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INFERRING EXPECTATIONS FROM OBSERVABLES: EVIDENCE FROM THE HOUSING MARKET

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ABSTRACT

We propose a new method to identify shifts in price expectations in the housing market through the accumulation of excess capacity. Expectations of future price increases (due to anticipated future demand for housing services) cause the current supply to increase, creating a temporary vacancy. We implement this intuition in a structural vector autoregression with sign restrictions and explore the effects of price expectations in the U.S. housing market. We find that price expectation shocks were a prime factor explaining the 1996–2006 boom, particularly in the Sand States. Expectation shocks at the boom's peak reflected implausible growth expectations and reversed during the bust.

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1 Introduction

Many economists agree that expectations about future real estate prices play a role in determining current prices.[1] At the micro-level, several studies document the relation between speculative investment activity (e.g., out-of-town investors) and transaction prices.[2] How to measure the actual contribution of expectation shifts to the aggregate price level, however, is still an open question. Studies that rely on survey data or estimated structural models have found little evidence that expectations have a large impact on aggregate price data.[3] Other studies have found that aggregate home prices include a great deal of unexplained variation, which they attribute to expectations.[4] To our best knowledge, this is the first study to use macro models to estimate the role of expectations based on observables.

We propose that the contribution of expectation shifts to aggregate house price fluctuations can be inferred from the dynamics of housing inventories. Our estimates rely on a simple mechanism: When agents anticipate that prices will appreciate in the *future* due to an expected increase in demand, they ramp up construction *today*, because construction is costly to adjust and needs to be smoothed over time. The result is a buildup of housing inventories in the near-term, together with rising prices. We propose a simple model that delivers this intuition and embed its predictions in a structural vector autoregressive model with sign restrictions.

Our idea for measuring expectations through the level of vacancies is inspired by academic work in the energy market. There, high inventories at times of rising prices could indicate that investors amass excess capacity in anticipation of future demand and prices rising further. Economists used these insights to infer expectations about the future demand for petroleum using oil inventories (Kilian and Murphy, 2014; Juvenal and Petrella, 2015; Knittel and Pindyck, 2016). Consistent with this idea, economists have noticed that in locations experiencing housing booms, vacancies tend to rise in tandem with prices and new construction (e.g., Malpezzi and Wachter, 2005; Glaeser, Huang, Ma, and Shleifer, 2017), however, this relationship has not been explored systematically to extract expectations.

[1]In the context of the U.S residential housing market boom from 1996 to 2006, see Shiller (2007), Foote, Gerardi, and Willen (2012), Case, Shiller, and Thompson (2015), Glaeser and Nathanson (2015), Adelino, Schoar, and Severino (2016), Gennaioli and Shleifer (2020), Kaplan, Mitman, and Violante (2020), and Foote, Loewenstein, and Willen (2021).

[2]See Bayer, Geissler, Mangum, and Roberts (2020), Glaeser (2013), Chinco and Mayer (2015), DeFusco, Nathanson, and Zwick (2017), Bailey, Cao, Kuchler, and Stroebel (2018), Gao, Sockin, and Xiong (2020), and Alter and Dernaoui (2020).

[3]See Piazzesi and Schneider (2009), Landvoigt, Piazzesi, and Schneider (2015), Landvoigt (2017), and Cox and Ludvigson (2019).

[4]See Dokko, Doyle, Kiley, Kim, Sherlund, Sim, and Heuvel (2011) and Glaeser, Gottlieb, and Gyourko (2012).

Figure 1. Response to Expected Demand for Housing Services Shock

The figure demonstrates the main mechanism in the study. It shows how the observed demand for housing services (D), price (P), supply of housing (S), and vacancy rate (V) (in bold) shifts in response to a positive price expectation shock (dashed). All variables are normalized to zero at $t = 1$.

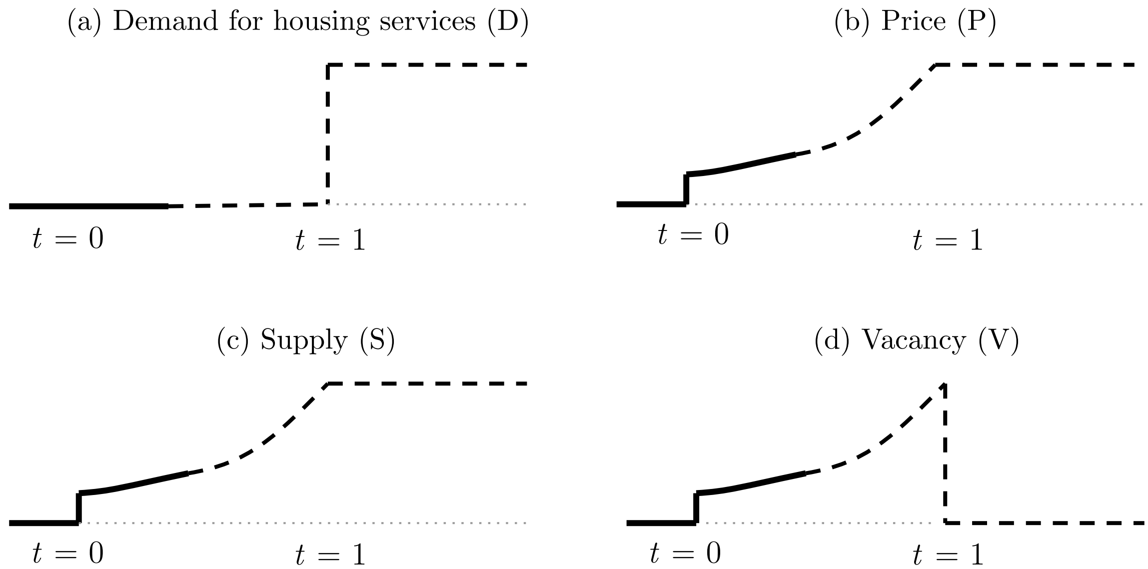


Figure 1 illustrates the mechanism we have in mind. Agents experience an expectation shock at $t = 0$: They expect prices to be higher in the future ($t = 1$). These price expectations can reflect expectations of higher demand for housing services, or an anticipated surge in construction costs, or higher prices.[5] For simplicity, the example focuses on an anticipated increase in demand for housing services. We are agnostic about whether expectations are rational or misguided—what is important for our model is that agents act in a manner that is consistent with their beliefs. At $t = 0$, the price already rises in line with the expected increase in the present discount value of future cash flows. In addition, because the adjustment costs of supply are convex (Rosenthal, 1999), the increase in supply will be smoothed over time, starting today. The new housing units remain vacant in the short run, until the demand for housing services arrives. Topel and Rosen (1988) describe this mechanism and write, "an anticipated transitory increase in future demand for housing services causes bubble-like price and investment responses" (p. 727). Indeed, during housing booms, construction activity has been documented to accelerate *ahead* of the expected demand for housing services,[6] resulting in high inventories of vacant properties.[7] Based on this behavior,

[5]E.g., the greater fool theory, see Liu and Conlon (2018).

[6]See Glaeser, Gyourko, and Saiz (2008), Haughwout, Peach, Sporn, and Tracy (2012), and Glaeser and Nathanson (2017).

[7]See Malpezzi and Wachter (2005), Mayer (2011), and Glaeser et al. (2017). Nathanson and Zwick (2018) show how supply-side speculation can lead to house price booms, even in regions with elastic housing supply where supply is expected to become inelastic.

our proposed procedure extracts expectations from observed quantities.

To solidify the intuition and fix ideas, consider the following examples of how vacancy, together with rising prices, is likely to reflect high price expectations. First, speculators purchase vacant homes because they hope to sell at a profit in the future. In fact, the interest in house flipping increased with the real estate prices, peaking in January 2007 (DeFusco et al., 2017). To curb speculation activity, some local authorities impose taxes on vacant properties. For example, following a boom in recent years in Vancouver, Canada, the province of British Columbia imposed in 2017 the Speculation and Vacancy Tax on vacant homes of 1% a year.[8] Second, current homeowners who plan to move to a new house often wonder about what to do first: buy first and then sell, or vice versa. Gibb, Marsh, Anundsen, and Larsen (2014) document that the decision depends on expectations. In hot markets (where prices are expected to rise), homeowners tend to buy and then sell, but in cold markets, they first sell and then buy.[9] Similarly, Bottan and Perez-Truglia (2020) find that households with higher price expectations delay selling their homes. Third, lenders relax their lending standards because they (or their investors) believe that houses are a safe collateral since house prices almost never decline. Homebuyers use the generous credit to buy vacant homes, with little downside. The common thread among these three examples is that vacancy in a strong market with rising prices indicates that agents anticipate prices will increase even further. They do not mind holding vacant homes for a short period despite the opportunity cost because they are confident the price will increase further.

To guide our empirical analysis, we describe the minimal set of conditions under which a high vacancy rate could be indicative of high price expectations. To this end, we sketch a simple model to illustrate the mechanism. The model includes four distinct shocks: demand for housing services, housing supply, mortgage rate, and expectations about future prices. Prices in the model are determined by rental rates and expectations about the discounted value of future prices (Poterba, 1984). We make additional standard assumptions, such as that the demand for housing services slopes downward, that the housing supply slopes upward with convex adjustment costs, and that the credit supply slopes upward. We also allow the demand for housing services to depend directly on the mortgage rate (due to affordability, e.g., Mian and Sufi, 2009; Ben-David, 2019). We also assume that suppliers of housing have lower bargaining power over rental rates when the vacancy rate is high. We separately discuss how shifts in credit standards are covered by our framework.

The primary purpose of the model is to motivate sign restrictions that describe the

[8] See https://www2.gov.bc.ca/gov/content/taxes/speculation-vacancy-tax.

[9] This advice is often provided to homebuyers. E.g., see Michele Lerner, Can I Buy a House Before I Sell My Home?, December 17, 2013, Realtor.com, https://www.realtor.com/advice/move/buy-or-sell-first/.

responses of the variables to the shocks. In particular, the model predicts that a positive shock to the demand for housing services will increase the supply of housing, the price of houses, and the mortgage rate, but will decrease the housing vacancy rate. Our interest lies in the effect of a shock to price expectations on observables. The model also predicts that a positive shock to price expectations will increase the housing supply, housing vacancies, house prices, and the mortgage rate.

By observing the dynamics of the fundamental variables over time and their deviations from the forecast, we can back out the extent to which various shocks—and of particular interest, the expectation shock—could have shaped them. To do so, we use the sign restrictions in a structural autoregression framework to estimate the effects of expectations on housing prices.[10] First, we estimate a Bayesian vector autoregression (BVAR) using observable variables. Next, we simulate shocks to the different variables for each point in time (demand for housing services, housing supply, mortgage rate, expectations) and explore which set of shocks could account for the forecasting errors, i.e., deviations from the VAR's predictions. The idea behind the approach is that forecast errors occur because unexpected shocks push an observed variable away from its natural course. We collect only time-series combinations of shocks that are consistent with the sign restrictions for the particular variables, as derived from the stylized model. The result is an estimate of the contributions of each shock to the housing price time series.

