

NBER WORKING PAPER SERIES

HOUSING BUBBLES

Edward L. Glaeser
Charles G. Nathanson

Working Paper 20426
<http://www.nber.org/papers/w20426>

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
August 2014

Edward Glaeser thanks the Taubman Center for State and Local Government for financial support. William Strange (the editor) provided much guidance and Rajiv Sethi both provided excellent comments. The views expressed herein are those of the authors and do not necessarily reflect the views of the National Bureau of Economic Research.

At least one co-author has disclosed a financial relationship of potential relevance for this research. Further information is available online at <http://www.nber.org/papers/w20426.ack>

NBER working papers are circulated for discussion and comment purposes. They have not been peer-reviewed or been subject to the review by the NBER Board of Directors that accompanies official NBER publications.

© 2014 by Edward L. Glaeser and Charles G. Nathanson. All rights reserved. Short sections of text, not to exceed two paragraphs, may be quoted without explicit permission provided that full credit, including © notice, is given to the source.

Housing Bubbles
Edward L. Glaeser and Charles G. Nathanson
NBER Working Paper No. 20426
August 2014
JEL No. R0,R31

ABSTRACT

Housing markets experience substantial price volatility, short term price change momentum and mean reversion of prices over the long run. Together these features, particularly at their most extreme, produce the classic shape of an asset bubble. In this paper, we review the stylized facts of housing bubbles and discuss theories that can potentially explain events like the boom-bust cycles of the 2000s. One set of theories assumes rationality and uses idiosyncratic features of the housing market, such as intensive search and short selling constraints, to explain the stylized facts. Cheap credit provides a particularly common rationalization for price booms, but temporary periods of low interest rates will not explain massive price swings in simple rational models. An incorrectly under-priced default option is needed to explain the formation of rational bubbles. Many non-rational explanations for real estate bubbles exist, but the most promising theories emphasize some form of trend-chasing, which in turn reflects boundedly rational learning.

Edward L. Glaeser
Department of Economics
315A Littauer Center
Harvard University
Cambridge, MA 02138
and NBER
eglaser@harvard.edu

Charles G. Nathanson
Department of Finance
Kellogg School of Management
Andersen Hall, 4th Floor, Room 401
2001 Sheridan Road
Evanston, IL 60208-2001
c-nathanson@kellogg.northwestern.edu

I. Introduction

Between 2000 and 2012, America experienced a great housing convulsion that had all the classic attributes of a real estate bubble. Housing prices rose dramatically and then fell, leaving average real housing prices in 2012 no higher than they were in 2000. Price growth, between 2000 and 2006, was much higher in some places than in others, and the places with the biggest price growth experienced the largest declines. Surprisingly, some of the biggest booms occurred in places like Phoenix and Las Vegas which appear to have few short-run limits on new construction (Nathanson and Zwick, 2014, Gao, 2014, Davidoff, 2013).

During the years of biggest boom—2003, 2004 and 2005—when the change in real housing price growth is regressed on the one year lag of price growth across metropolitan areas, the coefficient is greater than one. Price growth seemed to build upon itself. This phenomenon represents the more general tendency of price growth to show strong positive serial correlation at one year frequencies (Case and Shiller, 1989). There was also a clear pattern of spatial correlation, where a boom that started on the coast seems to have spread to neighboring in-land metropolitan areas (Ferreira and Gyourko, 2012).

The U.S. housing cycle that occurred between 2000 and 2012 is extreme but hardly unique. Other countries, such as Ireland and Spain, also experienced housing bubbles and crashes over those years. While Japan's housing market remained stable after 2000, Japan had experienced its own massive real estate cycle in the 1980s and early 1990s. American history is replete with examples of real estate booms and busts, from the days of the early Republic to the American convulsion of the early 1980s. In summarizing these events, Glaeser (2013) argues that while these events may clearly look like bubbles *ex post*, even at their height, prices could be reconciled with standard models of real estate evaluation.

In Section II of this essay, we begin with a simple user-cost model of housing value that we refer to as the linear asset pricing model or LAPM, following Head, Lloyd-Ellis and Sun (2014). This approach runs deep within real estate and housing economics, but it differs from the general equilibrium approach preferred by macroeconomists and discussed by Davis and van Nieuwerburgh in this volume. We begin with a simple model, rather than stylized facts, because a model is helpful when discussing which stylized facts are anomalous. In any user-cost model that descends from Poterba (1984), prices equal the expected value of the exogenous flow of discounted future benefits from home-owning.

The LAPM approach is not only rational, but it abstracts away from critical institutional features of the housing such as search and heterogeneity. Section II also discusses important institutional features of the housing market that differ from other assets including the extremely difficulty of short-sales, the extreme heterogeneity of the asset, the dominant role of amateur investors, and limited information about current asset values. These differences do limit the widespread

applicability of the user cost or LAPM formula, but it remains a useful benchmark with which to examine housing price fluctuations.

Section III discusses stylized facts about housing markets. We begin by noting the spatial heterogeneity of the recent boom and bust, the strong short term positive serial correlation of prices and the even stronger long term negative price change serial correlation. The short term positive serial correlation is difficult to square with the LAPM, but negative serial correlation over longer time horizons is more readily reconcilable with rationality if housing supply responses are delayed. We also discuss the movements in the quantities of housing, which can refer both to the volume of housing produced and the volume of housing sold. We end this subsection with a discussion of real estate bubbles in U.S. history that draws heavily from Glaeser (2013).

Section IV turns to rationalizing the seemingly irrational: economic approaches to understanding these gigantic fluctuations which maintain individual rationality assumptions. Models of search by heterogeneous consumers, such as Novy-Marx (2009), Head, Lloyd-Ellis and Sun (2014) and Guren (2014) can slow the diffusion of shocks to the housing demand and thereby generate momentum in prices over shorter time periods. Heterogeneous demand can also generate price volatility, if there are exogenous shocks to supply. We discuss the possible role of rational learning, but conclude that fully Bayesian updating has little power on its own to explain the stylized facts.

Our final attempt to explain the events with rational models is to discuss the possible role of credit. Mian and Sufi (2014) have compellingly made the case that subprime lending did push up prices in many areas. While lower interest rates will have only a modest impact on prices in the standard LAPM, assuming that individuals anticipate the mean reversion of interest rates (Cox, Ingersoll and Ross, 1985), an underpriced default option will allow rational bubbles to occur more readily. One natural explanation for charging borrowers too little for the risk of default is the existence of agency problems either within financial institutions or between mortgage originators and the eventual owners of securitized mortgages. We do not formally model the financial institution's structure, but assume that for some rational reason the agents of lenders are pushing cash out the door too quickly and cheaply. Naturally, overly cheap credit might also reflect over-optimism on the part of lending institutions or some other form of limited rationality.

Typically, rational bubbles in housing require a violation of the standard transversality condition: with such bubbles, the discounted infinite horizon expected value of the home is strictly positive. Moreover, rational bubbles are particularly difficult to deliver with even moderately elastic supply (Glaeser, Gyourko and Saiz, 2008). If default risk is underpriced, then rational bubbles can occur even with moderately elastic supply and without violating any transversality condition.

In Section V, we present a collection of less rational models of housing bubbles. We begin with models in which beliefs are exogenous including Glaeser, Gyourko and Saiz (2008), Piazzesi and Schneider (2009) and Nathanson and Zwick (2013). These models are useful for exploring the ways in which institutional features of the housing market interact with irrationality. For example, Glaeser, Gyourko and Saiz (2008) and Nathanson and Zwick (2013) both consider land availability; Piazzesi and Schneider (2009) consider search dynamics. While this line of work is potentially useful in generating ancillary predictions about housing bubbles (e.g. they are most common in areas where land supply limited in the long run), they cannot explain the ultimate source of beliefs about house prices.

We then turn to a second major class of models: extrapolation. In one class of extrapolative models, the belief formation process is ad hoc but assumed for a small class of traders. In a second class, the belief formation process follows from imperfect learning about a stochastic growth rate. In a sense, the first class assumes massive irrationality for the few while the second class assumes modest irrationality for the many. It may be that the first is more appropriate in standard financial markets where a small number of well-financed traders can drive markets, while the second class is more appropriate in housing markets.

A third class of models discusses other forms of limited rationality, including limited memory, basing models on short runs of data, rule-of-thumb buying strategies, and price estimates based on natural geographic comparisons. This discussion serves mainly to highlight the fact that once perfect rationality is dropped, an essentially infinite array of assumptions is possible. This is Tolstoy's Corollary: there is only one correct answer to an optimization problem but there are an uncountable number of wrong answers. We end by discussing social learning and the possible role of entrepreneurs, like real estate brokers, who attempt to persuade buyers that housing prices can only go up.

Finally, in Section VI, we discuss public policy implications of real estate bubbles. Two facts seem clear: real estate fluctuations exist and they have displayed a remarkable ability to wreak havoc on financial systems. While it may be impossible or infeasible to prick bubbles while they expand, it may still be possible to undertake protective actions to ensure that the bursting of the bubble will not cause as much damage in the future. There may also be social benefits from reconsidering those policies that encourage individuals to borrow heavily to invest in real estate. Section VII concludes.

II. The Linear Asset Pricing Model and the Idiosyncrasies of Housing

In Section III, we will present the core stylized facts about the housing market that need to be addressed by models of housing bubbles. For these facts to help inform a survey of housing

bubbles, we must start with some clarifying discussion and algebra. Bubbles are typically defined as periods in which asset prices “run well above or below the intrinsic value” (Fama, 1965). In the real estate context fundamentals can either mean the value based on the flow of rents, as in the “user cost” model and its LAPM variant, or the flow of well-being associated with living in a particular spot.

Housing markets are different from other asset markets. There exist real estate linked assets, includes Real Estate Investment Trusts (REITs) or Collateralized Mortgage Securities, that trade in large markets, but more typically, housing is bought and sold in small, decentralized transactions. This fact is obviously true in the enormous market for single family housing, but it is also true in the realm of commercial real estate as well. The dollar amounts of each sale may be larger, but ultimately the purchase of Rockefeller Center is just as idiosyncratic as the purchase of that Tudor home on the corner, if not more so.

The Linear Asset Pricing Model or User Cost Model

Nonetheless, the benchmark model of housing prices, often called the “user cost” model, assumes that there is a single price of housing that is paid by all buyers, who are typically home owners.² This price follows from an inter-temporal no arbitrage condition. The value of owning a home equals the benefits today plus the asset value tomorrow, or $R_t + \frac{E(P_{t+1})}{1+r} = P_t$, where P_t reflects price, R_t represents net benefits of owning and $\frac{1}{1+r}$ represents a constant discount factor. The “fundamental” value then equals $E(\sum_{j=0}^{\infty} (1+r)^{-j} R_{t+j})$. Empirically the values of R_{t+j} are either associated with observed market rents (Himmelberg, Mayer and Sinai, 2005) or the benefits of living in a particular area including amenities and income (Glaeser, Gyourko, Morales and Nathanson, 2014, Head, Lloyd-Ellis and Sun, 2014). These raw series can provide testable implications for the observed series of prices.

One important aspect of this approach is that it avoids any consideration of risk-aversion and portfolio composition. These issues are particularly important to the financial economists and macroeconomists who study housing, and they are addressed in the chapter by Davis and van Nieuwerburgh in this volume.

Shiller (1981) provides a famous, non-parametric approach to testing for excess variance by noting that since $\sum_{j=0}^{\infty} (1+r)^{-j} R_{t+j} = E(\sum_{j=0}^{\infty} (1+r)^{-j} R_{t+j}) + Error$ and since the error should be independent of the expectation, the variance of the fundamental must be greater than the variance of the price series. Of course, this is not true in the U.S. stock market, and it is not true in housing markets either. This calculation is somewhat compromised by time varying discount factors, which we will address later.

² Haughwout, Lee, Tracy and de Klaauw (2011) remind us that during the boom many of the buyers of single family homes were actually investors.

For work on housing markets, it is somewhat more common to assume a particular stochastic process for the fundamental, R_t , and to work with the formula implied by that quantity. We briefly consider the implications of four stochastic processes: $R_t = (1 + g_R)R_{t-1} + \epsilon_t^R$ (constant growth, i.i.d. error), $R_t = R_{t-1} + \epsilon_t^D + \theta\epsilon_{t-1}^D$ (no growth, moving average error), $R_t = \delta R_{t-1} + (1 - \delta)\bar{R} + \epsilon_t^D + \theta\epsilon_{t-1}^D$ (mean reverting, moving average error, e.g. ARMA(1,1)) and $R_t = R_{t-1} + g_t + \epsilon_t^D$, where $g_t = \lambda g_{t-1} + (1 - \lambda)\bar{g} + \epsilon_t^g$ (stochastic growth rate). The moving average process can create some persistence in price changes, but much less than the persistence in rent changes. The mean reverting process can create robust amounts of price mean reversion, but very small amounts of price momentum. The stochastic growth rate process can predict both mean reversion and at least modest momentum. That process can also yield relative high levels of price variance.

The simplest, non-stochastic process is to assume a constant growth rate for R_t so that $R_t = (1 + g_R)R_{t-1} + \epsilon_t^R$, where ϵ_t^R is an independently and idiosyncratically distributed (i.i.d.) noise term. In that case, the LAPM price becomes $\frac{(1+r)R_t}{r-g_R}$. One implication of this formula is that small differences in g_R can generate extreme differences in prices, especially when interest rates are low as Himmelberg, Mayer and Sinai (2006) emphasized. Since the LAPM version of the user cost model can imply extremely high price-rent ratios with seemingly reasonable parameter estimates, it can also make bubbles seem rational. The use of the LAPM in 2006 to justify the high prices at the peak of cycle suggests just how difficult it can be to identify a bubble while it is happening.

Shiller's (1981) insight was that even if it is hard to tell with price levels are compatible with a LAPM price, the model also yields predictions about price change variances and covariances that can be rejected by the data. The constant growth rate with i.i.d. error assumption implies that the standard deviation of price changes equals $\frac{1+r}{r-g_R}$, or the price-rent ratio, times the standard deviation of ϵ_t^R , which is also the standard deviation of changes in the rent. In other words, the ratio of standard deviation of price changes to the standard deviation of rent changes equals the price-rent ratio. That fact holds true for all time intervals, because the shocks are i.i.d. Moreover, this simple random walk with drift predicts neither positive serial correlation in short term price changes (momentum) nor negative serial correlation in long term price changes (mean reversion).

For the next two illustrative processes, we assume that $g_R = 0$. Given this simplification, we next complicate the shocks with a moving average component, and assume that $R_t = R_{t-1} + \epsilon_t^D + \theta\epsilon_{t-1}^D$, where ϵ_t^D is i.i.d. and $\theta \leq 1$. The implied LAPM price is $\frac{(1+r)R_t + \theta\epsilon_t^D}{r}$. The ratio of the standard deviation of price changes to the standard deviation of rent changes is $\frac{1}{r} \sqrt{\frac{(1+r+\theta)^2 + \theta^2 r^2}{1+\theta^2}}$. The serial correlation of rent changes is $\frac{\theta}{1+\theta^2}$, and the implied serial correlation in price changes

is $\frac{(1+r+\theta)r\theta}{(1+r+\theta)^2+\theta^2r^2}$, which must be less than $\frac{r\theta}{1+\theta^2}$. This implies that the serial correlation of prices must be less the interest rate times the serial correlation in prices. If $r = .1$, then an increase in the value of θ from 0 to 1 causes the serial correlation of rents to increase from 0 to .5, but the serial correlation of housing prices will rise only from 0 to .0475. Very large amounts of serial correlation in rents are associated with quite modest amounts of serial correlation in price changes.

