Expectations During the U.S. Housing Boom: Inferring Beliefs from Actions

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(Very Preliminary, Please Do Not Circulate)

Abstract

We assess the role of price expectations in forming the U.S. housing boom in the mid-2000s by studying the dynamics of vacant properties. When agents anticipate price increases, they amass excess capacity. Thus, housing vacancy discriminates between price movements related to housing demand shocks (low vacancy) and expectation shocks (high vacancy). We implement this idea using a structural VAR with sign restrictions. In the aggregate, expectations shocks are the most important factor explaining the boom, immediately followed by mortgage rate shocks. In the cross-section, expectations shocks are the major factor explaining price movements in the Sand States, which experienced unprecedented booms.

*We are grateful to Olivier Blanchard, Alex Chinco, Hamid Faruqee, Maja Ganarin, Ayhan Kose, Kenneth Kuttner, John Muellbauer, Prakash Loungani, Emil Stavrev, Martin Straub, participants at the Bundesbank-IMF-DFG conference, the SSES congress, and the International Monetary Fund and SNB Research seminars for very helpful comments. The views expressed here are those of the authors and not necessarily those of the International Monetary Fund or the Swiss National Bank. Ben-David is with The Ohio State University and NBER, Towbin is with the Swiss National Bank, and Weber is with the International Monetary Fund. Email: ben-david.1@osu.edu, pascal.towbin@snb.ch, and SWeber@imf.org

I. Introduction

There is an active debate among economists about the role that expectations played in forming the residential housing boom in the early 2000s. Several studies propose that expectations were a prime factor in forming the boom (Shiller (2007); Adelino, Schoar, and Severino (2016); Case, Shiller, Thompson, et al. (2015); Kaplan, Mitman, and Violante (2017)), however, their evidence often relies on a residual, i.e., unexplained variation is attributed to expectations. In contrast, studies that examined survey-based expectations find little evidence that explain the recent boom. Piazzesi and Schneider (2009) notes that only a small share of surveyed consumers in 2002–2006 said that current low prices or anticipated future price increases are reasons to buy a house.[1] Lambertini, Mendicino, and Punzi (2013) and Cox and Ludvigson (2018) incorporate these data into their models. Although survey-based expectations are correlated with real-estate booms in the last few decades (Lambertini et al. (2013)), they do not explain the 2000s boom, which is the largest residential boom in U.S. history (Cox and Ludvigson (2018)).

In this study, we propose to infer expectations from agents' actions. We use a simple model to demonstrate that high expectations of future prices lead agents to hoard excess capacity in the present. Thus—in some situations—excess capacity today, indicates that individuals anticipate higher prices tomorrow. We then incorporate the model's predicted sign restrictions in a structural VAR estimation to identify expectation shocks. These tools allow us to estimate the contribution of expectation shocks to the housing price boom, separately from shocks to factors such as housing demand, housing supply, and mortgage rate.

The idea that individuals invest in *excess capacity* when anticipating future prices to increase is not new in economics, however, it has not been systematically applied to the housing market. Originally, this idea has been implemented to identify expectation shocks in the energy market, where at times investors amass large quantities of oil in anticipation of price increases (Kilian and Murphy (2014); Knittel and Pindyck (2016); Juvenal and Petrella (2015)). In the real-estate market researchers noticed that during boom times individuals often hold vacant properties: e.g., Malpezzi and Wachter (2005), Mayer (2011), Glaeser, Huang, Ma, and Shleifer (2017). However, to our best knowledge there has not been an attempt to harness this observation to systematically assess the role of price expectations in

[1] In particular, during this period 20% to 31% of respondents thought that prices are low or expected to increase (Cox and Ludvigson (2018)). This is a low fraction of respondents, compared with the average of 33.2% across the 40 years that the survey has been in existence (1978–2017). In fact, the point in which the fraction of those expecting prices to improve was highest ever (69%) was in 2009, immediately after the collapse of house prices.

forming prices around the boom in the U.S. housing market in the early 2000s.

We flesh out the intuition that high vacancy may be a sign of high price expectations in a simple model that explores the determinants of aggregate housing prices considering four distinct shocks: housing demand, housing supply, mortgage rate, and expectation. We assume that current prices are determined by rental rates, current mortgage rates, and expectations of future prices. We make standard assumptions such as: housing demand slopes downwards, housing supply slopes upwards with convex adjustment costs, and credit supply slopes upwards. In addition, we assume that suppliers of housing have lower bargaining power over rental rates when vacancy is high.

The main purpose of the model is to generate sign restrictions that describe the relations between the variables. For example, the model predicts that a positive shock to housing demand increases housing supply, house prices, and the mortgage rate, but it decreases housing vacancies. Our interest lies in the effect of a shock to price expectations on the fundamental variables. The model suggests that a positive shock to price expectations increases housing supply, vacancy rate, house prices, and mortgage rate. Thus, by observing the dynamics of the fundamental variables over time, we can back out the extent to which expectations could have shaped them.

Once derived, we use the sign restrictions to estimate the effects of expectations on housing prices. First, we estimate a Bayesian Vector-Autoregression (BVAR) using observable variables for the entire country as well as for each state individually. Next, we decompose what shocks could account for forecasting errors, i.e., deviations from the model's predictions. The idea behind the approach is that forecast errors occur because something unexpected has happened—a series of shocks has hit the economy at each point in time. We collect only combinations of shocks that are consistent with the sign restrictions, as derived from the model. This analysis estimates the contribution of each shock to housing prices at any point in time.

It is important to distinguish our goal of establishing the contribution of price expectation *shocks* from previous work that examined how expectations develop endogenously. For example, Bordalo, Gennaioli, and Shleifer (2018b) and Bordalo, Gennaioli, Ma, and Shleifer (2018a) provide a framework in which irrational individuals develop biased expectations based on observing past performance. De Stefani (2017) analyzes real-estate expectations from the Michigan Survey of Consumers and finds that expectations are extrapolations of past price changes. Similarly, Adam, Kuang, and Marcet (2012); Burnside, Eichenbaum, and Rebelo (2016); DeFusco, Nathanson, and Zwick (2017); Chinco (2018) explore mechanisms through which expectations develop endogenously, e.g., through feedback among agents. In contrast to these studies, we are interested in the innovations to expectations, i.e., the part of expectations that *does not* arise endogenously, but rather is orthogonal to lagged observable variables. In our framework, endogenous expectations that develop in response to observable variables (e.g. past prices) would be absorbed in the autoregressive process.

Our results show that expectation shocks were important both on the national level and across states. On the national level, we find that price expectation shocks were the most important determinant of real estate prices in the boom, explaining about 27% of the magnitude of the boom. The next important shocks were mortgage shocks, accounting for about 24% of the boom's magnitude. In the cross-section of states, we find a high degree of heterogeneity. Expectation shocks are the most important determinant of the booms in the Sand States (Florida, California, Nevada, and Arizona), which experienced unprecedented price booms. Comparing the explanatory power of the various shocks to the boom, the contribution of expectations shocks amounts to about 35%. In other states, expectation shocks explain only 23%.

To seek further validity to our estimations, we examine the determinants of the bust across states. Among all shocks that hit the different states during the boom time, the one that explain the bust the best is the expectation shock. In other words, states that experienced the steepest expectation shocks during the boom, also experienced the deepest consequent bust. We do not find similar association with the other shocks that we explore (demand, supply, and mortgage rates). This finding is in line with the model of Burnside et al. (2016); Chinco (2018), who propose that booms are fueled by both fundamental demand as well as expectations, and bust occurs when agents' expectations about future prices dissipate.

Overall, our analysis shows that shocks to expectations about future prices were major contributors to the price evolution around the boom, both nationally and for some of the states. This result is in contrast to survey-based expectations that show little action during the period of 2002–2006 (Piazzesi and Schneider (2009)). We speculate that the source for the difference between the expectation measures is the population in question. The Michigan Survey of Consumers polls consumers, attempting to estimate the *average* expectations. Conversely, our method measures the expectations of the *marginal* buyers who actually transacted. Those are the individuals whose demand and expectations set prices.

Beyond contributing to the macro literature, our study contributes to the literature documenting speculative activity during the boom period. Soo (2018a) and Soo (2018b) measure expectations using real estate media and finds that local sentiment leads prices by two years and spreads from one location to the other. Other studies identify speculative expectations by detecting the activity of speculators. DeFusco et al. (2017) and Gao, Sockin, and Xiong (2017) find that speculative activity is related to extrapolation of past prices and causes sharper downturns. Chinco and Mayer (2015) document that the activity of out-oftown investors is taking place in locations that experienced sharper booms and subsequent busts. Bailey, Cao, Kuchler, and Stroebel (2018) analyze how expectation formation transmits through social interactions. Mian and Sufi (2017) present evidence linking credit and expectations channels and show that private-label securitizers, who are responsible for the expansion in credit supply, were more active in areas in which speculators operated. While these studies present evidence that speculation activity is linked to higher prices, it is difficult to quantify the contribution of price expectations to the development of the boom and consequent bust.