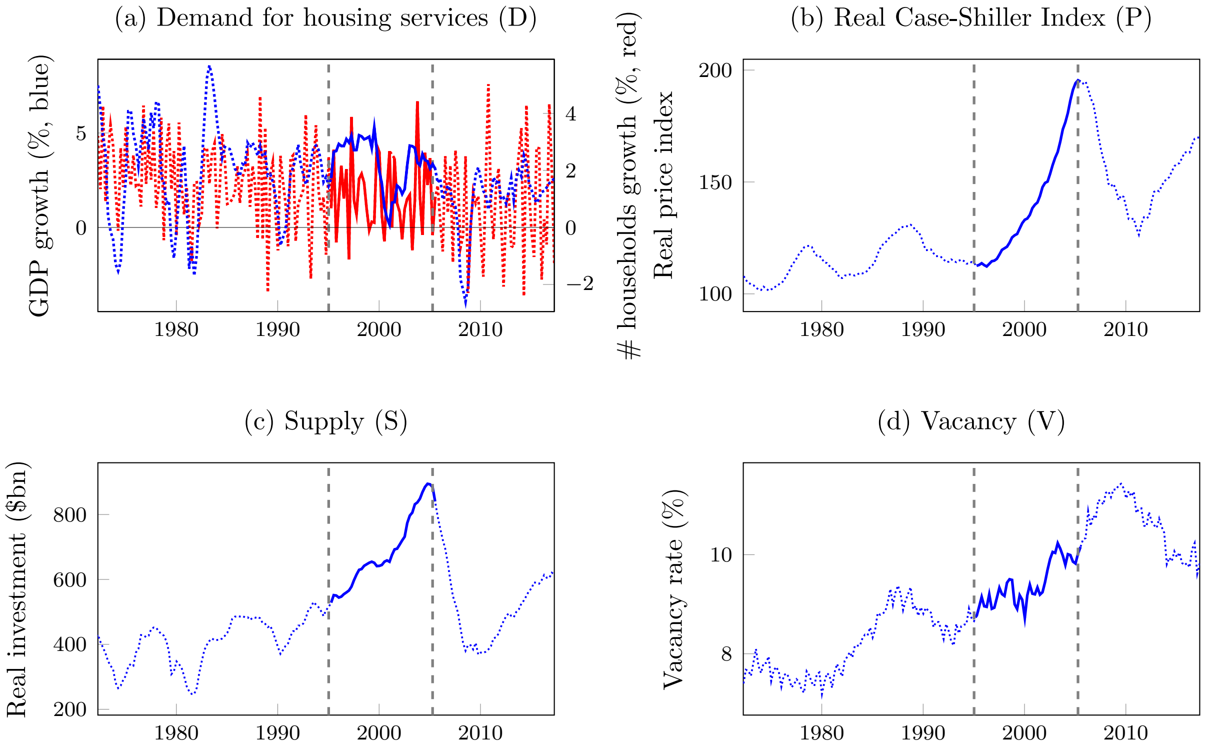
The analysis consists of three parts. In the first part, we estimate the model using national-level data for 1973–2018. Figure 2 shows data on the demand for housing services (proxied by GDP growth and new households formed), the supply of new homes (measured by real residential investment), house prices, and the vacancy rate. The figure shows that during the housing boom, housing supply increased substantially despite new household formations remaining within a narrow range and GDP growth not being particularly high. Some new homes were sold to the newly formed households, and some replaced existing dilapidated dwellings, and yet a significant fraction of homes remained in the hands of investors—vacant. Haughwout et al. (2012) estimate that during the 2000s boom, 3 to 3.5 million excess housing units were constructed at the same time that home prices increased at an unprecedented rate. As a result, the vacancy rate increased.[11] A similar, albeit more

[10]Canova and De Nicolo (2002) and Uhlig (2005) developed a framework of sign restrictions for structural vector autoregressive models. Previous work has used this framework to assess the effects of interest rate shocks (but not expectation shocks) on housing market variables (Del Negro and Otrok, 2007; Vargas-Silva, 2008; Jarociński and Smets, 2008; Sá, Towbin, and Wieladek, 2014; Bian and Gete, 2015; Ume, 2018). See Fry and Pagan (2011) for a review of the sign restrictions literature.

[11]We observe a further increase in the vacancy rate during the bust, when prices declined. The negative correlation between prices and vacancies is consistent with lower demand for housing services due to the deep recession.

Figure 2. GDP Growth, Housing Prices, Investment in Housing, and Vacancy Rates

The figure shows the time series of the annual year-on-year growth rate of the real gross domestic product (GDP; blue) and the annual year-on-year growth rate of the estimate of the number of U.S. households (Panel (a)), the national housing price index (Panel (b)), annual real private investment in housing ($bn, Panel (c)), and the vacancy rate (% of total homes, Panel (d)). The estimate of the number of U.S. households comes from series `TTLHHM156N` on `fred.stlouisfed.org`. The other sources are described in the data section.



muted, pattern can be observed in the late 1980s boom, but the vacancy rate behavior during the boom of the late 1970s does not conform with this pattern (vacancy rate does not increase). According to the estimation analysis, price expectation shocks were the second-most- important determinant of real estate prices during the 1996–2006 boom, explaining about 22% of the magnitude of the boom, slightly less influential than mortgage rate shocks (accounting for 29% of the boom's size). They also played a role during the 1980s boom, whereas the 1970s is mostly accounted for by mortgage rate shocks.

In the second part of our empirical analysis, we provide two pieces of evidence that the series we call *expectation shocks* is indeed likely to reflect changes in expectations. We document that our series of price expectation shocks is correlated with a series of GDP forecast revisions (Consensus Forecasts). In other words, the current year's expectations shock is correlated with the update in GDP projection (relative to the previous year's projection) for future years, which in turn proxies changes in expected future demand for housing services.

Furthermore, we estimate the model for each U.S. state separately for 1988–2017.[12] We document that expectation shocks mainly drove up prices in the Sand States (California, Florida, Arizona, and Nevada), which experienced unprecedented price booms. In addition, the contribution of the expectation and mortgage rate shocks is highly correlated across states, suggesting that the boom was largely driven by a common expectation and mortgage rate shock component, with states responding with different sensitivities. These results are consistent with the findings of Chinco and Mayer (2015) that the Sand States experienced a wave of speculative investments by out-of-town investors during the early 2000s.

In the third part of the analysis, we use our series of expectation shocks that we derived to better understand the nature of price expectations at the peak of the boom, in 2006. Our objective is to weigh the plausibility of these expectations and whether they contributed to the subsequent bust. We use a simple user-cost model to show that the contribution of the expectation shocks to the price at the peak of the boom can be interpreted as reflecting an expectation for annual house price growth that is permanently higher by 0.9 percentage points. This is a sizeable effect: In the three decades prior to the boom, the average yearly growth rate in our house price index amounted to just 0.2%. Hence, growth was expected to increase by an unprecedented rate of more than 400% in perpetuity. Next, we explore the relation between the contribution of the expectation shocks to the price at the boom peak and the following bust across states. We find that of the four shocks, the contribution of the expectation shock is the most correlated with the bust. We further document that the bust was driven by a reversal of boom-period shocks, primarily expectation and mortgage rate shocks, rather then by negative new shocks.

Overall, our study shows that vacancy rates could be useful in identifying the effects of expectations on real estate prices. Using the proposed methodology, we show that expectations about housing prices were likely implausible and eventually reversed, contributing to a boom-bust cycle. Our method could be used as a tool for policymakers to detect whether house prices are high due to expectations of further price increases.

2 A Stylized Model

In this section we propose a simple model that motivates the empirical estimation. The goal of the model is to derive the sign restrictions to identify the structural shocks that drive housing prices, under a minimal set of assumptions. The shocks we are interested in are shocks to the demand for housing services, the housing supply, mortgage rate, and price

[12] See a discussion in Guren, McKay, Nakamura, and Steinsson (2020) for the advantages of using the cross-section in macro-economic research.

expectation shocks.

The solution to the model implies a set of sign restrictions that we will apply to the data in Section 4, in which we estimate the role of the difference shocks, and, in particular, the expectation shock.

2.1 Model's Assumptions

Our identification approach relies on five underlying assumptions about the housing market. We embed these assumptions in a basic reduced-form model. The model is deliberately simple to make the underlying mechanisms transparent. Each assumption is backed by extensive theoretical and empirical literature. The aim of the model is to build an intuition for the relation between the observable variables under different shocks. Given the focus on observed variables when the shock hits, we abstract from the dynamics after the shock.

All endogenous variables are presented in capital letters and expressed in logs. Coefficients in lower-case letters are restricted to be positive, with subscripts reflecting the respective variables. ε_X denotes exogenous drivers of the endogenous variable X that are shocked.[13]

Assumption 1: Prices are forward-looking and depend on the mortgage rate and expected future prices.

We assume that current prices reflect the discounted value of the expected future income streams. 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 rate (I) (e.g., Poterba, 1984):

$$P = p_R R - p_I I + \varepsilon_{P^e} \tag{1}$$

The price, which is the present value of future cash flows, is higher when the mortgage rate is lower.[14] Importantly, to keep the problem tractable, we ignore the effects of depreciation and taxes.

Also, the above equation represents an arbitrage condition between the ownership and

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

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

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

rental segments of the market. Housing investors are indifferent between renting a house out or selling it. Accordingly, we only consider the overall housing market and do not model the choice between ownership and rental.[15] In that sense, the rental rate is the price for consuming housing services in a given period.

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 or with unrealistic expectations about future house prices increasing even further, as emphasized by Case and Shiller (2003). A combination of the two is an overreaction to a signal ("kernel of truth"), as in Bordalo, Gennaioli, Ma, and Shleifer (2020).[16]

As our model is a model of aggregate quantities, we do not specify or put restrictions on the expectations of agents, which could be heterogeneous. The expectations that we identify in the empirical procedure are those that are embedded in the market clearing price, and therefore reflect those of the marginal agents transacting.

Assumption 2: Demand for housing services is downward sloping with respect to the rental rate and depends negatively on the mortgage rate.

We make the standard assumption that the demand for housing services (D) decreases with the rental rate. Furthermore, when the mortgage rate is high, the demand for housing services is lower as well. This assumption is motivated by borrowing constraints in the form of debt service coverage ratios that are relieved through lower mortgage rates (Adelino, Schoar, and Severino, 2018a; Greenwald, 2018; Levitin, Lin, and Wachter, 2018).

It is important to note that the demand for housing services is understood as a demand for the *consumption* of housing services. Therefore, it is distinct from the demand to buy a

[15] In a similar fashion, occupants of houses are indifferent between renting or buying.

[16] 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, Glaeser and Nathanson (2017), Bordalo et al. (2020), and Bordalo, Gennaioli, and Shleifer (2018) provide frameworks in which individuals develop biased expectations based on observing past performance. Piazzesi and Schneider (2009), Adelino, Schoar, and Severino (2018b), Kuchler and Zafar (2019), Armona, Fuster, and Zafar (2019), and De Stefani (2017) use survey data to analyze macro- and real estate expectations and find that individuals form expectations based on their own experiences and on extrapolations from past price changes. Similarly, Adam, Kuang, and Marcet (2012), Burnside, Eichenbaum, and Rebelo (2016), DeFusco et al. (2017), Soo (2018), and Chinco (2020) explore mechanisms through which expectations develop endogenously, e.g., through social feedback among agents. In contrast to these studies and similar to Kaplan et al. (2020), we are interested in the innovations to expectations, i.e., the part of expectations that *does not* arise endogenously, but is uncorrelated with past information that is controlled for in the VAR. In our framework, endogenous expectations that develop in response to observable variables (e.g., past prices) are accounted for through the autoregressive process. Hence, endogenous expectations are implicitly allowed to affect the transmission of all of the four identified shocks. We show that, in addition, exogenous shifts in expectations have a separate role.

house as an *investment* since the buyer needs to live in the house to consume housing services. Most importantly, it excludes speculative demand for owning a house without actually living in it.