This moving average process does little to generate mean reversion at lower frequencies. To allow for this possibility, we assume that $R_t = \delta R_{t-1} + (1 - \delta)\bar{R} + \epsilon_t^D + \theta\epsilon_{t-1}^D = \bar{R} + \epsilon_t^D + \sum_{i=0}^{\infty} \delta^i (\theta + \delta)\epsilon_{t-1-i}^D$. The pricing formula becomes $P_t = \frac{(1+r)R_t}{1+r-\delta} + \frac{(1+R)(1-\delta)\bar{R}}{r(1+r-\delta)} + \frac{\theta\epsilon_t^D}{1+r-\delta}$. Generating mean reversion at longer frequencies is feasible with this type of auto-regressive process, but generating substantial momentum is even more difficult than in the in the simpler moving average process discussed above. A shock from last period can increase price growth today, as long as $\theta > \frac{(1+r)(1-\delta)}{r}$. This will hold if $\delta = 1$, which is the random walk case discussed above, but with higher levels of mean reversion even one period momentum becomes less and less plausible, and it is still impossible to get price change momentum that is nearly as big as rent change momentum.

Last, we consider stochastic growth rates. We assume that $R_t = R_{t-1} + g_t + \epsilon_t^D$, where $g_t = \lambda g_{t-1} + (1 - \lambda)\bar{g} + \epsilon_t^g$. The growth rate is persistent in the short term but ultimately reverts to the area level norm. These assumptions also imply that $g_t = \bar{g} + \sum_{i=0}^{\infty} \lambda^i \epsilon_{t-i}^g$, which implies a pricing formula of $P_t = \frac{(1+r)R_t}{r} + \frac{(1+r)^2(1-\lambda)\bar{g}}{r^2(1+r-\lambda)} + \frac{(1+r)\lambda g_t}{r(1+r-\lambda)}$. The ratio of the standard deviation of price changes to the standard deviation of rent changes is again roughly similar to the ratio of price-to-rent ratios. The one period autocorrelation of rental shocks is $\frac{\lambda}{\varphi(1-\lambda^2)+1}$, where $\varphi = \frac{Var(\epsilon_t^D)}{Var(\epsilon_t^g)}$. The one period auto-covariance of price changes equals $\frac{(1-\lambda^2+r)(1+r)^2\lambda}{r(1+r-\lambda)^2(1-\lambda^2)} Var(\epsilon_t^g)$ which is distinctly positive. The long-stickiness of growth rates in fundamentals provides the best chance of hitting high degrees of serial correlation in housing prices.

We have required the LAPM, so far, to only concern fundamentals, but as with most asset pricing equations, the one period indifference condition $R_t + \frac{1}{1+r}E(P_{t+1}) = P_t$ admits “rational bubbles” where $R_t + \frac{1}{1+r}E(P_{t+1} + Bubble_{t+1}) = P_t + Bubble_t$. The key requirement is that $\frac{1}{1+r}E(Bubble_{t+1}) = Bubble_t$. Such a bubble would violate the standard transversality condition requiring that discounted value of future housing prices to converge to zero as t goes to infinity. The bubble’s discounted value at all time periods will always equal its value today.

In their most plausible formulation rational bubbles are stochastic, so for example, the bubble will burst in each period with probability v . In this case, the bubble multiplies by $\frac{1+r}{1-v}$ during each period that it doesn't burst. While this formulation is mathematically conceivable, it requires buyers to expect that with some probability housing will become extraordinarily expensive within some reasonable probability. If, for example, a Las Vegas house in 2006 was valued at \$300,000 and one-half of that was a rational bubble: the market dropped by over 50 percent after the bust. Moreover, assume that buyers thought that there was a 50 percent chance that the bubble would burst in each year and that $r=.05$. If the bubble didn't burst, the home would have been worth \$465,000 in 2007 (with probably .5), \$811,500 in 2008) (with probably .25) and \$1.54 million in 2009 (with probably .125).

Is such price growth remotely plausible and is it compatible with other features of housing markets? Glaeser, Gyourko and Saiz (2008) argue that such price growth is incompatible with even moderately elastic supply. Presumably, builders in Las Vegas in 2009 would do anything to build houses that can be sold for such high prices. Moreover, this \$1.54 million dollar house would have to find buyers, at least some of which need down-payments. Would it be possible for price differences between similar regions to widen so extraordinarily and persist in expectation? As we will discuss later, we find this rational bubble formulation far more plausible if it occurs in a setting where lenders are providing borrowers with an under-priced default option.

What is Special about Housing?

While the LAPM model treats housing essentially as a standard security, this assumption is badly at odds with reality. Housing is idiosyncratic and traded individually. Search for housing can be a lengthy process. We now discuss how the salient aspects of the housing market make housing somewhat different from other securities.

This dispersed, idiosyncratic market means that there is no such thing as the current price of housing, in the same way as there is a current price of General Electric stock. Moreover, across the United States, and even across the larger metropolitan areas, the heterogeneity of markets is enormous. Between 2004 and 2006, FHFA price data show the value of homes in Phoenix increasing by over 50 percent. In nearby Albuquerque, New Mexico, prices rose only 17 percent over the same time period. In Fort Collins, Colorado, real prices actually fell during those two years.

Abel and Deitz (2010) visually split American housing markets into four groups based on their experiences from 2000 to 2008. Many had booms and busts and many avoided both booms and busts. A smaller number experienced booms without busts, like Casper, Wyoming. Even fewer areas, most notably Detroit, Michigan, experienced busts without booms. Cyclical activity also

differs substantially across countries, and ideally, housing models could also explain this heterogeneity.³

The fragmented housing market may help explain why post-boom drops are so much slower in housing markets than in other asset classes. The history of the U.S. Stock market is punctuated by particular days of infamy during which shares tumbled, such as October 24, 1929 (Black Tuesday), October 19, 1987 (Black Monday) and October 15, 2008. There is no comparable date in which housing prices plummet. During the last two general housing market slumps, it took several years for prices to hit bottom.

This slow adjustment process may also reflect transaction costs in housing, which slow sales and even price adjustments, or the markets' domination by "amateurs." Ordinary home buyers and sellers may have less up-to-date information than professional stock traders. These amateurs may also suffer more from "loss aversion" (as in Genesove and Mayer, 2001), which makes sellers unwilling to cut their asking prices even in the face of a market collapse.⁴ This loss aversion might also explain why market volumes drop dramatically during busts. Scheinkman and Xiong (2003) connect the high levels of trading during financial booms to heterogeneous beliefs, and that also seems likely to be relevant in housing markets.⁵

The market fragmentation of housing also helps explain why housing market "facts" tend to be cross-sectional as much as time series. For example, the mean reversion of housing prices is often illustrated by cross-sectional graph, such as Figures 1 and 2, showing the strong correlation between the degree of price growth during a boom period and the degree of price decline during the bust. Indeed, the tendencies of local real estate markets towards excess variance, high frequency momentum and lower frequency mean reversion, show up even controlling for national market trends.

The localization of markets also explains why housing economists rely on two distinct no arbitrage conditions to measure "appropriate" housing values. In the temporal user cost model, the flow benefit of owning a house at time t , plus the discounted value of the home at time $t+1$, must equal the cost of buying the house at time t (P_t) plus other costs such as taxes, effort involved in maintenance. The alternative, spatial no arbitrage condition is that the cost of living in Place A must equal the cost of living in Place B plus whatever extra benefits accrue to living in Place A relative to Place B, as in the Alonso-Muth-Mills model. Both equations are complicated by idiosyncrasies of mortgage borrowing, risk aversion, and transaction costs, but they provides useful starting points for thinking about asset prices and real estate bubbles.

³ Differential housing supply elasticities across countries may explain some of these differences (Caldera and Johansson, 2013).

⁴ We thank William Strange for emphasizing these points.

⁵ Hong, Scheinkman and Xiong (2006) also connect bubbles and volume, but their analysis also relies on lock-up constraints, such as those that faced internet entrepreneurs.

Implementing this simple inter-temporal user-cost formula is challenged by the difficulty of observing most of the key parameters. Prices may be seen by the econometrician, but little else can be directly observed. While the benefit of owning stocks for ordinary stockholders yields only dividend yields and price appreciation, the primary benefit of owning a home is that you get to live in the home and that may yield different benefits for different people. Moreover, ownership carries other costs. Some of these costs are directly observable, like property taxes, while others, such as the sweat of home care, are not. Limited observability of costs and benefits means that the no arbitrage condition in housing will always be far less precise than equivalent conditions in other asset markets.

The most straightforward means of quantifying the benefits of owning is to use rents. If owning and renting were otherwise identical, then the benefits of owning should be equal to the benefits of renting. Yet there are three reasons why identifying the flow value of owning housing with the prevalent rental rates is problematic: the homes aren't the same, the neighborhoods aren't the same and the unobserved costs aren't the same. Glaeser and Gyourko (2009) document that the observable differences between rental and owner-occupied structures are enormous: 64 percent of owner-occupied units are single-family detached as opposed to 18 percent of rental units. Owner-occupied units are also less likely to be located in central cities and more likely to be in neighborhoods that are rated as excellent by their residents. Finally, Goodman (2005) uses the 2003 American Time Use Survey and documents the significantly large amounts of time spent on home and yard maintenance by owners, but it is hard to quantify the costs of that effort.⁶

An alternative approach is to eschew rental data as being non-representative, and instead focus on measuring the benefits of locating in one metropolitan area rather than another following Rosen (1979) and Roback (1982). Local earnings and amenities are the typical sources of local benefits, but amenities are difficult to completely capture and the earnings of the marginal homebuyer are also not directly observed. Finally, since this approach is inherently comparative, it can only answer whether the fluctuation in price in one area seem reasonable relative to the fluctuations in price in some other place.

Housing is also different from stocks and bonds because housing is the democratic asset, owned by over 60 percent of American households. Policies and preferences come together to ensure that homeownership is dispersed among millions of Americans rather than concentrated in the hands of professional investors who rent them out. For these households, especially those with long horizons, housing looks more like a consumption good than a financial asset. Some caution therefore is needed while applying models typically used with stock market to the housing market, especially since we are all born short housing. Of course, some parts of the real estate market—like commercial properties, undeveloped land, and rental residential houses—are owned by investors calculating discounted future cash flows, and residential housing resembles a financial asset more in areas with these other types of properties (Nathanson and Zwick, 2014).

⁶Goodman (2005)

The widespread nature of housing ownership also creates policy-related issues relative to housing booms that are less present with other asset classes. Historically, housing risk was held by homeowners and by savings institutions. When a boom crashed, millions of ordinary people were worse off and the banking system was imperiled. The widespread nature of the pain and the potentially disastrous consequences of a banking system meltdown make serious policy response far more likely than when there is a bust in some smaller asset class. Few policy-makers argued that indebted investors in internet stocks had no obligation to repay their creditors in 2002, while many advocated against foreclosing on distressed home buyers in 2008.

Short-selling housing is hard and that contributes to the difficulty of arbitraging housing markets. It was hard for smart money to bet against booms, like Las Vegas in 2005. Short-sales are made particular difficult because of a lack of asset interchangeability (Nathanson and Zwick, 2014). Normally, a short is achieved by borrowing an asset from someone else, selling that asset and then promising to buy it back. Enormous variation in characteristics across houses makes such a home short sale process almost impossible. Short-selling collateralized debt obligations or Real Estate Investment Trusts is considerably easier but these assets are quite different than ordinary homes.

Glaeser and Gyourko (2009) point out that other, even simpler modes of arbitrage, such as delaying eventual purchases, are difficult to exercise because delaying a sure purchase introduces large amounts of risk in the portfolio of any average household. The limits of arbitrage in asset markets typically increase the possibility that prices will deviate from fundamentals (Shleifer and Vishny, 1997). The extreme limits of arbitrage in housing may make those deviations even larger.

A final peculiarity of housing markets is that the endogenous supply of new housing is so obvious that it cannot be ignored, while asset pricing economists routinely treat the supply of assets as being fixed. America built over nine million new housing units between 2002 and 2006. In 2005 alone, Las Vegas permitted almost 40,000 new housing units and Phoenix permitted over 60,000. Hall (2003) emphasized that there is also a supply of internet start-ups which surely should have influenced the willingness to pay for shares of existing companies in 2000, but many models of speculation treat the supply of assets as fixed.

During historic housing booms, price growth has typically been tempered in areas with long-run elastic supply. Between 1996 and 2006, nominal price growth was three times higher in areas where housing supply is inelastic than in areas where housing supply is elastic (Glaeser, Gyourko and Saiz, 2008). Yet many elastic cities experience large price increases as well during housing booms. For instance, Las Vegas and Phoenix, and cities in Florida and inland California—places with very elastic housing supply—witnessed many of the largest price increases in the nation between 2000 and 2006 (Nathanson and Zwick, 2014).

In our own research, we have taken different but complementary approaches to explaining these elastic price booms.⁷ Nathanson and Zwick (2014) argue that this phenomenon occurs in areas where housing supply is elastic today but will become inelastic soon. An example would be a growing city approaching a long-run development barrier. Investors speculate in the land markets about what the city will look in the future where new construction is difficult. This speculation leads to a boom and bust in the housing market, while the undeveloped land facilitates construction during the boom.

Glaeser (2013) takes a different approach and argues that ignoring the impact of elastic supply is a pervasive error made by real estate speculators in the U.S. throughout the century. In many of these episodes, it took time for housing supply to come on line. When speculators don't realize supply is adjusting gradually, price booms occur that are followed by busts.

These theories differ in their predictions for what precipitates the bust. According to Nathanson and Zwick (2014), the bust occurs when optimistic land speculators learn that their rosy beliefs were incorrect. In Glaeser's (2013) argument, the bust happens when supply is finally able to adjust. The recent elastic booms fit the former theory better. Construction was high throughout the boom in these cities and not just at the end. Furthermore, consumer demand started to weaken in 2006 (Mian and Sufi, 2010), suggesting that belief revisions about household demand coincided with the beginning of the bust. Glaeser's (2013) mechanism better captures some historic episodes, such as the New York skyscraper boom of the 1920s, where construction was difficult to supply quickly due to new technologies.

Our theories both depart from standard theories of rationality but in different ways. Glaeser (2013) assumes that all market participants make the same common error of under-forecasting future supply. This type of mistake has been suggested in other markets as well (Hoberg and Phillips, 2010; Greenwood and Hanson, 2013). In many U.S. cities, ignoring new local supply is largely irrelevant—the number of new homes is sufficiently small, and a general decision to ignore the supply-side is reasonable. More generally, given that economists believe that teaching economics has some value added, perhaps we shouldn't be surprised that most Americans are not innately gifted at grasping the workings of supply and demand.

In contrast, Nathanson and Zwick (2014) assume only that a few well-capitalized investors are very optimistic. This aspect is a feature because it involves a smaller aggregate deviation from rationality. But it also poses problems, because homeowners must disagree with the optimistic valuations of houses and buy them anyway. It is certainly possible that homebuyers desperately wanted to move to Las Vegas in the 2000s at any price and bought housing expecting a capital loss. Nathanson and Zwick (2014) show that short-selling of homebuilders that held large land portfolios increased during the boom, consistent with the existence of pessimists. But pessimistic homebuyers don't comprise the common way of looking at the housing market.

⁷ Gao (2014) and Sockin and Xiong (2014) also study this phenomenon.

III. Empirical Regularities of Housing Dynamics

At this point we turn to the empirical regularities of real estate dynamics. In some cases, these figures are intrinsically interesting, but in many cases, we are interested primarily in whether these facts are compatible with the simple LAPM or User Cost Model. We are interested primarily in facts that seem somewhat anomalous, and hence particularly worthy of future research. We chose to present facts after first discussing the benchmark LAPM or User Cost model precisely because facts can only be anomalous unless they conflict with the predictions of a basic model.

We divide this discussion into four sub-categories. First, we discuss excess variance in price movements relative to fundamentals. Since Shiller (1981) excess variance has been the biggest puzzle in asset markets more generally and it is also a significant puzzle in housing. We then discuss short-term momentum and longer term mean reversion of housing. We then turn to facts about quantities, rather than prices, by which we mean sales, vacancies and the amount of new construction. Finally, we end with a brief review of the longer history of real estate movements. This last discussion draws heavily on Glaeser (2013).

Excess Variance

Real estate is subject to fluctuations that are larger than seem to be justified by fundamentals—just like other asset markets (e.g. Shiller, 1981). If these fluctuations are not caused by underlying fundamentals, then they fit the popular notion of bubbles—price movements not caused by fundamentals. But this excess volatility is not uniform across time periods. Housing can be quite steady for many years, but there are periods when housing prices move far more dramatically in ways that are quite hard to square with fundamentals.