The rest of the paper is organized as follows. Section II introduces a simple model of a housing market that generates the sign restrictions. Section III and IV describe the empirical method and the datasets that are used in the study. Section V and VI describe the results of the analysis at the national and state-level, respectively. Section VII comparing the model-based to survey-based expectation measures. Section VIII provides concluding remarks.

II. A Simple Model

A simple housing market model may be described by five reduced form linear equations that embed five basic assumptions:

1. House prices are forward looking. They depend on the mortgage rate and expected future prices.
2. Housing demand is downward sloping.
3. Housing supply is upward sloping and subject to convex adjustment costs.
4. Suppliers of housing have less bargaining power when vacancies are high.
5. Credit supply is upward sloping.

All endogenous variables are presented in capital letters and expressed in logs. Coefficients in small caps are restricted to be positive, with subscripts reflecting the respective variables. ε_X denotes exogenous drivers of the endogenous variable X that are shocked. [2]

1. **Prices are forward looking and depend on mortgage rate and expected future prices**

$$P = p_r R - p_i I + \varepsilon_{P^e} \tag{1}$$

[2] The expected value of ε_X is not necessarily zero. Alternatively, the equations can be interpreted as a deviation from a steady state with $E(\varepsilon_X) = 0$.

This assumption can be motivated by the present discount value relationship between current house prices (P) and future house prices (ε_{P^e}) as well as rental rates (R) and mortgage rates (I) (Poterba, 1984). A lower mortgage rate increases the present discount value of a given future price.[3] At the same time, the above equation represents an arbitrage condition between rental and owner occupied housing. The suppliers of houses are indifferent between letting a house or selling it. Accordingly, we only consider the overall housing market and do not model the choice between selling and letting.[4] Importantly, to keep the problem tractable, we ignore the effects of depreciation and taxes.

Price expectations (ε_{P^e}) are treated as exogenous. The definition of an expectation shock does not specify whether expectations are "realistic" or "unrealistic." It is consistent both with a realistic response to new information about future housing fundamentals[5] or with unrealistic expectations about future house prices as emphasized by Case and Shiller (2003). A combination of the two is an overreaction to a signal ("kernel of truth") (Bordalo et al. (2018a)). Our framework treats the effects of expectations without differentiating whether expectations are rational or not.

2. **Housing demand is downward sloping**

$$D = -d_r R + \varepsilon_D \tag{2}$$

Housing demand (D) decreases with the rental rate (R). ε_D captures exogenous drivers of housing demand. Possible reasons for a positive demand shock are exogenous increases in population, higher personal incomes, or shifts in tastes. Importantly, housing demand is understood as demand for consuming housing services, i.e., as opposed to the demand to own a house. We use housing demand and demand for housing services interchangeably.[6]

[3] This result is obtained if we consider the current house price P_t as the expected present value of future rents R_{t+1}, discounted at rate I_{t+1}:

$$P_t = E_t \frac{R_{t+1} + P_{t+1}}{1 + I_{t+1}}.$$

[4] Vice versa, occupants of houses are indifferent between renting or buying.

[5] An example would be if housing investment activity today is triggered by the expectation that a large company (e.g., Amazon Inc.) moves its headquarters to a new location and brings additional future demand for housing services.

[6] For simplicity, housing demand does not depend directly on the mortgage rate. An extension where housing demand decreases with the mortgage rate would only have minor effects on the model's predictions. See footnote 12.

3. **Housing supply is upward sloping and subject to convex adjustment costs.**

$$S = s_P P + \varepsilon_S \tag{3}$$

Supply (S) is increasing in the price of housing. 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, Gyourko, and Saiz, 2008; Huang and Tang, 2012).

ε_S are exogenous determinants of supply. Negative supply shocks 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.

Note that the demand for housing services is decreasing with respect to the rental rate (the price for the current flow of rental services), whereas housing supply is increasing with respect to the price of housing (the price for current and discounted expected future flows of rental services, see Assumption 1). This is a simple way to represent the idea that housing supply is more responsive to future developments than housing demand. This higher sensitivity is a direct consequence of convex adjustment costs: Adjusting housing supply in a given period leads to adjustment costs that increase with the size of the adjustment, creating an incentive to spread it over several periods and adjust in a forward looking manner. Adjusting demand, instead, is costless and the consumption of housing services can be re-optimized each period. Hence, convex adjustment costs motivate that housing supply is more sensitive than housing demand to prices.[7]

4. **Suppliers of housing have lower bargaining power when vacancies are high**

$$V = S - D = -v_r R \tag{4}$$

Markets do not clear fully and there is a positive gap between housing demand and housing supply. $S - D = 0$ would reflect a frictionless market clearing condition. However, in the housing market there are search and matching frictions, which implies

[7]We also considered an extended model, where switching houses is costly and occupants take the future into account. Under such an assumption current housing demand would increase, when prices are expected to go up in the future. In a model where housing demand depends negatively on current rents and positively on house prices, our results still hold, as long as the demand response to house prices is sufficiently small relative to the supply response.

incomplete market clearing and the existence of vacancies (Wheaton, 1990; Leung and Tse, 2012; Head, Lloyd-Ellis, and Sun, 2014). The vacancy rate is given by the (log) difference between the supply and the demand for housing. The rental rate should decline as the stock of vacant houses increases, because high vacancy rates give housing suppliers relatively little bargaining power compared to a tight housing market with low vacancy rates.[8]

5. **Credit supply is upward sloping**

$$I = i_S S + \varepsilon_i \tag{5}$$

Mortgage credit is not perfectly elastic (Glaeser, Gottlieb, and Gyourko, 2012; Adelino, Schoar, and Severino, 2012). If there is a strong demand for mortgage credit, mortgage rates rise. A potential driver for mortgage credit demand is construction activity in the housing sector. Specifically, we assume that the interest rate increases with housing supply. The formulation is based on the view that housing construction is financed to some extent through loans. More housing is therefore associated with higher demand for mortgages and higher mortgage rates.

ε_i are exogenous determinants of mortgage rates. 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, Farhi, and Gourinchas, 2008)), or a lower credit risk spread for mortgage rates (for example, because banks take more risk).[9] Our approach does not attempt to disentangle the different causes.

Model's Solution

The solution to the five equation system is given by:[10]

$$\begin{aligned} S &= (v_r + d_r) \cdot \varepsilon_S^* + p_r s_P \cdot \varepsilon_D^* \\ &\quad - (v_r + d_r)\, p_i s_P \cdot \varepsilon_i^* + (v_r + d_r)\, s_P \cdot \varepsilon_{Pe}^* \end{aligned} \tag{6}$$

[8]See e.g. Rosen and Smith (1983) for an early model about the relationship between rents and vacancies and Table 7 in Gabriel and Nothaft (2001) for empirical evidence.

[9]Sá and Wieladek (2015) and Sá, Towbin, and Wieladek (2014) compare the importance of monetary policy and capital inflows shocks for the US and a sample of OECD countries, respectively.

[10] All exogenous factors are marked with a star because they are standardized by a positive constant:

$$\Omega = v_r + d_r + p_r s_P + (p_i + d_r)\, p_i i_S s_P.$$

$$
\begin{aligned}
V &= v_r \cdot \varepsilon_S^* - v_r\left(1 + p_i i_S s_P\right) \cdot \varepsilon_D^* \\
&\quad - v_r p_i s_P \cdot \varepsilon_i^* + v_r s_P \cdot \varepsilon_{Pe}^*
\end{aligned} \tag{7}
$$

$$
\begin{aligned}
I &= \left(d_r + v_r\right) i_S \cdot \varepsilon_S^* + p_r i_S s_P \cdot \varepsilon_D^* \\
&\quad + \left(d_r + v_r + p_r s_P\right) \cdot \varepsilon_i^* + \left(d_r + v_r\right) i_S s_P \cdot \varepsilon_{Pe}^*
\end{aligned} \tag{8}
$$

$$
\begin{aligned}
P &= -\left[p_r + \left(v_r + d_r\right) p_i i_S\right] \cdot \varepsilon_S^* + p_r \cdot \varepsilon_D^* \\
&\quad - \left(d_r + v_r\right) p_i \cdot \varepsilon_i^* + \left(v_r + d_r\right) \cdot \varepsilon_{Pe}^*
\end{aligned} \tag{9}
$$

We use the model to identify structural shocks with sign restrictions (Canova and De Nicolo, 2002; Uhlig, 2005).[11]

The main focus is on the identification of the price expectation shock. We compare the effects of shocks to house price expectation with shocks to the demand for housing services, to the supply of houses, and to the mortgage rate. We discuss how we can distinguish these shocks from price expectation shocks. Table I summarizes the identification restrictions of the baseline specification. All structural shocks have been normalized to imply an increase in the real price of housing.