The demand for housing services is modeled as

$$D = -d_R R - d_I I + \varepsilon_D, \tag{2}$$

where ε_D captures exogenous drivers of demand for housing services. Possible reasons for a positive shock to the demand for housing services are exogenous increases in the population, increases in household formation, higher personal incomes, or shifts in tastes (Green and Hendershott, 1996; Zabel, 2004; Green and Lee, 2016).

Assumption 3: Housing supply is upward sloping with respect to house prices and subject to convex adjustment costs.

We assume that the supply of housing (S) is increasing in the price of housing. This identifying assumption appears particularly valid at higher levels of aggregation as in our study (e.g., state or national level), where housing supply is somewhat elastic. The upward-sloping supply can be a result of various factors identified in the literature, including zoning regulations, land limitations, and rising construction costs (Glaeser et al., 2008; Huang and Tang, 2012). We consider house flippers to be part of the supply in our model; in general, they purchase derelict homes, improve their quality through investments, and sell them. Thus, flipping activity increases the supply of housing. A similar argument can be made for housing improvements (Choi, Hong, and Scheinkman, 2014).

The supply of housing is, therefore, expressed as

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

where ε_S represents exogenous determinants of supply. Negative supply shocks may arise from cost increases in the construction sector and changes in the regulatory environment that reduce the provision of land (e.g., zoning restrictions) or make it more costly to construct on existing land (Gyourko and Saiz, 2004).

Note that there is an important difference in the way we describe demand for housing services versus the supply of housing. While the demand for housing services is decreasing with respect to the rental rate (the price for the current flow of rental services), the supply of housing 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 the housing supply is more responsive than the demand for housing services to future developments. This higher sensitivity is a direct consequence of convex adjustment costs. Specifically, adjusting the 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 for housing services, instead, is costless, and the consumption of housing services can be re-optimized each period. Hence, convex adjustment costs motivate that the housing supply reacts both to current rents and to discounted future prices. In contrast, demand for housing services only responds to current rents.[17]

Assumption 4: Suppliers of housing have low bargaining power when vacancies are high.

In our model (as well as in the real housing market), markets do not clear entirely, and there is a positive gap between the housing supply and the demand for housing services (Wheaton, 1990; Leung and Tse, 2012; Head, Lloyd-Ellis, and Sun, 2014):

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

The vacancy rate is given by the (log) difference between the supply of and the demand for housing services. The rental rate declines 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. Rosen and Smith (1983) and Wheaton (1990) develop a model for a negative relation between rents and vacancies. Empirical evidence is provided, for example, in Gabriel and Nothaft (2001).

Assumption 5: Credit supply is upward sloping.

We assume that the supply of credit to the housing market is not perfectly elastic (see evidence in Adelino, Schoar, and Severino, 2012; Glaeser et al., 2012; Drechsler, Savov, and Schnabl, 2019). If the demand for housing credit is high, the mortgage rate rises. An important driver of housing credit demand is the value of the outstanding stock of housing

[17] We also considered an extended model in which switching houses is costly and occupants take the future into account. For example, one could imagine that young people move out earlier and that household formation increases when prices are expected to increase. In such a model, the demand for housing services depends negatively on current rents and positively on house prices. Our results still hold as long as the response of the demand for housing services to house prices is sufficiently small relative to the supply response or, put differently, as long as the cost of switching houses is sufficiently low compared to the cost of adjusting supply in a given period.

(i.e., the sum of log supply S and log house prices P). If the number of housing units increases or housing becomes more expensive, demand for credit increases and the mortgage rate rises:

$$I = i_H H + \varepsilon_I, \tag{5}$$

where $H = S + P$ and ε_I represent exogenous determinants of the mortgage rate. The mortgage rate could experience a surprise drop for several reasons. The decline could be the result of an expansionary monetary policy shock, as emphasized in Taylor (2007); a lower term premium on risk-free long-term bonds (e.g., due to higher demand for long-term safe assets, see Bernanke, 2005; Caballero, Farhi, and Gourinchas, 2008); or a lower lending spread above the risk-free rate (e.g., due to cheaper sources of capital for banks, see Justiniano, Primiceri, and Tambalotti, 2019). Our approach does not attempt to disentangle the various causes.[18]

2.2 The Model's Solution

The solution to the five-equation system is given by the following:[19]

$$\begin{aligned} P &= -\left[\left(1 + d_I i_H\right) p_R + \left(v_R + d_R\right) p_I i_H\right] \cdot \varepsilon_S^* + p_R \cdot \varepsilon_D^* \\ &\quad - \left[\left(d_R + v_R\right) p_I + d_I \cdot p_R\right] \cdot \varepsilon_I^* + \left(v_R + d_R\right) \cdot \varepsilon_{Pe}^* \end{aligned} \tag{6}$$

$$\begin{aligned} S &= \left[v_R + d_R + i_H\left(d_I p_R + d_R p_I + v_R p_I\right)\right] \cdot \varepsilon_S^* + p_R s_P \cdot \varepsilon_D^* \\ &\quad - \left(d_I p_R + d_R p_I + v_R p_I\right) s_P \cdot \varepsilon_I^* + \left(v_R + d_R\right) s_P \cdot \varepsilon_{Pe}^* \end{aligned} \tag{7}$$

$$\begin{aligned} V &= v_R\left[1 + i_H\left(d_I + p_I\right)\right] \cdot \varepsilon_S^* - v_R\left[1 + (1 + s_P) p_I i_H\right] \cdot \varepsilon_D^* \\ &\quad \left[v_R\left(d_I - p_I s_P\right)\right] \cdot \varepsilon_I^* + v_R\left[s_P + (1 + s_P) d_I i_H\right] \cdot \varepsilon_{Pe}^* \end{aligned} \tag{8}$$

$$\begin{aligned} I &= \left(d_R + v_R - p_R\right) i_H \cdot \varepsilon_S^* + i_H p_R\left(1 + s_P\right) \cdot \varepsilon_D^* \\ &\quad + \left(d_R + v_R + p_R s_P\right) \cdot \varepsilon_I^* + \left[\left(d_R + v_R\right)\left(1 + s_P\right)\right] i_H \cdot \varepsilon_{Pe}^* \end{aligned} \tag{9}$$

We also solve for the rent-to-price ratio but impose no restrictions on its response; instead,

[18] Sá et al. (2014) and Sá and Wieladek (2015) compare the importance of monetary policy and capital inflow shocks for the housing markets in the U.S. and a sample of countries in the Organisation for Economic Co-operation and Development (OECD), respectively.

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

$$\Omega = v_r + d_r + p_r s_P + \left(v_r + d_r\right) p_i i_H\left(1 + s_P\right) + d_I i_H p_R\left(1 + s_P\right).$$

we check empirically whether the predictions of the model are borne out by the data:

$$\begin{aligned} R - P &= [(p_R - 1)(1 + d_I i_H) + (d_R + v_R - 1)p_I i_H] \cdot \varepsilon_S^* + [1 + p_i i_H(1 + s_P) - p_R] \cdot \varepsilon_D^* \\ &+ [(d_R + v_R)\, p_I + p_I s_P + (p_R - 1)d_I] \cdot \varepsilon_I^* - [s_P + v_R + d_R + d_i i_H(1 + s_P)] \cdot \varepsilon_{P^e}^*. \end{aligned}$$

2.3 Using the Model to Motivate Sign Restrictions

In many cases, the sign of the responses of the observable variables to shocks is pinned down in the model. We can use its solution to motivate the sign restrictions on observable variables consistent with the four shocks of interest: the price expectation shock and shocks to the demand for housing services, to the supply of houses, and the mortgage rate. Our primary focus is on the identification of the price expectation shock.

Table 1 summarizes the identification restrictions of the baseline specification coming out of the model. All structural shocks have been normalized to imply an increase in the real price of housing.

Table 1. Baseline Shock Identification Restrictions

This table summarizes the baseline shock identification restrictions coming out of the model. All structural shocks have been normalized to imply an increase in the real price of housing.

	Shock to:			
	Housing Supply (ε_S^*)	Demand for Housing Services (ε_D^*)	Mortgage Rate (ε_I^*)	Price Expectation ($\varepsilon_{P^e}^*$)
Housing Price (P)	> 0	> 0	> 0	> 0
Housing Supply (S)	< 0	> 0	> 0	> 0
Vacancy Rate (V)	< 0	< 0	·	> 0
Mortgage Rate (I)	·	> 0	< 0	> 0

To be able to identify the model using the data, our methodology requires a unique combination of sign restrictions for each shock. Next, we discuss how we can distinguish the different shocks.

Price expectation shocks: A positive house price expectation shock leads to increases in house prices, the housing supply, vacancies, and the mortgage rate. The restriction on house prices follows from Assumption 1: The prospect of being able to sell the house at a higher price in the future leads to higher prices now. The supply of housing 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 also creates the incentive to start building now, causing the housing supply to increase. The increase in housing construction leads to higher demand for mortgage credit. Because the mortgage credit supply is not perfectly elastic, the increased demand for loans associated with higher prices and construction activity will lead to a higher mortgage rate (Assumption 5). The increase in vacancies relies on Assumption 4: Markets do not fully clear 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. The rent-to-price ratio is predicted to increase as prices increase, but current rents do not (Assumptions 1 and 2).

Mortgage rate shocks: A negative mortgage rate shock is characterized by a decrease in the real mortgage rate and increases in house prices and the housing supply. Lower interest rates increase current prices through their impact on the present discount value (Assumption 1).

Higher prices encourage supply (Assumption 3). The response of the vacancy rate is ambiguous, as the increase in supply in response to a lower mortgage rate may be more than compensated by higher demand for housing services because of relieved credit constraints ($v_R\left(d_I - p_I s_P\right)$, see Equation 8). The response of the rent-price ratio is again theoretically ambiguous: While a lower interest rate will drive up prices (Assumption 1), it may also drive up rents because of higher demand for housing services (Assumption 3). In practice, we expect the sensitivity of the demand for housing services to interest rate d_I to be relatively small, such that vacancies increase and the rent-to-price ratio decreases. While prices and supply move in the same direction as in the case of the price expectation shock, the opposite movement of the mortgage rate enables us to distinguish the two shocks.

Demand for housing services shocks: A positive shock in demand for housing services (i.e., occupying a house or moving to a bigger house) leads to an increase in house prices, an increase in the housing supply, a decrease in housing vacancies, and higher mortgage rates. The restrictions on house prices and housing supply are as in Jarociński and Smets (2008) and follow from Assumptions 1, 2, and 3: An upward shift in the demand for housing services curve leads to higher house prices and increases in the housing supply. An upward-sloping mortgage credit supply will lead to higher interest rates, as mortgage demand increases with higher prices and investment in housing (Assumption 5).

Because it takes time for the supply of houses to adjust, growth in the demand for housing services temporarily exceeds the increase 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.[20] The response of the rent-price ratio is ambiguous, as more demand for housing services pushes up both prices and rents.

Housing supply shocks: A negative housing supply shock is associated with a rise in house prices and decreases in the supply of housing and the vacancy rate. The restrictions on house prices and housing supply are again as in Jarociński and Smets (2008) and follow from Assumptions 1 and 3. An upward shift in the supply curve leads to higher prices and lower quantities. As there are now fewer houses for a given demand for housing services, the vacancy rate falls (Assumption 4). The response of the mortgage rate is ambiguous ($(d_R + v_R - p_R)\, i_H$, see Equation 9): Credit demand may either increase due to higher house prices or decrease because of lower construction activity (Assumption 5). The response of the rent-price ratio is also ambiguous, as less supply pushes down both prices and rents.

