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Price Expectations and the U.S. Housing Boom

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Abstract

Between 1996 and 2006 the U.S. has experienced an unprecedented boom in house prices. As it has proven to be diffcult to explain the large price increase by observable fundamentals, many observers have emphasized the role of speculation, i.e. expectations about future price developments. The argument is, however, often indirect: speculation is treated as a deviation from a benchmark. The present paper aims to identify house price expectation shocks directly. To that purpose, we estimate a VAR model for the U.S. and use sign restrictions to identify house price expectation, housing supply, housing demand, and mortgage rate shocks. House price expectation shocks are the most important driver of the boom and account for about 30 percent of the real house price increase. We also construct a model-based measure of exogenous changes in price expectations and show that this measure leads a survey-based measure of changes in house price expectations. Our main identification scheme leaves open whether expectation shifts are realistic or unrealistic. In extensions, we provide evidence that price expectation shifts during the boom were primaly unrealistic and were only marginally affected by realistic expectations about future fundamentals.

JEL Classification Numbers: E3, E4, R3

Keywords: Housing Market, House Price Expectations, Speculation, Housing Boom, VAR

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Contents

I. 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 the supply of houses and the demand for housing services (Iacoviello and Neri, 2010). 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 empirical argument for an important role of house price expectations is often indirect: it is a residual that cannot be explained by a model and its observed fundamentals.

Instead of treating speculation as a deviation from a benchmark, the present paper aims to identify shifts in house price expectations directly and compare their importance to other explanations. To that purpose, we estimate a structural VAR model for the United States and use sign restrictions to identify house price expectation shocks. We then compare their effect to other shocks, including shocks to mortgage rates and shocks to the demand for housing services and the supply of houses. Our identification of expectation 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 house price expectation shock. In response to a price expectation shock, house prices and residential investment increase, but as the current demand for housing services remains unchanged, the vacancy rate increases.

Results indicate that house price expectation shocks are the most important driver of the recent U.S. housing price boom between 1996 to 2006, explaining about 30 percent of the increase. Over the entire sample, their contribution to fluctuations in housing prices in the U.S. has been smaller, accounting for about 20 percent of the long run forecast error variance of house prices. This suggests that the large contribution of price expectation shocks is historically exceptional. Regarding other shocks, mortgage rate shocks are the second most important driver of the boom: their contribution amounts to about 25 percent. Over the entire sample, they are the most important driver and account for almost 30 percent of the long run forecast error variance. Shocks to the demand for housing services and supply of houses play a subordinated role for fluctuations in house prices, both for the boom period and over the entire sample. Taken together, the four shocks explain about 70 percent of the house price boom, leaving a residual of about 30 percent. This indicates that attributing the entire residual that cannot be explained by standard shocks to price expectations will lead to an overestimation of their contribution. We also find that a model-based measure of house price expectations is positively correlated with leads of a survey based measure of house price expectations. The positive correlation with leads indicates that our measure contains similar information as a survey-based measure. In addition, it tends to provide the information more timely. This supports our identification scheme.

Our main identification scheme is agnostic about why expectation shifts occur. In principle, the identified shocks encompass both realistic shifts in perceptions about future fundamentals and unrealistic shifts driven by “animal spirits”. We provide evidence which suggests that “unrealistic expectations” as emphasized by Case and Shiller (2003) are more important than “realistic expectations”. First, in our baseline specification, positive price expectation shocks lead to an initial expansion and a delayed contraction in residential investment. The delayed contraction suggest that overly optimistic expectations have led to over-investment in the residential real estate sector, which is then corrected. Second, in an extension we distinguish between realistic and unrealistic expectation shocks, where only the former are profitable in the long-run. Unrealistic price expectation shocks play a more important role in driving house prices than realistic expectation shocks during the recent boom.

The previous empirical literature that explores the role of expectations and speculation in the housing market can be broadly divided into three groups. A first group of papers looks at large deviations from benchmark models and notes that such deviations may have occurred because of shifts in house price expectations. Glaeser et al. (2012), for example, find that easy credit cannot explain the full extent of the housing boom and conclude that this leaves 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 before the crisis was in line with the monetary policy predicted by the model, while residential investment and housing prices were well above predicted levels, suggesting that monetary policy has not contributed to the boom. 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)”. There are also a number of papers that use deviations from benchmark models to detect bubbles in housing markets. A popular benchmark is, for example, the average price-to-rent or the price-to-income ratio (see e.g. Case and Shiller, 2003; Leamer, 2002). A weakness of such an indirect approach is that it is difficult to distinguish between a misspecified model and irrational expectations. The role of expectations may be overestimated, if the underlying model is misspecified or omits important features of the housing market. Himmelberg et al. (2005), for example, argue that the often used price-rent ratio is an inadequate measure to judge the sustainability of house price increases and that user cost models that rely on imputed rents should be employed instead. With these adjustments, they find no evidence for a house price bubble in 2004. Similarly, Smith and Smith (2006) make a case against a housing bubble in 2006: “under a variety of plausible assumptions about fundamentals, buying a home at current market prices still appears to be an attractive long-term investment.”

The second group of papers relies 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 share of respondents emphasize the investment motive. They conclude that this motive is a “defining characteristic of a housing bubble”. The survey responses can, however, also be interpreted differently. Quigley (2003), for example, 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. The authors find that shocks to expectations explain a substantial share of house price movements. Ling et al. (2015) find that survey-based sentiment indicators have predictive power regarding future house price developments, even when controlling for fundamentals. Our paper provides an alternative approach to measure shifts in expectations that does not rely on surveys and allows for contemporaneous interactions between shifts in expectations and housing market variables. Gete (2015) also identifies expectation shocks without relying on survey data. In comparison to our paper, the study uses a different identification scheme (relying on the response of the ratio of consumption to investment) and does not compare the importance of expectation shocks to mortgage rate and supply shocks.

A third group of papers consists of microeconometric studies that investigates the effect of speculation on local housing conditions. Chinco and Mayer (2014) provide evidence that out-of-town second house buyers tend to behave like misinformed speculators and find that a relative increase in out-of-town second house buyers is associated with house price increases and house price misalignments in several US states. Bayer et al. (2011) document that the housing boom in Los Angeles coincided with an increase in speculative investors, which are defined as investors that purchase a house with the aim of selling it at a higher price. None of these studies looks at the aggregate, macroeconomic importance of speculative activity.

This paper is also related to a more theoretically oriented literature that studies the role of expectations in house price models. Adam et al. (2012) investigate how the housing market responds to economic shocks, if agents update their expectations in a Bayesian fashion. Burnside et al. (2011) build a model where agents change their expectations about house prices because of social dynamics. Regarding the link between expectations and vacancies, 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.

Finally, macroeconometric methods to study the role of speculation in other markets exist. Kilian and Murphy (2014) use a structural VAR to identify speculative activity in the oil market, relying on the behavior of oil inventories. As we discuss below there are some conceptual similarities between vacancies in the housing market and inventories in the oil market, but also important differences.

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

II. Empirical Framework

This section introduces 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.

A. Model and Data

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

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

$\mathbf{e}_t$ is a reduced-form error term with variance-covariance matrix $\mathbf{\Sigma}$, p is the lag length and $\mathbf{A}_i$ are coefficient matrices. Our sample comprises more than 40 years of quarterly data that cover the period from 1973Q3-2014Q2. We chose a lag length of 2 and an uninformative prior.

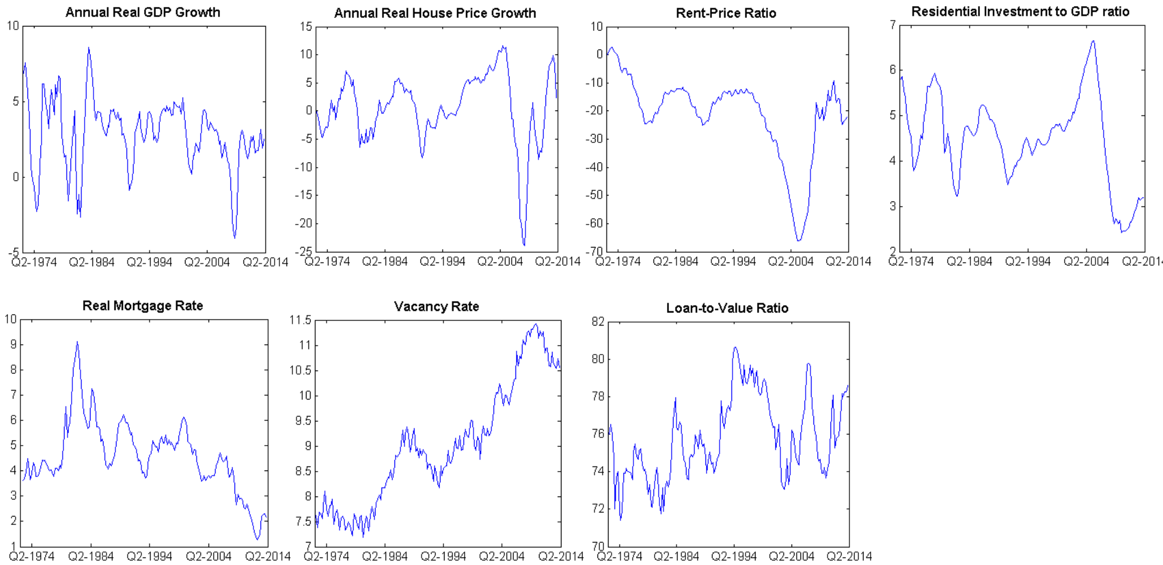
The quarterly growth in the housing price ($\triangle P_t$) is measured by the first difference of the log Shiller real house price index (Shiller, 2005). The log of the real private residential investment to real GDP ratio ($H_t - RGDP_t$) is from the Bureau of Economic Analysis. The vacancy rate (V_t) is given by the overall ratio of vacant houses relative to the total housing stock excluding seasonal factors (Census Bureau).[1] The real mortgage rate (i_t) is approximated by the nominal contract rate on the purchases of existing single family homes provided by the Federal Housing Financing Agency (FHFA) less the long-term inflation expectations, measured by the 10-year-ahead forecast of the inflation rate (Macroeconomic Advisers, downloaded from Haver).[2] The loan-to value ratio at purchase of the house (LTV_t) is from FHFA. It contains information about credit standards that are not interest rate related. The rent-to-price ratio ($R_t - P_t$) is computed as the log of the ratio between the housing CPI component (Bureau of Labor Statistics) and the nominal Shiller house price index. Finally, the log difference of US Real GDP ($\triangle RGDP_t$) is taken from the Bureau of Economic Analysis. Figure 1 shows the evolution of the respective variables.