How big is the standard deviation of price changes for metropolitan area housing markets? Glaeser, Gyourko, Morales and Nathanson (2014) report that the standard deviation of one-year price changes in the U.S. ranges from \$2,000 in the Sunbelt to \$13,300 in coastal cities over the 1990-2004 period. Five year price volatility ranges from \$5,400 in the Sunbelt to \$48,000 in coastal cities. Using the entire sample of cities for which FHFA data is available, we estimate a standard deviation of price changes over the 1980-2004 period of slightly under \$10,000.

Are these numbers large or small? If they are benchmarked against changing rent values, they seem slightly large during the early time period. The standard deviation of rent changes using the REIS data suggests a standard deviation of about \$623 of annual rent changes. Thus over the 1980-2004, the standard deviation of price changes is about 16 times higher than the standard deviation of rent changes. But this difference is not wildly out of line with the price-rent ratio over the same period so the price variance doesn't seem all that excessive.

The same picture emerges when we compare price changes with the changes predicted by changes in income. Glaeser et al. (2014) compare price changes with those predicted by volatility in income, at least as measure by the average income of buyers found using the HMDA data. The volatility of prices over the 1990-2004 is roughly similar to that predicted by income volatility. If BEA data on personal income across the entire metropolitan area is used instead of the income of new buyers alone, then the price volatility does appear to be significantly too high in coastal metropolitan areas. Head, Lloyd-Ellis and Sun (2014) similarly find variances that are in line with those predicted by a simple housing model.⁸

The real excess variance appears during periods, like that between 2001 and 2010 when prices temporarily explode (Wheaton and Nechayev, 2008). During this period rents were relatively constant, and incomes didn't move much. Yet the standard deviation of price changes is over \$20,000. This is an extraordinary amount of variation across metropolitan areas that doesn't appear to be related to any obvious changes in fundamentals. Figure 3 shows the path of rents and prices in New York and San Francisco, where it is obvious the rents had peaked and were falling before the housing price boom crested.

As such, the data does not suggest that housing prices display the same ubiquitous excess variance found in other asset classes. Instead, housing prices experience brief moments of extreme variance that punctuate longer periods of general stability. For example, the 1991-1996 period was an era of extraordinary price stability across America's metropolitan areas. Therefore, the puzzle is not to explain constant price variation, but rather periods when prices briefly explode and then tumble.

The Shape of a Bubble: Short Run Momentum and Long Run Mean Reversion

For most observers, bubbles mean more than just excess asset price variance. Few people would describe as a bubble the movements of a price series: $P_t = \hat{P}_t + \mu_t$, where P_t is the realized price, \hat{P}_t represents the price based on fundamentals and μ_t reflects idiosyncratic white noise, independently drawn each day or every week. Such a price series would be manic indeed, but not sustained, and manic high frequency movements would have little impact on investment and probably not much on financial systems either.

In the popular influenced by classic descriptions such as Kindleberger (1978), bubbles have a defined shape. They begin with an early uptick, perhaps representing real good news or a little bit of early froth. That surge escalates, and during this growth period of the bubble, price growth escalates and the path of prices is convex. Ultimately, the bubble ends either in a violent crash or in a slow deflation.

⁸ Other approaches find somewhat more excess volatility. Gelain and Lansing (2013) find excess volatility in price-rent ratios relative to "a simple Lucas-type asset pricing model." Ambrose, Eichholtz and Lindenthal (2013) find excess price volatility over a 355 period in the Netherlands relative to fundamentals.

Just like other markets, housing price changes display positive serial correlation at higher one-year frequencies and mean reversion at lower frequencies like five year periods (Cutler, Poterba and Summers, 1991, Glaeser, Gyourko, Morales and Nathanson, 2014). In normal periods, this momentum and mean reversion just seem like the normal course of affairs. During a great housing price event, such as the period between 2000 and 2012 for the U.S., or the 1980s in Japan, the momentum and mean reversion define the shape of a bubble.

Over the 1980-2004 period, the one period serial correlation of prices ranges from .75 in coastal metropolises to .6 in the Sunbelt, when we allow city-specific trends. The raw coefficient when price prices are regressed on lagged price changes across the entire sample from 1980 to 2012 is about .63 with or without city-specific trends. Head, Lloyd-Ellis and Sun (2014) report an even larger coefficient of .75.

These figures are remarkably high relative to the serial correlation of either rent or income changes. Both of these numbers are approximately .25. In the benchmark dynamic urban model of Glaeser et al. (2014), that serial correlation in fundamentals implies a price correlation that is essentially zero. The search model of Head, Lloyd-Ellis and Sun (2014) generates significant positive serial correlation in price but still far below the serial correlation seen in the data.

The positive serial correlation in one year price changes is particularly high during booms. Table 1 shows the price correlation when price growth is regressed on lagged price growth year by year. As Figure 4 also shows, the coefficient is over one at the height of the boom. This tendency of price growth to spiral is one of the most salient aspects of booms and one of the most difficult facts to reconcile with simple models of housing price formation.

While housing prices show momentum at high frequencies they mean revert at lower frequencies. Over five year periods, the correlation of price changes on lagged price changes ranges from -.24 in the Sunbelt to -.57 in Coastal metropolises. Figures 1 and 2 show the extremely strong five year mean reversion over the last decade.

This mean reversion is reasonably compatible with rational models, even if the magnitude of changes during this particular period is not. The dynamic urban model of Glaeser et al. (2014) essentially predicts mean reverting prices similar to those seen in the data. This price mean reversion is predicted both by mean reverting income processes and by new construction.

Quantities vs. Prices

There are also significant facts about quantities of housing that dynamic models need to explain. Quantities both have a purely physical component—the number of houses being produced—and a market related component – the number of housing on the market at a given point in time.

Housing supply related experts tend to focus on the former numbers. Experts on search and market dynamics focus on the latter number.

The volatility of construction is significant, especially in the Sunbelt. The standard deviation of annual permits in Sunbelt metropolitan areas is over 5000 units. In coastal metropolitan areas, the standard deviation falls to under 2000 units. While these numbers are significant, they do not appear to be particularly high relative to the number predicted by reasonable estimates of housing supply functions and the volatility of local income changes.

Permitting behavior shows remarkable persistence at one year periods as well. The serial correlation of permits over one year periods is significant over .5. Again, this is compatible with the predictions of a simple rational model. If the costs of building increase with the amount of building, then it is sensible for booms to persist over multiple years.

For five year permitting periods there is substantial mean reversion, which appears less compatible with a rational model. In a sense, this seems to reflect a pattern where periods of overbuilding are followed by periods of under building. Perhaps this represents an example of excessive exuberance in construction.

Head et al. (2014) also document that housing sales data shows significant persistence in the data. This is compatible with their model at one year frequencies, but there is too much sales persistence in the data, relative to their model, at longer frequencies.

Another particularly important stylized fact is the well-known relationship between sales volatility and price over the cycle. Markets are extremely active during booms and then dry up during busts. Some authors have interpreted this as evidence for nominal loss aversion on the part of sellers (Genesove and Mayer, 2001).

Bubbles in History

Given the rich history of real estate bubbles, it is useful to distinguish between two different classes of events: real estate fluctuations that are driven partially, at least initially, by new information coming from outside the real estate market itself and real estate fluctuations that appear to be driven primarily, sometimes almost exclusively, by events without the local housing market. Before 1980, real estate movements seem to have been typically associated with major uncertainty about external events.

The Chicago land boom of the 1830s, used by Shiller (2005) and others as an example of speculative mania, had a clear origin: the announcement that the state would fund a canal that would link the Great Lakes system with the Mississippi River system via the Chicago river. High cotton prices drove the Alabama boom of 1819 and high wheat prices helped justify Iowa land prices in 1910. In both cases, land buyers would eventually be burned, but price

movements have justifications beyond merely the extrapolation of price movements within the housing market itself. We aren't suggesting that these buyers were rational or that prices were themselves justified by fundamentals, but simply that these movements reflected more than buying based on past price movements.

By contrast, it is harder to see what external event could have motivated many of the price booms during the 2002-2006 period. The leading candidate is the proliferation of subprime technologies that expanded credit to low income borrowers. This demand shock is not as clear as historic ones that involved the founding of cities. But Mian and Sufi (2009) present evidence that less credit-worthy neighborhoods saw greater price increases during the boom. Investors may have had uncertainty about the long-run effects on housing demand of this credit expansion (Nathanson and Zwick, 2014).

Bubbles driven by exuberance about some external event can presumably take on any shape whatsoever, so long as prices eventually fall. A new announcement may spur an immediately price jump which persists temporarily and then collapses, or the initial announcement may lead to ongoing price increases. An internally-driven bubble must, however, display the positive serial correlation in price growth-- the momentum that has come to almost define housing bubbles. The price growth itself is the news and the event that generates even more price growth. At the extreme, this creates the Alpine convex price pattern seen in places like Phoenix during the boom.

In this view, then all bubbles are defined by large variance of price changes, relative to fundamentals and eventual mean reversion. Internally-driven bubbles must also display positive serial correlation of price changes at higher frequencies. High levels of variance, positive serial correlation of price changes at high frequencies and mean reversion at low frequencies are all well-known features of housing markets (Cutler, Poterba and Summers, 1991, Glaeser et al, 2014). It is more debatable whether these features reflect the workings of bubbles or changes in fundamentals such as interest rates.

IV. Rationalizing the Seemingly Irrational: Search, Heterogeneity and Agency Problems in Credit Markets

We now turn to the economic approaches that have been used to help understand housing price movements that do not seem to be in line with the simple version of the LAPM discussed above. In this section, we discuss explanations that assume rational buyers. In the next section, we focus on less rational theories. We split these rational theories into three groups: “search, learning and momentum”, “changing credit conditions” and “rational bubbles and agency problems.”

Search, Learning and Momentum

We have already emphasized that housing markets were, in reality, highly decentralized markets with a great deal of heterogeneity. Search is a major feature of this market and there is no way that buyers or sellers can simply observe the current price of housing. Decentralization therefore is related to the level of information in the housing market, and those authors who suggest that features like momentum can represent learning are either implicitly or explicitly relying on the decentralization of the market. Several authors such as Wheaton (1990) and Krainer (2001) have shown that search and learning can help explain key features of housing price dynamics. Han and Strange (this volume) survey the literature on search models in housing.

We will turn to limited information later, but even with perfect information decentralized markets, especially when combined with some price stickiness, can lead to staggered price responses to shocks which can create momentum in realized average prices. In Head, Lloyd-Ellis and Sun (2013), individuals enter into the housing market and choose whether to search for a home or just to rent. Some homeowners decide whether to sell or rent their houses. An increase in local area income causes an influx into the city. This influx causes a conversion of vacant homes to rental units, because matching renters is far easier than matching owners, and it also cause a gradual build-up in the number of would-be buyers, not all of whom are immediately matched with houses to buy.

This build-up of buyers causes market tightness to increase over time. The rising number of buyers to sellers causes prices to increase even further. Eventually, new construction brings prices back down. This paper does an admirable job of fitting a number of features of the housing market, including patterns of sales and vacancies. But most notably it manages to predict price momentum due to increasingly tight markets because of unmatched buyers.

Yet this model does not really predict bubbles. It predicts that a positive shock might take several periods to work its way through the system, but not that the price movement might be many times greater than the price movement implied by fundamentals. As such, this type of search model seems like can clearly be part of the explanation for the structure of housing bubbles, especially their price momentum, but not for the bubbles themselves.

Guren (2014) provides an alternative search model that can also generate sticky adjustments to shocks. Guren (2014) assumes that sellers change their prices only every other period—there is an ad hoc stickiness in the model. As a result, only one-half of sellers change their prices during each period and the other half keeps their prices fixed. Sellers who price high, relative to the market, don't attract many searchers to their homes. This means that sellers are slow to react to upward demand shocks, because quick leaps to the equilibrium prices will make it hard to sell

the property. The slow equilibration process can lead to momentum, even if there is perfect information about the state of demand.

There are limitations to the power of this type of argument. First, it is a better argument for upside momentum than downside momentum. Pricing high leads to slow foot traffic of buyers, but pricing low does not, which means that there is no real force stopping sellers from adjusting prices downward quickly.⁹ Second, there is nothing in this argument that can lead to excess volatility, without some outside force such as exogenous beliefs. However, once there is an external forcing process creating excess volatility, as in Piazzesi and Schneider (2011), then a decentralized market can exacerbate the impact of that outside force.

In these models, search primarily refers to matching the idiosyncratic features of the house with the tastes of idiosyncratic buyers, not learning about market fundamentals. Yet it is surely true that buyers and sellers also gradually learn about market fundamental through the search process. Even if they observe listed prices before the search process begins, search enables them to assess unit quality more thoroughly. Time spent on the market also acquaints buyers with actual sales prices for units that they have observed. This represents a form of learning about the state of the market.

There is ample evidence of ignorance and learning within housing markets. Clapp, Dolde and Titiroglu (1995) provide evidence on the existence of various forms of rational learning. Levitt and Syverson (2008) illustrate that home sellers appear to be somewhat uninformed about the state of the market. Yet while incorrect beliefs certainly have the power to move markets in many ways, it is unclear if rational learning can really generate particularly large movements in housing prices.

Rational learning suggests that buyers have formed some Bayesian estimate of the state of fundamentals and that estimate changes over time as new evidence trickles into the market. Generally, rational ignorance leads to less variance, not more, because individuals recognize how little they know. Shiller's (1981) variance bounds test essentially lives off this point. Moreover, standard learning models still won't have predictable errors, so regular momentum or mean reversion in beliefs is incompatible with standard Bayesian learning.

To make this point precise, return to the standard user cost argument in which $R_t + \frac{E(P_{t+1})}{1+r} = P_t$, and to focus on learning assume that $r=0$ and $R_t = 0$, so in this case, $E_t(P_{t+1}) = P_t$. It is impossible for anything known at time t to regularly predict the updating between t and $t+1$, so $Cov(P_{t+1} - E_t(P_{t+1}), P_t - P_{t-1})$ must equal zero. This fact implies that highly rational learning on its own will not help us to understand momentum or mean reversion. Learning by individuals

⁹ Novy-Marx (2009) provides a more symmetric amplification mechanism that operates through bargaining and the flow of entrants. This stimulating paper treats the flow of buyers as the primitive, rather than rents or the value of living in the locale. As such it is hard to determine how these results relate to the excess variance that we are discussing here.

who are rational but ignorant seems unlikely to generate – on its own – any of the three salient features of price dynamics that we have discussed above.

This claim does not mean to suggest that semi-rational learning, employing rules of thumb (as in Shiller, 1999) or extrapolating, will not help explain housing price patterns. This seems quite likely, but we will address these issues later as we turn to less rational models.

Changes in Credit Conditions

Perhaps the most popular “rational” model of housing price changes is that they reflect changing credit market conditions. Yet the common view that housing crisis was caused by subprime mortgages and a global lending glut has difficulty making sense of the heterogeneity across the U.S. Credit markets are national or global, so if easy credit was the cause, then why did Houston experience almost no boom and bust while the cycle in Las Vegas was particularly dramatic? These differences are also incompatible with a common, credit-caused demand shock interacting with heterogeneous supply (Davidoff, 2013). The heterogeneity across countries is also heard to explain if the boom is solely the result of a massive flood of global lending.

Certainly, there is considerable evidence that easier credit did induce buying among subprime households in the years before 2007 (e.g. Mian and Sufi, 2009) and lower interest rates are generally associated with higher housing prices (e.g. Poterba, 1984). The rise of subprime lending certainly the boom establishes little about causality because the lending itself may be a reflection of overoptimistic beliefs which are causing both phenomena.¹⁰ Mian and Sufi’s (2009) contribution is a tight focus on causal inference which has considerably increased our confidence that subprime lending boosted prices, yet even in their work, subprime lending seems to only explain a modest fraction of the rise of housing prices.