2.4 The Role of Credit Standards

Thus far, we have focused on constructing a model that accounts for just as many shocks as are needed to isolate our shock of interest: the price expectation shock. The objective of the simple model is to illustrate the economic mechanism that gives rise to the co-movement of the vacancy rate and price that allows us to trace this shock. Because we are focusing strictly on what is needed for its identification, the model could conceivably miss important forces that can also shape real estate prices. Specifically, some scholars have argued that lax credit standards contributed to the boom in the early 2000s.[21]

In the following paragraphs we assess how the relaxation of credit standards are accounted for in our empirical estimation. We distinguish between two complementary cases: shifts in credit standards that arise endogenously and shifts in credit standards that arise exogenously.

Endogenous changes in credit standards mean that lenders change their standards in response to shocks already captured by our model. We focus our discussion on endogenous changes in response to price expectation shocks (see also Foote et al., 2021) Specifically, lenders may allow less creditworthy borrowers to take mortgages in response to price expectation shocks, since lenders rely on the increasing value of the collateral.

If the higher expected value of the collateral mostly translates into lower credit risk premia (thereby more than compensating for higher spreads because of higher credit demand

[20]As discussed under Assumption 2 in Section 2.1, the identified shock to the demand for housing services thereby focuses on exogenous variations in the demand for housing services. Still, it does not capture an increase in housing demand for investment purposes.

[21]See Duca, Muellbauer, and Murphy (2011), Favilukis, Kohn, Ludvigson, and Van Nieuwerburgh (2012), Favilukis, Ludvigson, and Van Nieuwerburgh (2017), Greenwald (2018), and Griffin, Kruger, and Maturana (2020).

and inelastic credit supply), this will be captured as a mortgage rate shock in our framework. If the laxer non-price credit standards associated with higher expectations strongly encourages the actual consumption of housing services (i.e., strong enough to lead to a decline in vacancies), they would be captured by shocks to the demand for housing services.

If the relaxation in credit standards finances speculators, their activity would continue to be captured by price expectation shocks in our framework: e.g., speculators use the more generous credit to buy vacant homes because they believe that house prices will never decline and that they have little equity exposure. Housing supply is likely to increase, but the demand for housing services remains unchanged. As a result, the vacancy rate increases.[22] Hence, the price expectation shock will also capture speculation that is financed by an endogenous relaxation of credit standards.

An exogenous relaxation of credit standards may occur when a regulatory change allows banks to allocate lower risk-based capital toward mortgages, or when a technological change lowers the cost of financing or changes monitoring incentives (e.g., private-label securitization). A relaxation in credit standards such as loan-to-value (LTV) ratio limits will increase the availability of housing to financially-constrained households, causing the demand for housing services to increase. Hence, laxer credit standards encourage the consumption of housing services (e.g., young adults move out of their parents' houses earlier) and would be captured by a shock to the demand for housing services.[23] In addition, laxer credit standards may translate into lower credit risk premia, because of a lower expected compensation for credit risk, in which case they would be captured by mortgage rate shocks.

In an extension to our baseline estimation, presented later in Section 5.2, we introduce the possibility of exogenous shocks to LTV. We distinguish between shocks to the demand for housing services that are associated with a loosening of LTV standards (called LTV shocks) and other shocks to the demand for housing services. The results in that section show that introducing an LTV shock does not change materially the relative importance of the other shocks, and that the LTV shock itself has a moderate effect.

[22]For similar reasons, mortgage fraud could also endogenously arise. Many mortgage fraud cases are about misrepresenting the borrower as credit worthy or the collateral as more valuable than it really is. Given that fraud is costly (if discovered), households are more likely to engage in such a fraud when mortgage rates are lower (i.e., applicants are closer to being qualified) or expectations are higher.

[23]The argument here is that looser credit standards would increase overall demand for housing services, thereby pushing up both rents and prices. Greenwald and Guren (2019) present a model in which rental and owner-occupied markets are allowed to be segmented. In segmented markets, looser credit standards can encourage a shift from renting to owning, which will push up the prices of owner-occupied homes but not rents. We acknowledge that our approach does not directly consider this possibility. However, Kaplan et al. (2020) provide evidence against strong segmentation, citing a large number of owner-occupied properties being converted to rental properties. Furthermore, Begley, Loewenstein, and Willen (2019) show that during the boom the price of rental properties increased relative to owner-occupied properties, which counters the hypothesis that loosened credit standards boosted the price of owner-occupied properties only.

3 Data

We use datasets at two aggregation levels. First, we use national-level data, aggregated at the quarterly level. Second, we use state-level data, aggregated at the annual level.

3.1 National-level Data

The change in the real housing price (ΔP) is measured by the log difference of the national real Case-Shiller house price index. Housing supply is approximated by real private residential investment data from the Bureau of Economic Analysis (ΔS). The real mortgage rate (I) is approximated by the nominal contract rate on the purchases of existing single-family homes,[24] less the long-term inflation expectations, measured by the 10-year-ahead forecast of the inflation rate.[25] The log of the rent-to-price ratio ($R - P$) is computed as the log difference between the housing component of the Consumer Price Index (Bureau of Labor Statistics) and the nominal Case-Shiller house price index. Finally, the log difference of U.S. real gross domestic product (GDP; $\Delta RGDP$), which we use as a control for economic activity, is taken from the Bureau of Economic Analysis. In the extension in which we identify LTV shocks, we use the LTV ratio at the time of house purchase from FHFA.

Of particular importance in our analysis is the series of vacancy rates (V). Recall that we consider the entire housing market and are interested in a series for overall vacancies. This series is given by the overall ratio of vacant houses that are part of the market relative to the total housing stock, excluding seasonal factors (Census Bureau). The Census uses the following definitions: "Vacant homes" are vacant year-round (i.e., excluding seasonal vacancies) and include "vacant for rent," "vacant for sale," "held off the market," and "rented or sold."[26]

Our national-quarter-level dataset covers the period from 1973Q1 to 2018Q1. Figure 1 in Appendix A shows the evolution of the respective variables.

[24] Provided by the Federal Housing Financing Agency (FHFA).

[25] Macroeconomic Advisers, downloaded from Haver Analytics (http://www.haver.com/).

[26] "Vacant for rent" consists of vacant units offered for rent and those offered for both rent and sale. "Vacant for sale" comprises units for sale only; it excludes units for both rent and sale.[27] "Vacant units held off the market" includes units held for occasional use, temporarily occupied by persons with a usual residence elsewhere, and vacant for other reasons. "Vacant units rented or sold" consists of year-round vacant units that have been rented or sold, but the new renters or owners have not moved in as of the day of the Census interview. See further details at https://www.census.gov/housing/hvs/definitions.pdf.

3.2 State-level Data

We also use state-level data to provide more granular evidence about the shocks contributing to the boom and bust that could be validated against more micro-level evidence. One may consider to look at even more granular data, e.g. at the MSA level. Two factors speak against more granular data: First, our mechanism relies on somewhat elastic housing supply. State level data has the advantage that it averages out effects from local (intra-state) inelastic supply that may have driven some of the variation in prices.[28] Second, housing vacancy data at MSA level are available only since 2005 (see Census website), which is a too short period to analyze the drivers of low-frequency movements.

State-level vacancy data are available since 1987 at the annual frequency. Our final state-year dataset covers the years 1988 to 2017 for 49 states and Washington, DC.[29] The log changes in the real house price indexes (ΔP) are provided by the FHFA. The change in the supply of housing (ΔS) is measured as the log of new private housing permits, using data from the U.S. Census Bureau.[30] Vacancy (V) data series are available for owner-occupied homes as well as for rental homes from the U.S. Census Bureau. Because we are interested in the aggregate vacancy at the state-year level, we combine these data into a single number using the weights of homeownership, based on region-year homeownership statistics from the U.S. Census Bureau.[31] State-year–level mortgage rates (I) are available on the FHFA website, deflated using the national 10-year inflation expectation. To capture long-run dynamics in prices and to control for economic activity, we include the housing price–to–median income ratio, with median income data coming from the U.S. Census Bureau.[32]

4 Estimation Method

This section introduces the empirical framework of the study. We first present the econometric model and then describe the identification approach and discuss the inference from the computational implementation.

[28]Saiz (2010) shows that the extent to which supply is limited determines the sensitivity of prices to the demand for housing services and Nathanson and Zwick (2018) expand the conclusion to supply that is expected to be limited in the future.

[29]Oklahoma is excluded due to missing data.

[30]Data on residential investment are 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.

[31]Due to limited data availability, we focus on the vacancy categories "vacant for rent" and "vacant for sale."

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

4.1 Econometric Model

For the national-level analysis, we estimate a Bayesian vector autoregressive (BVAR) model of the following 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

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

$\mathbf{e}_t$ is a reduced-form error term with variance-covariance matrix $\mathbf{\Sigma}$; L is the lag length; and $\mathbf{A}_i$ are coefficient matrices.[33]

The first four variables in the BVAR are required for identification.[34] The inclusion of the rent-to-price ratio is motivated by the co-integrating relation 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 residential investment to the GDP ratio and GDP growth allow us to compute the level response of residential investment and GDP. Furthermore, the responses of real GDP and the rent-to-price ratio allow us to assess the consistency of the responses to theoretical arguments.

4.2 Computational Implementation

We sample the regression coefficients A_i and covariance matrix Σ from the posterior distribution, with an uninformative prior distribution.[35] 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 using a random orthonormal matrix Q

[33] For the state-level regression, $\triangle S_t$ is proxied by new private building permits; $RGDP_t$ is dropped; and the log of the rent to price ratio $R_t - P_t$ is replaced by the log of the ratio of houses price to state median income. Data come from the U.S. Census. L equals 2 for the national-level regressions and 1 for the state-level regressions.

[34] We introduce the housing price in the first difference and use the ratio of residential investment to GDP to account for co-integrating relations and deterministic trends. However, we apply the sign restrictions on the levels of house prices and residential investment.

[35] Σ is drawn from an inverted-Wishart distribution $IW(\Sigma_{OLS}, T)$, and the 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 estimates.

($B = VQ$). Q is sampled as in Rubio-Ramírez, Waggoner, and Zha (2010).[36] The Q matrices are orthonormal random matrices. Given a 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 1 for all shocks, we keep the draw. We constrain the sign restriction to hold for the first two periods for all of the variables' responses in the case of the quarterly national data and for one period in the case of the annual state-level data. We repeat the procedure until we accept 5,000 models.

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.

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 84^{th} percentiles. As is standard in the literature, historical decompositions are constructed using point estimates, i.e., discarding parameter uncertainty. Doing so facilitates the interpretation of results, as it ensures that the individual contributions adds up to the total.

5 Results: National-Level Analysis

We begin our review of national-level results with a discussion of the impulse response functions of the identified shocks (Section 5.1). This discussion prepares the ground for the main object of interest in the study: the contribution of price expectation shocks to the housing booms, in particular, those of the 2000s (Section 5.2).