Table I **Baseline Shock Identification**

	Shock to:			
	Housing supply (ε_S^*)	Housing demand (ε_D^*)	Mortgage rate (ε_i^*)	Price expectation (ε_{Pe}^*)
Housing supply (S)	< 0	> 0	> 0	> 0
Vacancy rate (V)	< 0	< 0	> 0	> 0
Mortgage rate (I)	< 0	> 0	< 0	> 0
Housing price (P)	> 0	> 0	> 0	> 0

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

Price expectation shocks: A positive house price expectation shock leads to an increase in house prices, an increase in housing supply, an increase in vacancies, and an increase in the mortgage rate. The restriction on house prices follows from Assumption 1:

[11] While not needed for identification, for later use it is also convenient to derive the solution for the rent-price ratio, which derives directly from equation 1 and solutions for the price and the mortgage rate:

$$
\begin{aligned}
R - P &= \left[\left(p_r - 1\right) + \left(d_r + v_r\right) p_i i_S\right] \cdot \varepsilon_S^* + \left(1 + p_i i_S s_P - p_r\right) \cdot \varepsilon_D^* \\
&\quad + \left[\left(d_r + v_r\right) p_i + p_i s_P\right] \cdot \varepsilon_i^* - \left(s_P + v_r + d_r\right) \cdot \varepsilon_{Pe}^*
\end{aligned}
$$

It follows that the sign of the impact of housing demand and housing supply shocks on the rent-price ratio is ambiguous, it is pinned down for expectation and mortgage rate shocks.

the prospect of being able to sell the house at a higher price in the future leads to higher prices now. Housing supply increases as a result of Assumption 3: 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 housing supply to increase. The increased housing construction leads 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 5). 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 not affected by expectations, the vacancy rate rises.

Mortgage rate shocks: A negative mortgage rate shock is characterized by a decrease in the real mortgage rate, an increase in house prices, in housing supply and the vacancy rate. Lower interest rates increase current prices through their impact on the present discount value (Assumption 1). Higher prices encourage supply (Assumption 3). The vacancy rate increases due to higher supply.[12] 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 housing supply, a decrease in housing vacancies, and higher mortgage rates. The restriction on house prices and residential investment are as in Jarociński and Smets (2008) and follow from Assumptions 1, 2, and 3: an upward shift of the demand curve leads, to higher house prices and higher housing supply . Upward sloping mortgage credit supply will lead to higher interest rates, as loan demand increases with higher investment in housing (Assumption 5). 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 housing demand 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.

Housing supply shocks: A negative housing supply shock is associated with a rise in house prices, a fall in in the supply of housing, in the vacancy rate, and the interest rate. The restrictions on house prices and residential investment are again as in Jarociński and Smets

[12]If, as discussed in footnote 6, housing demand depends negatively on the mortgage rate, the response of the vacancy rate is ambiguous. The intuition is that the increase in supply in response to lower mortgage rate may be more than compensated by higher demand. Our results are not sensitive to that restriction. In particular, leaving the sign for the response of the vacancy rate to the mortgage rate shock in the BVAR unrestricted, the estimation still yields that the vacancy rate responds positively to a negative mortgage rate shock and the contribution of the four shocks is nearly unchanged.

(2008) and follow from Assumptions 1 and 3. An upward shift of the supply curve, leads to higher prices and lower quantities. As there are now fewer houses for a given demand, the vacancy rate falls (Assumption 4). Less construction also reduces credit demand and leads to lower mortgage rates (Assumption 5).

There are some similarities between vacancies in the housing market and inventories in the oil market. Knittel and Pindyck (2016) 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. 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.

III. Estimation Method

This section introduces the empirical framework of the study. It first presents the econometric model and then details the identification approach and discusses the inference from the computational implementation.

A. Econometric Model

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

$$\mathbf{y}_t = \sum_{i=1}^{L} \mathbf{A}_i \mathbf{y}_{t-i} + \mathbf{e}_t, \quad \text{with} \quad \mathbf{e}_t \sim \mathrm{N}(\mathbf{0}, \mathbf{\Sigma}) \quad \forall\, t = 1, ..., T \tag{10}$$

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

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

$\mathbf{e}_t$ is a reduced-form error term with variance-covariance matrix $\mathbf{\Sigma}$, L is the lag length and $\mathbf{A}_i$ are coefficient matrices.

The first four variables in the BVAR are required for identification.[13] The inclusion of the

[13] We introduce the housing price in first difference and use residential investment to GDP to account for cointegrating relationships and deterministic trends. However, we apply the sign restrictions on the levels of

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, Plosser, Stock, and Watson, 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 computing the level response of residential investment and GDP. Furthermore, the responses of real GDP and the rent-to-price ratio allow to assess the consistency of the responses with theoretical arguments.

B. Computational Implementation

We sample the regression coefficients A_i and covariance matrix Σ from the posterior distribution, with an uninformative prior distribution.[14] 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-Ramírez, Waggoner, and Zha (2010).[15] 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 in Table I for all shocks, we keep the draw. We constrain the sign restriction to hold for the first two periods for all variables' responses. We repeat the procedure until we accept 10,000 models.[16]

In contrast to exact identification schemes (e.g. zero restrictions), error bands for standard vector-autoregression (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.

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house prices and residential investment.

[14] 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 ordinary least squares (OLS) estimates.

[15] We compute Q by drawing an independent standard normal matrix X and apply the QR decomposition $X = QR$.

[16] The number of rotations needed to obtain 10,000 acceptances varies with the specification. In the baseline model about 2 percent of the rotations are accepted.

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.

IV. Data

We conduct our analysis at both the national-quarter level as well as the state-year level.

A. National-level Data

The change in the real housing price (ΔP) is measured by the national real Shiller house price index. The change in the housing supply is approximated by the log of the real private residential investment to real GDP ratio from the Bureau of Economic Analysis (ΔS). The vacancy rate (V) is given by the overall ratio of vacant houses relative to the total housing stock excluding seasonal factors (Census Bureau). The real mortgage rate (I) 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). The rent-to-price ratio ($R-P$) 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 ($\Delta RGDP$), which we use as a control for economic activity, is taken from the Bureau of Economic Analysis. our national-quarter level dataset covers the period from 1976Q1-2018Q1. Figure 1 shows the evolution of the respective variables.

B. State-level Data

The state-year level data come from several sources. Data limitations constrain the state-level analysis to the annual frequency. The changes in the state-year real house price indexes (ΔP) are provided by the Federal Housing Finance Agency (FHFA). The change in the supply of housing (ΔS) is measured as the state-year new private housing permits