Moreover, it is far from clear whether volatile interest rates can create massive housing price fluctuations in a purely rational model, or at least a model without bubbles. We explore rational bubbles with overly cheap credit in the next subsection. Here we briefly discuss the impact of credit market changes in the standard LAPM.

One standard version of the LAPM implies that $P_t = \frac{(1+r)R_t}{r-g_R}$, or price equals the $1+r$ times the flow value of housing divided by the difference between the interest rate and the growth rate of fundamentals. This formula would seem to imply an extremely tight relationship between prices and interest rates, especially in a high growth environment. This formula was used during the boom to justify extremely high prices.

¹⁰ A similar argument can be made about the correlation between investors buying homes and the boom (e.g. Haughwout et al., 2011). The investors seem more likely to be a reflection of market enthusiasm than to be an independent cause of rising prices.

But while this formula is correct in a static interest rate environment, it is not correct in a world in which interest rates are dynamic. For if interest rates mean revert, then buyers during periods when interest rates are low should expect to sell when interest rates are higher are vice versa. Rational expectations about the changing value of interest rates should cause buyers to be less responsive to changes in interest rates than a naïve application of this formula would suggest.

Unfortunately, dynamic interest rate models do not yield easy closed form solutions for housing prices, but Glaeser, Gottlieb and Gyourko (2013) simulate rational prices in a world in which interest rates followed a mean-reverting Cox-Ingersoll-Ross diffusion process. They find that the implied semi-elasticity of prices with respect to interest rates (the derivative of log prices with respect to a change in the interest rate) can drop by as much as two-thirds when the mean reversion of interest rates is taken into account. So while the naïve model predicts a relationship between interest rates and prices that is large enough to explain much of the price increase between 2001 and 2006, a forward-looking model cannot. Moreover, the relationship between interest rates and prices implied by the forward looking model does a better job of fitting the historical relationship between prices and rates over the long run.

There are at least three other theoretical forces that tend to reduce the connection between interest rates and housing prices. Elastic supply will tend to reduce any connection between demand side forces, like credit conditions, and prices. The ability to refinance in the future will similarly make current conditions less important. Finally, if buyers discount the future using their own internal discount factor, rather than the market rate of interest, then that market rate of interest is predicted to have a smaller impact on price.

A final issue is the exactly timing of interest rate changes over the period from 2003 to 2010. Prices continued to rise despite the slight rise in interest rates after 2004. Prices fell dramatically despite declining interest rates after 2007. The observed price changes can still be explained as reflecting changing credit market conditions, since interest rates do not reflect the probability of actually getting a loan.

We do not mean to suggest that credit conditions are irrelevant in housing markets or in explaining bubbles, but simply that the relationship is not the simple one suggested by the LAPM. The LAPM is based on assumptions of rationality yet applying such a static model to a dynamic interest rate process assumes buyers are myopic, not rational. To provide an intellectually coherent framework, we must more fully embrace bounded rationality, and we will turn to that shortly.

Interest rates are only one aspect of credit markets. Mortgage approvals and down payment requirements may also shape housing price increases, and foreclosures may exacerbate housing price decreases. The simplest model for understanding why such credit conditions matter is to assume a variant of the LAPM with individual heterogeneity to allow for a downward sloping demand curve for housing. In such a model, the value of R_t differs by consumer and is denoted

$R_t(i)$, and consumers continue are willing to spend as much as $\frac{(1+r)R_t(i)}{r-g_R}$. The consumers with the highest valuations will be inframarginal consumers and we assume that there is a distribution $G(R_t)$ of these valuations across the set of feasible buyers. If N_S denotes the number of homes being sold, and N_D denotes the number of potential buyers of whom only a fraction θ can manage financing, then $(1 - G(R_t^*))\theta N_D = N_S$, where R_t^* reflects the valuation of the marginal buyer.

In this model, an increase in the availability of credit, captured by the parameter θ , will act to increase aggregate demand. The derivative of price with respect to θ is $\frac{(1-r)(1-G(R_t^*))}{(r-g_R)\theta g(R_t^*)}$, and the elasticity of price with respect to θ equals $\frac{1-G(R_t^*)}{R_t^*g(R_t^*)}$, which is exactly the same as the elasticity of price with respect to the number of potential buyers. In principle, this type of calculation can justify a robust relationship between approval rates and prices, just as the LAPM seems to justify a robust relationship between interest rates and prices, but some of the same issues arise. We are assuming a permanent change in approval rates, but periods of easy credit tend to be followed by periods of tight credit.

If approval rates rise temporarily, then buyers should expect future approval rates to fall. Buyers should anticipate this future drop, and this should cause buyers who expect to resell to become less sensitive to current credit availability. Mean reversion should likewise occur for down payment requirements and this will also dampen the connection between prices and credit market conditions. A fully specified dynamic model linking time-varying approval rates to housing prices has not yet been written but it would be a worthy addition to the literature.

We have implicitly assumed mortgage approval is unrelated to the individual's valuation of the house, and that those who are denied credit are a random subsample of the buying population. That need not be the case. Individuals with financing may be richer and willing to pay more, or conversely, individuals who were initially denied financing might be particularly eager to buy housing, perhaps because they are more risk-taking. One way to understand the striking findings of Mian and Sufi (2009) on the connection between subprime mortgage affordability increased prices is that more lenient lending made it possible for high risk, but highly optimistic, buyers to enter the market.

Stein (1995) provides an alternative mechanism through which credit markets influence price fluctuations. If individuals are largely credit constrained, then a price movement upwards creates significant capital gains for existing owners which then enables them to purchase even larger houses. By contrast, a price drop will mean that these buyers are essentially locked into their existing homes and cannot buy elsewhere (Ferreira, Gyourko and Tracy, 2010). There is a housing price multiplier because past housing price appreciation is providing the cash to fuel future housing price purchases.

While this subsection has focused primarily on the credit market causes of the price boom, there is also a significant literature connecting credit markets with the price bust and the adverse consequences of that bust. Perhaps the most common idea is that housing busts generate defaults and defaults then have adverse consequences of the health of the housing market. Palmer (2013) documents compellingly that the wave of defaults that followed the 2007 bust were the result of falling prices, not the composition of buyers who received credit immediately before the bust.

Campbell, Giglio and Pathak (2011) document both that forced sales, such as default, receive lower prices but that they also seem to lower the prices of nearby homes. Fisher, Lambie-Hanson and Willen (2013) find that the negative effect of condominium foreclosures on their neighbors seems localized to the particular address. Mian, Sufi and Trebbi (forthcoming) found that housing prices dropped more after 2007 in states that made it easier for lenders to foreclose on housing.

Why would defaults cause housing prices to drop? Guren and McQuade (2013) highlight three effects: distressed sellers tend to be more impatient and sell for less, buyers will become more choosy because they have more of a chance of interacting with a distressed seller and homeowners who default are themselves priced out of the market. Taken altogether, they estimate that foreclosures may have exacerbated the price decline by as much as fifty percent.

Credit institutions may also impact the consequences of housing market downturns. Somewhat obviously, the impact that housing busts have on financial institutions is due primarily to the fact that these institutions are providing credit for real estate investors, sometimes directly and sometimes by holding real estate related securities, such as collateralized mortgage obligations. More subtly, housing prices appear to have a substantial wealth effect and falling housing prices have led to substantial reductions in consumer spending and associated economic activity (Mian, Rao and Sufi, 2013).

The compelling work of Mian and Sufi (2014) documents a wealth effect of housing that seems far stronger than the wealth effect of stock prices. Case, Quigley and Shiller (2005) found a similar result. One explanation for this phenomenon is that stocks are owned by wealthier people who are not credit constrained, while homes are owned by people who often are credit constrained. Relaxing a credit constraint can easily have a far more powerful effect on spending than making an unconstrained individual wealthier, which may in turn explain why housing booms and busts appear to exert an outsized influence on the larger economy.

We now turn to rational bubble models in which credit market conditions can engender the possibility of dramatic price swings.

Agency, Underpriced Default Options and Rational Bubbles

We have already discussed the two difficulties facing models of rational bubbles in real estate: the standard violation of the transversality condition and the less standard problem of predicting an essentially unbounded supply of new housing. These difficulties become far less severe if home buyers are charged too little for the possibility of defaulting on their mortgage.

We know more formally model the mortgage process so that buyers initially pay only a fraction “ d ” of the purchase price of the house. At the end of the period, they either sell the house and repay the mortgage or default, and we assume that default carries a cost of “ z ”, to capture the fact that many individuals fail to default even when that default would seem to be in their own interest.

$$(1) R_t = dP_t - \beta E \text{Max}(P_{t+1} - (1+r)(1-d)P_t, -z),$$

where r is the market discount rate, possible adjusted to address default risk. It is natural to assume that $\beta \leq \frac{1}{1+r}$, since home-buyers presumably always have the ability to earn the market rate by savings (or by just not borrowing money) but they can’t always borrow freely, and hence they may value future dollars at a rate above the market rate. To clarify issues, we assume that there is no uncertainty in R_t , so in the absence of bubbles, prices will remain fixed so $P = \frac{R}{d(1-\beta)+\beta(1-d)r}$, which is the flow value divided by a weighted average of effective discount rates. The weights depend on the extent to which the loans are self financed.

In this case, a deterministic bubble would satisfy: $B_{t+1} = \left(\frac{d}{\beta} + (1+r)(1-d)\right)B_t$, which creates the same challenges involving the transversality condition and infinite housing supply. While deterministic bubbles don’t seem to be feasible, stochastic bubbles can exist if they lead to default in negative states of the world. We consider a bubble with a value of B_t that takes on a value at $t+1$ of B_{t+1} with probability $1 - v$ and 0 otherwise. We simplify by assuming that $P_F = \frac{R}{d(1-\beta)+\beta(1-d)r}$ is the fundamental value in all cases so that the price with the bubble equals $P_F + B_t$. We assume further that if the bubble bursts, the homebuyer defaults. The technical condition for this to be optimal is that $P_F(d(1+r) - r) + z < B_t$. The equilibrium condition for a stochastic bubble is that

$$(2) \frac{(d+(1-v)\beta(r-d(1+r)))P_F - R + v\beta z + (d+(1-v)\beta(1+r)(1-d))B_t}{(1-v)\beta} = B_{t+1}$$

In the extreme case where $P_F = R = z = 0$, so the bubble alone remains, this converts to $B_t \frac{d+(1-v)(1-d)(1+r)\beta}{(1-v)\beta} = B_{t+1}$. The bubble’s value increases but only if it fails to burst, i.e. with probability $1 - v$, hence the discounted value at time $t+j$ equals $B_t(d + (1-d)(1-v)(1 +$

$r)\beta)^{t+j}$. If $(1 - v)(1 + r)\beta = 1$, so that the interest rates are set so that the discounted expected value of a loan of one dollar is equal to one, then $\frac{B_t}{(1-v)\beta} = B_{t+1}$ or so $B_t = \beta^j E(B_{t+j})$ bubble maintains its expected value.

The standard transversality condition is that $\lim_{j \rightarrow \infty} \beta^j E(B_{t+j}) = 0$, and so this structure violates this condition. As the transversality condition holds for the fundamental part of the housing value, violating the transversality condition implies that people expect that in the long run, the bubble component alone will determine the home's value. Diba and Grossman (1988) argue that such explosive behavior implies that rational bubbles are impossible, especially when assets can be supplied into the market. Santos and Woodford (1997) similarly suggest that the conditions that admit bubbles are "fragile."¹¹ Influenced by these papers, we also believe that rational bubbles seem implausible when they imply extraordinarily future high housing values.¹²

Bubbles become far more plausible if lender under-price default risk. If interest rates are set too low, so that $1 > d + (1 - d)(1 - v)(1 + r)\beta$, then lenders aren't fully compensated for the threat of default. In this case, the expected value of the bubble decreases over time and the transversality condition is not violated. Housing prices will rise with the bubble, but the rises may be less extreme. Still, there is a non-zero probability that housing prices will become extremely high, and this should predict an enormous supply response.

There are conceivably ways of salvaging the model with endogenous supply. Perhaps, builders are sufficiently risk averse and it takes enough to build so that anticipating the possibility of a burst necessarily leads to limited production. This would be most plausible if v is high so that the probability of default is quite high. Still, the fact remains that construction was extremely high in Phoenix, Las Vegas and Miami during the recent boom, which makes the case for this type of rational bubble model more difficult to make.

Moreover, since fully priced risk would require the bubble to rise quickly enough to violate the transversality condition, this finite price bubble requires the underpricing of risk. This underpricing does seem to be a regular feature of booms, but why does it occur? One explanation is that lenders are irrational, for some reason, but that violates the spirit of this section which is to explain real estate bubbles with rational models.

The alternative explanation, which has been offered by many observers, is that there is an agency problem within the lending sector (Diamond and Rajan, 2009, Green, 2008), perhaps because of Federal deposit insurance (Demsetz, Saldenberg and Strahan, 1997). In principle, this could

¹¹ These arguments are different than the alternative view that bubbles cannot exist because they will be arbitrated away. Abreu and Brunnermeier (2003) make a compelling case that this is unlikely in financial markets and the power of arbitrage is even weaker in housing.

¹² Kivedal (2013) finds evidence for the existence of a bubble in the housing market between 2000 and 2013, but concludes that it is more likely to be irrational than rational. Giglio, Maggiori, and Stroebel (2014) reject infinitely-lived bubbles in the UK and Singapore by comparing very long-run housing rental contracts to infinite ownership rights..

occur within banks themselves even if those banks have no deposit insurance and hold mortgages on their own balance sheets, The CEO hires agents to make loans at an appropriate interest rates. Their compensation is increasing with the number of loans or the average interest rate paid, but limited liability precludes severe punishment in the state of the world when the bubble bursts. The result is that agents compete and the market rate of interest charges too little for default risk. Pavlov and Wachter (2006) argue that if some bankers are under-pricing default risk, competition may push all bankers to under-price default risk.

The larger debate over agency risk in lending concerns the creation of mortgage-backed securities. In this version of the hypothesis, mortgage originators have little incentive to screen for risk because they pass those risks downstream to the eventual security holder who has little ability to appropriately learn the truth. The presence of mortgage insurers, such as Fannie Mae and Freddie Mac, further decreases the incentive to price appropriately for risk. Puranandam (2011), for example, finds that banks that originated loans primarily to distribute them to downstream investors generated “excessively poor quality mortgages.” Piskorski, Seru and Vig (2010) find a link between securitization and default, which Adelino, Gerardi and Willen (2010) hotly dispute.

Of course, this type of model still raises questions. If the risk comes from a systemic bubble, rather than idiosyncratic risk, then investors should be able to understand that they are subsidizing the home buyers. The nature of the rational bubble is that its features are widely known and homebuyers supposedly understand the risks perfectly. If they understand the risks, then so should the ultimate investors. Agency problems typically occur when there is local information that can't be observed by the principal, but there is nothing local about a system-wide bubble.

Perhaps the best explanation for why systemic risk might be subsidized is that the government is bearing the tail risk. If the public sector is bearing the tail risk for political reasons, then this still could lead to underpriced default risk which encourages the emergence of rational bubbles. Nonetheless, this theory would still have to explain why private mortgage insurers led the way into the subprime lending that would be at most risk from a bubble bursting.

A slightly different alternative to this purely qualitative rational bubble model is to use the options pricing model of Krainer, LeRoy and O (2009) and ask, as in Glaeser (2013), how much housing prices would increase if borrowers were given a non-priced default option. The model requires a switch to continuous time, so we must assume that the flow value of the house equals $r(t)$, where r follows a geometric Brownian motion. The drift is g_R ; the variance is σ^2 . Individuals discount at a rate, but pay in interest on their mortgage each period or r times the outstanding debt or $r(1 - d)Price$, where $Price$ refers to the initial purchase price. The borrowers is only paying the interest on the mortgage. We assume costless default and the purchase price of the house will then satisfy

$$(3) P_t = \frac{\rho}{\rho d + r(1-d)} \left(\frac{z^z (\rho - g_R)^z (r(1-d)P_t)^{1+z}}{\rho^{1+z}} R_t^{-z} + \frac{R_t}{\rho - g_R} \right)$$

where $z = \frac{g_R - .5\sigma^2 + \sqrt{(g_R - .5\sigma^2)^2 + 2\sigma^2\rho}}{\sigma^2}$. The first term in brackets represents the value of the default option; the second term reflects the value of the house without any possibility of defaulting. By calibrating the model, Glaeser (2013) estimates of just how much an unpriced default option could contribute to higher housing prices during historic booms. This approach assumes that the market rate and the private discount rate are the same and then calculates the value of the first term in the expression. Typically, this represents less than 17 percent of the price for more recent price swings, which is surely an overestimate since it assumes that interest rates incorporated none of the cost of potential default.