5.1 Impulse Response Functions

Figure 3 depicts the response of the six 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

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

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

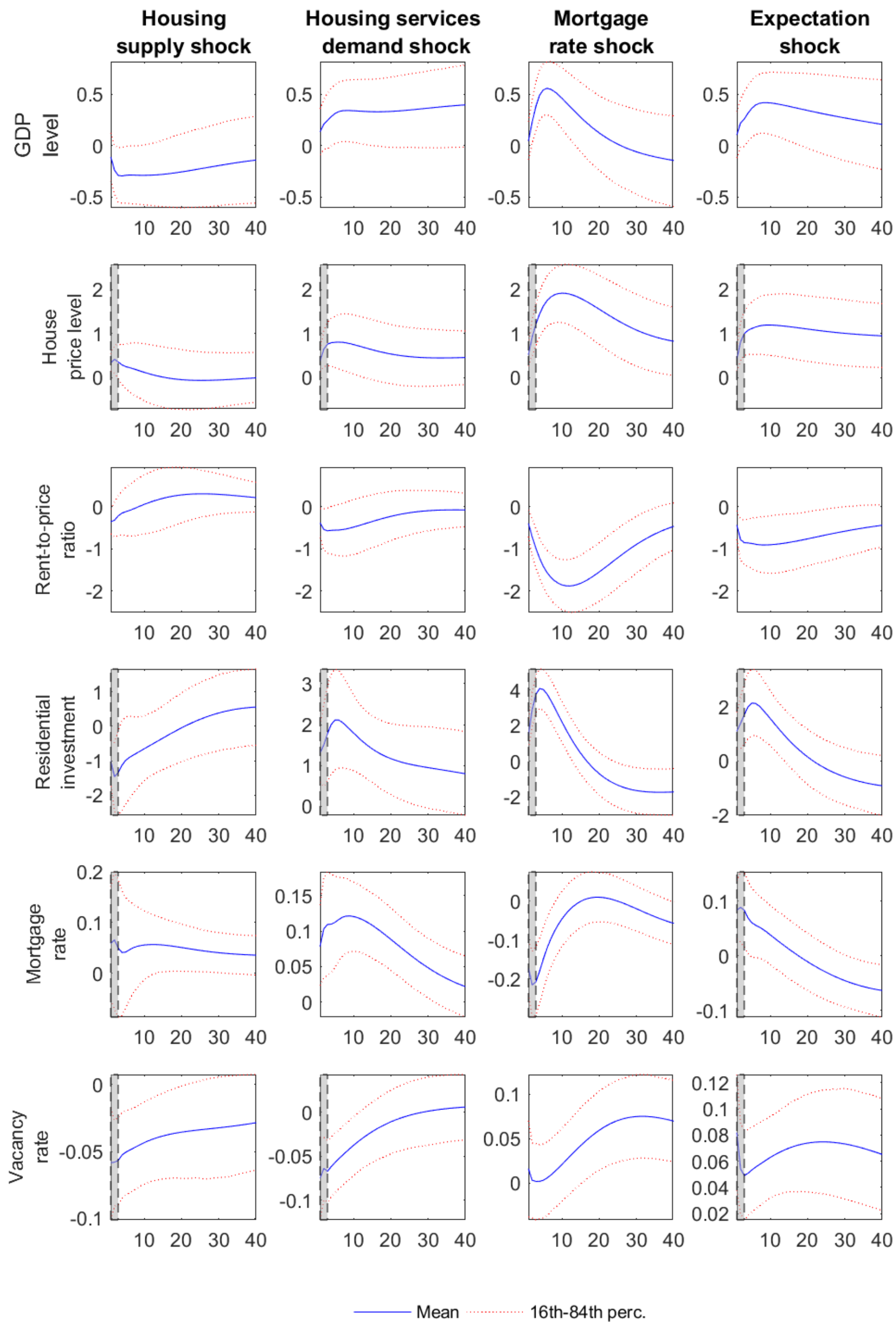
In response to a positive one-standard-price-expectation shock, house prices rise in the first three years by about 1.2% and then start to decline slowly. The rent-to-price ratio falls initially, consistent with the (unrestricted) sign prediction from the model, implied by Assumption 1 (i.e., house prices reflect the present discount value of future rents and the sale price). Residential investment increases on impact by close to 1% and follows a hump-shaped pattern, peaking at about 2%. The hump-shaped response of investment is consistent with convex adjustment costs (Assumption 3). Investment peaks six quarters after the expectation shock. After about six year, it persistently falls below its pre-shock path. This 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 falls below initial levels, 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 six years. This pattern 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 in house prices and residential investment to that of a positive price expectation shock. Quantitatively, however, a mortgage rate shock is associated with substantially stronger responses in residential investment, and the house price increase is also 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 (GDP) increase dissipates. The rent-to-price ratio initially decreases, as we would expect from the present value relationship discussed under Assumption 1, if interest rates fall. The vacancy rate increases persistently. Both of these (unconstrained) responses imply that the sensitivity of demand for housing services to interest rates (d_I) is limited.

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 they do in response to the price expectation shock, but the response is more persistent. House prices rise by less than they do 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 quickly

Figure 3. Baseline Model: Impulse Response Functions

This figure shows the pointwise mean of accepted impulse response functions, which is the main summary measure, along with pointwise 16^{th} and 84^{th} percentile error bands. These measures are described in Section 4.2. The identification assumptions are summarized in Table 1. The gray shaded areas mark periods for which sign restrictions have been imposed. The units on the y-axis represent cumulative log differences.



turns insignificant. Hence, house prices and rents grow by about the same amount. The pattern is also consistent with the simple model described above, where the response of the rent-to-price ratio is ambiguous, as prices and rents move in the same direction. The mortgage rate rises by about 10 basis points in response to increased housing activity. It remains relatively elevated for an extended period, in line with the persistent increase in residential investment. The vacancy rate drops initially but within five years returns to its pre-shock path, suggesting that increased residential investment closes the gap between the demand for housing services and the supply of housing.

Negative supply shocks are associated with an increase in house prices and a contraction of residential investment and output. As in the case of a shock to the demand 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.

5.2 Contribution of Price Expectation Shocks to the Housing Boom

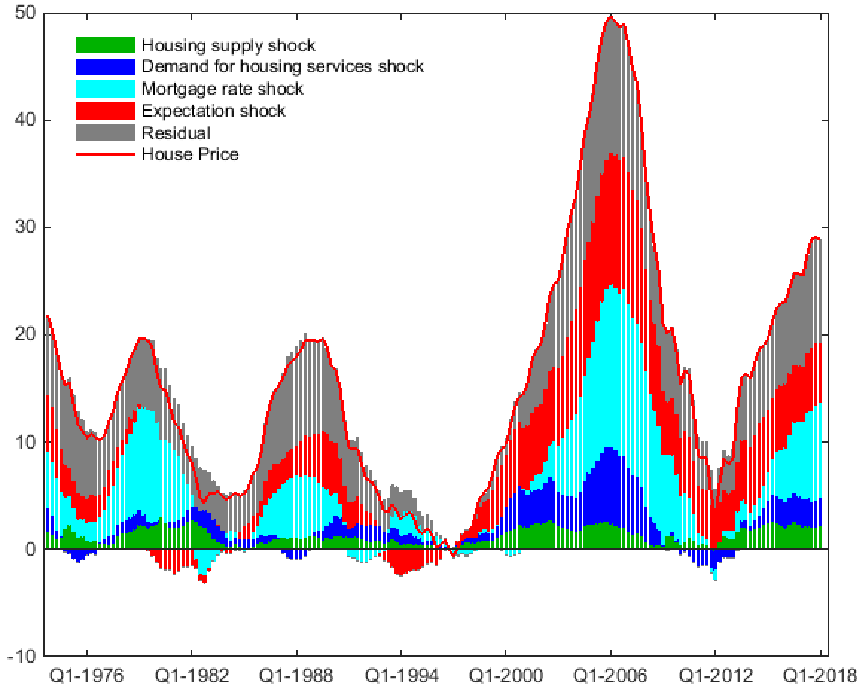
This section explores how the four identified shocks contributed historically to housing dynamics at specific points in time. Figure 4 displays the decomposition of real house prices over time. The solid red line is the log real house price (normalized to zero at the starting point of the boom period in 1996Q4). The log house price is presented in deviation from its deterministic path (i.e., the path house prices would have taken according to the VAR forecast if no shock had 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 the model is only partially identified. Quantitative results are shown in Table 2.

The four identified shocks explain a substantial share of the house price increase in the run-up to the crisis. About 70% of the increase between 1996Q4 and 2006Q1 is explained by the four identified shocks in the baseline model. The most substantial contribution comes from mortgage rate shocks, explaining 29% of the increase. The second-most-important contribution comes from price expectation shocks, accounting for about 22% 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. Shocks to the demand for housing services and the supply of housing account only for a small fraction of the boom (5% and 13%, respectively). Finally, as our model is only partially identified; there is a sizable unexplained residual of about 22%. The deterministic component explains a small part, less than 10%.

To put the explanatory power of our four-shock model in perspective, consider a model

Figure 4. Decomposition of Real House Prices

This figure shows the contribution of the different shocks to national home prices between 1973Q1 and 2018Q1. The solid red line is the log real house price (normalized to zero at the starting point of the boom period in 1996Q4). It is presented as the 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 units on the y-axis represent cumulative log differences.



that accounts only for the three traditional shocks (housing supply, demand for housing services, and mortgage rate).[37] In such a model, structural shocks explains only about 50% of the house price increase in the 2000s boom. Attributing the residual that cannot be explained by conventional shocks to expectations would overestimate the contribution of expectation shocks to the 2000s house price boom, since there remains an unexplained residual even with expectation shocks.

In a model in which we distinguish between shocks to the demand for housing services associated with LTV increases (labeled LTV shock) and those that are not (labeled shock to demand for housing services), the contribution of the price expectation shock is slightly smaller. Still, it remains the most critical contributor to the boom after the mortgage rate shock. The overall contribution of exogenous LTV shocks to the price boom is limited. This result is in line with empirical studies showing that the LTV distribution and mortgage approval rates did *not* change materially during the boom and bust years and across the

[37] Hence, the identification 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.

United States (Glaeser et al., 2012; Adelino et al., 2018a).[38]

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, as they explain more than 50% of the path (see Table 2). However, the contribution of the mortgage rate shock (about 38%) and demand for housing services shock (about 20%) mattered more in the bust than in the boom.

Table 2. Contribution of Shocks to Price Boom and Bust

The table shows the share of the change in house prices explained by the respective shock. The baseline identification assumptions are summarized in Table 1.

	Shock to:						
Model:	Housing Supply	Demand for Housing Serv.	Mortgage Rate	Expect-ations	LTV	Deter-ministic	Residual
	Contribution to Boom (1996Q4–2006Q1)						
Baseline	4.5	12.9	28.6	21.9		9.5	22.5
Baseline							
— excl. expectation	4.8	14.6	30.3			9.5	40.7
— with LTV	3.8	13.8	26.7	18.6	7.6	10.8	18.7
	Contribution to Bust (2006Q2–2012Q1)						
Baseline	6.0	20.3	37.9	19.8		−7.7	23.7
Baseline							
— only shocks up to 2006Q1	2.5	6.4	14.5	5.6		−7.7	10.3
— only shocks from 2006Q2	3.5	13.9	23.4	14.2		−7.7	13.4
— excl. expectation	6.3	22.6	38.4			−7.7	40.3
— with LTV	5.3	18.2	36.7	16.1	11.7	−10.0	21.8

The larger contribution of shocks to the demand for housing services to the bust can mainly be attributed to new negative shocks (from 2006Q2), consistent with a decline in income during the recession. The high contribution of mortgage rate shocks to the house price decline partly reflects the reversion of house prices from boom shocks. It also reflects new contractionary mortgage rate shocks.[39] Similarly, both old and new expectation shocks contributed to the bust. The contribution of shocks to the housing supply remains minor.

Going back further in time, expectation shifts also played a role in other house price

[38] For example, Adelino et al. (2018a) report that lenders indeed provided larger mortgages relative to income during the boom period; however, LTV remained constant over the boom and bust periods because mortgage size increased with the value of assets, keeping LTV constant. In their Figure 10, the authors show that, between 1996 and 2012, LTV distribution stayed almost constant in both boom and non-boom states.