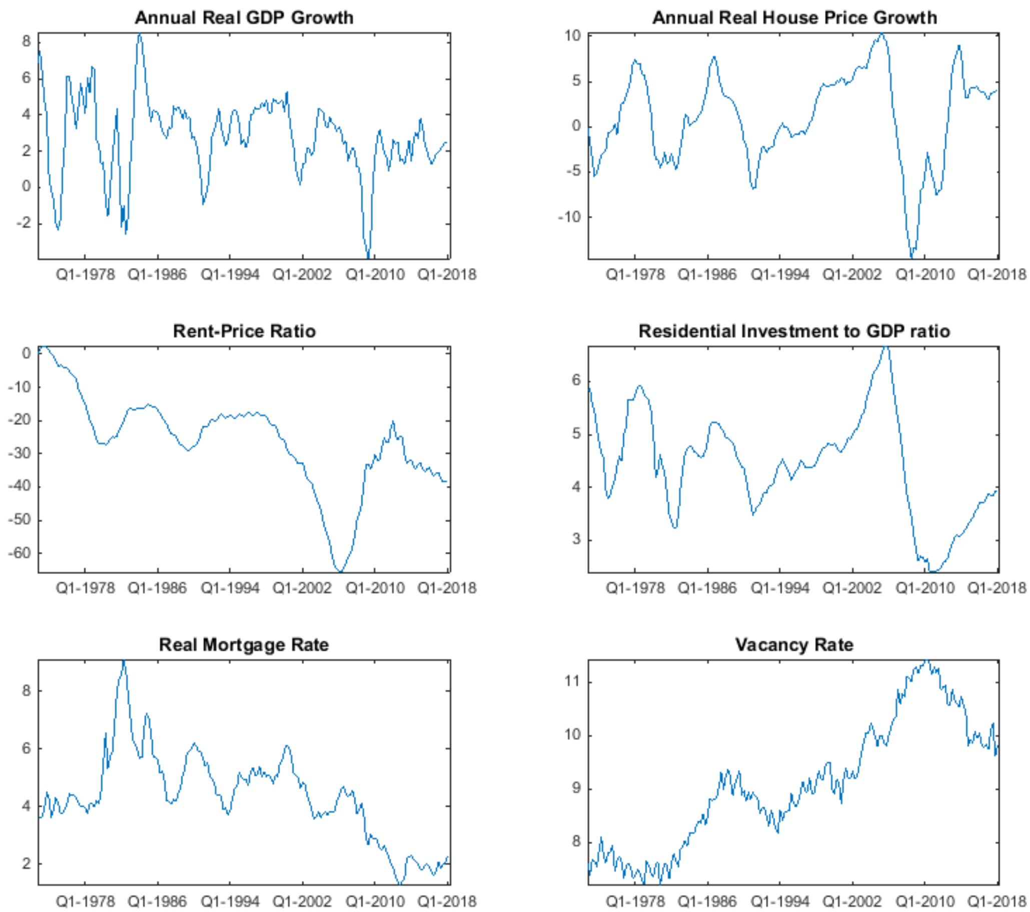


Figure 1: **Evolution of Variables Over Time**

data from Census Bureau.[17] Vacancy (V) data is available for owner-occupied homes as well as for rental homes by the St Louis Fed. Since we are interested in the aggregate vacancy in the state-year level, we combine these data into a single number using the weights of home-ownership, where region-year home-ownership statistics come from the Census Bureau. State-year level mortgage rates (I) are available on the FHFA website, deflated using national CPI. To capture long run dynamics in prices and control for economic activity, we include the housing price-to-median income ratio, where the latter is from Census Bureau.[18] Our final state-level dataset covers the period 1988 to 2016 for all 50 states.

Since the magnitude of the boom varied across the U.S., we turn to examining local variation in housing prices as well as the different shocks. Ideally, we would perform the analysis at the Metropolitan Statistical Area (MSA) or Commuting Zone (CZ) levels. Prior studies found that some MSAs experienced unusual price increases in the early 2000s. For example, between 2000Q4 and 2006Q4, nominal housing prices increased in the Miami MSA by 163%, in the Phoenix MSA by 110%, and in the Las Vegas MSA by 115%. Unfortunately, housing vacancy data, which is a necessary component for identifying the expectation shock, is available only since 2005 for rental properties and since 2015 for home-owned properties at the MSA level (see Census website). A second best approach is to examine state-level data, where vacancy data is available since 1987. The disadvantage at this level of aggregation is that it masks the within-state variation. The price variation during both the boom and bust at the state level is less dramatic than it is in some of the MSAs. Yet, it is notably higher than the aggregate U.S. For example, from 2000Q4 to 2006Q4 the national nominal housing price index increased by 70%. In contrast, Florida experienced a nominal price increase of 121%, Arizona of 107%, and Nevada of 103%.

V. Results: National-level Analysis

The first subsection 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 housing boom of the 2000s, which is treated in the second subsection. The third subsection presents results from the forecast error variance decomposition, i.e., the importance of the different shocks over the entire sample period.

[17]Data on residential investment is not available at the state-level. Housing permits promise to be a fair proxy as they tend to lead residential investment by only a few months and are positively correlated with the actual investment.

[18]There is no comparable data on rents at state level. Therefore we do not include the rent-price ratio in the state level regressions. We do not include state-year real GDP merely to preserve degrees of freedom.

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 and the sign of the shock is normalized, such that the response of the house price is positive (i.e. a positive expectation shock and negative mortgage rate shock). The responses of real house prices, real residential investment, and real GDP are displayed in levels.

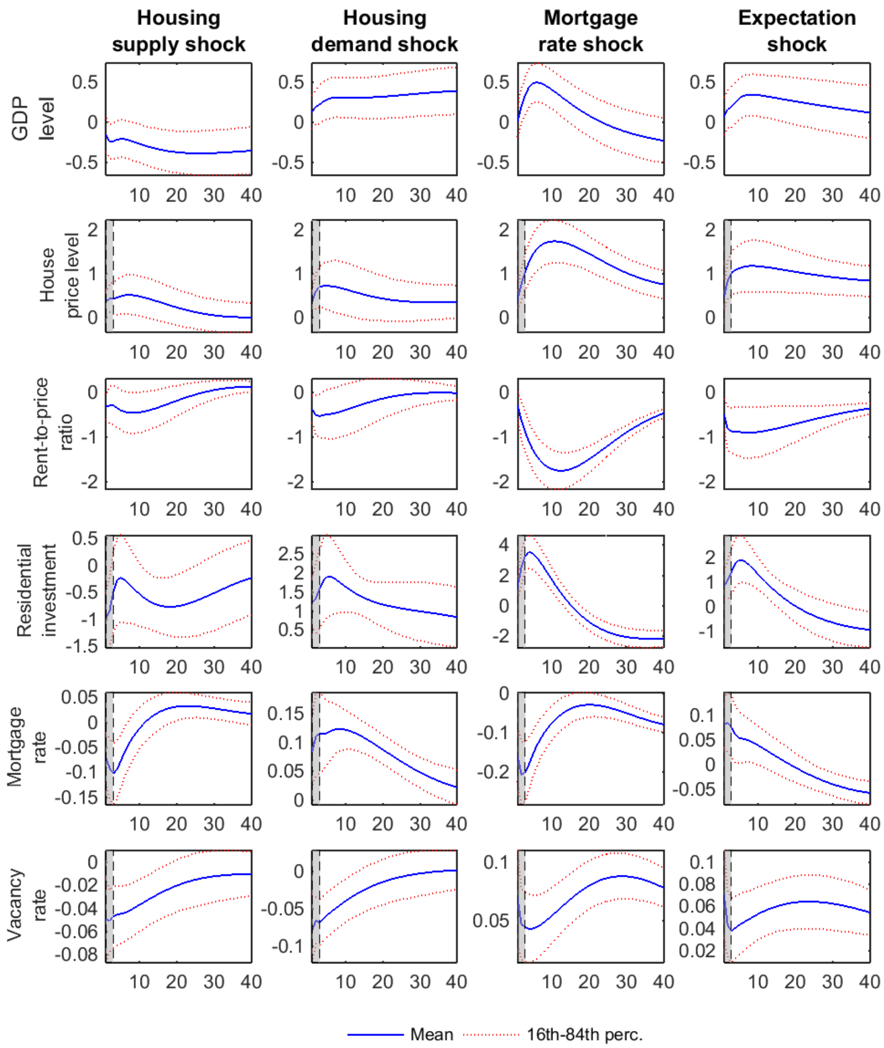


Figure 2: **Baseline Model: Impulse Response Functions**

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 III.B. The identification assumptions are summarized in Table I. A grey shaded area marks periods where sign restrictions have been imposed.

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.

In response to a positive price expectation shock, house prices rise in the first three years by about 1.2 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 1), this unrestricted pattern is consistent with the postulated increase of expected future house prices. 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. Real GDP increases only temporarily. 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 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.

A negative mortgage rate shock leads to qualitatively similar responses of house prices and residential investment as positive price expectation shock. Quantitatively, however, a mortgage rate shock is associated with substantially stronger responses of residential investment and output, and the house price increase is somewhat larger. The response of variables are, however less persistent. As in the case of the price expectation shock, residential investment falls below zero over the medium term and the temporary output increase dissipates. The rent-to-price ratio initially falls, as we would expect from the present value relationship discussed under Assumption 1, if interest rates fall. The vacancy rate increases persistently.

Positive shocks to the demand for housing services are associated with a persistent 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. 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 1. 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.[19] The mortgage rate rises by about 10 basis points in response to increased 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 5 years back 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. 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 and is not driven by expectations.

B. Contribution of Price Expectation Shocks to the Housing Boom

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 1997Q1). The log house price is presented 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). 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 six shocks are identified.