The first 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. It allows us to capture long run dynamics in prices, while only including stationary variables (see, for example, King et al., 1991). Real GDP growth is included to capture general economic conditions. The combined responses of the residential investment to GDP ratio and GDP growth allow to compute the level response of residential investment and GDP. Furthermore, both the responses of real GDP and the rent-to-price ratio allow to assess the consistency of the responses with theoretical arguments.

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

[2] The average maturity of the interest rate is 27 years and hence does not coincide exactly with the horizon of the inflation expectations. However, it is plausible that the expectation 10 year ahead accurately reflect the expectations of inflation at longer horizon.

Figure 1. Evolution of Variables over Time



Sources: BEA, BLS, Shiller, FHFA, Census Bureau, and Haver.

B. Identification

Structural shocks are identified with sign restrictions (Canova and De Nicolo, 2002; Uhlig, 2005). The main focus is on the identification of the price expectation shock. We compare the effects of the expectation shock to those of the demand for housing services, the supply of houses and mortgage rate shocks and discuss how we can distinguish these shocks from price expectation shocks. Table 1 summarizes the identification restrictions of 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.

1. The supply of houses 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.

2. The demand for housing services is downward sloping. Hence, lower prices increase the demand for housing.

3. Credit supply is upward sloping (Glaeser et al., 2012; 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.

4. 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.

5. House prices are forward looking (Poterba, 1984) and depend on expected future prices and interest rates. The prospect of being able to sell houses in the future at a higher price, will lead to higher current prices. A lower interest rate increases the present discount value of a given future price.[3]

Price expectation shocks. A positive house price expectation shock leads to an increase in house prices, an increase in residential investment, an increase in vacancies, and an increase in the mortgage rate. An expectation shock is defined as a shift in expectations about future house prices by households and housing investors. The restriction on house prices follows from Assumption 5: the prospect of being able to sell the house at a higher price in the future leads to higher prices now. Residential investment increases as a result of Assumption 1: as large adjustments to the supply of houses are more costly than small changes, 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. Because mortgage credit supply is not perfectly elastic, the increased demand for loans associated with higher construction activity will lead to higher mortgage rates (Assumption 3). The increase in vacancies relies on Assumption 4: markets do not clear fully because of search and matching frictions. As supply increases and the current demand for housing services is unchanged, the vacancy rate rises. Finally, we impose that the expectation shock cannot go along with an increase in the LTV ratio. While this is not strictly necessary for the identification, it allows us to avoid capturing elements related to easing lending standards which are not captured by lower mortgage rates such as LTV standards. In the robustness section of the paper we will identify a separate LTV shock.

This definition of an expectation shock leaves it open whether the increase in expectations is "realistic" or "unrealistic". It is consistent both with a realistic response to new information about future housing fundamentals or with unrealistic expectations about future house prices as emphasized by Case and Shiller (2003). The identification approach presumes, however, that people act rationally given their expectations about future house prices. For example, construction will increases because of adjustment costs. In an extension, we will distinguish between realistic and unrealistic expectation shifts.

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 high inventories, as traders store the oil for future sale. Kilian and Murphy (2014) use this insight to identify speculative demand shocks in the oil market.

[3]This result is obtained for example if we consider the current house price P_t as the expected present discounted value of future rents R_{t+1}, discounted at rate r_{t+1}: $P_t = E_t \frac{R_{t+1}+P_{t+1}}{1+r_{t+1}}$

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. When prices are expected to rise, there is an increase in construction activity and people are reluctant to sell now, because they expect higher profits by selling later.

Mortgage rate shocks. A negative mortgage 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), a lower term premium on risk-free long term bonds (e.g. because there is higher demand for long term save assets (Bernanke, 2005; Caballero et al., 2008)), or because of a lower risk spread for mortgage rates (for example, because banks take more risk).[4] Our approach does not attempt to disentangle the different causes. Lower interest rates decrease the opportunity costs of buying a house, as they increase its present discount value (Assumption 5). Higher demand for housing pushes up prices (Assumption 1). The increased demand for houses is met by an increase in residential investment (Assumption 2). The response of the vacancy rate is indeterminate. It depends on the relative sensitivity of housing supply and demand to the mortgage rate. 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 price expectation shocks.

Housing demand shocks. A positive shock in the demand for housing services (i.e. occupying a house) 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 demand for housing services 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) and follow from Assumption 1 and 2: 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 (Assumption 3). In standard search and matching models higher demand is associated with lower vacancies (Head et al., 2014). As it takes time for the supply of houses to adjust, demand growth temporarily exceeds the growth in supply, which reduces the vacancy rate (Assumption 4). The restriction on vacancies is crucial to distinguish the demand for housing services shock from an expectation shock. The identified demand shock thereby focuses on exogenous variations in the demand for housing services, but does not capture an increase in housing demand for investment purposes.

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[4] Sá and Wieladek (2015) and Sá et al. (2014) compare the importance of monetary policy and capital inflows shocks for the U.S. and a sample of OECD countries, respectively.

Table 1. Baseline Shock Identification

	Shock to:			
	Housing supply	Housing demand	Mortgage Rate	Price Expectation
House prices	> 0	> 0	> 0	> 0
Res. Inv.	< 0	> 0	> 0	> 0
Mortgage rate		> 0	< 0	> 0
Vacancy rate	< 0	< 0		> 0
Loan-to-Value				< 0

Note: All structural shocks have been normalized to imply an increase in the real price of housing.

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 cost increases in the construction sector and 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. The restrictions on house prices and residential investment are as in Jarocinski and Smets (2008) and follow from Assumption 1 and 2. An upward shift of the supply curve, everything else fixed, leads to higher prices and lower quantities. As there are now fewer houses for a given demand, the vacancy rate falls (Assumption 4).

C. Computational Implementation

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 until we accept 10000 models.[7]

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

[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 X and apply the QR decomposition $X = QR$.

[7] The number of rotations needed to obtain 10000 acceptances varies with the specification. In the baseline model about 2 percent of the rotations are accepted.

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. We proceed similarly for the historical decomposition and the variance forecast error decomposition and use the pointwise mean as our baseline measure. As error bands, we report the pointwise 16^{th} and 86^{th} percentile. 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 add up to the total. In the robustness section, we also discuss alternatives to the pointwise mean measure, including the pointwise median and the single accepted impulse response function that is closest to the mean of all accepted impulse response functions.

III. RESULTS

The following section starts with a discussion of the impulse response functions of the identified shocks. This discussion prepares the ground for the main interest of the study: the contribution of price expectation shocks to the recent boom and bust of house prices and their historical relevance for house price movements. The following section presents results from the forecast error variance decomposition. The next section compares model-based measures of house price expectations to survey-based measures. The last section differentiates between shocks driven by "realistic" and "unrealistic" price expectations.

A. Impulse Response Functions

Figure 2 depicts the response of the seven variables in the VAR to the four identified shocks. In each case the size of the shock is normalized to one standard deviation. The responses of real house prices, real residential investment, and real GDP are displayed in levels and calculated from the responses of the growth rates of house prices, real GDP and the residential investment to GDP ratio. For each impulse response function, we report the pointwise mean and the pointwise 68 percent error bands, reflecting parameter and identification uncertainty. A grey shaded area marks periods where sign restrictions have been imposed.

A positive price expectation shock leads to an initially positive response of real house prices, residential investment, the vacancy rate, and the mortgage rate. House prices rise in the first three years by about 1.5 percent and then start to decline slowly. The rent-to-price ratio declines initially. If we think of the house price as the present discount value of future rents and sale price (Assumption 5), this pattern is consistent with an increase of expected future rents or future house prices. Similar to house prices, the rent-to-price ratio starts to revert back after about three years.