[39] The mortgage rate fell less than predicted by the VAR given the other variables' evolution. Thus, a positive mortgage rate shock materialized in the period directly after the housing price peak.

booms, but not in every boom (see again Figure 4). Expectation shocks were an important driver of the boom of the late 1980s but played almost no role in the boom of the late 1970s. The latter was dominated by the mortgage rate shock, consistent with the notion that monetary policy was loose in the pre-Volcker period.

6 Validation of the Expectation Shocks

The novelty of our approach is the extraction of expectation shocks from observable housing data. In this section, we provide evidence that the expectation shock series is, indeed, likely to reflect shocks to expectations.

We present evidence from two sources. First, we compare the expectation shock series to macro-forecast revisions. Second, we repeat our tests in the cross-section of states and explore whether the expectation shocks at the peak of the 2006 boom line up with existing evidence of speculation activity across locations.

Overall, the results in this section provide validation for our expectation shock measure. We find that the expectation shocks that we derived from our econometric procedure, when applied to U.S. national-level data, are indeed correlated with the time series of GDP forecast revisions. In the cross-section, expectation shocks are larger for states that prior literature has identified as having had high speculative housing investment in the early 2000s.

6.1 Comparing Expectation Shocks with Macro-Forecast Revisions

As discussed above, expectation shocks reflect the anticipation of further price increases possibly due to, among other things, higher future rents (or equivalently, higher demand for housing services). Therefore, one way to validate the model-derived expectation shocks is to compare them to revisions to economic prospects by macro-economic forecasters. These, in turn, should reflect changes to expectations about future demand, including for housing services.

The macro-economic forecast revision data are based on a survey of private-sector GDP forecasts that is conducted by Consensus Economics, known as Consensus forecasts. Our forecast measure is annual GDP growth, which is the average of GDP forecasts made by hundreds of economists. Because economists participating in the survey provide GDP forecasts and not housing price forecasts, we anticipate that the expectation shock series derived from real estate data will be only partly correlated with the Consensus forecast revision series.New shocks, unrelated to the housing market, may partly explain the residual, and they should not affect the interpretation of the results: by construction, new shocks are orthogonal to the information set embedded in the VAR.

Forecast revisions are based on the update of the forecast for the year $t+1$, i.e., the difference between forecasts made at two different points in time, at the end of year t and and at the end of year $t-1$, for the same future year $(t+1)$. Because the object of the forecast is the same, GDP growth in year $t+1$, the difference between two forecasts made in different years is likely to partly reflect an expectation shock, i.e. an exogenous shift in expectations.

We then compare the revision in the GDP forecast at the end of year t with the expectation shocks that hit at time t. Because our shock measure is quarterly, we take the sum over four quarters.[40]

Figure 5 presents evidence that the series of expectation shocks and forecast revisions are indeed correlated ($R^2 = 0.29$), providing validity to our approach to identifying expectation shocks. The correlation is statistically significant and stronger than for shocks to the demand for housing services ($R^2 = 0.18$), mortgage rate shocks ($R^2 = 0.02$), and supply shocks ($R^2 = 0.01$). Using instead forecast revisions of medium-term output growth confirms our results (with all correlations lower but still statistically significant for expectation shocks).

6.2 Expectation Shocks in the Cross-Section of States

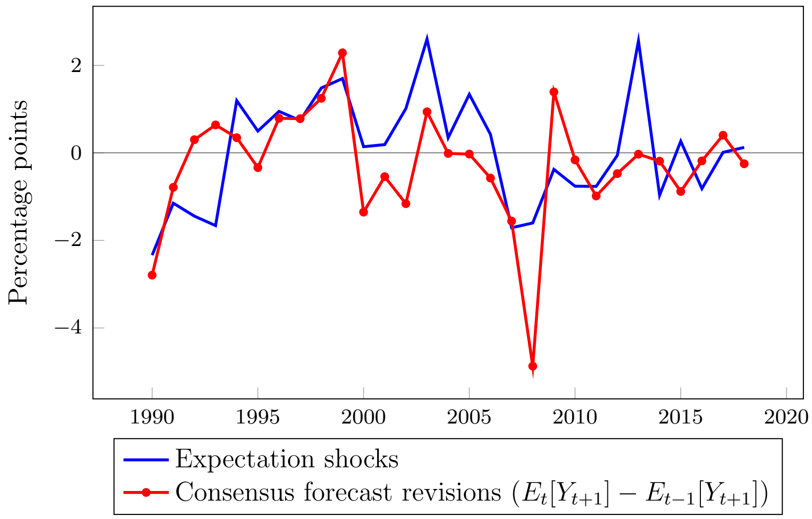
Another way to provide evidence for the validity of expectation shocks (and other shocks) is to derive state-level shocks and compare them with the observations made in prior studies about the sources of the boom in different states. Our analysis uses state-year data from 1988 to 2017. We rerun the BVAR analysis and simulations at the state level. We conduct the analysis independently for each state.

We are interested in exploring two aspects of the shocks across states. First, we study the contribution of expectation shocks to housing prices in different states, and in particular in the Sand States, which are known for speculative investment during the early 2000s. We show that in these states expectation shocks were indeed larger. Second, we explore the correlation of state-level with national-level shocks. We find that shocks to mortgage rates and expectations have a greater common component, while shocks to the demand for housing services and to supply have a greater local component, as expected.

[40] There are two major rounds of forecasts each year, in April and in October. The cut-off date for the April round is usually before the Q1 values for the year t are known. Hence, abstracting from high-frequency indicators, they can approximately be considered as a forecast using the information available at the end of the preceding year $(t-1)$. For our analysis, we use this April forecast; the results do not materially change if we use the October forecast of the preceding year as our measure for GDP growth expectations in $t-1$.

Figure 5. Time Series of Expectation Shocks and Consensus Forecast Revisions

The figure shows the alignment of the expectation shock series derived from U.S. housing data and the GDP forecast revision for the coming year. The figure presents the series of expectation shocks and the Consensus forecast revisions between two forecasts for the same calendar year: one made one year ahead, and the other made at the beginning of the forecasting year. Quarterly expectation shocks are summed up over the corresponding year.



6.2.1 The Distribution of Shocks Across States

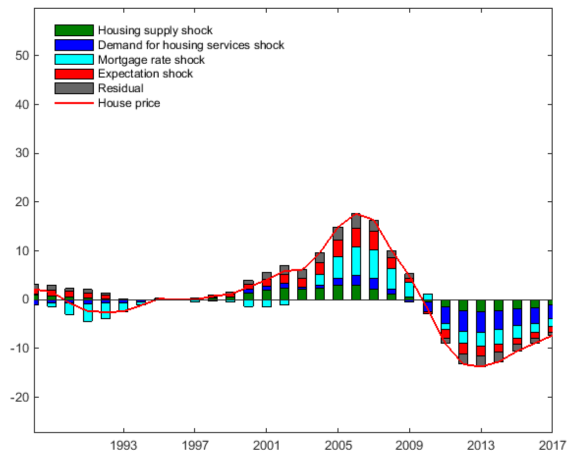
Prior literature provides some clues about which states experienced which shocks. Mayer (2011) documents that there was significant heterogeneity in the magnitude of the U.S. housing boom. The locations that experienced unprecedentedly large booms were cities in the Sand States: Las Vegas (Nevada), Miami (Florida), Phoenix (Arizona), Los Angeles (California), and San Diego (California). Chinco and Mayer (2015) find evidence that out-of-town investors invested in these cities, suggesting high expectation shocks in the Sand States. Indeed, when splitting the sample into Sand States and all other states , the Sand States stand out for the relatively high contribution of the expectation shock to their price evolution (see Figure 6).

Figure 7 shows how the four types of shocks contributed to the evolution of prices during the boom. Each panel presents the 20 states where the shock contributed the most to the price increase of the boom period, 1996–2006. Panel (a) reiterates the earlier result that the expectation shock most contributed to the boom in the Sand States, confirming the transaction-level results in Chinco and Mayer (2015). Panel (b) shows that the contribution of the mortgage rate was also pronounced in the Sand States, though to a lesser degree. Panel (c) shows that the contribution of the shock to the demand for housing services was the greatest in California, consistent with the argument in Ferreira and Gyourko (2011). Panel (d) shows that the contribution of the supply shock was the greatest in relatively

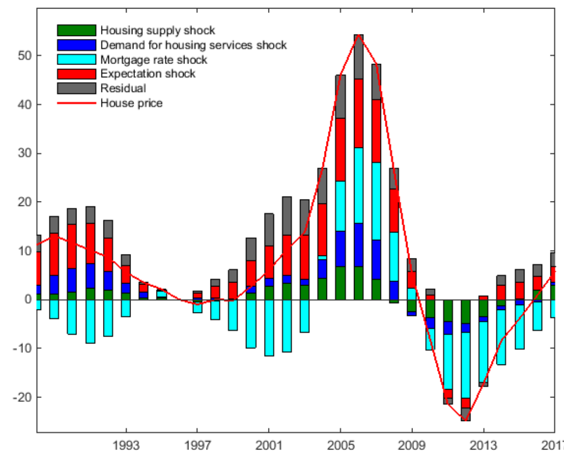
Figure 6. State-level Contribution of Shocks to the Price Evolution

This figure presents the contribution of the different shocks to house prices at the state level. Panel (a) shows the average across contributions for all states excluding the Sand States. Panel (b) shows the average across contributions for the four Sand States (Arizona, California, Florida, and Nevada). In each chart, the analysis was performed at the state level and equally averaged across all participating states. The solid red line is the log real house price (normalized to zero at the starting point of the boom period in 1996). The house price path is shown 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 units on the y-axis represent cumulative log differences.

(a) All states, excluding Sand States



(b) Sand States



densely populated states, consistent with evidence in the literature (Glaeser, Gyourko, and Saks, 2005; Glaeser et al., 2008; Saiz, 2010).