The four identified shocks explain a substantial share of the house price increase in the run up to the crisis. About 80 percent of the increase between 1997Q1 and 2006Q1 is explained by the four identified shocks in the baseline model. The largest contribution comes from price expectation shocks, explaining 27 percent of the increase. The second most important contribution comes from mortgage rate shocks accounting for about 24 percent of the rise. 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 supply shocks account only for a small fraction of the boom (12 and 10 percent). Finally, as our model is only partially identified, there is a sizable unexplained residual of about 18 percent. The deterministic component explains a small part, less than 10 percent.

[19] The pattern is also consistent with the simple model that implies an expectation shock to unambiguously reduce the rent-price ratio, while the response of the rent-price ratio to a housing demand shock is necessarily smaller and could even be positive.

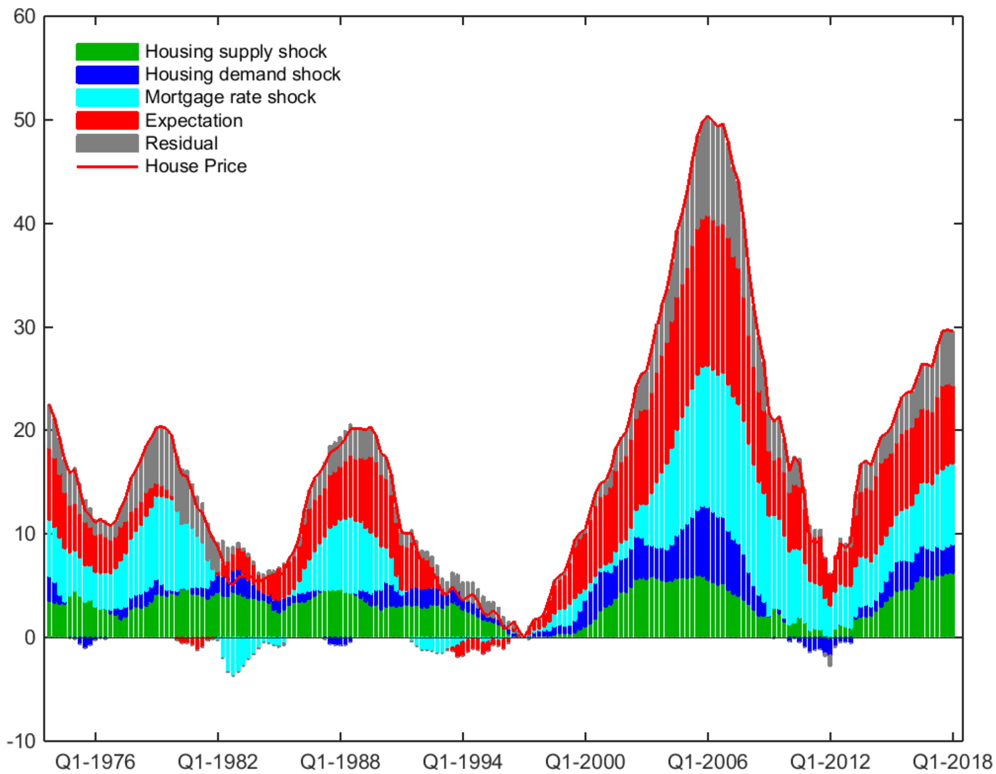


Figure 3: **Historical Decomposition of Real House Price Developments**

The solid line is the log real house price (normalized to zero at the starting point of the boom period in 1997Q1) 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 I.

Table II **Contribution of Shocks to Price Boom and Bust**

	Shock to:					
Model:	Housing Supply	Housing Demand	Mortgage Rate	Expectations	Deter-ministic	Residual
			Contribution to Boom (1997Q1 - 2006Q1)			
Baseline	10.1	12.3	24.3	26.5	9.2	17.7
Baseline excl. Expectation	10.9	23.6	30.8		9.2	25.5
			Contribution to Bust (2006Q2 - 2012Q1)			
Baseline	13.5	18.9	24.2	26.5	-7.7	24.5
Baseline excl. Expectation	10.2	29.4	40.6		-7.7	27.5

The Table displays the share of the change in house prices explained by the respective shock. The baseline identification assumptions are summarized in Table I.

In a model that accounts only for the three traditional shocks (housing supply, housing demand, and mortgage rate)[20] the contribution ascribed in our model to the expectation shock would be partly assigned to the demand shock (as the higher demand for housing services can coexist with a vacancy rate increase under the traditional identification assumptions) and remains partly unexplained (increases the residual contribution). In our view, these results suggest that accounting for price expectation shocks is not only relevant by itself, but also relevant to better estimate the contribution of other shocks to the boom. At the same time attributing the residual that cannot be explained by conventional shocks to expectations would paint a wrong picture about the contribution of expectation shocks to house price changes.

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, the mortgage and expectation shocks explain more than 50 percent of the path (see Table II). The contribution of the expectation shock (about 27 percent) is slightly larger than the contribution of the mortgage rate shock (about 24 percent).

The role of demand shocks during the bust is somewhat larger than during the boom, with a contribution that amounts to roughly 20 percent. As shocks to the demand for housing services have persistent effects on house prices, the decline can mainly be attributed to new

[20]Hence, the identification would be identical to the one described in Table I without any constraints on the vacancy rate and no identification of the price expectation shock.

Table III **Variance Decomposition**

Quarter ahead	Shock to: Housing Supply	Housing Demand	Mortgage Rate	Expectations	Residual
	Real Housing Price				
1	13	15	18	19	35
4	9	13	24	19	34
16	10	14	23	18	35
40	10	14	28	18	36

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 I.

negative shocks, consistent with a decline of income during the recession. The contribution of supply shocks remains minor.

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 III).

The mortgage rate and price expectation shocks are again the most important drivers of the variation in housing prices. Price expectation shocks account for about 18 percent and mortgage rate shocks for 23 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.

The supply shocks account for around 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 35 percent of the variation in the house price remains unexplained by the four shocks, which is larger than the residual's contribution during the boom period.

VI. Results: State-level Analysis

Next, we expand the analysis to the state level. This extension allows us to verify that our inference about the roles of the different shocks agrees with observations of prior research about the sources of the boom in different states. Our data is based on state-year data for

1988 to 2016. The analysis pursues a similar BVAR analysis and simulations at the state level, and is done independently for each state.

We begin the discussion of the results by presenting charts of the components contributing the evolution of prices averaged across states. Mayer (2011) documents that there was a significant heterogeneity in magnitude of the U.S. housing boom. The locations that experienced unprecedentedly large booms were cities in the Sand States: Las Vegas (Nevada), Miami (Florida), Phoenix (Arizona), as well as Los Angeles and San Diego (California). At the state level, the magnitude of these booms in our data were in the order of 40% to 50% (in real terms, from 1996 to 2006). The busts in these locations were correspondingly deep: 60% to 90% from peak to though (2006-2012).

Figure 4 shows the average contributions of the different shocks to the boom and bust in log terms, equally-weighted across states. As for the national level, the house price path is shown in deviation from the deterministic path, i.e. the path house prices would have taken if no shock occurred since the starting point. The top chart of the figure shows the shock contributions for all states, excluding the Sand States. The figure shows that at the peak of the boom (2006), the main shock contributing to the average magnitude of the boom was the mortgage shock (about 29 percent of the average magnitude of the boom not driven by the deterministic component), followed by the expectation shock (about 23 percent). Housing demand and housing supply shocks are smaller in magnitude (jointly about 27 percent) and the remainder explained by the residua). Different from the national level analysis, a sizeable share of the entire boom (a bit less than 1/2) is accounted for by the deterministic component. [21]

A similar ordering of the contribution of the shocks can be observed in the bust period (2006–2012): mortgage shock is the prime contributor, immediately followed by expectation shocks.[22]

The bottom chart in Figure 4 shows the contribution of shocks to the boom in the Sand States (Arizona, California, Florida, and Nevada). A first observation to make is that the magnitude of the boom is almost three times bigger than the average magnitude of the boom in other states (top chart). In contrast to the order of importance of shocks in the non-Sand States, here the most important shock is the expectation shock (about 35 percent of the

[21]The contribution of the higher deterministic component may be a result of short sample size and larger influence of initial conditions, i.e. unobserved shocks that occurred before the sample start (Hamilton, 1994). The role of the these initial conditions disappears as the sample length increases. In some states, there is also structural upward trend in real house prices.

[22]Because the time-series for the individual states are relatively short, the deterministic path often captures a relative larger part of the increase in housing prices, leaving less variation to be explained by shocks. As a result, the boom and bust appear less dramatic in the charts (where the deterministic component is omitted) than in the raw data. This issue has significantly lower effect at the national level.

magnitude of the component of the boom that is driven by shocks). The mortgage shock follows in importance (about 25 percent of the boom). Supply and demand shocks have a minor role in the boom (they account for about 25 percent combined). The deterministic trend is of lesser importance in comparison to non sand states and accounts for about 25 percent of the boom.