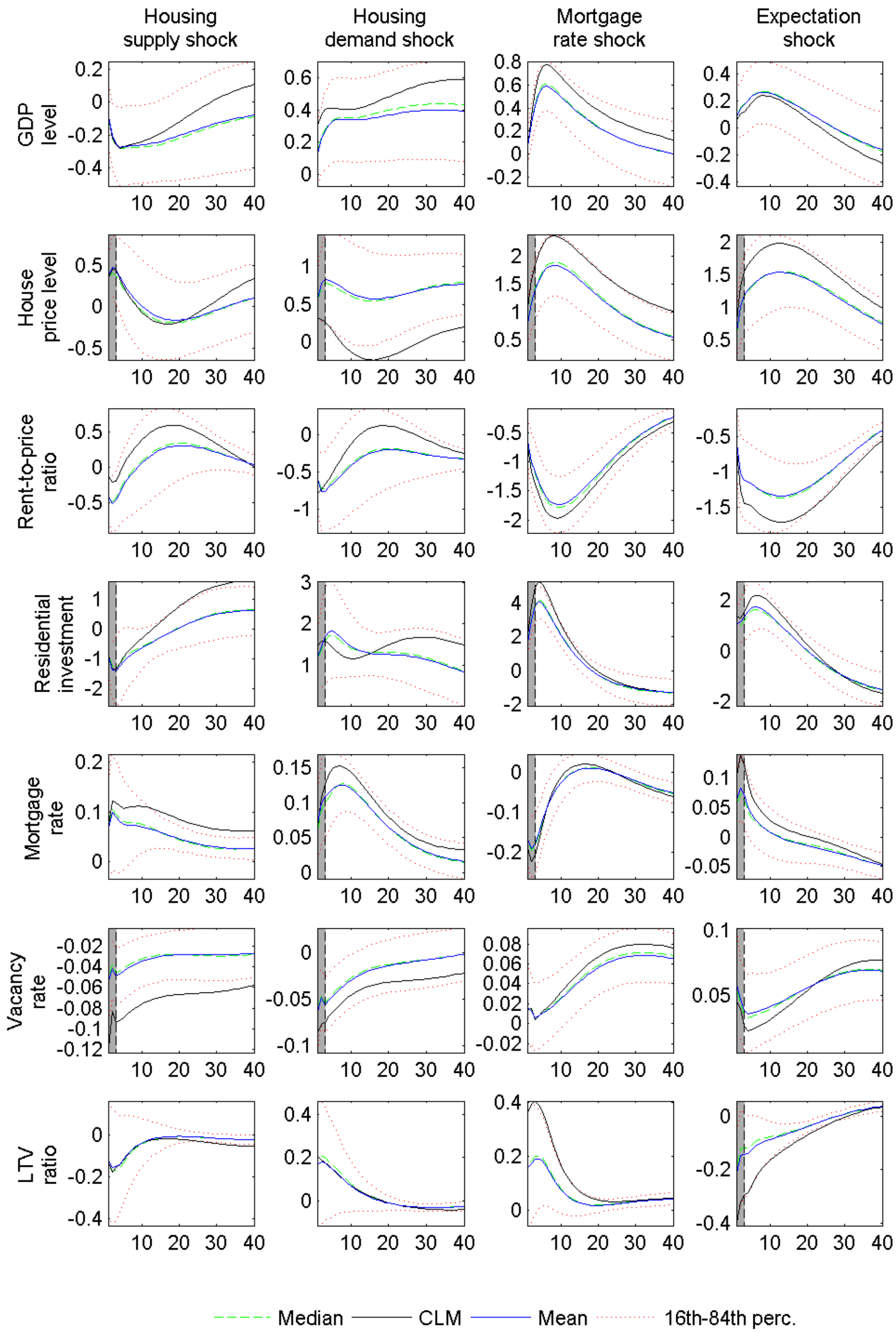
Residential investment increases on impact by close to 1 percent and follows a hump-shaped pattern, peaking at about 2 percent. After 6 quarters investment starts to contract and persistently falls below its pre-shock path after about five years. Such a pattern is consistent with the hypothesis that overly optimistic expectations about future housing conditions are compensated in the medium run with persistently lower residential investment. The response of GDP follows a similar pattern. GDP rises in the initial quarters by up to 0.2 percent and starts to fall after around 2 years.[8] The point estimate eventually turns negative, but, in contrast to the response path of residential investment, error bands include zero. The real mortgage rate increases by roughly 8 basis points in the first year due to higher mortgage demand. The real mortgage rate then starts to decline and eventually undershoots, consistent with persistently low residential investment and low demand for mortgages. At the same time, the vacancy rate is increasing for an extended period, reverting slowly only after about 6 years. This suggests that a persistent excess supply follows the expansion in construction, underpinning the need for residential investment to decline below its pre-shock path for a prolonged period.

The negative mortgage rate shock leads to qualitatively similar responses of house prices, residential investment, vacancies and output as the price expectation shock. Quantitatively, however, a mortgage rate shock is associated with substantially stronger responses of residential investment and output, whereas the house price increase is of about equal magnitude. The response of house prices is, however, less persistent, as prices start to fall after about two years. The response of both output and residential investment to mortgage rate shocks is two to three times larger than the response to the price expectation shock. As in the case of the price expectation shock, residential investment falls below zero over the medium term. The rent-to-price ratio initially falls, as we would expect from the present value relationship discussed under Assumption 5, if interest rates fall. The vacancy rate remains unchanged on impact, but starts to increase after about 1 year, consistent with spare capacity resulting from the rise in residential investment. The loan-to-value ratio increases significantly after about one year by 0.2 percentage points, implying a faster increase in loan volumes relative to housing prices in response to mortgage rate shocks.

Positive shocks to the demand for housing services are associated with an increase in residential investment, real housing prices, and output. Residential investment and output rise initially by about the same amount as in response to the price expectation shock, but the response is more persistent. House prices rise by less than in response to price expectation shocks, but the increase is again much more persistent. Different from the price expectation shock, the response of the rent-to-price ratio is weak: although it falls initially, the response turns quickly insignificant. Hence, house prices and rents grow by about the same amount. The difference between the response to price expectation and demand for housing services shocks is in line with the present discount value relationship discussed under Assumption 5. A shock to the demand for housing services affects current fundamentals in the housing market, driving up both prices and rents. The increase of house prices in response to the expectation shock is driven by expectations, with little effect on current rents. The mortgage rate rises by about 10 basis points in response to increased

[8] Igan and Loungani (2012) using a standard VAR framework for individual countries, find that the average impact of a 1 percent increase in housing prices is a 0.2 percent increase in GDP growth.

Figure 2. Baseline Model: Impulse Response Functions



Note: Mean depicts the pointwise mean of accepted impulse response functions and is the main summary measure, along with pointwise 16^{th} and 84^{th} percentile error bands. These measures are described in Section II C. Median and CLM (closest-to-mean) are alternative summary measures described in Section IVA. The identification assumptions are summarized in Table 1. A grey shaded area marks periods where sign restrictions have been imposed.
Source: Authors' calculations.

housing activity and remains elevated for an extended period, in line with the persistent increase in residential investment. The vacancy rate drops initially, but returns within less than 3 years back to to its pre-shock path, suggesting that increased residential investment closes the gap between the demand for housing services and the supply of houses.

Negative supply shocks are associated with an increase in house prices and a contraction of residential investment and output. The initial contractions in residential investment and output are of about the same order of magnitude as the expansions in response to housing demand or price expectation shocks. Residential investment and output revert, however, faster back to their respective pre-shock paths. The increase in house prices is reversed after two years. As in the case of the demand shock for housing services, the response of the rent-to-price ratio is insignificant at most horizons, as we would expect from Assumption 5 if the shock mainly affects current fundamentals.

B. Contribution of Price Expectation Shocks to the Housing Boom And Bust

The present section explores how the four identified shocks contributed historically to housing dynamics at specific points in time. Figure 3 displays the historical decomposition of real house prices. The solid line is the log real house price (normalized to zero at the starting point of the boom period in 1996Q4) in deviation from its deterministic path, i.e. the path house prices would have taken if no shock occurred since the starting point of the sample.[9] The colored bars indicate the contribution of the four shocks to the observed path. Finally, there is an unexplained residual that occurs because only four out of the seven shocks have been identified.

The four identified shocks explain a substantial share of the house price increase in the run up to the crisis (see also Table 2). About 70 percent of the increase between 1996Q4 and 2006Q1 is explained by the four identified shocks in the baseline model. The largest contribution comes from price expectation shocks, explaining 30 percent of the increase. The second most important contribution comes from mortgage rate shocks accounting for about 25 percent of the rise.[10] The price path generated by these two shocks increases monotonically over the boom period. The contribution from the mortgage rate shock gains in importance after the 2001 recession, 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 a sizable unexplained residual of about 30 percent.[11] In a model that accounts