This calculation again illustrates that if credit markets are responsible for the extreme volatility of housing bubbles, then it seems more likely they do so by making conditions ripe for bubbles. This view suggests that there is not an automatic link between housing prices and easy credit, but rather that easy credit is a necessary – but not sufficient—cause of extreme price volatility.

V. A Menagerie of Modest Madness: Bounded Rationality and Housing Markets

We now turn to less than rational models that have also been used to investigate real estate fluctuation and typically those models involve buyers who hold excessively optimistic beliefs about future housing price growth. The Case and Shiller surveys of recent buyers suggest that such beliefs certainly exist. For example, Case and Shiller (2003) reports that buyers in Orange County, California, in 1988 expected prices to rise by 14.3 percent per year over the next ten years and in 2003, they expected prices to rise by 13.1 percent annually over the next ten years. Case, Shiller and Thompson (2012) report that expected price growth over the next ten years from buyers in Middlesex County, Massachusetts, fell from 10.6 percent in 2004 to 3.1 percent in 2012.

These striking survey results need a grain of salt, for they are surely muddled by innumeracy and wishful thinking. Yet, even if the numbers appear excessive, they surely capture an important reality. Many buyers during booms seem to have expectations that are wildly optimistic and often at odds with the views of economists and the experience of longer-term price trends.

We begin this section with exogenous belief models, in which individuals for some reason have beliefs that are unduly optimistic. As models in which beliefs are entirely flexible and determined outside of the model have the potential to “explain” any housing event, they are not particularly compelling as theories without some added ingredient. Exogenous belief models are typically used to illustrate some other point about housing markets, such as the role of search or

endogenous housing supply. The second class of models that we consider are extrapolative beliefs, and we consider both a naïve version where extrapolation is merely assumed and a more sophisticated version in which extrapolation emerges out of cognitive limitations. We then turn to the broad class of models with cognitive limitations that involve shorter time horizons and simple models of housing price formation. We end with a discussion of social learning.

Exogenous and Heterogeneous Beliefs: Search, Endogenous Housing Supply and Land Acquisition

The simplest way to get a bubble is just to assume that individuals are unduly optimistic. Since $P_t = R_t + \beta E(P_{t+1})$, we can justify almost any price process imaginable by assuming differential values for $E(P_{t+1})$. Similarly, if pricing values a growth formula like $P_t = \frac{R_t}{1-(1+g_R)\beta}$, then exogenous changes in the belief about future rent growth will naturally cause fluctuation in the price and anything is possible. Since anything is possible, the exogenous optimism model on its essentially fails as social science, for it cannot be rejected by the data, and a model that cannot be rejected cannot be tested. Essentially, in the move from perfect rationality to exogenous beliefs we have moved from a theory with predictions that are too narrow to a theory that has predictions that are too broad. If we believe that beliefs are not perfectly rational, and we want to test that hypothesis, then we must assume a particular structure for beliefs that can be tested.

While the assumption of exogenous beliefs cannot be tested on its own, it does provide testable implications when nested in a larger model. Two examples of this structure are Glaeser, Gyourko and Saiz (2008), and Nathanson and Zwick (2014). Glaeser, Gyourko and Saiz (2008) assume that bubbles are generated by random increases in buyers' valuation of homes. They examine how this exogenous shift in demand interacts with supply.

During a boom, holding the degree of irrational surge constant, prices with more inelastic supply will have greater increases in price and lower increases in quantity. This claim merely makes the point that the logic of Economics 101 continues to operate even if the demand curve is being shifted by irrationality. This point follows Becker (1962). After the bubble, the impact of supply elasticity is ambiguous. If supply is extremely inelastic, then the bubble will have had no impact on quantity during the boom and hence little impact on prices after the boom is over. This may reflect the reality of northern California or Massachusetts. In extremely elastic places, bubbles cause explosions in home building, but the elasticity of housing supply itself mutes the impact of overbuilding ex post, as long as the area continues to build at all.

Nathanson and Zwick (2014) also explore exogenous belief shifts, but their focus is on heterogeneity. They assume that individual investors have different prior beliefs about the value of real estate in a different area. They rule out the possibility that beliefs will converge through a

learning process. Optimists buy up all the land and the rental housing. But owner-occupied housing stays dispersed among residents of all beliefs because some residents prefer owning over renting, and they have diminishing marginal utility of housing. Optimistic beliefs influence house prices most in areas with ample land or rental housing. Prices are less prone to bursts of extreme optimism in housing markets that only have owner-occupied housing and no undeveloped land.

This observation explains why many elastic areas, which are those with undeveloped land, have such large house price booms. Nathanson and Zwick (2014) show that land price increases capture nearly 100% of the dispersion in house price increases across metro areas. Furthermore, several U.S. public homebuilders acted like speculators by taking large positions in the land market between 2001 and 2006, and then suffering large capital losses. Short-selling of homebuilder stock rose dramatically during this period, providing evidence of pessimists who disagreed with the homebuilders' high valuations of land.

Extrapolative Beliefs

Perhaps, the most popular alternative to rationality in housing markets (and perhaps finance as well) is extrapolation, occasionally called momentum trading, or backwards looking investors. Clapp and Tirtiroglu (1994) is an early example of this assumption in housing economics. In the real estate context, Glaeser (2013) refers to extrapolators as Gordonians because of their blind use of the Gordon growth formula. The principle is simply that investors use a formula like $P_t = \frac{(1+r)R_t}{r-g_R}$, and they use the recent growth rate in past prices to infer the growth rate in fundamentals. There are two ways of generating this type of behavior. One option is to assume that these erroneous beliefs arrive exogenously in a small share of the population. A second option is to derive these beliefs as the result of primitives.

The choice between these two options is somewhat connection to the decision about whether to assume that the extrapolative bias is ubiquitous or particular to a few odd eggs. Finance has a tradition going back to DeLong, Shleifer, Summers and Waldman (1990) of assuming that irrationality is limited to a small share of the market and then what impact this irrationality would have on market-wide prices. The appeal of this approach is that irrationality can be assumed for only a few, preserving the possibility that most of us are rational.

Barberis, Greenwood, Jin and Shleifer (2013) document how a small number of extrapolative buyers can move prices in financial markets. Piazzesi and Schneider (2009) provide an elegant example of this tradition transplanted into housing markets, which makes the point that if there is only a modest share of the stock renters with extrapolative beliefs that small share of the stock can become a large share of the flow of new home purchases, since the flow of purchases is only a small share of the stock.

Guren (2014) follows a similar tack of examining the impact of a minority of backward looking investors (i.e. extrapolators) in his model of search and slightly sticky prices. He finds that his model also exacerbates the power of a small amount of irrationality, allowing it to propagate throughout the system. In particular, small numbers of extrapolators create significant positive serial correlation in housing prices.

While Piazzesi and Scheider (2009) do persuasively show that a small number of optimistic buyers can make a boom, we think that 2002-2006 boom is best seen as a far more widespread burst of optimism. We agree that boom-level prices may not have reflected the majority opinion, and surely did not reflect the views of a sizable minority of housing market skeptics. Yet millions of Americans thought that these high prices made enough sense to purchase houses. Perhaps these homebuyers were extrapolating recent price increases, or perhaps they were passive and not evaluating house prices carefully because of long horizons. The available survey data (Case, Shiller, and Thompson, 2012) suggests that optimistic beliefs were ubiquitous among buyers during the boom period, although that comes with the usual caveats on survey data.

A moderate deviation from strict rationality can either take the form of large deviations from rationality for a small number of people or small deviations from rationality for much larger groups. While some economists may be comfortable just assuming that large numbers of home buyers follow ad hoc extrapolative beliefs, we prefer assuming smaller deviations from rationality since these deviations must apply to such a large number of home buyers.

One means of micro-founding extrapolative beliefs is to assume that investors are unsure about the growth rate in the fundamental. We illustrate our point with a spectacularly simple model in which $R_t = R_{t-1} + g_R$. The correct pricing formula that satisfies $P_t = R_t + \beta P_{t+1}$. The correct pricing formula is that $P_t = \frac{R_t}{1-\beta} + \frac{\beta E_t(g_R)}{(1-\beta)^2}$.

What will a rational individual infer from a change in prices? Presumably the price change reflects both the change in R_t and the change in $E_t(g_R)$. We can assume that the price at time 0 reflected only $\frac{R_0}{1-\beta}$, because there was no information about the growth rate. At time t+1, a new set of buyers emerged who observed the value of R_1 and observed past prices which in turn enabled them to uncover the value of g_R . The new price would be $\frac{R_1}{1-\beta} + \frac{\beta(R_1 - R_0)}{(1-\beta)^2}$, reflecting both the change in the level of demand and the change in the assessment of the growth rate.

Now consider the price at time t+2. If these buyers were sophisticated, they would look at prices at time zero and time one, and correctly infer both the current level of demand and the growth rate g_R which equals $(1 - \beta)^2(P_1 - P_0)$. The correct pricing formula would be $P_2 = \frac{R_2}{1-\beta} + \beta(P_1 - P_0) = P_1 + (1 - \beta)(P_1 - P_0)$. There would be momentum, but only because there is a persistent growth rate. The prices would not be growing up any faster than that fixed growth rate.

However, assume that these buyers were less sophisticated and they thought that the change in prices only reflected a change in the level of demand. They inferred the growth rate from the change in past prices, assuming that past price changes do not reflect any change in beliefs about past growth rates. In essence, these buyers are cursed in the phrase of Eyster and Rabin (2005), which means that individuals mistakenly believe that “other player’s actions depend less on their types than they actually do.”

Eyster and Rabin’s (2005) idea is that it is difficult to fully infer the motives of others, and as a result we don’t always make sense of market outcomes. For example, to avoid the winner’s curse, bidders must understand that if others bid less, then they must have worse signals about the value of the good being sold. Individuals will take bets when they shouldn’t, because they don’t recognize that an individual who offers to bet with them is implicitly signaling some private information.

In housing markets, a failure to understand past sales behavior may mean that buyers don’t recognize that past price increases already reflect expectations about future price increases. We formalize this idea by assuming that individuals at time t , believe that $P_1 - P_0 = \frac{R_1 - R_0}{1 - \beta}$ instead of $\frac{R_1 - R_0}{(1 - \beta)^2}$. This is essentially what happens when individuals plug past price growth in the standard capitalization formula. Their willingness to pay in period 2 then equals $P_2 = \frac{R_2}{1 - \beta} + \frac{\beta(P_1 - P_0)}{1 - \beta} = P_1 + \left(1 - \beta + \frac{\beta^2}{1 - \beta}\right) (P_1 - P_0)$. The level of momentum has increased, perhaps dramatically, because the growth rate is being inferred from the change in prices, which themselves already included changing expectations about the growth rate.

Glaeser and Nathanson (2014) are developing a more sophisticated version of this approach in which growth rates are stochastic, and past prices are informative about the current rate of fundamental growth. The critical weakness again that delivers extrapolation, and hence positive serial correlation, is that homebuyers believe that past price movements reflect changes in fundamentals rather than changes in beliefs about the growth rate.

Cognitive Limitations: Natural Expectations, Spatial Benchmarking and Rule of Thumb Spending

That particular model is part of a general class of models of cognitive limitations many of which have the potential to add to our understanding of real estate fluctuations. Shiller (1999) reviews many of the standard behavioral tics which may influence housing markets. The intellectual challenge is that there are so many potential, plausible cognitive limitations that it is hard to naturally focus on any particular one. We will discuss several types of cognitive limitation here,

and the extrapolation discussed above can also be seen as one example of cognitive limitation: the inability to think through how other people think.

Fuster, Laibson and Mendel (2010) offer one particular form of cognitive limitation that they title natural expectations. Natural expectations models require agents to make predictions using only an excessively parsimonious model. For example, if the true R_t process was described as $R_t - R_{t-1} = B_1(R_{t-1} - R_{t-2}) - B_2(R_{t-2} - R_{t-3}) + \epsilon_t$, then the agents might attempt to estimate the regression by fitting only $R_t - R_{t-1} = \widehat{B}_1(R_{t-1} - R_{t-2}) + \epsilon_t$. This obviously has the capacity to create mistakes, but does it naturally generate excess volatility or strong one period price momentum.

Applying the usual pricing formula ($P_t = R_t + \frac{1}{1+r}E(P_{t+1})$) implies that homebuyers with rational expectations would be willing to pay $\frac{(1+r)^3 R_t - (1+r)((1+r)B_1 - rB_2)R_{t-1} - (1+r)^2 B_2 R_{t-2}}{r(1+r)(1+r-B_1) - rB_2}$.

Homebuyers with natural expectations would set $P_t = \frac{(1+r)^2 R_t - (1+r)\widehat{B}_1 R_{t-1}}{r(1+r-\widehat{B}_1)}$.

In Table 2, we simulate the impact of these beliefs assuming that $B_1 = \widehat{B}_1 = .9$, $B_2 = .8$ and that $B_1 = \widehat{B}_1 = .5$ $B_2 = .3$. The interest rate is .04 and the standard deviation of the shock is \$1,000. We do not believe that these parameter choices are realistic. They are instead chosen to illustrate what is necessary for natural expectations to deliver high degrees of momentum and excess volatility. The medium persistence case still has considerable more momentum than either income or rents. In that case, the volatility is slightly increase by moving from rational to natural expectations. There is considerably more mean reversion with natural expectations, because the buyers do not realize that positive shocks today will lead to negative shocks in two periods. However, this does not generate significant price momentum. Since even the natural expectations agents recognize that a shock today will become a shock tomorrow, this positive effect is built immediately into prices and this means that there is little extra momentum created by this cognitive limitation.

In the truly extreme case of massive short run persistence and massive medium run mean reversion, we do indeed get momentum in prices with natural expectations, but not with rational expectation. The rational expectations understand that a positive shock today will be offset soon and as a result price move far less. The natural expectations agents have much more severe price movements and significant momentum. This momentum turns into mean reversion when the true nature of the process inserts itself. Of course, these natural expectations agents are making mistakes on a massive scale with some degree of regularity, which may be difficult for many economists to accept. We find this exercise interesting, but believe that the assumptions needed for natural expectations to fit the housing price data are just too extreme.

One particularly important use of natural expectations, however, is that they may explain why homebuyers so often appear to miss the power of supply to bring prices back down to earth. If it always takes time to build new housing units, then making predictions based on short time periods will always mean missing the power of supply. This will mean that natural expectations will typically lead to a demand-side analysis only and lead buyers to fail to predict that supply will eventually cause prices to converge.

To illustrate this point, we assume that $R_t = \theta_t - \alpha N_t$, where θ_t is the exogenous demand shock and N_t reflects the supply of new housing. We assume that $\theta_{t+1} - \theta_t = \delta + \rho(\theta_t - \theta_{t-1} - \delta) + \varepsilon_{t+1}$, so the true process is indeed a one period moving average. We allow a two period production process $E_t(P_{t+2}) = c_0 + c_1 I_{t+1}$ and $N_{t+1} = N_t + I_t$. This means that the production decision that determines the stock at t+2 is made with the information available as of time t.

We consider three possibilities. First, it is possible that both the home buyers and the home builders are completely rational. This is the case shown in the first column of Table 3. In this case there is modest volatility, significant mean reversion and little price momentum. Buyers anticipate all the future changes, but it remains true that new building causes initial shocks to disappear over time.