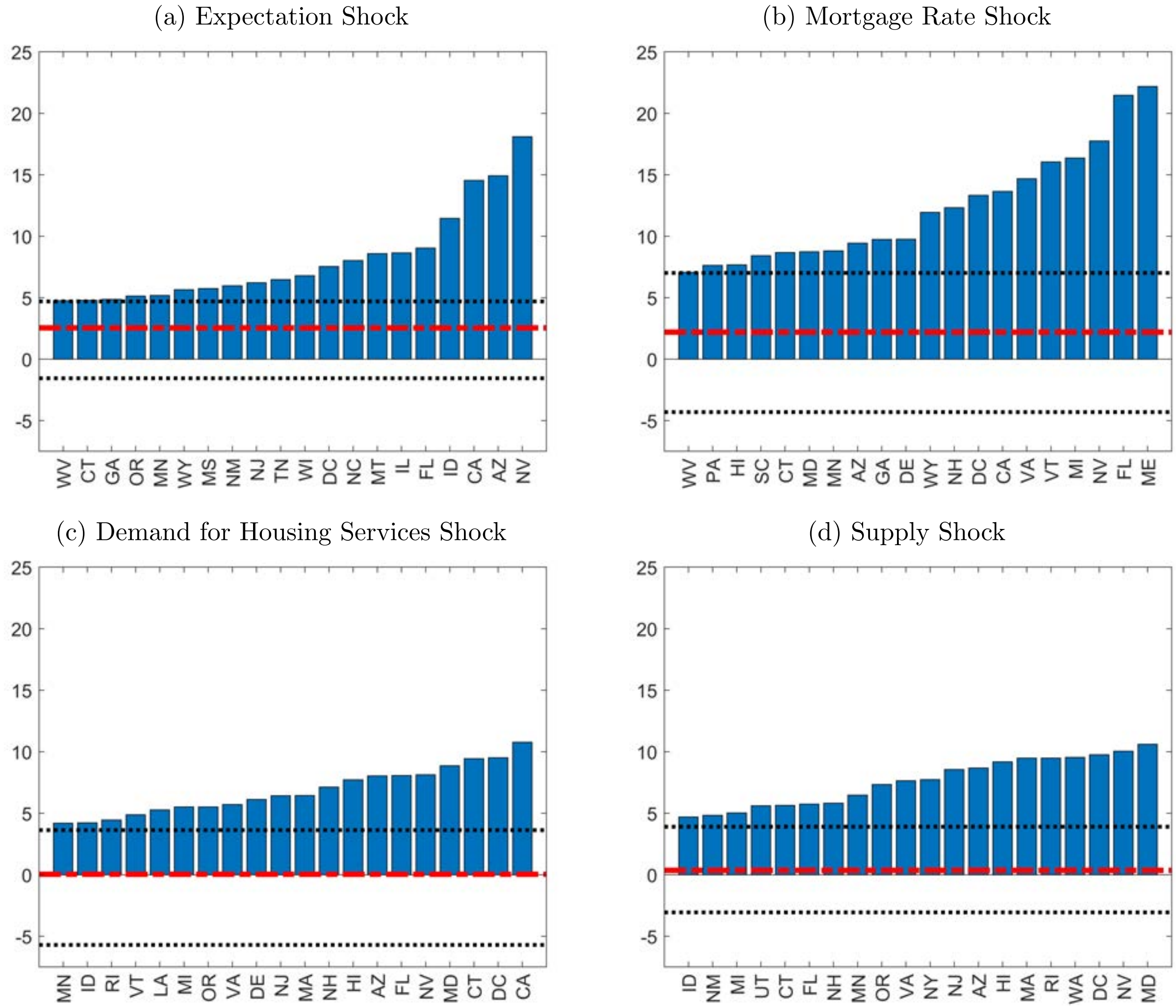
Overall, the state-level analysis supplements our observations from the national-level data. As at the national level, we observe that expectation and mortgage rate shocks were the most important contributors to the evolution of housing prices during both the boom and bust periods. Yet, we see considerable geographic variation in the effects. The boom and bust were most severe in the Sand States, where expectation shocks contributed the most to the large magnitude of the price fluctuations. In other states, mortgage rate shocks generally had the largest effect, followed by expectation shocks. Supply shocks appear to have mattered most during the boom in densely populated states.

6.2.2 National Versus State Shocks

An important question is whether the four different shocks lead to house price movements that are common across the nation or whether state-specific movements dominate. The answer to this question can also validate or discredit our analysis. For example, one would expect that mortgage rate shocks generate price movements that are to a large extent common to all states, given common determinants such as monetary policy and term pre-

Figure 7. State-level Contribution of Shocks to the Boom (1996–2006)

The figure shows the contribution of the four types of shocks to the evolution of prices during the boom in various states. The bars show the contribution of the top 20 states (log real house prices). The dashed lines show the minimum (black), maximum (black), and median (red) of the remaining 30 states. The units on the y-axis represent cumulative log differences.

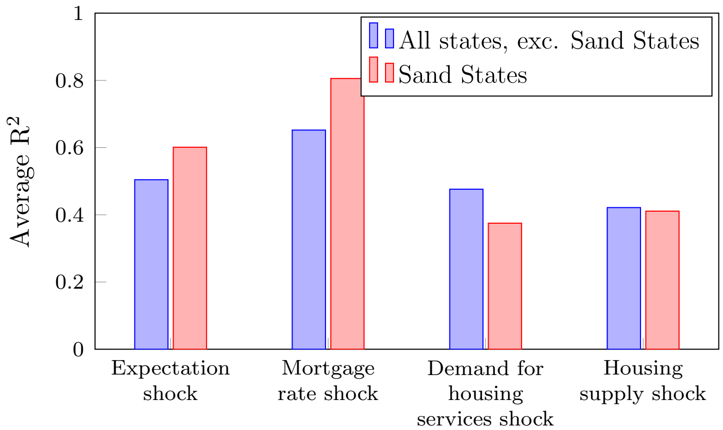


mia. In contrast, demand for housing services and supply of housing are likely to have some state-specific components.

We use principal component analysis to measure the extent to which the four shocks lead to common price movements across states. Specifically, for each shock, we take the first difference of the average price path generated by the respective shock in each state and calculate the first principal component from this panel. To account for differences in volatility, the variables are standardized to have a mean of zero and a standard deviation of one.

Figure 8. Share of Price Movements Explained by National Component

For each structural shock, we take the first difference of the average price path generated by the respective shock in each state and calculate the first principal component from this panel. The figure shows the share of the variance that is explained by the first principal component (R^2), averaged across states. We report separate results for Sand States and for the remaining states.



The results of the analysis are presented in Figure 8, which shows the share of the variance that is explained by the first principal component (R^2), averaged across states. We report separate results for the Sand States and for the remaining states. The figure shows, as expected, that a large share of the variation induced by mortgage rate shocks is common across states. Similarly, albeit with different magnitude, price movement induced by expectation shocks also has a strong common component, particularly in the Sand states.The strong common component in the contribution of expectation shocks also sheds light on Del Negro and Otrok (2007)'s finding that monetary policy alone cannot account for the unusually strong national component in the housing boom of the early 2000s. Of course, the common component could be a result for bottoms-up aggregation of similar expectation shocks (Kuchler and Zafar, 2019) or simply a nationwide expectation shock. The national component plays a smaller role in price movements generated by shocks to the demand for housing services and the supply of housing.

Furthermore, the analysis shows that the common component of mortgage rate and expectation shocks explains a larger share of the variance in the Sand States. This finding indicates that the large role of expectation shocks in the Sand states does not stem from state-specific events, but rather is the result of higher sensitivity in these states to a common national component.

7 The Nature of Expectation Shocks During the 2000s Boom

In this final section, we use our measure of expectation shocks to assess the nature of price expectations toward the peak of the 2000s boom. Our analysis consists of two parts. First, we quantify the price expectations that were embedded in 2006 housing prices. Second, we explore the relation between the collapse in housing prices in 2006–2012 and the reversal of earlier expectation shocks. The results in this section indicate that the boom-period expectations were of a magnitude that had not been seen at least since late 1800s, and that those expectations reversed and contributed to the depth of the bust.

7.1 The Economic Significance of the Expectation Shocks

As documented in Section 5.2, a substantial portion of housing prices at the peak of the 2000s boom can be ascribed to cumulative price expectation shocks. Because those expectation shocks indicate that agents anticipated further increases in prices, e.g., to future demand for housing services, we can estimate how realistic those expectations were.

Our results imply that expectation shocks accounted for about 22% of the national rise in prices between 1996Q1 and 2006Q1. Given the 73% increase in our benchmark real price index during this period, this means that prices were about 16% higher in 2006Q1 because of price expectation shocks. The question is, then, what this 16% represents in terms of future expected price growth.

To get an idea about implied expectations of future growth, we use a rough back-of-the-envelope calculation based on the simplest user-cost model of housing (Poterba, 1984; Himmelberg, Mayer, and Sinai, 2005). In this model, people are indifferent between owning and renting, accounting for interest rate costs (I), depreciation and property taxes (δ), and capital gains (i.e., average expected future price growth g). The rent-to-price ratio consistent with this condition is

$$\frac{R}{P} = I - g + \delta. \tag{11}$$

We can then solve for the implied growth rate g, given the other parameters.

We can do the same exercise in a counterfactual scenario where no price expectation shocks occurred. In that world, house prices are a fraction $\tau = 16\%$ lower. In addition, we take the simplifying assumption that current rents are not affected by price expectation shocks:[41]

$$\frac{R}{P^*} = \frac{R}{P(1-\tau)} = I - g^* + \delta. \tag{12}$$

With the interest rate and other housing costs unchanged, the entire difference in the rent-to-price ratio must be accounted for by a different implied growth rate g^*. Solving for the differential between g and g^* gives

$$g - g^* = \frac{R}{P}\left(\frac{\tau}{1-\tau}\right). \tag{13}$$

The implied growth rate differential $(g - g^*)$ is therefore independent from the level of interest rates or from depreciation and property taxes. In addition to our estimate for τ, the only other parameter for which we need to make an assumption is the (non-indexed) rent-to-price ratio. We use the median asking rent in the U.S. divided by the median asking sale price, both from the U.S. Census (Table 11A). This gives us an estimate for the rent-to-price ratio of 4.5% in 2006Q1.

Given our assumptions about the contribution of price expectation shocks and the rent-to-price ratio, the difference in the implied price growth rate amounts to 0.9 percentage points. This is a sizeable effect: In the three decades prior to the boom, the average yearly growth rate in our house price index was just 0.2 percentage points (see similar estimations in Shiller, 2015, going back to 1890s). Hence, growth was expected to increase by more than 400% in perpetuity compared to historical values.[42] The realized value in the 12 years following the end of the boom amounted to −1.2 percentage points.

We conclude, therefore, that the expectation shock during the 1996–2006 period is only consistent with average price growth rates that have not been observed historically.

7.2 Unfulfilled Boom Expectations and the Bust

We have shown that price expectation shocks were an important determinant in the mid-2000s real estate boom. As discussed in the introduction, expectation shocks reflect expectations of higher prices in the future, e.g., due to anticipated increases in demand for housing services. Given that the 2000s boom ended up with a bust, it is important to understand the extent to which the expectation shocks that drove the boom were reversed or whether new and negative price expectation shocks kicked in.

We conduct two analyses to answer this question. First, we explore the cross-sectional

[41] Price expectation shocks tend to lower rents because of an increase in supply. Accounting for this effect would increase the rent-to-price ratio $\frac{R}{P^*}$ in a counterfactual scenario that does not have expectation shocks and thereby would also increase our estimate of the implied growth rate differential $g - g^*$.

[42] Including the boom period would increase the average value from 0.2 to 1.5 percentage points and imply an expected growth increase of 50% in perpetuity.

relation between the magnitude of boom-period expectation shocks and the magnitude of the subsequent bust. Then, we examine whether the bust is associated with a reversal of boom-period expectation shocks or with new expectation shocks.

Our results show that the 2006–2012 bust was deeper for states that had larger boom-period contribution of expectation shocks, and to a lesser extent, larger contribution of other shocks. The bust is primarily associated with a reversal of earlier expectation shocks, rather than new negative expectation shocks.

7.2.1 Boom-Period Expectation Shocks and the Subsequent Bust

We begin by examining the relation between boom-period shock contributions and the magnitude of the bust. We use the cross-section of states to explore which of the four shocks that caused the boom can also 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 9, we present scatter plots of the depth of the state-level bust, as a function of the contribution of the various shocks to the boom. The figure shows that the price expectation shock explains the bust the best ($\mathrm{R}^2 = 0.46$). However, upon a closer examination, the high explanatory power of the depth of the bust by boom-time expectation shocks is really driven by a small number of outliers: the Sand States.

The contributions of the other shocks are also positively correlated with the depth of the bust; however, the explanatory power of each is weaker (R^2s range between 0.26 and 0.33).