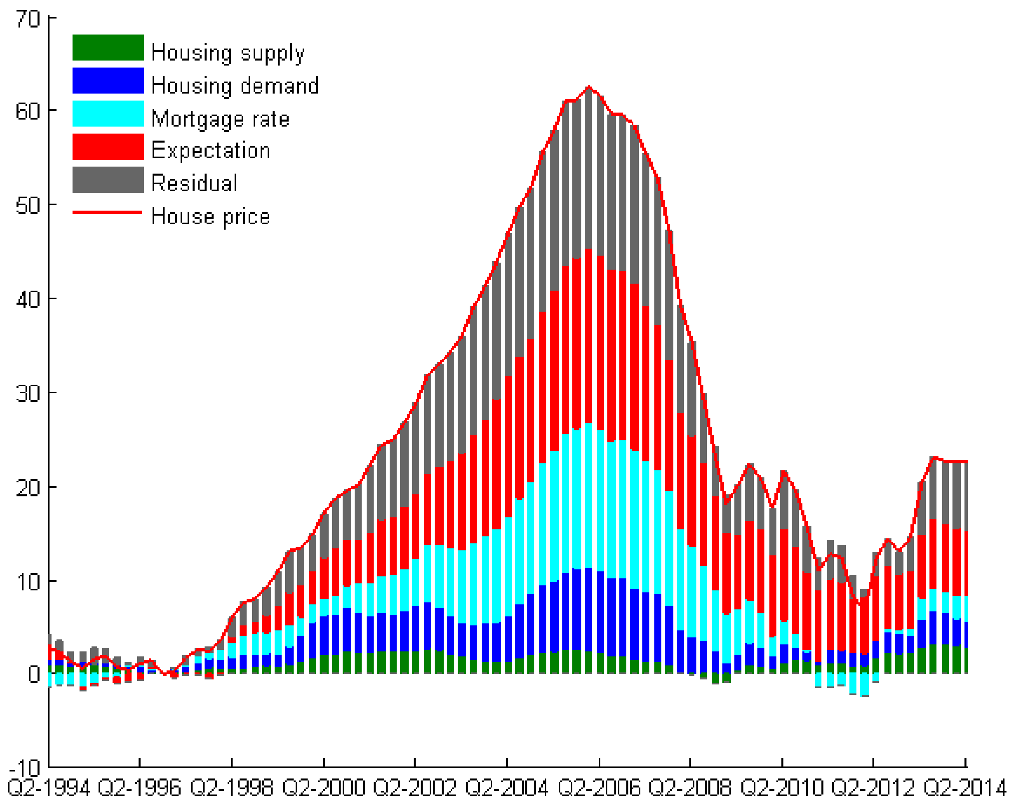
[9] Table 2 reports additionally the contribution of the deterministic component, i.e. the path the house prices would have taken if no shocks had occurred after 1996Q4. It is influenced by the initial conditions and the estimated long term growth rate of real house prices.

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

[11] The deterministic component explains a negligibly small part.

only for the three traditional shocks (housing supply, housing demand, and mortgage rate)[12] the contribution of the residual would nearly double to about 50 percent. Overall, our results therefore suggest that price expectation shocks have been an important factor behind the boom, but that attributing the entire residual that cannot be explained by conventional shocks to expectations would strongly overestimate their contribution.

Figure 3. Historical Decomposition of Real House Price Developments



Note: The solid line is the log real house price (normalized to zero at the starting point of the boom period in 1996Q4) in deviation from its deterministic path, i.e. the path house prices would have taken if no shock occurred since the starting point. The bars indicate the contribution of the four shocks and the unexplained residual to the observed path. The identification assumptions are summarized in Table 1.
Source: Authors' calculations.

Turning now to the decline in real house prices that started in 2006Q2 and ended in 2012Q1, the historical decomposition reveals that the decline was again mainly driven by mortgage rate and price expectation shocks. Taken together, they explain more than 50 percent of the path (see Table 2). The contribution of the mortgage rate shock (about 30 percent) is larger than the contribution

[12]Hence, the identification follows closely Jarocinski and Smets (2008) and would be identical to the one described in Table (1) without any constraints on the vacancy rate and no identification of the price expectation shock.

of the price expectation shock (about 20 percent). At first sight this might appear counter intuitive, given the decline in policy rates. Two main factors explain the negative contribution from mortgage rate shocks: First, the mortgage rate fell less than predicted by the VAR given the other variables' developments. Thus, a positive mortgage rate shock materialized in the period directly after the housing price peak. Second, mortgage rate shocks that occurred before the housing peak start to contribute negatively after the housing peak. This is a result of the hump-shaped response of house prices to mortgage rate shocks. As mortgage rate shocks have a less persistent impact on prices than price expectation shocks, the pace of the declining support to housing prices is faster. The role of demand shocks during the bust is about equal to their role during the boom, with a contribution that amounts to roughly 15 percent. As shocks to the demand for housing services have persistent effects on house prices, the decline can mainly be attributed to new negative shocks, consistent with a decline of income during the recession. The contribution of supply shocks remains minor.

Table 2. Contribution of Shocks to Price Boom and Bust

	Shock to:						
	Housing	Housing	Mortgage	Expectation		Deter-	Residual
Model:	Supply	Demand	Rate	Unreal.	Real.	ministic	
			Contribution to Boom (1996Q4 - 2006Q1)				
Baseline	4.0	14.4	24.7	30.1		-0.9	27.6
Baseline excl. Expectation	7.4	21.7	23.1			-0.9	48.8
Unrealistic and realistic	4.9	14.4	23.4	31.0	8.6	-0.9	18.7
			Contribution to Bust (2006Q2 - 2012Q1)				
Baseline	2.9	13.9	31.9	22.8		-0.9	29.4
Baseline excl. Expectation	6.5	22.1	27.2			-0.9	45.2
Unrealistic and realistic	4.2	12.4	31.1	30.5	3.1	-0.9	19.6

Note: The Table displays the share of the change in house prices explained by the respective shock. The baseline identification assumptions are summarized in Table 1. In rows entitled "Unrealistic and realistic" the first number in the column "Expectation" denotes the contribution of the unrealistic shock and the second number the contribution of the realistic shock (see Section IIIE).

Source: Authors' calculations.

C. Forecast Error Variance Decomposition

While the previous section has looked at the importance of the different shocks during boom and bust periods, the present section analyzes their importance over the entire sample, using a forecast error variance decomposition (see Table 3). The mortgage rate and price expectation shocks are again the most important drivers of the variation in housing prices. However, in comparison to the contribution during the boom, their order of importance is reversed. Price expectation shocks account for about 20 percent and mortgage rate shocks for 28 percent of house price variation at the ten year horizon. Hence, the contribution of the mortgage rate shock is slightly higher than during the boom period. The contribution of the price expectation shock is still substantial, but the large contribution during the recent boom period is historically exceptional.

Table 3. Variance Decomposition

Quarter ahead	Housing supply shock	Housing demand shock	Mortgage rate shock	Expectation shock	Residual
			Real Housing Price		
1	8	16	27	18	31
4	7	14	28	21	30
16	8	14	28	20	30
40	8	14	28	20	30

Note: The Table displays the share of the forecast error variance explained by the respective shocks at various forecast horizons. Shocks are identified as summarized in Table 1.

Source: Authors' calculations.

The supply shocks account for less than 10 percent and the demand shocks for about 15 percent of the variation in house prices, broadly in line with the contribution during the boom period. About 30 percent of the variation in the house price remains unexplained by the four shocks, which is of roughly similar magnitude as the residual's contribution during the boom period.

D. Comparison of Price Expectation Shocks with Surveys about Price Expectations

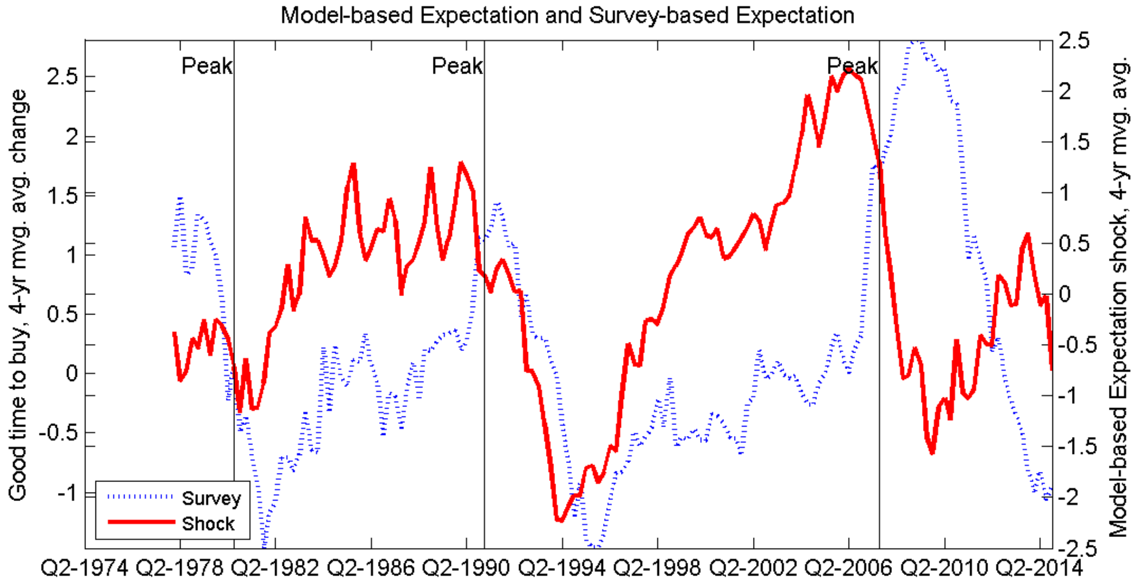
The present section compares a price expectation measure derived from our empirical model with a survey-based measure of house price expectations. This allows us to check whether the identified expectation shocks correlate with independent measures for house price expectations. A strong positive correlation between the model-based measure and the survey-based measure would support our identification scheme.

As a model-based expectation measure, we compute the four-year rolling average of price expectation shocks, based on the mean of the set of identified shocks at each point in time. The corresponding survey measure is the four-year rolling average of the change in the share of respondents in the Michigan Survey of Consumers reporting that it is a good moment to buy a house, because prices are favorable.[13] We use a rolling average window to remove volatile short-term movements.

