inc, April

Kuttner, Kenneth (2012) 'Low interest rates and housing bubbles: Still no smoking gun.' Department of Economics Working Papers 2012-01, Department of Economics, Williams College, January

Lambertini, Luisa, Caterina Mendicino, and Maria Teresa Punzi (2013) 'Expectation-driven cycles in the housing market: Evidence from survey data.' *Journal of Financial Stability* 9(3), 518–529

Leung, Charles Ka Yui, and Chung-Yi Tse (2012) 'Flippers in Housing Market Search.' 2012 Meeting Papers 434, Society for Economic Dynamics

Mian, Atif, and Amir Sufi (2009) 'The consequences of mortgage credit expansion: Evidence from the u.s. mortgage default crisis.' *The Quarterly Journal of Economics* 124(4), 1449–1496

Peterson, Brian M. (2012) 'Fooled by search: Housing prices, turnover and bubbles.' Working Papers 12-3, Bank of Canada

Quigley, John (2003) 'Comment on case and shiller: Is there a bubble in the housing market?' *Brookings Papers on Economic Activity* 34(2), 343–362

Rubio-Ramirez, Juan F., Daniel F. Waggoner, and Tao Zha (2010) 'Structural Vector Autoregressions: Theory of Identification and Algorithms for Inference.' *Review of Economic Studies* 77(2), 665–696

Sá, F., and T. Wieladek (2011) 'Monetary Policy, Capital Inflows, and the Housing Boom.' Cambridge Working Papers in Economics 1141, Faculty of Economics, University of Cambridge, May

Sá, Filipa, Pascal Towbin, and Tomasz Wieladek (2014) 'Capital Inflows, financial structure and housing boomss.' *Journal of the European Economic Association* 12, 522–546

Shiller, Robert J. (2007) 'Understanding recent trends in house prices and homeownership.' *Proceedings - Economic Policy Symposium - Jackson Hole* pp. 89–123

Taylor, John B. (2007) 'Housing and monetary policy.' *Proceedings* pp. 463–476

Uhlig, Harald (2005) 'What are the effects of monetary policy on output? Results from an agnostic identification procedure.' *Journal of Monetary Economics* 52(2), 381–419

Wheaton, William C (1990) 'Vacancy, search, and prices in a housing market matching model.' *Journal of Political Economy* 98(6), 1270–92