In all cases, we allow the homeowners to correctly understand the dynamics of demand, but not to fully understand the dynamics of supply. In both of our semi-rational cases, we assume that home buyers believe that supply is fixed. In columns (2) and (3), buyers believe that supply is fixed at the current rate of supply. In columns (4) and (5), buyers believe that supply will be fixed at the level supplied next period. We also have two possibilities for the degree of rationality about home builders. In columns (2) and (4), home builders choose I_{t+1} assuming that $I_{t+1} = I_{t+2}$. In columns (3) and (5), builders are completely rational.

In all cases, these near rational assumptions fail to deliver any price momentum. The failure to anticipate supply responses just does not deliver a reason for price growth to follow price growth. There is momentum in the demand fundamentals, but the natural expectations buyers build that into their period t prices. However, the buyers limited ability to anticipate supply does exacerbate price volatility and price mean reversion. The price volatility is higher because they do not anticipate the fact that rents will be declining over time as new supply enters into the market. Mean reversion is higher because price rise more initially, but then come back down to earth quickly.

Somewhat surprisingly to us, this semi-rationality reduces the volatility of construction changes. As prices move around a great deal, construction moves less. A second less studied form of cognitive limitation is spatial benchmarking. This rule of thumb takes the spatial equilibrium logic of the Alonso-Muth-Mills model and the Rosen-Roback model and applies it to prices, rather than rents. This type of logic was used historically to convince investors in the wisdom of

Los Angeles real estate prices during the boom of the 1880s, and it is compatible with the Ferreira and Gyourko (2012) evidence on the spatial spread of the boom during the last decade.

This logic will be particularly problematic if there are supply differences that differ across areas. To consider an extreme example, assume that in city A (Los Angeles) the supply is fixed, and $R_{t+j} = e^{gj}R_t$ so the benefits are deterministically growing. Applying the pricing formula $P_t = \int_{j=0}^{\infty} e^{-rj} R_{t+j} dj$. implies that prices in city A should equal $P_t = \frac{R_t}{r-g}$.

Assume that at a point in time city B yields benefits $R_t - \delta$. Naïve spatial extrapolation would then imply that the price in city B should equal $\frac{R_t - \delta}{r-g}$ and this would indeed be rational if prices in city B were also increasing at the rate g . One reason why the formula might be radically wrong is that the growth rates differ in the two areas. In that case, static comparisons lead to incorrect pricing.

The error could instead be endogenous, even if growth rates were similar as long as supply conditions were different. To illustrate this case, assume that R_t is fixed at R_A in city A and that there is no new supply, and as such prices should equal $\frac{R_A}{r}$. In city B, supply is flexible and $R_t = \theta_B - \alpha N_t$. At time zero, $\theta_B - \alpha N_0 = R_A$ so initially the two places yield comparable returns. We assume a supply curve so that cost equal $c_0 + c_1 \dot{N}$ which must also equal the price. To ensure that there is always some construction, we assume that $\frac{R_A}{1-\beta} > c_0$.

The rational pricing and growth equations in city B satisfy $\dot{N} = \left(\frac{\theta_B - \alpha N_0}{r} - c_0 \right) \frac{r(r+c_1)}{c_1 r(r+c_1) + \alpha} e^{-c_1 t}$, $P = c_0 + \left(\frac{\theta_B - \alpha N_0}{r} - c_0 \right) \frac{c_1 r(r+c_1)}{c_1 r(r+c_1) + \alpha} e^{-c_1 t}$. The rents may start the same, but they will soon differ because of excess supply and initially prices should reflect this expected convergence.

If individuals in City B persist in using the pricing formula that is appropriate for city A, so that prices equal $\frac{\theta_B - \alpha N_t}{r}$, then $\dot{N} = \frac{1}{c_1} \left(\frac{\theta_B - \alpha N_t}{r} - c_0 \right)$, which will initially be larger than under rational pricing. This will lead to overbuilding in the short run, and eventually prices that will lie below their level under rational pricing.

A third way in which prices may diverge from rationality is that buyers follow other prescribed rules of thumb. Some options that have been discussed are always spending as much as they can afford, given current interest rates. If the marginal homebuyer has an income of Y dollars, and is able to get a no down payment mortgage, then the maximum willingness to pay is some fixed fraction times Y divided by the interest rate. This rule of thumb suggests a high elasticity of price with respect to interest rates, but one that is no different than in the standard model. It also suggests that the price of housing will be decoupled from the benefits of housing, which does run counter to centuries of economic thinking. Money illusion can also contribute to “housing

frenzies” if buyers overestimate the future costs of real interest payments when inflation is high, and will then bid more for housing as inflation drops (Brunnermeier and Juilliard, 2008).

One added possibility is that individuals hop from one type of belief formation to another. For example, they may sometimes be rational but become adaptive during periods of sustained growth. Alternatively, they may just ignore future price appreciation much of the time during periods when such appreciation seems unlikely or is just salient. During those periods, prices track rents, but if an event makes the prospect housing price appreciation salient, then buyers start making potentially biased forecasts about future housing price growth.

Social Learning and the Entrepreneurs of Error

The previous section focused on learning from past prices movements, but there are many other influences that shape individuals beliefs about housing prices. Perhaps the most pervasive and important source of information that humans rely upon are the statements of people around us. Most of the time these social influences are relatively benign, but in some cases, these influences may reflect private motives at odds with the individuals’ own best motives.

The early literature on manias emphasized the rational causes of imitation. Froot, Scharfstein and Stein (1992), for example, emphasized the strong incentives of investors with short horizons to focus on the same sources of information. Bikchandani, Hirschleifer and Welch (1998) and Banerjee (1992) both present models of information cascades, where individuals rationally imitate one another. DeCoster and Strange (2012) apply this logic to developers, who imitate one another because they assume that their peers have made their decisions based on valuable information about the state of the world. The result can be a glut of overbuilding.

These forces will only become more powerful if the urge to imitate exceeds the purely rational. One natural version of this is to again assume a type of “Cursed” behavior, where individuals underestimate the social causes of the behavior of others. In this case, each new buyer infers that the mass of preceding buyers is acting on private information, rather than just following the leader. In this case, each new buyer believes that the actions of the herd contain an extraordinary rich amount of information, whereas in reality, the mob might just be following the leader of a single person. This type of incorrect inference will tend to make herd behavior extreme powerful and manias extremely common.

While DeCoster and Strange emphasize builders’ decisions, this same logic could relate to buying homes in a particular locale, such as Las Vegas in 2005. According to this view, the large numbers of Las Vegas buyers provides evidence to new buyers that Las Vegas is an excellent investment. This logic then encourages an even larger rush of buyers.

The literature has expanded beyond imitating actions to following advice. One notable paper in this genre is Hong, Scheinkman and Xiong (2008), which argues that interested advisors may play an important role in encouraging the role of bubbles. According to this view, there are individuals who have an interest in selling stock or real estate. These advisors provide misleading information to buyers who then act on these incorrect messages. Real estate agents do have the motive to encourage buyers to bid and are typically given plenty of time in which to make that case.

Naturally, these models assume a degree of irrationality—individuals still listen to advisors who are patently self-interested. Yet this attention to the opinions of others may itself be an entirely sensible rule of thumb. Most of the time, advice is given disinterestedly (i.e. one's spouse or mother advises that you wear a coat because it is raining) and it is best not to waste too much effort trying to understand the motives behind the advice. Perhaps, we follow the advice that we are given because that is a relatively sensible strategy most of the time.

We are not ruling out any number of possible models with cognitive limitations, but this research agenda is sufficiently early that we suspect that concentrating on a small number of alternatives to complete rationality is sensible. We suspect that there is an agenda around extrapolative beliefs involving theoretical research, normal empirics and lab work that will be highly productive. A better understanding of why the implications of elastic supply seem to be so often ignored also seems relevant. Finally, for exploring some elements of housing institutions or policies, it will remain sensible to take the easy if hard to defend approach of just assuming exogenous beliefs.

VI. Public Policy and Bubbles

Real estate bubbles relate to public policy both positively and normatively. On the positive side, many observers have argued that government policies, including the low interest rates, the Community Reinvestment Act and support for Fannie Mae and Freddie Mac, caused the bubble and its bust (e.g. Wallison, 2009). We have already argued that it is hard to see any simple connection between easy credit and the housing bubble, which leads us to be cautious about accepting the view that such policies obviously caused the boom. It remains, of course, possible that these policies exacerbated the bubble and its financial implications, but it seems hard to blame the government for the fluctuation. Moreover, the history of real estate bubbles suggests that they have often occurred when government intervention is minimal (Glaeser, 2013).

We turn to the normative, public policy implications of housing bubbles, for different parts of the public sector. Most obviously, macroeconomic institutions, such as the Federal Reserve Board, debate whether to engage in policies explicitly aimed at reducing the volatility of asset bubbles,

including real estate bubbles. Bank and credit regulators have oversight over institutions that are deeply impacted by real estate fluctuations. How does the existence of real estate bubbles impact optimal banking regulations? The federal government engages in a series of housing market policies, including the home mortgage interest deduction. Should these policies be changed in light of recent real estate volatility? Finally, local land use regulations are largely responsible for shaping housing supply. These regulations also interact with housing bubbles (Glaeser, Gyourko and Saiz, 2008).

We have no intention of resolving these policies issues now, but we note them primarily as enduringly important topics. The Federal Reserve Board has historically abstained from taking steps to deflate asset bubbles. For example, in 2005, Janet Yellen articulated the current orthodoxy that monetary policy should not be used to deflate a housing bubble. She asked “if the bubble were to deflate on its own, would the effect on the economy be exceedingly large” and refuted that claim. More importantly, she argued that monetary policy is not “the best tool to use to deflate a house-price bubble.”

History has not been kind to her first argument against intervention. The real estate bust did have widespread adverse consequences and the threat of future housing busts seems quite real. To be fair, many housing economists (including at least one of us) were at least as mistaken as she was. Still, after learning the Great Recession, future policy-makers should never be so confident that a housing downturn won't have serious consequences.

But what awareness of the risks means for macroeconomic policy-making is far less clear. Yellen's point that monetary policy is not a good way to “deflate a house-price bubble” is just as tenable today as it was in 2005. Moreover, since housing price booms can reflect real forces, as well as bubbles, it may be foolish to constantly attempt to run counter to rising prices. The policy conclusion is uncertain, but that provides a far clear implication that more research is needed on macroeconomic stabilization policy when real estate volatility is large.

The volatility of real estate prices also impacts financial market regulation. The Lehman Brothers bankruptcy was closely connected with its exposure to real estate related subprime mortgage risk. Indeed, the securitization of mortgages has been blamed both for helping to create the bubble but also for ensuring that the pain of the downturn is more widely experienced. Yet the spreading of that risk may have reduced the adverse consequences of the bubble for the banking system itself, since fewer mortgages were being held directly on the books of lending institutions.

The obvious implication of centuries of real estate booms and busts is that real estate is not a riskless asset. Regular mean reversion means that high prices today may well mean low prices tomorrow. Presumably, these facts should inform banking regulation if the goal of such regulation is to reduce the risk of financial distress within the sector.

One suggested reform is that regulators should anticipate mean reversion when assessing asset values for capital requirements. If prices have risen by 75 percent over the past five years, then historical experience suggests that a 25 percent drop over the next five years is not unreasonable. One proposal is to value real estate related capital based on its future expected value.

Yet there are many reasons to be cautious about changes of this kind. Real estate is not the only asset that displays mean reversion (Cutler, Poterba and Summers, 1991), but if real estate is the only asset that is subject to such treatment then this may distort the movement of capital. Whatever formula is used to assess long run value will surely be subject to gaming by lending institutions and political influence by policy-makers seeking their own pet objectives. Again, the only conclusion that can be definitively drawn now is the need for further investigation.

The Federal government has explicit policies that promote homeownership typically by subsidizing lending. The home mortgage interest deduction implicitly subsidizes home borrowing. While borrowing for business investments may also be deductible, typically the returns to those investments are taxed. By contrast, the government does not tax the implicit rental income earned by a homeowner. The government sponsored enterprises, Freddie Mac and Fannie Mae, as well as the Federal Housing Administration, have also all encouraged home borrowing by providing a guarantee against default.

The presence of real estate bubbles matters deeply for the wisdom of encouraging leveraged bets on real estate through public policy. If real estate was a safe, boring asset that rarely experienced major fluctuations, then encouraging home owning could be seen as a safe means of encouraging asset accumulation. However, high levels of volatility mean that government policies that support leveraged borrowing can have the unfortunate impact of creating a class of homeowners who are massively indebted because they borrowed to buy housing that has lost its value.

To a certain extent, this downside risk is offset by the fact that the cost of living for these homeowners has dropped. Owning itself is something of a hedge since we are all born short housing (Sinai and Souleles, 2007). Yet there is also a covariance between local housing prices and local labor markets which helps explain why the downturn was associated with so many foreclosures. Those foreclosures provide a tangible example of the risks associated with encouraging leveraged real estate investments particularly for lower income Americans.

The supporters of pro-home borrowing policies will often point out the large share of housing in the portfolios of many Americans, as if this proves that subsidizing homeownership is the natural path towards encouraging asset accumulation. Yet since many of these policies make it easier to borrow with low down payments, they also reduce the incentive to save before buying. There is a severe need for a more serious literature about the portfolio implications for ordinary Americans of encouraging home borrowing, especially in light of significant house value volatility.

The final relevant policy area relating to real estate bubbles concerns the land use policies of local government. Housing supply is determined, at least in part, by regulations at the local level. Housing supply then in turn influences the nature and duration of real estate bubbles. The first order correlation is that these events do appear to be more extreme in more restricted areas, both in places that currently cannot build (Glaeser, Gyourko and Saiz, 2008) and in places where investors anticipate future regulatory constraints that make supply difficult (Nathanson and Zwick, 2014).

Does it therefore follow that in a world with real estate bubbles it is even more valuable to reduce the barriers to new building? Not necessarily. Even if we were confident that fewer restrictions on building might make bubbles less common or less extreme, we could not conclude that reducing land use restrictions would reduce the social costs of bubbles. For one of those costs is overbuilding and overbuilding will be more severe in places where land use is more restricted. It seems doubtful, for example, that the price boom between 2001 and 2006 caused any serious over-building in San Francisco or the suburbs of Boston, because so little new housing was built and prices remained significantly above construction costs even after the bust. These restrictions may have caused price swings to be more severe but they also limited the hangover from excess building supply. The social cost of overbuilding will be most severe in areas in which supply is elastic and bubbles still occur.

Overall, this policy section has provided no clear policy directives and that is precisely the point. The policy implications of real estate bubbles are far from clear. Economists have not spent all that much time researching this issue, partially because of our unwillingness to accept the existence of bubbles. Yet the hair-raising events of 2000-2012 make it plain that real estate can experience enormous convulsions, whether we choose to use the word “bubble” or not. Surely, economists must press on to deliver a better apparatus for understanding the consequences of different housing and banking policies in a world where real estate can be very volatile.

VII. Conclusion

This paper has argued that real estate experiences impressive booms and busts, which can reasonably be referred to as bubbles. Generally prices move too much to be fully explained by changes in either rents or observable fundamentals. Housing prices display substantial momentum at high frequencies, and they mean revert at lower frequencies. These general features were greatly exacerbated during the great boom and bust of the 2000 to 2012 period. Moreover, real estate convulsions have appeared regularly throughout U.S. and world history often with dire consequences.

The economics of real estate bubbles is still in its infancy, for until 2005, the dominant economic view was that such bubbles do not exist. This orthodoxy paralleled the general assumption in

financial economics, at least until the dot com bust of 2000. It seems silly now to believe that housing price changes are orderly and driven entirely by obvious changes in fundamentals operating through a standard model.

Moving ahead there are two broad classes of models that have and will continue to shed light on these great housing convulsions. The first class essentially attempts to explain these housing market features with essentially rational actors. We have discussed two variants of these models. First, several papers examine housing dynamics through the lens of a search model. These models can generate substantially more momentum than standard models, because it takes time for shocks to work their way through the system. To date, these models generally do not deliver large amounts of excess volatility, just momentum and mean reversion, but those are themselves significant contributions and it remains possible that future models of learning and search will also generate significant excess volatility, although there are reasons to doubt that this will occur.