Figure 4 shows a close co-movement of the survey-based and the model-based expectation measure. Furthermore, the model-based measure leads the survey-based measure. Table 4 confirms this pattern: the model-based expectation measure is strongly and positively correlated with leads of the survey measure. The positive correlation is statistically significant. A potential explanation for the leading property of the model-based expectation measure is that it reflects

[13] Respondents include both, those saying that it is a good moment to buy because prices will rise and those who believe it is a good moment to buy because prices are low, thus implicitly judging prices to be higher in the future.

Figure 4. Survey-based Expectations versus Model-based Expectations



Note: The model-based expectation measure is the four-year rolling average of price expectation shocks, based on the mean of the set of identified shocks at each point in time. The survey measure is the four-year rolling average of the change in the share of respondents in the Michigan Survey of Consumers reporting that it is a good moment to buy a house because prices are favorable. Vertical lines mark peaks in the housing price.

Sources: Michigan Survey of Consumers and authors' calculations.

transactions among buyers and sellers in the housing market. Survey respondents may not be as well informed about the housing market. The survey is conducted with a general panel of consumers, of which not all are involved in the decision to buy a house. The model-based measure also seems to lead the house price cycle slightly, typically starting to decline before house prices peak. The survey-based measure, by contrast, starts to decline after the house price peak.[14]

For comparison purposes, we construct equivalent model-based measures of the other three shocks (Table 4).[15] It turns out that the model based expectation measure based on price expectation shocks has the strongest correlation with the survey-based measure. The correlation for demand and supply shock based measures is weak and mostly not statistically significant. For mortgage rate shocks, the correlation is stronger, but not as strong as for price expectation shocks.

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[14]An exception is the peak in the late seventies. The marked real house price peak occurs because of high inflation, while nominal house prices do not reach a peak.

[15]The corresponding figures are in an appendix.

Table 4. Correlation of Model-based Expectation Measure (t) with Survey-based Measure (t+i)

	Number of years ahead (i)				
Shock:	0	1	2	3	4
Expectation	-0.03	0.28	0.54	0.68	0.70
	(0.70)	(0.00)	(0.00)	(0.00)	(0.00)
Housing supply	-0.32	-0.19	-0.01	0.14	0.29
	(0.00)	(0.03)	(0.92)	(0.12)	(0.00)
Housing demand	-0.31	-0.06	0.07	0.03	-0.02
	(0.00)	(0.49)	(0.41)	(0.76)	(0.84)
Mortgage rate	-0.16	0.08	0.34	0.49	0.57
	(0.08)	(0.34)	(0.00)	(0.00)	(0.00)

Note: The model-based measures are the four-year rolling average of the relevant shock, based on the mean of the set of identified shocks at each point in time. The survey measure is the four-year rolling average of the change in the share of respondents in the Michigan Survey of Consumers reporting that it is a good moment to buy a house because prices are favorable. P-values are in parentheses.

Sources: Michigan Survey of Consumers and authors' calculations.

E. Realistic versus Unrealistic Price Expectation Shocks

In housing, similar to other asset markets, anticipations of the future play a major role. Rather than being a source of disruption, the anticipation of future events can be supportive of the well functioning of the housing market. The baseline identification strategy for the impulse response functions leaves open why expectations shifts occur and allows the price expectation shock to encompass perfectly "realistic" expectations and "unrealistic" expectations. This section attempts to disentangle price expectation shocks into expectation shocks based on realistic views about future fundamentals and expectation shocks based on unrealistic views.

To further distinguish between realistic and unrealistic price expectation shocks, we introduce an additional constraint on the net present discount value of housing. The basic idea is that if a house purchase is based on unrealistic expectations, it cannot be profitable as a long term investmenti. Hence, the corresponding ex-post net present discount value of the investment must be negative. We start from the present discount value relationship, where the net present discount value of a house purchase at time 0 with investment horizon T ($NPV_{0,T}$) is a function of the purchase price P_0, future rental (or rent-equivalent) incomes R_t, future resale price P_T and discount rates $1 + i_t$.

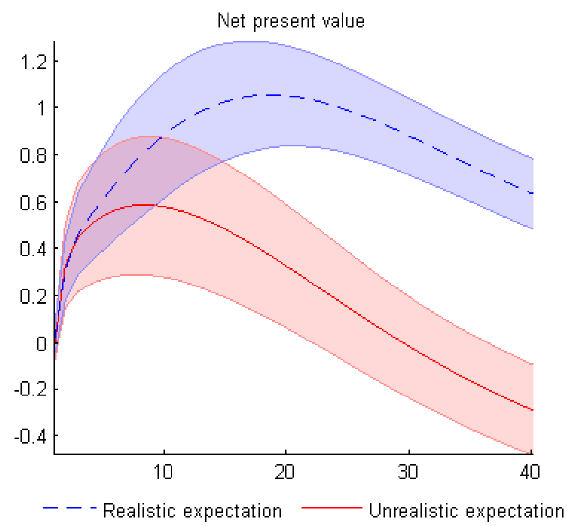
$$NPV_{0,T} = -P_0 + R_0 + \sum_{t=1}^{T-1} \frac{R_t}{\prod_{s=1}^{t}(1+i_s)} + \frac{P_T}{\prod_{s=1}^{T}(1+i_s)}$$

Following Campbell and Shiller (1988), the percent change in the net present value $n\hat{p}v$ as a result of the shock can be log-linearly approximated as:

$$n\hat{p}v_{0,T} = -\hat{P}_0 + \sum_{t=0}^{T-1} \rho^t(1-\rho)\hat{R}_t + \rho^T\hat{P}_T - \sum_{t=0}^{T-1} \rho^t\hat{i}_t,$$

where a hat denotes the log deviation from the pre-shock path, T is the investment horizon, and ρ is the average ratio of the house price to the sum of house price and rent.[16] The expression includes no expectation operator. It is an ex-post relationship, based on the realized values of the fundamentals. According to our definition, unrealistic price expectation shocks carry an ex post negative net present discount value in the long-term. This occurs if future realized rents and house prices are relatively low, and mortgage rates are relatively high. Identified expectation shocks with positive net present discount value are classified as realistic, because the investor has made long term profits. To refelct the long term, we choose an investment horizon of $T \in (40, \infty)$,[17] which implies that npv must turn negative (latest) after forty quarters in the case of an unrealistic expectation shock.

Figure 5. $NPV_{0,T}$ for Expanding Investment Horizon



Note: Lines depict the pointwise mean of the net present value as of time zero for an expanding investment horizon T. Values are based on accepted impulse response functions for rents and mortgage rates over time 0 to T and the housing price as of T for the realistic (dotted blue line) and the unrealistic (solid red line) expectation shocks. Shaded areas describe the pointwise 16^{th} and 84^{th} percentile error bands of the respective shocks. The identification assumptions are summarized in the main text of Section IIIE.
Source: Authors' calculations.

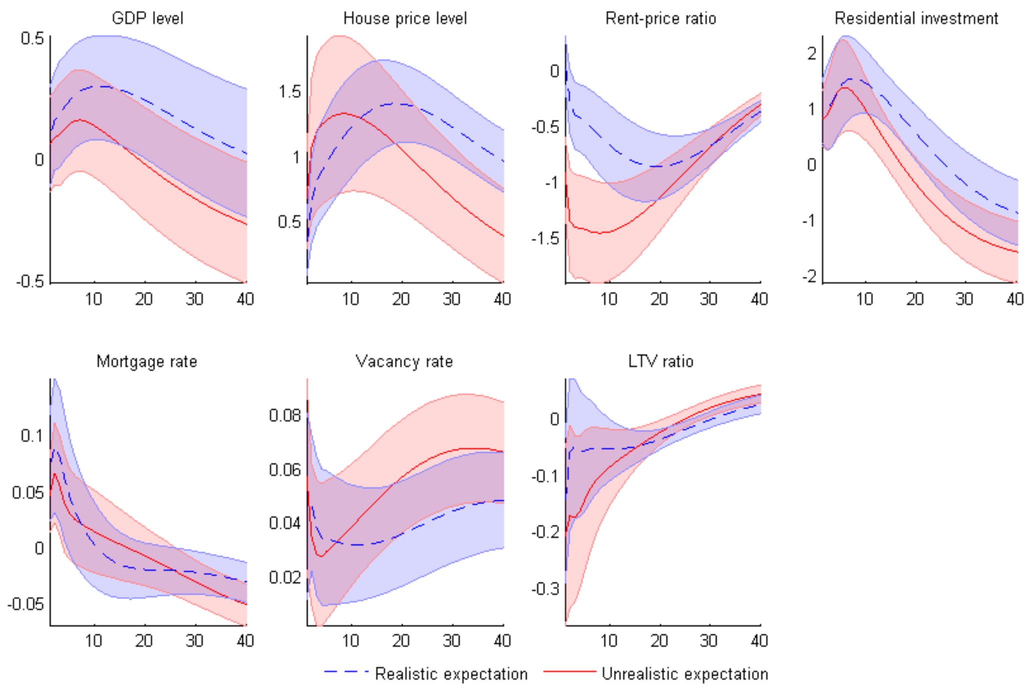
Figure 5 depicts the net present discount value of an investment made at time 0 (when the shock

[16]We fix $\rho = 0.98$ based on the median quarterly rent-to-price ratio in the U.S. in 1996, which is close to 1.3% (see Campbell et al., 2009).

[17]In practice, we constrain the relationship to hold for all quarters from 40 quarters to 200 quarters after the shock, when the respective npv's have effectively converged to the long term level.

hits) over an expanding investment horizon.[18] Initially, the NPV of both realistic and unrealistic shocks are positive. As time passes and the investment horzion extends, more information arrives and it becomes evident that the long-term return turns out to be negative in the unrealistic case. On average this occurs after about seven years.