Next, we present for each state the absolute contributions to the boom of the individual shocks separately in Figure 5. Panel A depicts the contribution of the expectation shock to the price increase in the boom. While there is a gradual increase in contribution across states, a discreet jump in importance of the expectation shock can be observed for Sand States (Arizona, California, Nevada, Florida) as well as Idaho. The magnitude of the contribution of this shock is between 20 percentage points in the case of Arizona, down to 10 percentage points for Idaho. The rest of the states experienced significantly lower expectation shocks of between –1 to 7 percentage points.

Panel B of Figure 5 shows contribution of the mortgage shock for all states. Mortgage shocks contributed the most to the District of Columbia, Virginia, Nevada, Florida, South Carolina, and Washington. The magnitude of the contributions to these states' booms is in the order of 12 to 16 percentage points. The contribution of the mortgage shock to the boom in the rest of the states ranges from –1 to 10 percentage points.

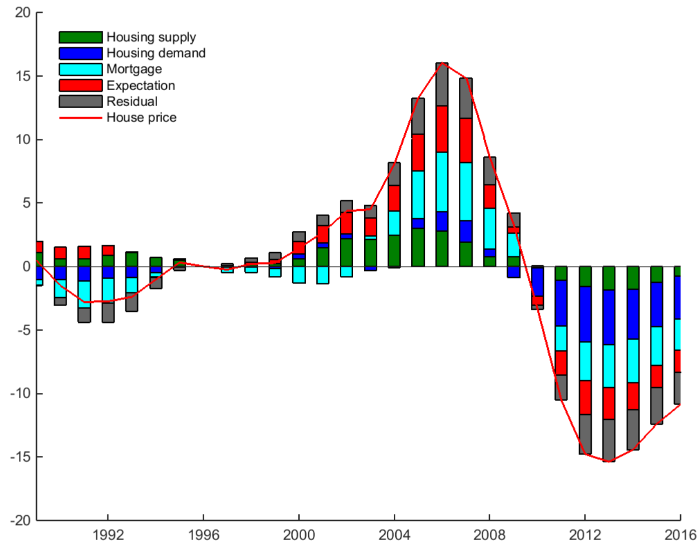
In Panel C of Figure 5, we present the contribution of demand shocks to the boom. The panel shows that California stands out with a contribution of 12 percentage points, while for all other states, the contribution of the demand shock ranges between –7 to +7 percentage points. The result that the demand shock had the most significant contribution to California is consistent with the interdependent analysis of Ferreira and Gyourko (2017), showing the California experienced a boom, driven by fundamental demand.

Panel D of Figure 5 shows the contribution of the supply shock to the boom of the different states. It shows that several of the most densely populated states have a high supply shock contribution including Maryland and Rhode Island, which stand out with a contribution of 14 percentage points. The contribution to other states' boom ranges from –6 to 10 percentage points.

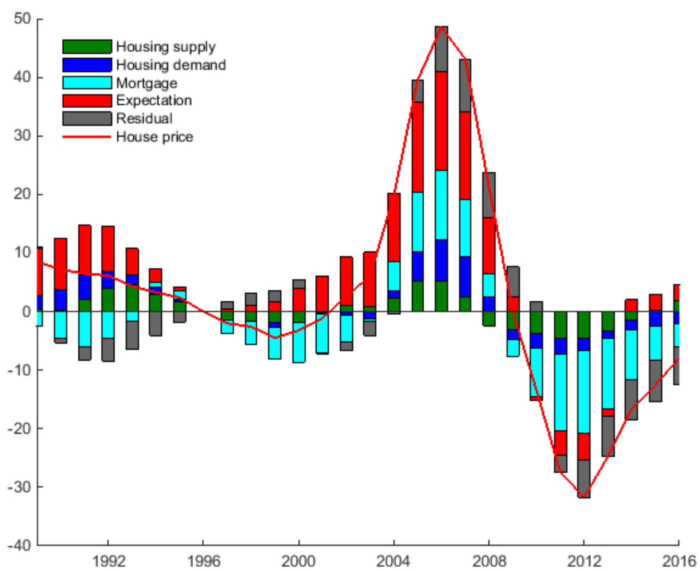
Overall, the cumulative results in Figure 5 show that among the shocks, expectation and mortgage rate shocks have the largest effect on the states' booms. Demand and supply shocks have smaller effects.

Another useful way to look at the results is through heat maps:[23] boom (Figure 6) and bust (Figure 7). Figure 6 shows the expectation shock was most important in the Sand States, as discussed earlier. For the mortgage shock, there is no particular geographical

[23]Hawaii and Alaska are excluded only for visual ease from these charts.



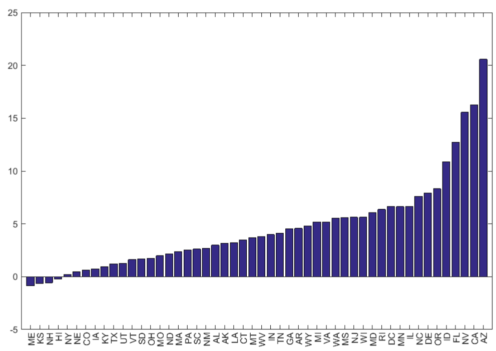
(a) All States, excluding Sand States



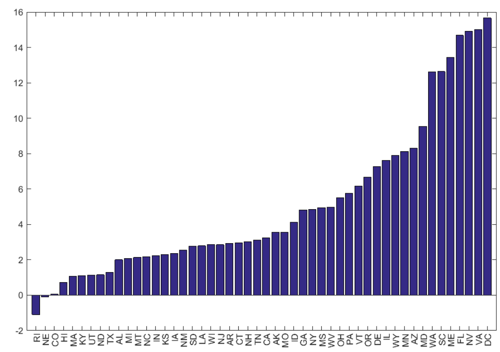
(b) Sand states

Figure 4: **State-level Contribution of Shocks to the Price Evolution**

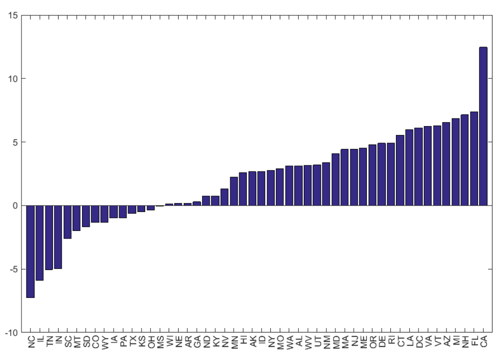
The solid line is the log real house price. The house price path is shown in deviation from the deterministic path,in deviation from its deterministic path, i.e., the path house prices would have taken if no shock occurred since the starting point.The bars indicate the contribution of the four shocks and the unexplained residual to the observed path. The analysis was performed at the state level and equally-averaged across all states. The top figure shows the average across contributions for all states excluding Sand States. The bottom figure shows the average across contributions for the Sand States (Arizona, California, Florida, and Nevada).



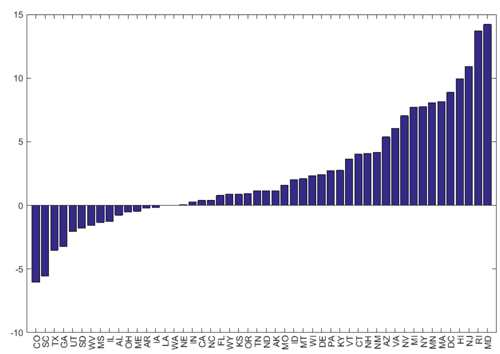
(a) Expectation shock



(b) Mortgage shock



(c) Demand shock

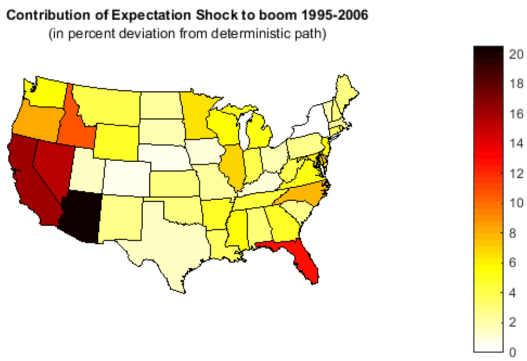


(d) Supply shock

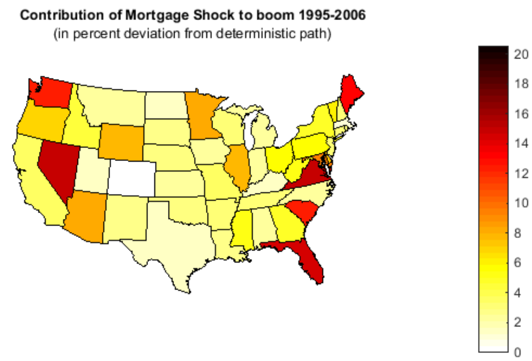
Figure 5: **State-level Contribution of Shocks to the Boom (1996–2006)**

The figure shows the contribution of different shocks to the evolution of prices of the boom. The maps show the state-level contribution of the different states for the period 1996–2006. The color scheme shows the magnitude of the contribution of the shock the size of the boom, in percentage points.