A second form of rational model stresses that if agency problems lead to interest rates that charge too little for default risk then rational bubbles can occur without violating any transversality conditions. These models still tend to predict that prices will become enormously high with positive probability. This implication is difficult to square with elastic housing supply, which suggests that these events are far more plausible in highly constrained areas. These rational bubble models do not imply that cheap credit will always cause a real estate bubble, but they do suggest that cheap credit is a necessary condition.

The second class of models drops the assumption of perfect rationality. We have discussed several different types of these models, including models in which beliefs were just assumed to be fixed and heterogeneous. While that assumption is useful for highlighting cross-sectional aspects of the housing markets, we suspect that productive veins of behavioral real estate research going forward will focus on extrapolative beliefs and simple forms of limited cognition. We sketched a path towards grounding extrapolation as the result of cognitive limitations of the form discussed by Eyster and Rabin (2005). It also seems possible that cognitive limitations may lie behind buyers' apparent tendency to repeatedly ignore the power of housing supply to determine prices.

Understanding the causes of real estate bubbles seems particularly critical, because these events clearly have large social consequences. We cannot plausibly hope that these asset price fluctuations will vanish, but it is at least possible that we can reduce their costs through better public policy-making. Unfortunately, we are still far from having enough knowledge to confidently recommend any particular policy actions.

References

- Abel Jaison R. and Richard Deitz. 2010. "Bypassing the Bust: The Stability of Upstate New York's Housing Markets During the Recession." *Federal Reserve Bank of New York Current Issues in Economics and Finance*, 16(3).
- Abreu, Dilip, and Markus K. Brunnermeier. 2003. "Bubbles and crashes." *Econometrica*, 71(1): 173-204.
- Adelino, Manuel, Kristopher Gerardi, and Paul Willen. 2010. "What Explains Differences in Foreclosure Rates? A Response to Piskorski, Seru, and Vig." Federal Reserve Bank of Atlanta Working Paper 2010-8.
- Ambrose, Brent W., Eichholtz, Piet. and Lindenthal, Thies. 2013. "House Prices and Fundamentals: 355 Years of Evidence." *Journal of Money, Credit and Banking*, 45(2-3): 477–491.
- Banerjee, Abhijit V. 1992. "A simple model of herd behavior." *The Quarterly Journal of Economics* 107(3): 797-817.
- Barberis, Nicholas, Robin Greenwood, Lawrence Jin, and Andrei Shleifer. 2013. "X-capm: An extrapolative capital asset pricing model." Working Paper 19189. National Bureau of Economic Research.
- Becker, Gary S. 1962. "Irrational Behavior and Economic Theory." *The Journal of Political Economy*, 70(1): 1-13.
- Bikhchandani, Sushil, David Hirshleifer, and Ivo Welch. 1998. "Learning from the behavior of others: Conformity, fads, and informational cascades." *The Journal of Economic Perspectives*, 12(3): 151-170.
- Brunnermeier, Markus K., and Christian Julliard. 2008. "Money illusion and housing frenzies." *Review of Financial Studies*, 21(1): 135-180.
- Caldera, Aida and Asa Johansson. 2013. "The price responsiveness of housing supply in OECD countries." *Journal of Housing Economics*, 22(3): 231-249.
- Campbell, John Y., Stefano Giglio, and Parag Pathak. 2011. "Forced Sales and House Prices." *American Economic Review*, 101(5): 2108-31.
- Case, Karl E., John M. Quigley and Robert J. Shiller. 2005. "Comparing Wealth Effects: The Stock Market versus the Housing Market." *Advances in Macroeconomics*, 5(1): 1-32.
- Case, Karl E., and Robert J. Shiller. 1989. "The Efficiency of the Market for Single Family Homes," *American Economic Review*, 79(1): 125—137.

- Case, Karl E., and Robert J. Shiller. 2003. "Is there a bubble in the housing market?" *Brookings Papers on Economic Activity*, 2: 299-362.
- Case, Karl E., Robert J. Shiller, and Anne Thompson. 2012. "What have they been thinking? Home buyer behavior in hot and cold markets." National Bureau of Economic Research No. w18400.
- Clapp, John M., and Dogan Tirtiroglu. 1994. "Positive feedback trading and diffusion of asset price changes: evidence from housing transactions." *Journal of Economic Behavior & Organization*, 24(3): 337-355.
- Clapp, John M., Walter Dolde, and Dogan Tirtiroglu. 1995. "Imperfect information and investor inferences from housing price dynamics." *Real Estate Economics*, 23(3): 239-269.
- Cox, John C., Jonathan E. Ingersoll Jr, and Stephen A. Ross. 1985. "A theory of the term structure of interest rates." *Econometrica: Journal of the Econometric Society*, 53(2): 385-407.
- Cutler, David M., James M. Poterba, and Lawrence H. Summers. 1991. "Speculative dynamics." *The Review of Economic Studies*, 58(3): 529-546.
- Davidoff, Thomas. 2013. "Supply Elasticity and the Housing Cycle of the 2000s." *Real Estate Economics*, 41(4): 793-813.
- DeCoster, Gregory P. and William C. Strange. 2012. "Developers, Herding, and Overbuilding." *The Journal of Real Estate Finance and Economics*, 44(1-2): 7-35.
- DeLong, J. Bradford, Andrei Shleifer, Lawrence H. Summers, and Robert J. Waldmann. 1990. "Positive feedback investment strategies and destabilizing rational speculation." *The Journal of Finance*, 45(2): 379-395.
- Demsetz, Rebecca S., Marc R. Saldenber and Philip E. Strahan. 1997. "Agency problems and risk taking at banks." Federal Reserve Bank of New York Research Paper 9709.
- Diamond, Douglas W. and Raghuram Rajan. 2009. "The Credit Crisis: Conjectures about Causes and Remedies." NBER Working Paper No. 14739.
- Diba, Behzad T. and Herschel I. Grossman. 1988. "The Theory of Rational Bubbles in Stock Prices." *The Economic Journal*, 98(392): 746-754.
- Eyster, Erik, and Matthew Rabin. 2005. "Cursed equilibrium." *Econometrica*, 73(5): 1623-1672.

- Fama, Eugene F. 1965. "The Behavior of Stock-Market Prices." *Journal of Business*, 38(1): 34-105.
- Ferreira, Fernando and Joseph Gyourko. 2012. "Heterogeneity in Neighborhood-Level Price Growth in the United States, 1993-2009." *American Economic Review*, 102(3): 134-40.
- Ferreira, Fernando, Joseph Gyourko and Joseph Tracy . 2010. "Housing busts and household mobility," *Journal of Urban Economics*, 68(1): 34-45.
- Fisher, Lynn M., Lauren Lambie-Hanson, and Paul S. Willen. 2013. "The Role of Proximity in Foreclosure Externalities: Evidence from Condominiums." The Federal Reserve Bank of Boston Public Policy Discussion Paper No. 13-2.
- Froot, Kenneth. A., Scharfstein, David S. and Stein, Jeremy C. 1992. "Herd on the Street: Informational Inefficiencies in a Market with Short-Term Speculation." *The Journal of Finance*, 47(4): 1461–1484.
- Fuster, Andreas, David Laibson, and Brock Mendel. 2010. "Natural expectations and macroeconomic fluctuations." *The Journal of Economic Perspectives*, 24(4): 67-84.
- Gao, Zhenyu. 2014. "Housing Boom and Bust with Elastic Supplies." Job Market Paper, Princeton University.
- Gelain, Paolo, and Kevin J. Lansing. 2013. "House prices, expectations, and time-varying fundamentals." Norges Bank Research Working Paper.
- Genesove, David, and Christopher Mayer. 2001. "Loss aversion and seller behavior: Evidence from the housing market." *The Quarterly Journal of Economics*, 116(4): 1233-1260.
- Giglio, Stefano, Matteo Maggiori, and Johannes Stroebel. 2014. "No-Bubble Condition: Model-Free Tests in Housing Markets." Working Paper.
- Glaeser, Edward L. 2013. "A Nation of Gamblers: Real Estate Speculation and American History." *American Economic Review*, 103(3): 1-42.
- Glaeser, Edward and Joseph Gyourko. 2009. *Rethinking Federal Housing Policy*, American Enterprise Institute: Washington DC.
- Glaeser, Edward, Joshua D. Gottlieb and Joseph Gyourko. "Can Cheap Credit Explain the Housing Boom?" 301-359 in *Housing and the Financial Crisis*, Edward L. Glaeser and Todd Sinai, editors. University of Chicago Press: Chicago.
- Glaeser, Edward L., Joseph Gyourko, Eduardo Morales, and Charles G. Nathanson. 2014. "Housing dynamics: An urban approach." *Journal of Urban Economics*, 81 (2014): 45-56.

- Glaeser, Edward L., Joseph Gyourko, and Albert Saiz. 2008. "Housing supply and housing bubbles." *Journal of Urban Economics*, 64(2): 198-217.
- Goodman, Jack. 2005. *Housing Situation and Time Use*. Hartrey Advisors.
- Green, Richard K. 2008. "Imperfect information and the housing finance crisis: A descriptive overview." *Journal of Housing Economics*, 17(4): 262–271.
- Greenwood, Robin, and Samuel G. Hanson. 2013. "Issuer quality and corporate bond returns." *Review of Financial Studies* 26(6): 1483-1525.
- Guren, Adam. 2014. "The Causes and Consequences of House Price Momentum." Job Market Paper, Harvard University.
- Guren, Adam, and Tim McQuade. 2013. *How Do Foreclosures Exacerbate Housing Downturns?* Harvard University Mimeo.
- Hall, Robert E. 2003. *Deal Engines: The Science of Auctions, Stock Markets, and E-Markets* W. W. Norton & Company: New York.
- Han, Lu, and William C. Strange. Forthcoming. "What is the Role of the Asking Price for a House?"
- Haughwout, Andrew, Donghoon Lee, Joseph S. Tracy, and Wilbert Van der Klaauw. 2011. "Real Estate Investors, the Leverage Cycle, and the Housing Market Crisis." Federal Reserve Bank of New York Staff Report No. 514.
- Head, Allen, Huw Lloyd-Ellis and Hongfei Sun, 2014. "Search, Liquidity, and the Dynamics of House Prices and Construction," *American Economic Review*, 104(4): 1172-1210.
- Himmelberg, C., Mayer, C., Sinai, T., 2005. "Assessing high house prices: Bubbles, fundamentals, and misperceptions." *Journal of Economic Perspectives*, 19 (4): 67–92.
- Hoberg, Gerard, and Gordon Phillips. 2010. "Real and financial industry booms and busts." *The Journal of Finance* 65(1): 45-86.
- Hong, Harrison, Jose Scheinkman, and Wei Xiong. 2006. "Asset float and speculative bubbles." *The Journal of Finance*, 61(3): 1073-1117.
- Hong, Harrison, Jose Scheinkman, and Wei Xiong. 2008. "Advisors and asset prices: A model of the origins of bubbles." *Journal of Financial Economics*, 89(2): 268-287.
- Kindleberger, Charles P. 1978. *Manias, Panics, and Crashes: A History of Financial Crises*, New York: Basic Books.

- Kivedal , Bjørnar Karlsen. 2013. "Testing for rational bubbles in the US housing market." *Journal of Macroeconomics*, 38(B): 369–381.
- Krainer, John. 2001. "A theory of liquidity in residential real estate markets." *Journal of Urban Economics*, 49(1): 32-53.
- Krainer, John, S. F. LeRoy, and M. O. 2009. "Mortgage Default and Mortgage Valuation." Federal Reserve Bank of San Francisco Working Paper No. 2009-20.
- Levitt, Steven D., and Chad Syverson. 2008. "Market distortions when agents are better informed: The value of information in real estate transactions." *The Review of Economics and Statistics*, 90(4): 599-611.
- Mian, Atif, Kamalesh Rao, and Amir Sufi. 2013. "Household Balance Sheets, Consumption, and the Economic Slump." *The Quarterly Journal of Economics*, 128(4): 1687-1726.
- Mian, Atif, and Amir Sufi. 2009. "The consequences of mortgage credit expansion: Evidence from the US mortgage default crisis." *The Quarterly Journal of Economics*, 124(4): 1449-1496.
- Mian, Atif and Amir Sufi. 2010. "Household Leverage and the Recession of 2007–09" *IMF Economic Review*, 58(1): 74–117
- Mian, Atif and Amir Sufi. 2014. *House of Debt: How They (and You) Caused the Great Recession, and How We Can Prevent It from Happening Again*. University Of Chicago Press: Chicago.
- Mian, Atif, Amir Sufi, and Francesco Trebbi. Forthcoming. "Foreclosures, house prices, and the real economy." *Journal of Finance*.
- Nathanson, Charles G., and Eric Zwick. 2013. "Arrested Development: Theory and Evidence of Supply-Side Speculation in the Housing Market." Job Market Paper, Harvard University.
- Novy-Marx, Robert. 2009. "Hot and Cold Markets." *Real Estate Economics*, 37(1): 1–22.
- Palmer, Christopher. 2013. "Why Did So Many Subprime Borrowers Default During the Crisis: Loose Credit or Plummeting Prices?" MIT Job Market Paper.
- Pavlov, Andrey and Wachter, Susan M. 2006. "The Inevitability of Marketwide Underpricing of Mortgage Default Risk." *Real Estate Economics*, 34(4): 479–496.
- Piazzesi, Monika, and Martin Schneider. 2009. *Momentum traders in the housing market: survey evidence and a search model*. Working Paper 14669. National Bureau of Economic Research.
- Piskorski, Tomasz, Amit Seru, and Vikrant Vig. 2010. "Securitization and distressed loan renegotiation: Evidence from the subprime mortgage crisis." *Journal of Financial Economics* 97(3): 369-397.

- Poterba, James. 1984. "Tax Subsidies to Owner-Occupied Housing: An Asset Market Approach." *Quarterly Journal of Economics*, 99(4): 729-745.
- Purnanandam, Amiyatosh. 2011. "Originate-to-distribute Model and the Subprime Mortgage Crisis." *Review of Financial Studies*, 24 (6): 1881-1915.
- Roback, Jennifer. 1982. "Wages, Rents, and the Quality of Life." *Journal of Political Economy*, 90(4): 1257-78.
- Rosen, Sherwin. 1979. "Wage-Based Indexes of Urban Quality of Life". In *Current Issues in Urban Economics*, edited by Peter Mieszkowski and Mahlon Straszheim. Baltimore: Johns Hopkins University Press.
- Santos, Manuel S. and Michael Woodford. 1997. "Rational Asset Pricing Bubbles." *Econometrica*, 65(1): 19-57.
- Scheinkman, Jose A., and Wei Xiong. 2003. "Overconfidence and speculative bubbles." *Journal of political Economy* 111(6): 1183-1220.
- Shiller, Robert J. 1981. "Do Stock Prices Move Too Much to be Justified by Subsequent Changes in Dividends?" *American Economic Review*, 71 (3): 421-436.
- Shiller, Robert J. 2005. *Irrational Exuberance*. New York: Random House LLC.
- Shiller, Robert J. 1999. "Chapter 20: Human behavior and the efficiency of the financial system" in: J. B. Taylor & M. Woodford (ed.), *Handbook of Macroeconomics*, 1(1): 1305-1340.
- Shleifer, Andrei, and Robert W. Vishny. 1997. "The limits of arbitrage." *The Journal of Finance*, 52(1): 35-55.
- Sinai, Todd, and Nicholas S. Souleles. 2007. *Net worth and housing equity in retirement*. Working Paper 13693. National Bureau of Economic Research.
- Sockin, Michael, and Wei Xiong. 2014. "Learning about the Neighborhood: A Model of Housing Cycles." Princeton University Working Paper.
- Stein, Jeremy C. 1995. "Prices and Trading Volume in the Housing Market: A Model with Down-Payment Effects." *Quarterly Journal of Economics*, 110(2), 379-406.
- Wallison, Peter J. "The True Origins of This Financial Crisis," *The American Spectator*, February 2009, accessed August 13, 2014, <http://spectator.org/articles/42211/true-origins-financial-crisis>.
- Wheaton, William C. 1990. "Vacancy, Search, and Prices in a Housing Market Matching Model." *Journal of Political Economy*, 98(6): 1270-1292.