Figure 6. Realistic and Unrealistic Price Expectation Shocks: Impulse Response Functions

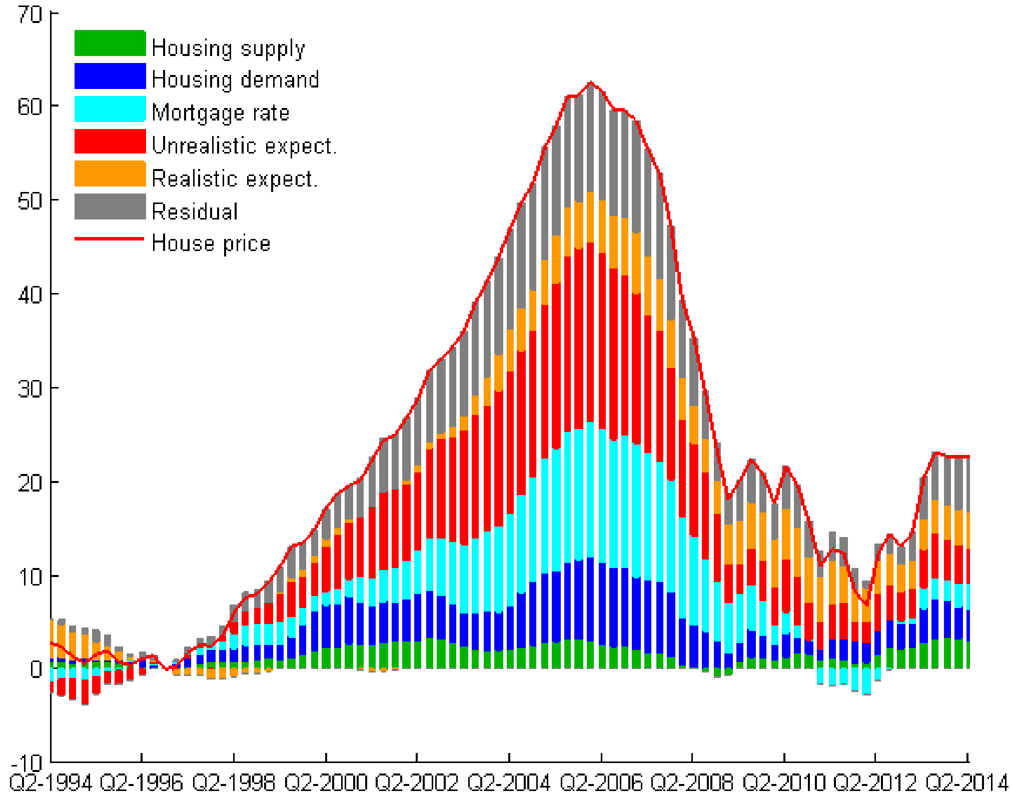


Note: Lines depict the pointwise mean of accepted impulse response functions for the realistic (dotted blue line) and the unrealistic (solid red line) expectation shocks. The blue and red shaded areas describe the pointwise 16^{th} and 84^{th} percentile error bands of realistic and unrealistic expectation shocks, respectively. The identification assumptions are summarized in the main text of Section IIIE.
Source: Authors' calculations.

Figure 6 compares the impulse response functions of an unrealistic and a realistic price expectation shock. In the first two years, the house price increases are of similar magnitude for both shocks. However, in subsequent years, house prices fall in response to an unrealistic expectation shock, whereas they increase persistently in response to a realistic expectation shock. Similarly, the initial increase in residential investment is comparable across the two shocks, but the subsequent fall in residential investment is more pronounced in response to the unrealistic expectation shock. The vacancy rate responds more strongly to the unrealistic shock over the medium term, consistent with a larger excess supply (despite lower investment activity). Finally, output only increases significantly in the case of the realistic shock. For the unrealistic shock, it tends to fall over the medium run.

[18]Thus, the x-axis for NPV refers to the expanding investment horizon k=T. For example, in the first period the ex post NPV is based on rental income R earned in that period plus the discounted house price P/(1+i). In period k=2, the NPV is based on discounted rental income in period 1 and 2 and the discounted house price in Period 2 and so on.

Figure 7. Realistic and Unrealistic Price Expectation Shocks: Historical Decomposition



Note: The solid line is the log real house price (normalized to zero at the starting point of the boom period in 1996Q4) in deviation from its deterministic path, i.e. the path house prices would have taken if no shock occurred since the starting point. The bars indicate the contribution of the five shocks and the unexplained residual to the observed path. The identification assumptions are summarized in the main text of Section IIIE.
Source: Authors' calculations.

Concerning the historical decomposition, unrealistic price expectation shocks account for a substantially larger share of the housing boom (Table 2, Figure 7) and explain 31 percent of the increase between 1996Q4 and 2006Q1, similar to the contribution of the price expectations shock in our baseline specification. Realistic price expectations only explain 9 percent of the overall price increase. During the bust, unrealistic expectation shocks are also the main driver of the decrease in housing prices, accounting for about 30 percent of the fall. With only 3 percent, the contribution of realistic shocks is again substantially smaller. The estimated contributions of mortgage rate, demand for housing services, and housing supply shocks to boom and bust barely change as a result of the new identification scheme. The overall residual that remains unexplained is a bit smaller, as we would expect when increasing the number of identified shocks. The decrease is, however, relatively small, in line with the minor contribution of the realistic expectation shock.

IV. Robustness

In this section, we explore several changes to the baseline specification. We consider alternative summary measures of the set of accepted impulse response functions, investigate the effects of alternative modeling choices including sample length, lag length, accounting for trends, alternative price measures, and identify an additional LTV shock.

A. Alternative Summary Measures of the Set of Accepted Impulse Responses

As discussed in Section II C, there are several alternative ways to summarize the set of accepted impulse response functions. The present section shows that our main results are robust to the use of alternative summary measures.

Much of the literature (see, for example Uhlig, 2005) reports the pointwise median, but this measure has recently been criticized. Fry and Pagan (2011) criticize the practice of using the pointwise median, because the median at each horizon may be obtained from different accepted impulse response functions, 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 the pointwise median as reference point, 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 in the main section 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.

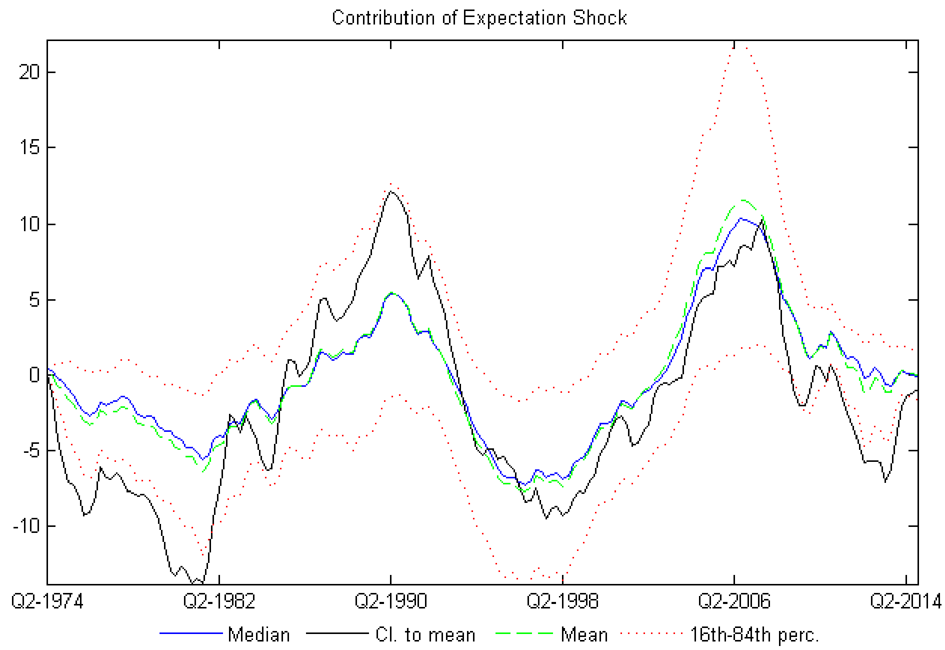
To address these concerns, we compare our baseline measure (the pointwise mean of accepted impulse response functions) to the single impulse response function that is closest to the pointwise mean (closest-to-mean measure).[19] As an established benchmark, we additionally report the pointwise median. We report both a comparison for impulse response functions and for the historical decomposition.

Figure 2 depicts alternative summary measures of the impulse response functions. The alternative summary measures confirm our main results. For all variables, the pointwise median measure is almost indistinguishably from the pointwise mean, indicating a symmetric distribution of the accepted impulse response functions. The single impulse response function that is closest to the pointwise mean is nearly always within the 68 percentile range. However, in some cases, there are important deviation from the pointwise mean and pointwise median, as emphasized by Fry and

[19]The closest to mean model is obtained by finding the rotation which minimizes the squared percent difference between the point-wise mean impulse response functions and the respective model's impulse response to all identified shocks for all seven response variables for the first two quarter, i.e. the length of the imposed sign restriction.

Pagan (2011). Most notably, for the response to mortgage and price expectation shocks the closest-to-mean measure implies a stronger response of real house prices and residential investment, while for the demand shock the response of house prices is weaker.