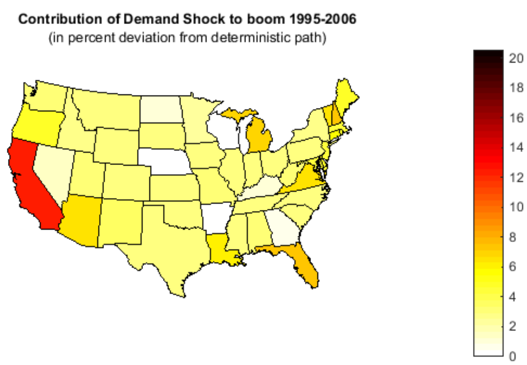
clustering: the effect of the shock appears throughout the country. The demand shock was important primarily for California. The supply shock was important mostly in North-East states including Maryland and Rhode Island.



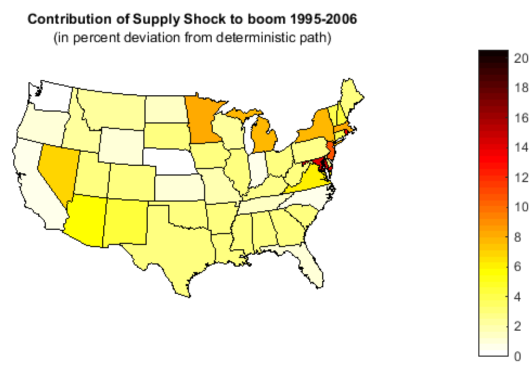
(a) Expectation shock



(b) Mortgage shock



(c) Demand shock

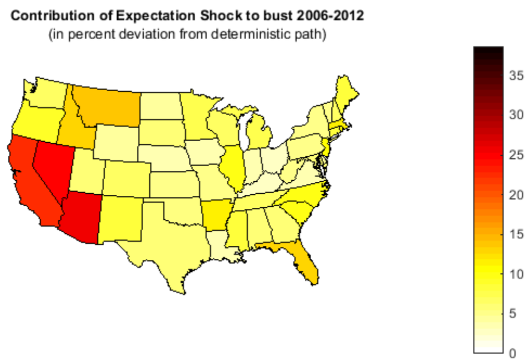


(d) Supply shock

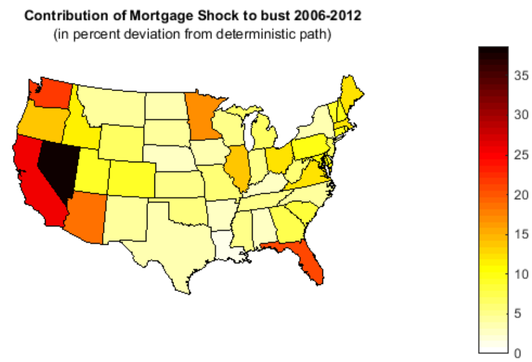
Figure 6: **State-level Contribution of Shocks to the Boom (1995–2006)**

The figure shows the contribution of different shocks to the evolution of prices. The maps show the state-level contribution of the different states for the period 1996–2006. The color scheme shows the magnitude of the contribution of the shock the size of the boom, in percentage points.

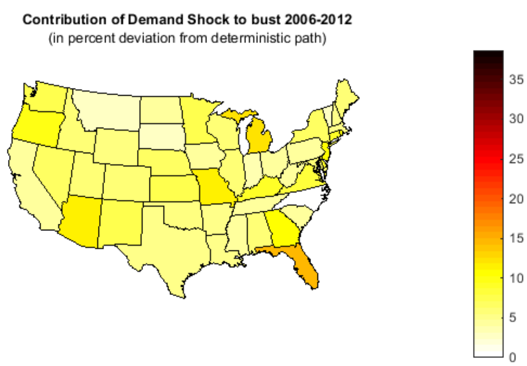
When examining the contribution to the bust (2006–2012) (Figure 7), the picture mirrors the boom in most, albeit not all, cases. Expectation shocks had the greatest contribution in Nevada, California, and Arizona, followed by Florida, Idaho, and Montana. Mortgage shock had the greatest contribution to the bust in Nevada and Florida, followed by California, Michigan, Washington, and Georgia. Demand shocks have contributed to the bust 5 to 10 percentage points nation-wide. Supply shocks have barely contributed to the bust, with the exception of Nevada.