Wheaton, William C., and Gleb Nechayev. 2008. "The 1998-2005 Housing "Bubble" and the current "Correction": What's Different This Time?" *Journal of Real Estate Research*, 30(1): 1-26.

Yellen, Janet L. 2005. "Housing Bubbles and Monetary Policy" Presentation to the Fourth Annual Haas Gala. San Francisco, CA. At <http://www.frbsf.org/our-district/press/presidents-speeches/yellen-speeches/2005/october/housing-bubbles-and-monetary-policy/051021.pdf>

Table 1
Correlation of Price Growth on Lag of Price Growth

(1)	(2)	(3)	(4)	(5)	(6)
<i>Year</i>	<i>Log Growth from a Year Ago</i>	<i>Coefficient on Lag Growth</i>	<i>SE on Lag Growth</i>	<i>r²</i>	<i>Observations</i>
1980	-0.03	0.00	0.15	0.00	79
1981	-0.04	0.29	0.10	0.07	116
1982	-0.01	0.20	0.12	0.02	131
1983	-0.01	0.03	0.06	0.00	135
1984	-0.01	0.08	0.05	0.02	146
1985	0.00	0.37	0.05	0.24	168
1986	0.03	0.59	0.05	0.42	187
1987	0.02	0.81	0.05	0.55	214
1988	-0.01	0.78	0.06	0.42	238
1989	0.00	0.33	0.04	0.16	297
1990	0.00	0.34	0.06	0.10	326
1991	-0.01	0.11	0.04	0.02	337
1992	0.01	0.21	0.02	0.19	349
1993	0.00	0.68	0.04	0.41	359
1994	0.02	0.89	0.04	0.56	366
1995	0.00	1.14	0.05	0.54	381
1996	0.02	0.17	0.02	0.15	392
1997	0.00	0.52	0.05	0.20	396
1998	0.03	0.17	0.03	0.07	397
1999	0.01	0.46	0.04	0.21	397
2000	0.01	1.19	0.08	0.33	399
2001	0.04	0.57	0.03	0.41	399
2002	0.03	0.44	0.03	0.35	399
2003	0.03	1.10	0.04	0.70	400
2004	0.04	1.11	0.03	0.73	401
2005	0.06	1.48	0.04	0.74	401
2006	0.07	0.83	0.04	0.57	401
2007	0.01	0.02	0.03	0.00	401
2008	-0.05	0.52	0.07	0.13	401
2009	-0.04	1.22	0.04	0.69	401
2010	-0.08	0.33	0.02	0.43	401
2011	-0.06	0.54	0.02	0.54	401
2012	-0.03	0.58	0.04	0.36	401

Source: FHFA

Table 2
Fixed Supply Model

(1)	(2)	(3)	(4)	(5)
Horizon	Medium Persistence		High Persistence	
	Rational	Projection	Rational	Projection
<i>Price Change Volatility</i>				
1 year	32,600	52,800	29,800	349,000
3 year	56,700	86,000	51,300	649,000
5 year	72,900	94,000	65,000	434,600
<i>Price Change Serial Correlation</i>				
1 year	0.01	0.05	0.01	0.35
3 year	-0.01	-0.34	-0.04	-0.85
5 year	0.00	0.20	0.00	-0.20

Table 3
Variable Supply with Low Construction Costs

(1)	(2)	(3)	(4)	(5)	(6)
Horizon	Full Rational	$\tilde{I} = I_t$		$\tilde{I} = I_{t-1}$	
		Semi	Rational	Semi	Rational
<i>Price Change Volatility</i>					
1 year	6,000	50,400	51,300	51,600	52,500
3 year	9,700	50,500	51,300	73,000	74,300
5 year	11,300	50,700	51,300	73,000	74,300
<i>Price Change Serial Correlation</i>					
1 year	-0.03	-0.50	-0.50	0.00	0.00
3 year	-0.27	-0.50	-0.50	-0.50	-0.50
5 year	-0.37	-0.49	-0.50	-0.50	-0.50
<i>Construction Volatility</i>					
1 year	5,500	2,000	2,000	2,000	2,000
3 year	14,600	5,900	6,000	5,900	6,000
5 year	22,300	9,600	9,800	9,600	9,800
<i>Construction Serial Correlation</i>					
1 year	0.75	0.96	0.96	0.96	0.96
3 year	0.55	0.92	0.92	0.92	0.92
5 year	0.41	0.88	0.87	0.88	0.87

Figure 1

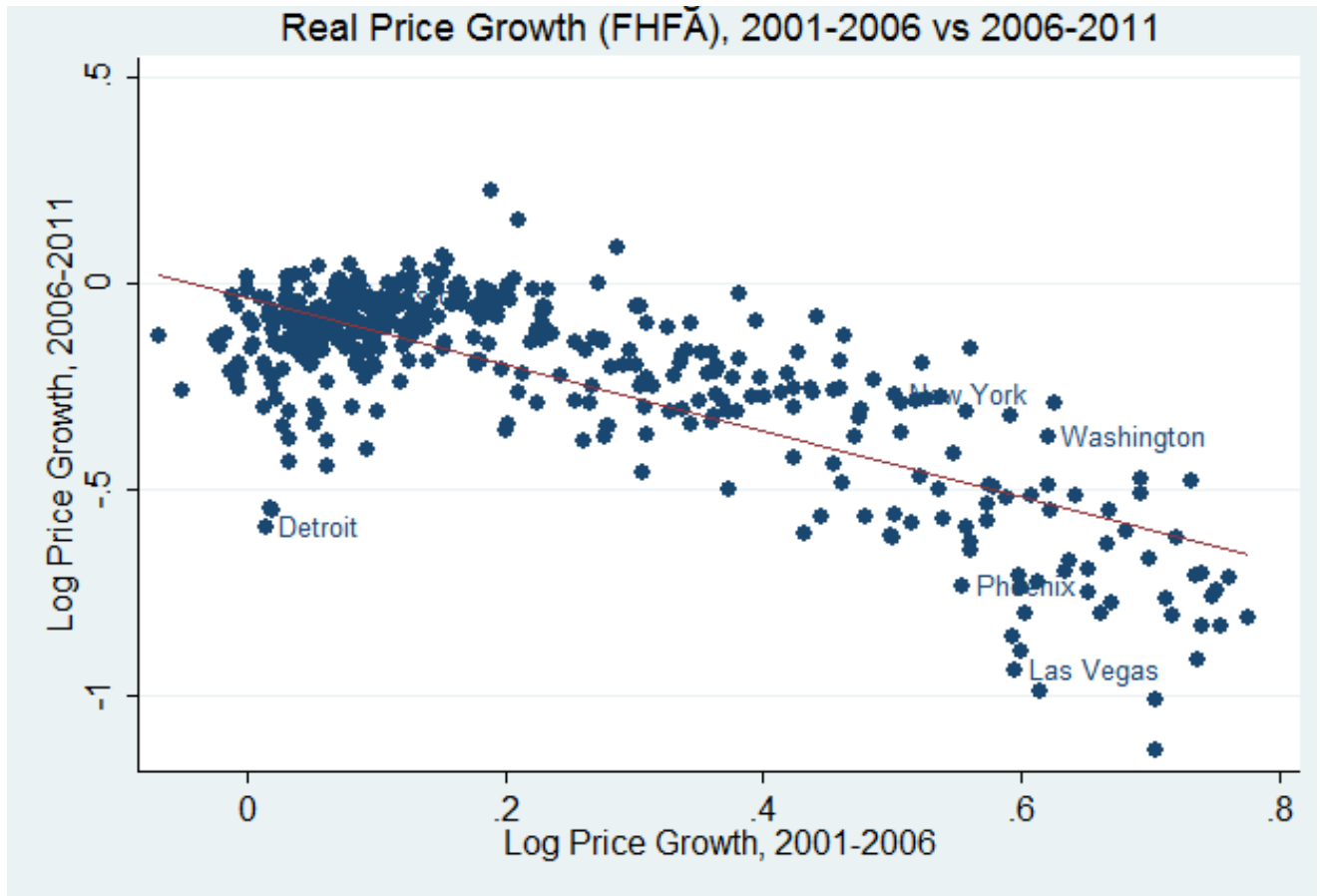


Figure 2

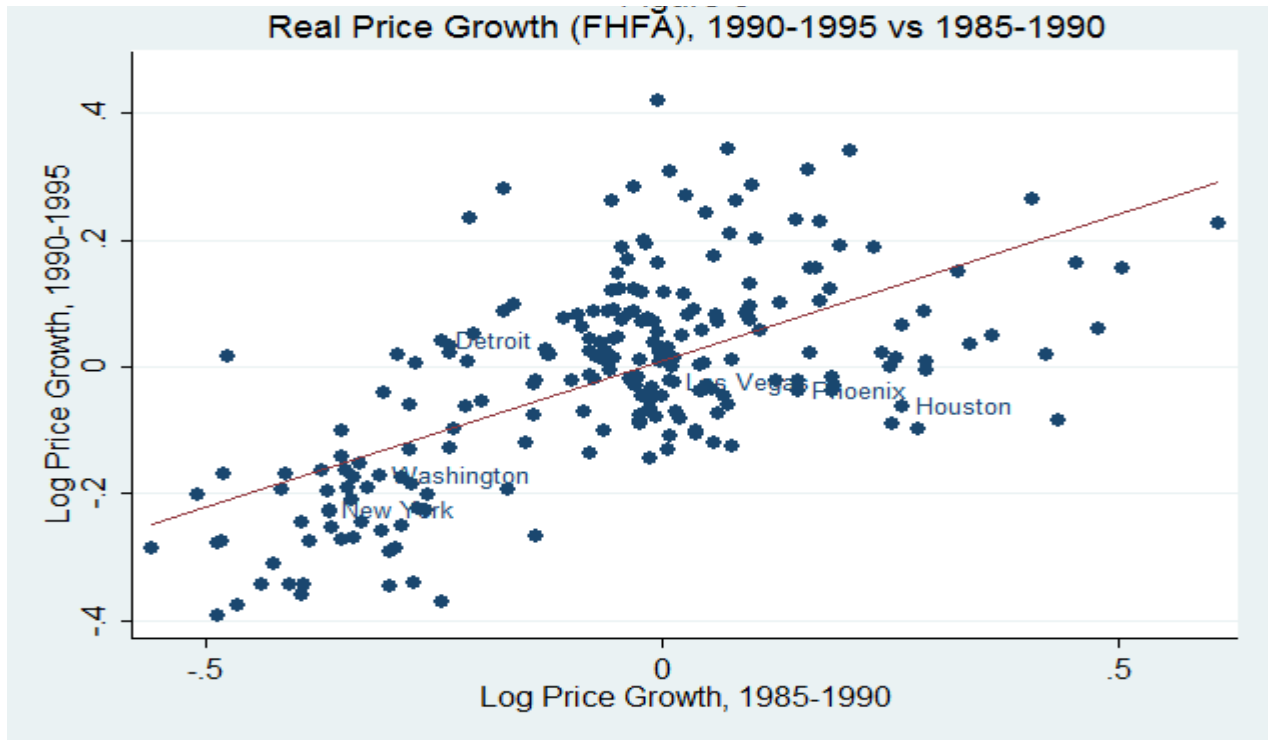


Figure 3

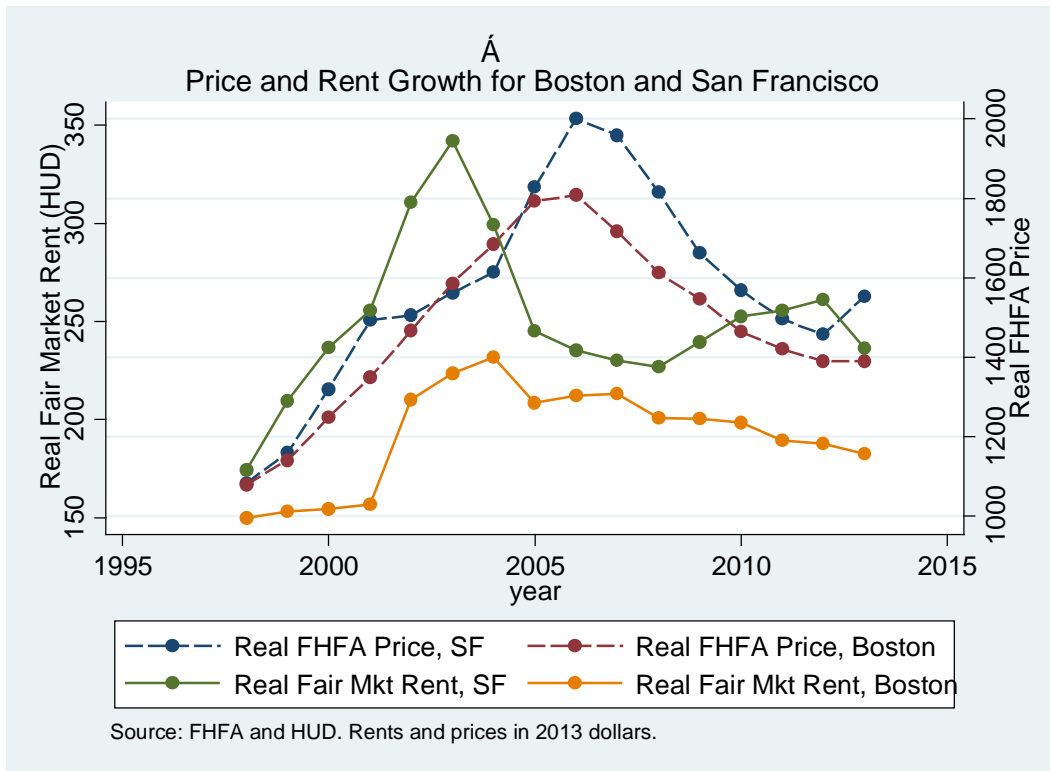
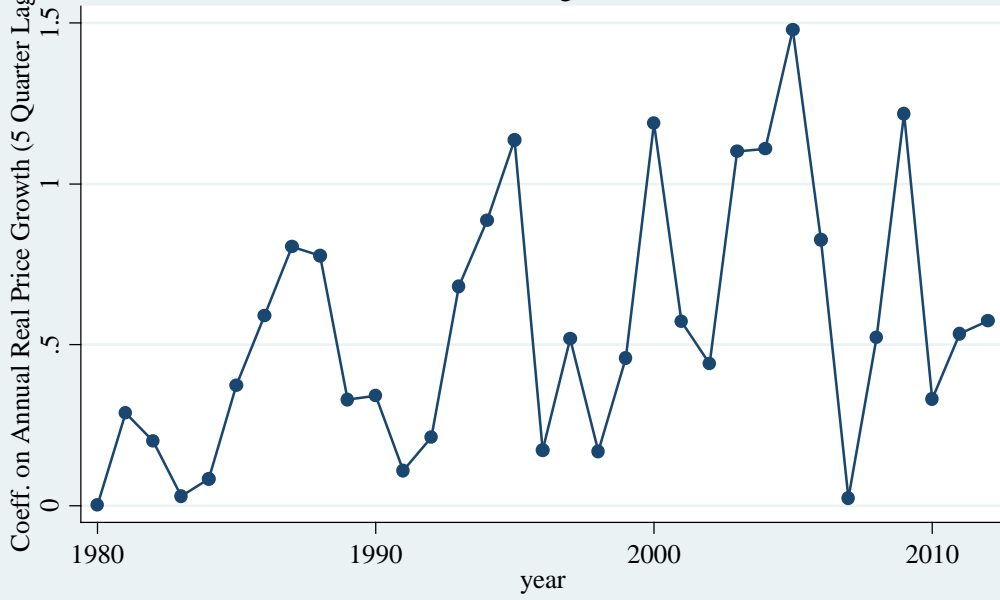


Figure 4
Real Annual Price Growth on Lag of Real Annual Price Growth



Note: Dependent variable is 1st Quarter Annual Growth
Source: FHFA