Figure 8. Historical Contribution of Price Expectation Shock to Real House Price Developments



Note: Mean (dashed green line) depicts the historical contribution based on the pointwise mean and is the main summary measure, along with pointwise 16^{th} and 84^{th} percentile error bands (dotted red lines). These measures are described in Section IIC. Median (solid blue line) and Cl. to mean (closest-to-mean, solid black line) are alternative summary measures described in Section IVA. The identification assumptions are summarized in Table 1.
Source: Authors' calculations.

In the historical decomposition, the contribution of the price expectation shock using pointwise mean and pointwise median measures are again similar (see Figure 8). Also the contribution of the price expectations shock measured by the closest-to mean tracks the path of the pointwise mean fairly well. As a consequence, the contribution of the price expectations shock to the boom is again close to 30 percent (Table 5). The contribution of the mortgage rate shock lies at about 40 percent and therefore is substantially larger while the contribution of supply shock and residual are smaller in this specification.

B. Different Sample Length, Lag Length, and Trends

The coefficients in the VAR are restricted to be constant over time. To address the possibility of a structural break as result of the financial crisis, we re-estimate the baseline model excluding post-2007Q4 observations.

Table 5 shows that the contribution of the price expectation shocks during the boom period remains of similar magnitude, only the mortgage rate shock is somewhat smaller. Furthermore, we investigate to which extent our estimate of the contribution of unrealistic expectation shocks to the boom is driven by the large decline of house prices during the housing bust, which could only be observed ex-post. We, therefore, re-estimate the model for the shorter sample period identifying unrealistic and realistic price expectation shocks. The unrealistic expectation shock remains with a contribution close to 20% a more important driver than any of the traditional shocks. Different to the full sample estimates, the realistic expectation shock plays with about 25% an even more important role. This suggests that without the data from the housing bust, the model would still have attributed a considerable share of the increase in the housing price to expectation shocks, but would have overestimated the contribution of realistic shocks.

Table 5. Contribution of Shocks to Price Boom, Alternative Models

	Shock to:							
	Housing	Housing	Mortgage	Expectations		LTV	Deter-	Residual
Model:	Supply	Demand	Rate	Unreal.	Real.		ministic	
Closest to mean	-3.2	11.2	40.3	28.8			-0.9	23.8
Until 2007Q4	2.6	11.5	17.2	26.7			13.8	28.3
Unreal./Real. until 2007Q4	2.1	8.6	13.3	19.4	24.6		13.8	18.2
4 lags	8.0	14.8	8.4	26.2			10.4	32.3
i_t,V_t in first diff.	10.2	10.3	26.4	21.4			7.7	24.1
LTV shock	3.9	12.4	23.4	28.4		13.4	-0.9	19.5
First-time LTV	6.9	7.3	15.1	20.1		39.0	-29.1	40.7
CoreLogic price	4.2	10.4	17.6	25.3			12.1	30.4
CENSUS price	2.0	8.3	40.5	22.5			5.8	20.9

Note: The Table displays the share of the change in house prices explained by the respective shock. In row entitled "Unreal./Real. until 2007Q4" the first number in the column "Expectation" denotes the contribution of the unrealistic shock and the second number the contribution of the realistic shock (see Section IIIE).

Source: Authors' calculations.

Increasing the number of lags from two to four also leaves our main results unaffected. The largest contribution again comes from the price expectation shock. The contribution from the mortgage rate shock is substantially smaller, while the contribution from the deterministic component increases. While increasing the number of lags enlarges in principle the information set, estimates should be interpreted with care due to the large number of regressors.

Although economic theory suggests that both the vacancy rate and the real mortgage rate should be stationary, they are highly persistent in practice. There is a mildly declining trend for the mortgage rate and an increasing trend for the vacancy rate for the available sample period. To account for this trend behavior we re-estimate the model using the first differences of vacancy rate and mortgage rate. First-differencing these two variables leaves the contributions of the four shocks largely unaffected. The contribution of the price expectation shock is somewhat lower, accounting for a bit more than 20 percent of the increase. The contribution of the mortgage rate shock is of similar magnitude as in the baseline specification. Demand for housing services shocks become less important, while supply shocks and the deterministic component become more important.

C. Accounting for Shocks to LTV Standards

Several studies (Duca et al., 2011; Ariccia et al., 2012) argue that a decline in banks' lending standards as measured by the LTV ratio has been an important factor behind the US house price boom.[20] The mortgage rate shock only captures changes in banks' interest rate terms (e.g. the risk premia), but does not account for changes in non-interest rate terms, such as LTV standards. In the present section, we investigate whether additionally identifying an LTV shock affects the estimated contribution of the price expectation shock.[21] The LTV shock is identified with the following additional sign restrictions: LTV shocks cause an increase in house prices, residential investment, and the mortgage rate. As the mortgage rate shock, the LTV shock makes owning a house more attractive and house prices and residential investment rise. Demand for mortgage credit rises, which puts upward pressure on the mortgage rate (Assumption 3). The response of the mortgage rate distinguishes the LTV shock from the mortgage rate shock. The LTV shock can also be distinguished from the price expectation shock, because we impose that expectation shocks cannot go along with an increase in the LTV ratio. The bank may speculate on the higher prices that drive the LTV down in the future. As the anticipation must come from banks, we classify such an event as a decline in lending standards. In that sense, our approach provides a lower bound for the contribution of the price expectation shock, because it excludes events where mortgage growth is too strong and, therefore, speculation from the banking side. Similarly, the LTV shock needs to be different from a shock to the demand for housing services. For the housing demand shock, we therefore impose the additional restriction that the LTV ratio cannot increase. This is different from the baseline specification, where some LTV shocks could have been classified as housing demand shocks. The discussed sign restrictions are summarized in Table 6.

Table 6. Shock Identification including LTV Shock

	Shock to:				
	Housing supply	Housing demand	Mortgage rate	Expectation	LTV
House prices	> 0	> 0	> 0	> 0	> 0
Res. Inv.	< 0	> 0	> 0	> 0	> 0
Mortgage rate		> 0	< 0	> 0	> 0
Vacancy rate	< 0	< 0		> 0	
Loan-to-Value		< 0		< 0	> 0

Note: All structural shocks have been normalized to imply an increase in the real price of housing.

The results again are shown in Table 5. The contribution of the four previously identified shocks are essentially unchanged compared to the baseline identification. The contribution of the newly identified LTV shock to the boom is notable and accounts with about 13 percent for a comparable

[20] By contrast, recent studies by Gete (2015) and Justiniano et al. (2015) find a small role for LTV shocks in the U.S..

[21] Non-interest rate related 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 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.

share of the increase as the demand for housing services shock and for a higher share than the supply shock.

Duca et al. (2011) argue that the average LTV ratio provides an inadequate picture of LTV standards, as it includes repeat buyers which tend to have more home equity when prices rise and may thus be able to finance their new purchase at a lower LTV. Based on American Housing Survey data, they have constructed an alternative time series that measures the LTV of first time home buyers.[22] Using this alternative LTV measure reduces the sample length by 7 years, because the variable starts later (1978) and finishes earlier (2011). In this alternative specification, the contribution of the LTV shock triples and it becomes the dominant shock. The contribution of the price expectation shock remains more important than the mortgage rate shocks, but declines to about 20 percent. There is also an important negative contribution of the deterministic component, amounting to about minus 30 percent. The large contribution of the deterministic component indicates a high sensitivity to initial conditions, as the highly persistent first-time buyer LTV measure induces near unit-root behavior into the VAR. Taking the first difference of the first-time LTV measure to account for non stationarity results in values that are close to those estimated for the standard LTV measure. Namely, the contributions from supply, demand, mortgage rate, house price expectation, and LTV shocks are 2.3, 8.9, 25.4, 28.1 and 22.3 percent.

D. Alternative Price Measures

In the final robustness test, we assess the sensitivity of the results to the choice of the house price index. We use two alternative measures: the CoreLogic and the Census Bureau index. The CoreLogic, like the Shiller house price index, is based on "repeat sales" methodology. Both, therefore, have the advantage to control for home characteristics. There are, however, some difference in coverage and weighting (see Noeth and Sengupta, 2011, for more detail).

A limitation of both measures is the omission of sales of new homes. Thus, we also employ the Census Bureau price index, which reports the national median sales price of new single-family homes. The results in Table 5 confirm the relative importance of supply, demand, mortgage, and price expectation shocks for the rise in house prices. However, for both indices, the contribution from price expectation shocks is between 20 and 25 percent, somewhat lower than in the baseline case. In the case of the CoreLogic index this is mirrored by a substantially higher joint contribution from the deterministic component and the residual. In the case of the Census Bureau new house sales index, it is the contribution of the mortgage rate shocks, which makes up for the difference, suggesting that the mortgage sensitivity of the prices of new houses is higher.

[22]We would like to thank the authors for sharing the series with us. Another study confirms that first time buyers tend to have a higher average LTV share (Patrabansh, 2013). However, this study finds little difference in the changes over time of the first-time buyer LTV relative to the repeat buyer LTV ratio.

V. Conclusion

A number of observers has suggested that shifts in house price expectations have been an important driver of the US house price boom that preceded the financial crisis. Arguments in favor of this hypothesis have either been indirect by using deviations from benchmark models or have relied on survey measures of house price expectations. The present paper proposes an empirical strategy to quantify the contribution of price expectation shocks directly using observed housing variables. It uses a structural VAR framework and identifies price expectation shocks with sign restrictions. We argue that if there is an exogenous increase in expectations about future house prices, economic theory delivers a number of predictions on the behavior of variables, such as current house prices, residential investment and vacancy rates that can be used to distinguish the price expectation shock from traditional shocks such as mortgage rate, demand for housing services, and housing supply shocks.