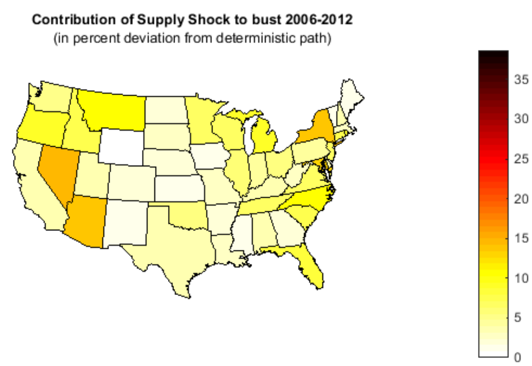
(a) Expectation shock



(b) Mortgage shock



(c) Demand shock



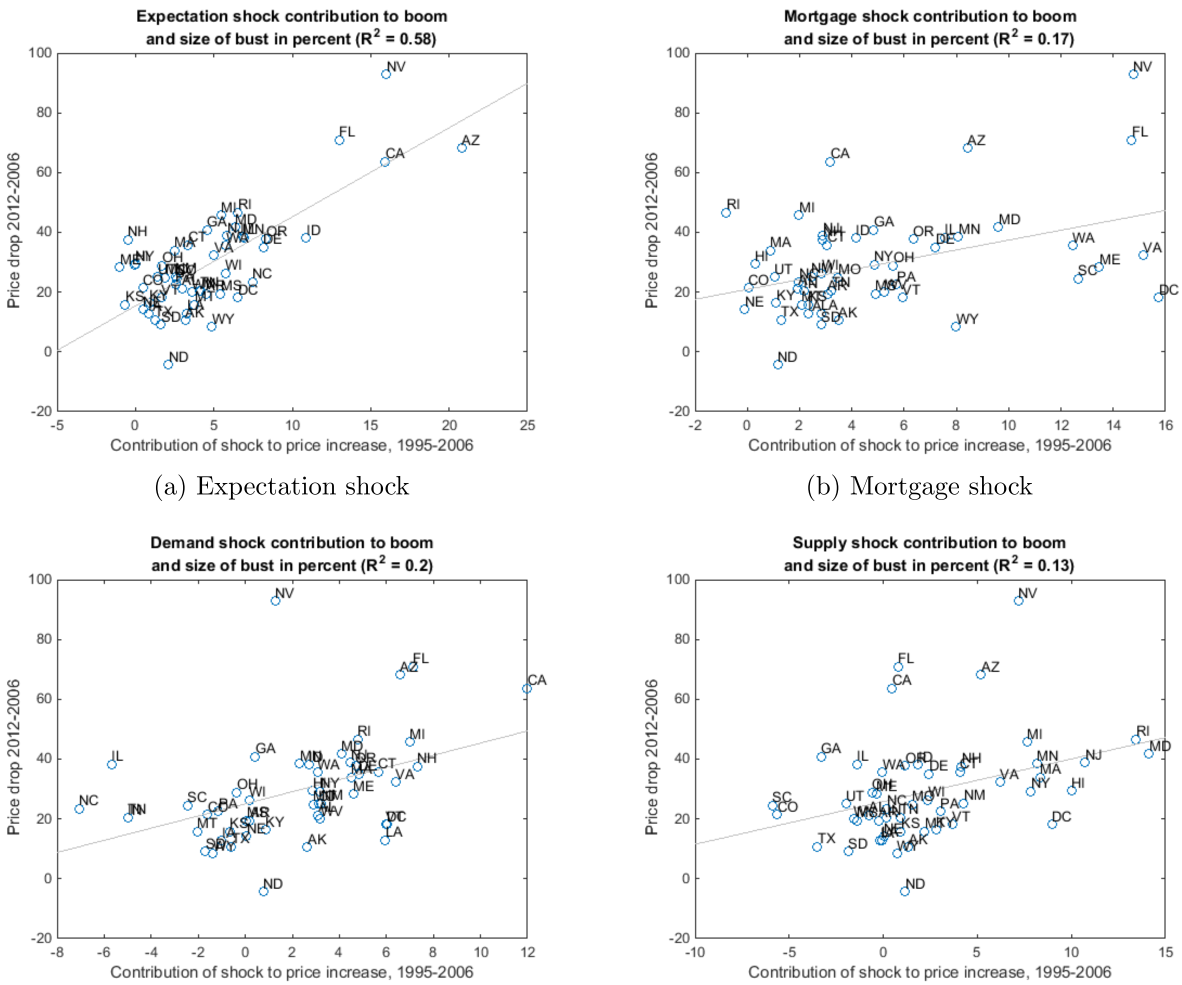
(d) Supply shock

Figure 7: **State-level Contribution of Shocks to the Bust (2006–2012)**

The figure shows the contribution of different shocks to the evolution of prices. The maps show the state-level contribution of the different states for the period 2006–2012. The color scheme shows the magnitude of the contribution of the shock the size of the boom, in percentage points.

Overall, the state-level analysis supplements our observations from examining the data at the national level. As in the national level, we observe that expectation and mortgage shocks were the most important to the evaluation of housing prices during both the boom and bust periods. Yet, there is a considerable geographical variation in the effects. The boom and bust are most severe in the Sand States, where expectation shocks contributed the most to the large magnitude to price fluctuations. In other states, mortgage shocks generally have the largest effect, followed by expectation shocks. Supply shocks appear to have mattered most during the boom in densely populated states, while contributing little to lower prices in the bust, when demand dragged down prices nation-wide.

The bust in the residential market cannot be seen as an independent event from the preceding boom. In this section, we explore which of the four shocks that caused the boom can explain also the bust. Our examination is to some extent a test of Burnside et al. (2016), who propose that booms are built based on a some good news and some expectations about future growth, and that busts reflect the reversal of these expectations.



(a) Expectation shock

(b) Mortgage shock

(c) Demand shock

(d) Supply shock

Figure 8: **Contribution of Shocks to the Boom and the Consequent Bust**

The chart show the state-level depth of the bust (2006–2012) as a function of the contribution of the different shocks to the evolution of the boom (1996–2006).

Our analysis is using the cross-section of states to explain the bust. In particular, we measure the correlation between the contribution of the shocks to the *boom*, with the depth of the following bust. In Figure 8 we present scatter plots of the depth of the state-level bust, as a function of the contribution of the different shocks to the boom. The chart shows that the shock that explains the bust the best is the price expectation shock ($R^2 = 0.58$). The contributions of the other shocks are also positively correlated with the depth of the bust, however, the explanatory power is significantly weaker (R^2s range between 0.13 and 0.20). Overall, we view this result as corroborating the model of Burnside et al. (2016) about how real-estate booms develop and why they collapse.

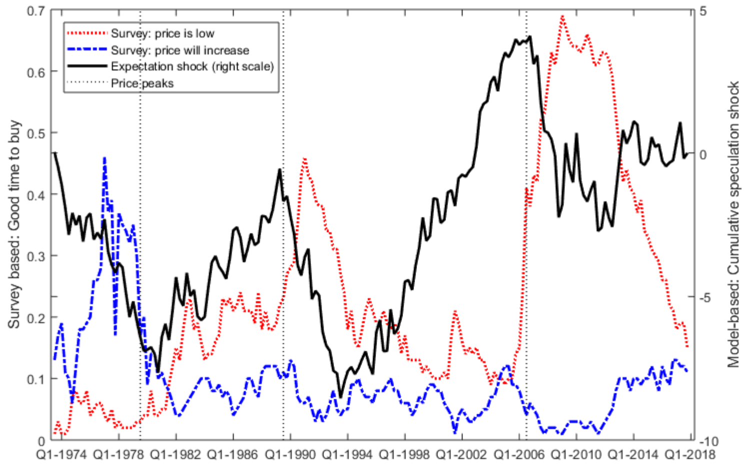
VII. Comparing Model-based and Survey-based Expectations

The most widely-used measure of expectations in the literature is drawn from surveys (e.g., Piazzesi and Schneider (2009); Lambertini et al. (2013); Cox and Ludvigson (2018)). In this section, we compare the expectation measure derived from our empirical model with the expectation measures derived from the Michigan Survey of Consumers. The survey asks respondents to comment whether this is generally a good time or bad time to buy a house.[24] Then, respondents are asked for the reason for their answer. The reasons that are related to expectations about future prices are: "because current prices are low" and "because prices will increase." For our analysis we combine the two responses, since from an economic point-of-view both mean the same: that prices are expected to increase in the future.

In Figure 9 we overlay the time series of the responses with our measure of expectations. As noted previously by Piazzesi and Schneider (2009), the chart shows that there is not much movement in survey-based expectations during the boom of 2002–2006. Instead, an unprecedented fraction of survey respondents perceive prices as low following 2008 (the bust). Our measure of expectations, in contrast, captures very high expectation shocks during the boom years and negative expectation shocks in the bust.

One way to reconcile these results is the difference between the surveyed population and the population our model captures. The goal of the survey is to provide a snapshot of expectations of a representative sample of consumers. Since most individuals do not actively look to buy a home, their views have little weight in setting prices. In contrast, buyers of excess capacity, whose expectations we capture, participate in the market. Those are people who transact on the margin, and therefore their beliefs are instrumental in setting prices.

[24] See survey instrument on `https://data.sca.isr.umich.edu/fetchdoc.php?docid=24776`.



(a) Price Expectations

Figure 9: **Survey-based vs. Model-based Expectations**

The chart compares survey-based expectations from the Michigan Survey of Consumers and expectation shocks resulting from our model. The survey expectations show the fraction of people who respond to the reasons for which it is a good time to buy homes: current prices are low (red dashed line), or future prices will increase (blue dashed line). The cumulative expectation shocks based on our model is presented in black solid line.

VIII. Conclusion

A number of observers has suggested that shifts in house price expectations have been an important driver of the U.S. house price boom that preceded the financial crisis. Arguments in favor of this hypothesis have been obtained either indirectly by using deviations from benchmark models, relying on measures of house price expectations (survey, media), or using local evidence about speculators.

We present a novel approach to quantify the contribution of price expectation to the housing boom, based on agents' actual actions. Our main identification tool is the insight that high price expectations result in agents amassing capacity, so that they could benefit from higher future prices. This approach allows us to separate price expectation shocks from shocks to mortgage rates, shocks to demand for housing services, and shocks to housing supply.

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 27% of the increase. Another 24% of the increase in house prices is explained by mortgage shocks. After accounting for demand and supply shocks (10% and 12%, respectively), 18% of the price increase still remains 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 overestimate their contribution.

Our analysis provides also new insights about the contributions of the shocks in the cross-section. We find that price expectation shocks were main contributors to the booms in the Sand States (Arizona, California, Florida, and Nevada). Furthermore, we observe that mortgage rate shocks were important contributors to the booms in many states that did not experience particularly large booms (e.g., Virginia), but did not account for a significant part of the boom in all Sand States. As far as to the demand shock, California's boom stands out as the one state that was influenced the most by it, while most states experienced a drag from demand shocks during the bust period. Densely populated states were amongst those most affected by the supply shock in the boom. In total, these cross-sectional observations add to the validity of our results, as they corroborate with observations of other, independent, research (Mayer (2011); Chinco and Mayer (2015); Ferreira and Gyourko (2017)).

Among the different shock contributions to the boom that we explored, only positive price expectation shocks during the boom predict the depth of the consequent house price bust. This fact is consistent with a model of housing boom and bust by Burnside et al. (2016), suggesting that optimistic views fuel the boom, and when they are reversed, a bust occurs.

Our expectation measure produces a materially different picture than the one arising from survey data. As some researchers noted (Piazzesi and Schneider (2009)), the average sentiment during the boom period across the U.S. was not necessarily speculative. However, our results show that in pockets across the U.S., *marginal* investors behaved in a speculative manner, gathering excess capacity in anticipation of future price increases. Their actions were sufficient to drive up home prices during the boom period and depress them in the consequent bust.

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