7.2.2 The Reversal of Boom-Period Expectation Shocks and the Bust

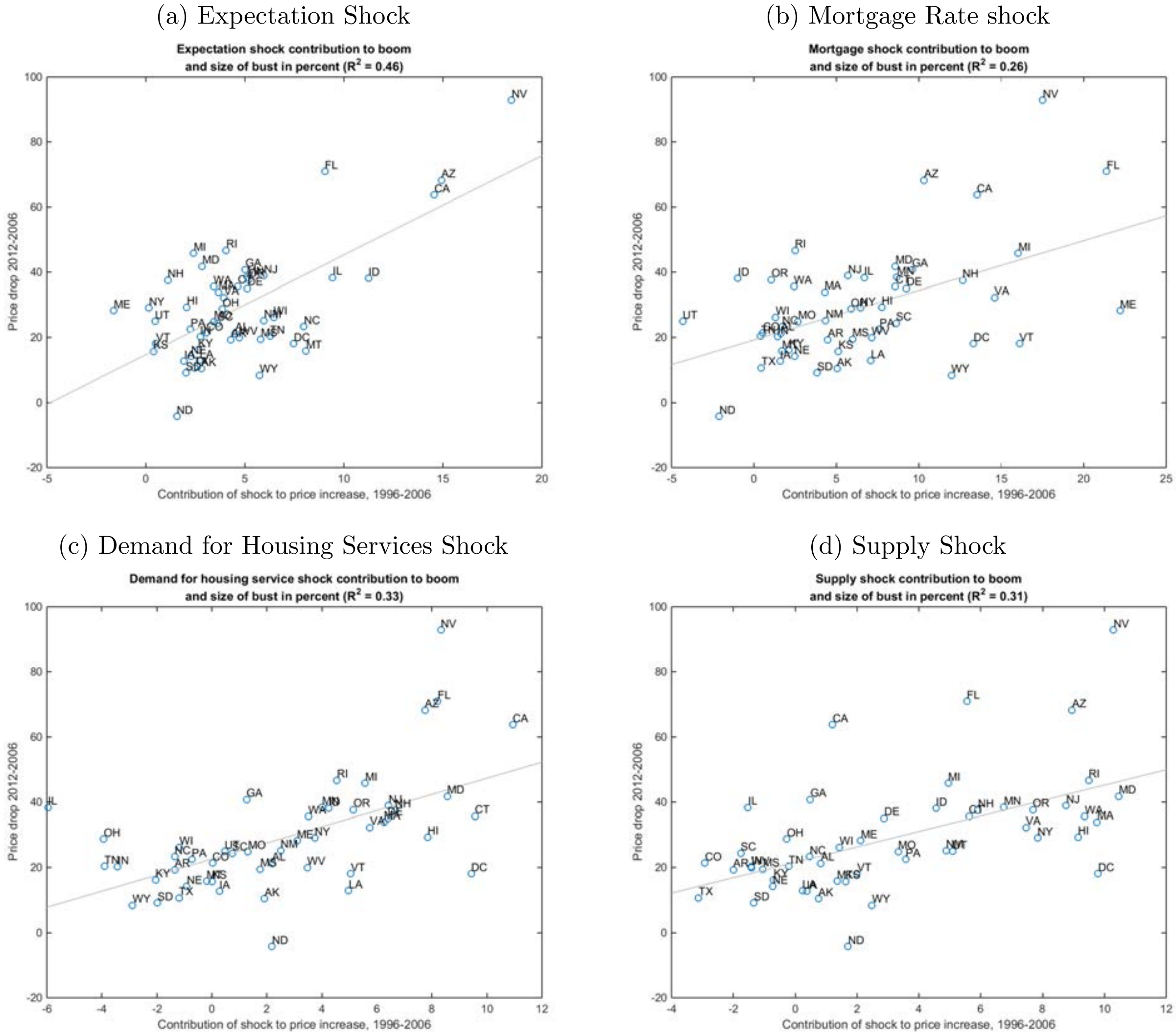
In the second approach, we split the contribution of the identified shocks to the bust pre-2007 shocks (old shocks, i.e., shocks that hit the economy up to 2006) and post-2006 shocks (new shocks, i.e., shocks that hit after 2006). Then, we examine which of the two sets of expectation shocks contributed to the bust: reversion of old positive shocks, or new negative shocks.

The results of the analysis are presented in Figure 10. The figure shows that the contribution of old expectation shocks reverts both in the Sand States and the other states. These results are consistent with the model of Burnside et al. (2016), in which booms are followed by busts when the expectations of optimistic agents are not fulfilled.

The analysis also explains the earlier observation that the Sand States experienced both a large expectation shock during the boom and a very significant bust. The price expectation shock component in these states was especially large during the boom, and these old shocks reverted during the bust (Figure 10, Panel (b)).

Figure 9. Contribution of Shocks to the Boom and the Subsequent Bust

The figure shows the state-level depth of the bust (2006–2012) as a function of the contribution of the four shocks to the evolution of the boom (1996–2006). The units on the x- and y-axes represent cumulative log differences.



(a) Expectation Shock

(b) Mortgage Rate shock

(c) Demand for Housing Services Shock

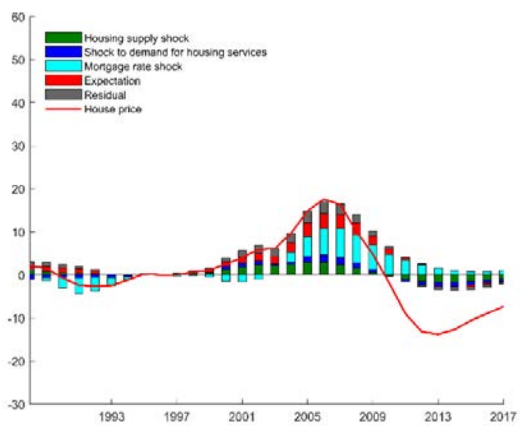
(d) Supply Shock

The other shock for which the size of the boom contribution appears to explain the size of the bust in the Sand States well is the mortgage rate shock. In fact, the contribution of this shock was positive pre-2006 and and then undershoots the deterministic no-shock path, with the contribution turning negative during the bust. This finding could potentially reflect downward price pressure due to foreclosures of highly leveraged properties. In Panel (a) of Figure 10, we observe that in the rest of the states, the contribution of old mortgage shocks reverses to about zero and does not undershoot. Old supply shocks and shocks to the demand for housing services explain a smaller share of the bust in both the Sand States and the other states.

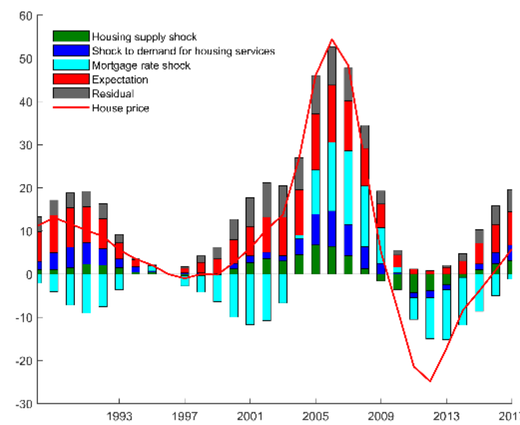
Figure 10. The Contribution of Old and New Shocks to the Bust

This figure presents the contribution of expectation shocks to the bust of 2006–2012. Panel (a) shows the contributions of pre-2006 shocks on the post-2006 period . The sample includes all sample states, except the Sand States. Panel (b) shows the contributions of pre-2006 shocks on the post-2006 period for the four Sand States (Arizona, California, Florida, and Nevada). Panel (c) shows the contributions of post-2006 shocks on the post-2006 period. The sample includes all sample states, except the Sand States. Panel (d) shows the contributions of post-2006 shocks on the post-2006 period for the four Sand States. In each chart, the analysis was performed at the state level and equally averaged across all participating states. The solid red line is the log real house price (normalized to zero at the starting point of the boom period in 1996). The house price path is shown 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 units on the y-axis represent cumulative log differences.

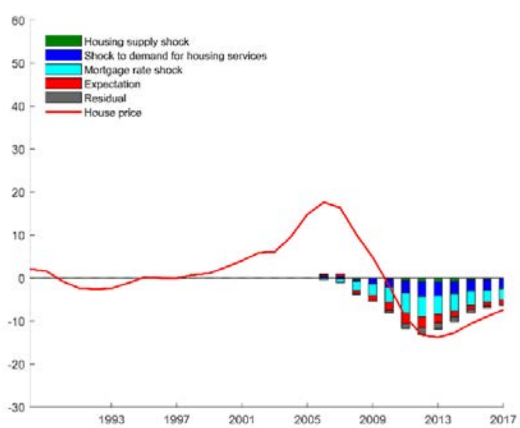
(a) Old shocks: All states, excluding Sand States



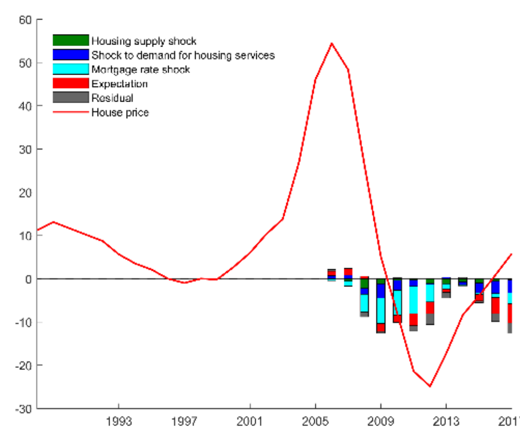
(b) Old shocks: Sand States



(c) New shocks: All states, excluding Sand States



(d) New shocks: Sand States



New shocks (post-2006) account for an important share of the bust in non-Sand States (Figure 10, Panel (c)) and explain almost the entire undershooting. In particular, starting from 2009, negative shocks to the demand for housing services play an important role in these states. This may be a result of the economic recession that affected demand for housing services in all states, including those that did not experience large booms beforehand. New negative mortgage shocks also contribute to the bust, in line with tighter credit conditions. Negative expectation shocks explain a part of the bust, which may indicate that the national bust—driven by the Sand States—also shifted expectations at the state level. The contribution of new supply shocks is negligibly small. For the Sand States, old shocks explain most of the undershooting; the only new shocks that matter are mortgage rate shocks, again in line with a tightening in national credit conditions.

8 Conclusion

We propose a new way to measure expectations in the real estate market. While economists agree that expectations about future prices are likely to be an important determinant of current prices, expectations are hard to measure based on aggregate variables.

Our method is based on the observation that because construction capacity is costly to adjust, investors smooth construction over time when price expectations are high. As a result, a temporary vacancy forms contemporaneously with price increases. Hence, agents' actions indicate their beliefs.

We implement this intuition in a simple theoretical model and apply its insights using a vector autoregressive model with sign restrictions. Our approach allows us to separate price expectation shocks from shocks to the mortgage rate, shocks to the demand for housing services, and shocks to the supply of housing.

The estimation results show that price expectation shocks, although second to mortgage rate shocks, are important in explaining the 2000s housing boom and are correlated with forecast revisions of broader macroeconomic economic prospects. In the cross-section, the role of expectation shocks was particularly important in the Sand States. Our results also show that the bust (2006–2012) was largely driven by earlier expectation shocks that reversed (were not fulfilled), especially in the Sand States.

Beyond the methodological and economic contributions, our results can help policy makers develop tools based on observed vacancy rates to assess the degree to which present prices are based on expectations of future price appreciation.

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Appendix A Time Series of Main Variables

Figure 1 shows the time series evolution of the main variables used in the analysis.

Figure 1. Evolution of Variables Over Time

The figure shows the time-series evolution of the main variables used in the analysis. The units on the y-axis represent cumulative log differences.