We find that the contribution of price expectation shocks to the U.S. housing boom in the 2000s has been substantial. In our baseline specification, price expectation shocks explain roughly 30% of the increase. Another 30% of the increase in house prices remains, however, unaccounted for by the four identified shocks. This indicates that attributing the entire residual that cannot be explained by standard shocks to price expectations will lead to an overestimation of their contribution. We also find that a model-based measure of house price expectations is strongly positively correlated with leads of a survey based measure of house price expectations. This indicates that our measure contains similar information as a survey-based measure, but tends to provide the information more timely. Our approach to identify price expectation shocks leaves the reason why expectations change open. When using an additional constraint to distinguish realistic from unrealistic price expectation shocks, we provide evidence that the housing boom was driven to an important extent by unrealistic price expectations.

The analysis has focused on exogenous changes in expectations. An interesting topic for future empirical research is how expectations respond endogenously to other shocks, as, for example, investigated theoretically in recent research by Adam et al. (2012) and Burnside et al. (2011).

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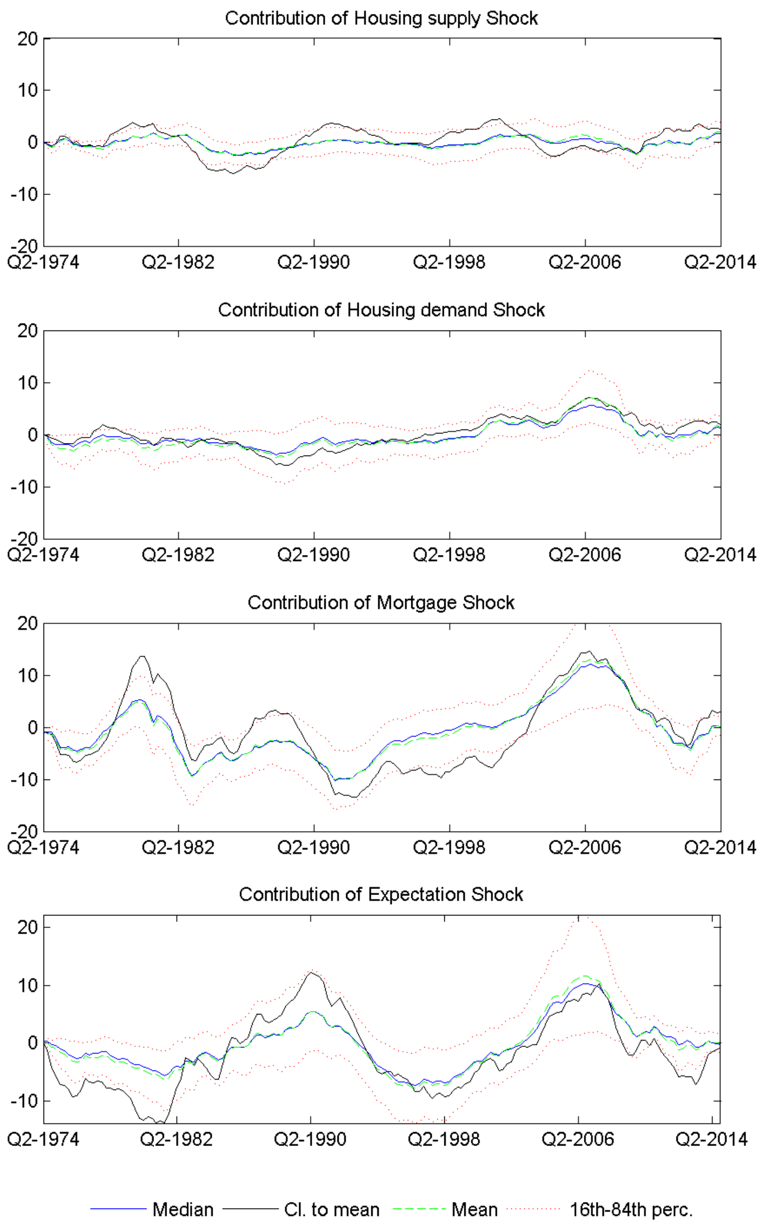
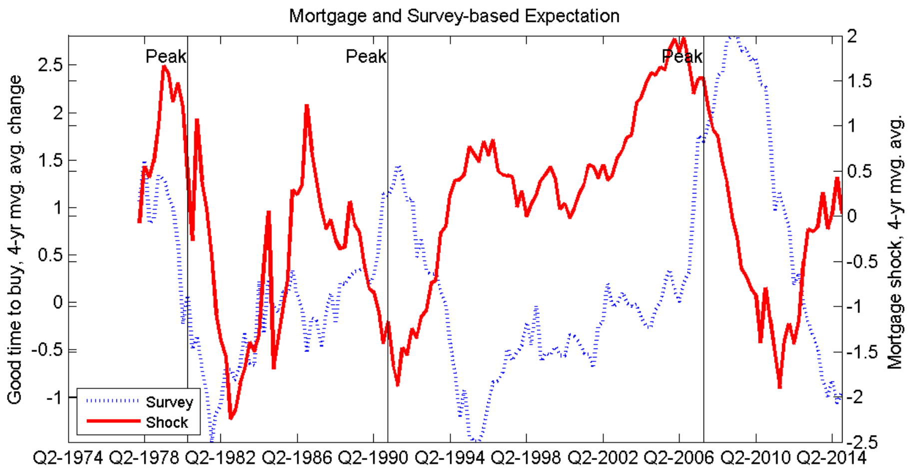
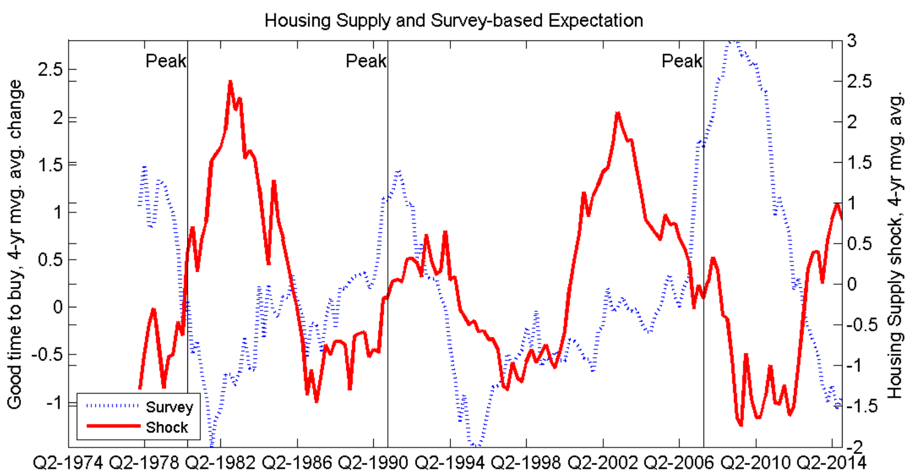
Annex I. Historical Contribution of All Shocks to House Price Developments, Alternative Models

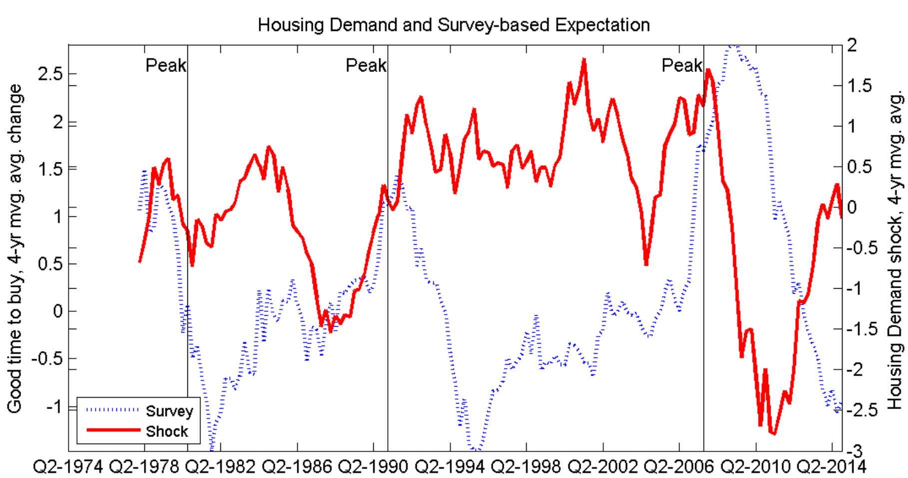


Note: Mean (dashed green line) depicts the historical contribution based on the pointwise mean and is the main summary measure, along with pointwise 16^{th} and 84^{th} percentile error bands (dotted red lines). These measures are described in Section IIC. Median (solid blue line) and Cl. to mean (closest-to-mean, solid black line) are alternative summary measures described in Section IVA. The identification assumptions are summarized in Table 1.
Source: Authors' calculations.

Annex II. Survey-based Expectations versus Shocks







Note: The model-based measures are the four-year rolling average of the relevant shock, based on the mean of the set of identified shocks at each point in time. The survey measure is the four-year rolling average of the change in the share of respondents in the Michigan Survey of Consumers reporting that it is a good moment to buy a house because prices are favorable. Vertical lines mark peaks in the housing price.
Sources: Michigan Survey of Consumers and authors' calculations.