Appendix

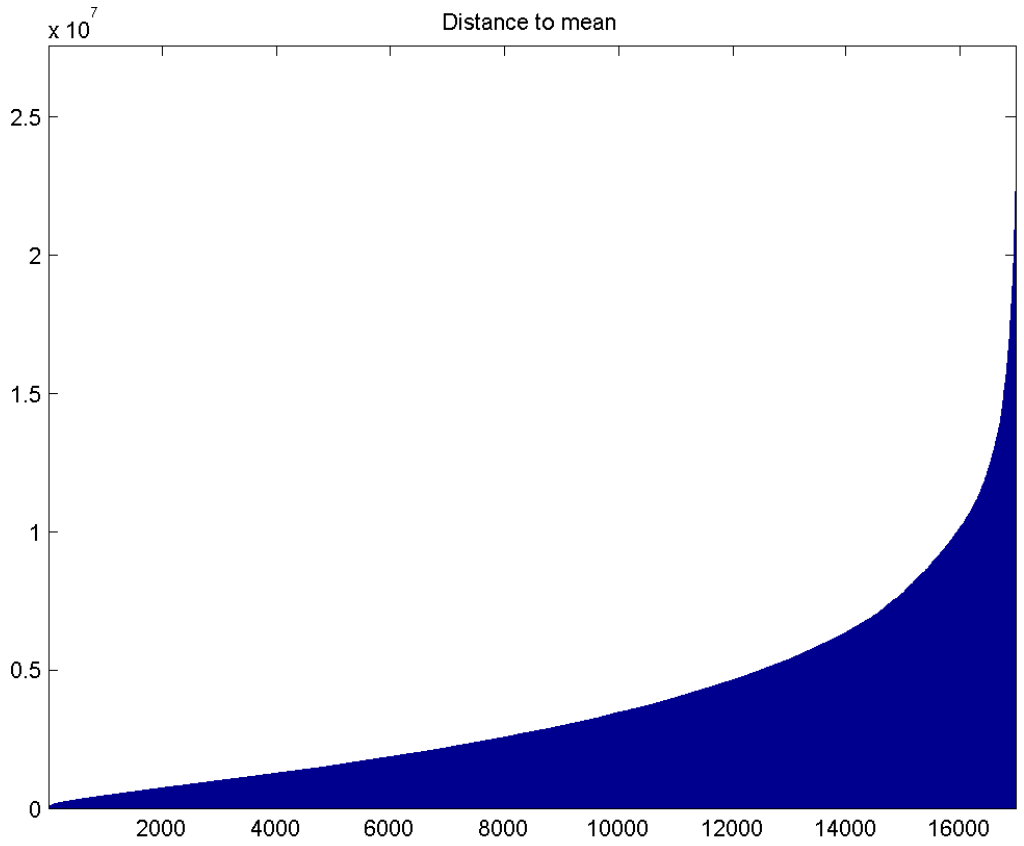
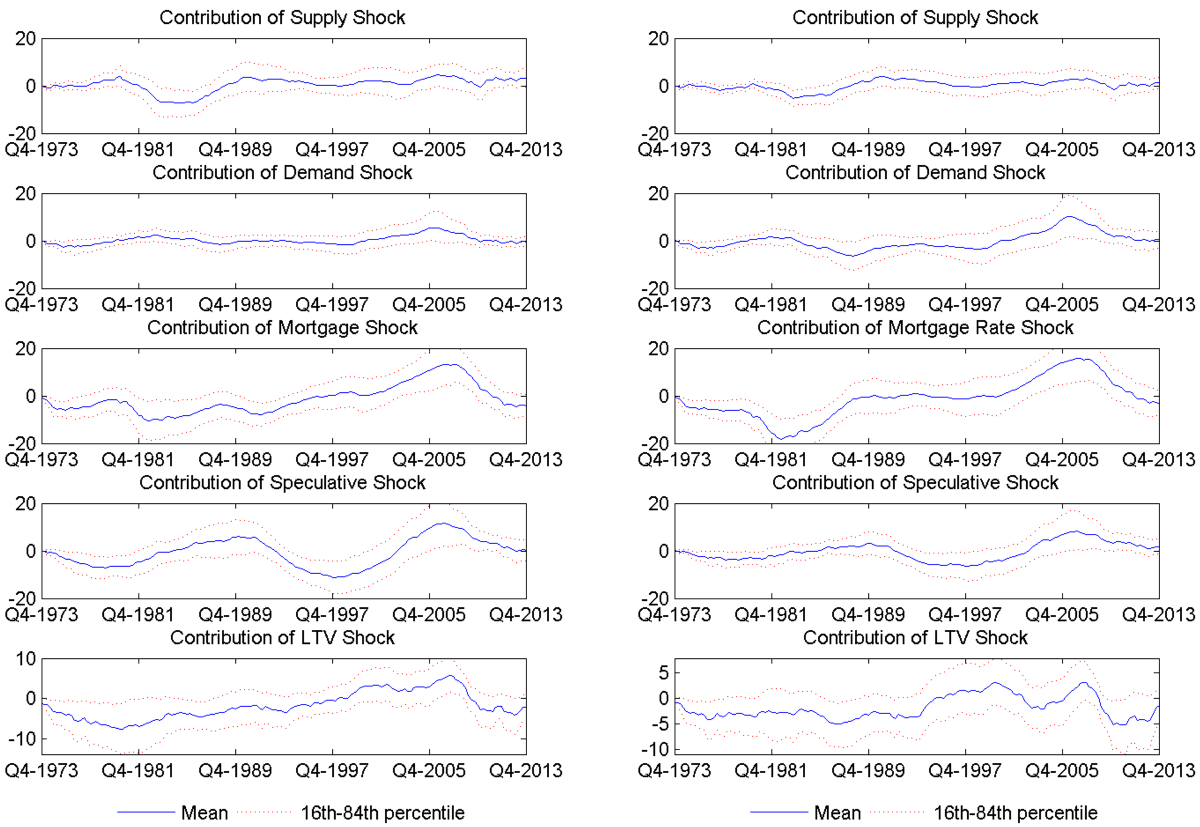


Figure 7: Distance of all accepted models to mean in the baseline model (Sum of squares of differnece of respective model to mean IRF)



(a) Base model including LTV

(b) Model (a) using detrended rates

Figure 8: Historical contribution (Alternative models)