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### **Bubbles, Post-Crash Dynamics, and the Housing Market**

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## **Bubbles, Post-Crash Dynamics, and the Housing Market**

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## Abstract

This paper documents and explains previously unrecognized post-crash dynamics following the collapse of a housing market bubble. Although home prices in Phoenix doubled 2004-2006, the relative price of small-to-large homes remained strikingly constant. That changed following the crash when small-home relative prices fell up to 80 percent. We argue that post-crash exit of speculative developers allowed relative prices to diverge while differences in demand elasticities and turnover associated with job loss pushed small-home values down relative to large homes. As speculative developers return relative prices should revert back to pre-boom levels, consistent with mean reversion that began in 2011. The implied post-crash mispricing of homes can be mitigated if cities publish size-stratified home price indexes.

## I. Introduction

Between January 2004 and January 2006 housing prices in the Phoenix metropolitan area doubled. This dramatic rise in values is displayed in Figure 1a which plots indexes from a repeat sales model of single family residential housing transactions in Phoenix from early 2000 to 2011. Also apparent in Figure 1a, prices rose at a smooth and modest pace from 2000 through 2003, and then crashed 2007-2009 until stabilizing in early 2009. The intense boom-bust pattern in price is mirrored in home sales in Figure 1b: sales reached record highs in mid-2005 and all but disappeared by mid-2007. These patterns are well known. Figures 2a and 2b, however, illuminate a further set of patterns that have largely gone unnoticed. Figure 2a plots house price indexes 2000-2013 for different home-size segments that capture the 5<sup>th</sup> to the 95<sup>th</sup> size percentiles of the market.<sup>1</sup> Notice that prices move together across market segments up to the peak of the boom in 2006. As the crash deepened, however, prices fell below pre-boom levels and small-home prices fell further than large-home values. Markets began to recover in 2011 with home prices rising roughly 50 percent 2011-2013. Nevertheless, construction remained depressed (Figure 2b) and relative prices exhibit mean reversion with small-home prices rising further than large-home prices (Figure 2a). We emphasize that these patterns are robust to more refined stratifications of the market into twenty size categories as will be presented later in the paper.

The primary goal of this paper is to explain these patterns and to bring to light a number of features of post-crash housing market dynamics that have escaped attention. We develop a

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<sup>1</sup> Stratifying the market in this manner bears some resemblance to recent papers by Leventis (2012), McMannus (2013), and McMillen (2013), all of which stratify repeat sales measures of housing markets into price tiers (e.g. high, medium, and low). Nevertheless, our emphasis on house size as the stratifying measure is fundamentally different as house size remains fixed across turnover dates in contrast to relative price levels. In addition, our emphasis on house size allows us to tie our empirical work to underlying economic forces as will become apparent. The price-tier papers, in contrast, tend to focus on statistical properties of the estimated indexes without seeking to explain the underlying patterns.

simple model that highlights the role of speculative developers in a growing market. A central prediction of the model is that the presence of spec-home developers should ensure that relative prices remain constant across home-size segments because developers direct new construction to the highest yielding market segment. Post-crash exit of spec-home developers allows for the possibility that relative prices across home-size segments diverge, but does not ensure that this will occur or that most of the other patterns noted above will emerge. To explain these other patterns additional arguments are needed.

As our initial point of departure, we consider the nature of the 2004-2006 price boom as this has implications for post-crash dynamics. Three pieces of evidence suggest that the boom was a bubble driven by unrealistic buyer expectations of future returns. First, despite rapid growth since 1990, the Phoenix MSA is still surrounded by vast amounts of open, easily developed land.<sup>2</sup> This suggests that the long run supply of land for new development should remain highly elastic for years to come, an implication of which is that even large positive demand shocks should have little impact on price.<sup>3</sup> Second, drawing on the present-value model, we evaluate the change in investor expectations of future rent growth necessary to support the doubling of price 2004-2006. We argue that results strain credibility. Third, quality adjusted sale-to-list price ratios also shot up in 2004 for small homes up to mansions. We argue that this pattern is consistent with buyer expectations of future housing returns having risen beyond those of seller expectations. This interpretation is especially cogent in the market for mansions. In

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<sup>2</sup> Haughwout, et al (2012) report that during the 2000-2006 housing boom in Phoenix, quarterly sales of raw land for new residential development typically totaled 10,000-20,000 acres per quarter.

<sup>3</sup> The 1975-2011 history of house price movements in the United States offers a useful comparison. Based on repeat sale indexes from the Federal Housing and Finance Agency (FHFA), Rosenthal (forthcoming), reports that real annual house price growth at the national level in the United States averaged roughly 0.66 percent per year between 1975 and 2011. At the census region level, analogous values range from small negative rates up to a high of 2.2 percent per year for the Pacific region. Measured at these levels of geography, the United States has extensive open land and a very elastic supply function for new development. Just as extensive supplies of open land have dampened house price growth in the U.S. overall, the same should apply to Phoenix.

that sector, the idiosyncratic nature of the homes and related institutional features ensure that sellers never adopt a bidding war marketing strategy in which list price is set below anticipated sale price. Based on these arguments we conclude that the 2004-2006 boom was a bubble.

In the aftermath of a price bubble, a simple supply-demand model indicates that price must fall below pre-boom levels in order to clear the market given unwarranted construction in the years prior to the crash. This is consistent with patterns above. Downward sloping demand for home size also ensures that any divergence in relative price across home-size segments must be associated with greater declines in small-home values. This is because buyers will never bid more for a small home than a large home, *ceteris paribus*. Unusually high post-crash turnover rates among smaller homes because of job loss and mortgage default then pushed small home prices down relative to larger homes, something we confirm empirically. Inelastic demand for smaller homes may also contribute to post-crash price divergence across home-size segments.

As the recovery sets in, our simple model predicts sharp increases in price with limited new construction as observed in Figure 2b. A related implication is that price increases should moderate once price rises to a level sufficient to prompt new construction. At that point, speculative developers will once again become active and relative prices across home-size segments should return to pre-boom levels. Anticipation of that event helps to explain mean reversion in relative prices which is evident since 2011 (see Figure 2a).

A problem with this modeling structure is that as markets recover, we *expect* small home prices to rise relative to larger home values based on contemporaneous information. Assuming similar risk exposure across home-size segments, this suggests that small homes are expected to yield higher risk-adjusted returns, a violation of the efficient market hypothesis. We believe that the resolution of this inconsistency is that most investors in the Phoenix housing market are

*unaware* of the patterns highlighted above. In part, this is because we are unaware of any widely publicized house price indexes for Phoenix or any other major metropolitan area that are stratified based on home-size segments. An implication is that Phoenix and other cities prone to volatile housing markets can reduce mispricing by producing and publicizing size-stratified local house price indexes on a contemporaneous basis.

To develop these and other results, the following section outlines a simple model of the problem faced by a speculative housing developer. Section 3 describes our data and outlines the repeat-estimation method used to produce the various quality adjusted indexes for our analysis. Section 4 provides evidence that the 2004-2006 boom in price was a bubble in the sense that price rose above levels that forward looking investors should have recognized as sustainable. Section 5 examines post-crash house price dynamics and emphasizes the implications of durable housing and turnover. We conclude in Section 6.

## **II. Speculative developers**

This section outlines a simple model that highlights the influence of speculative developers on relative prices across home-size segments of the market. Suppose that housing markets are competitive and there are two types of homes,  $H_1$  and  $H_2$ . Type-1 units are produced using  $\theta$  units of capital ( $k$ ) while type-2 homes are produced using 1 unit of capital. Each unit of capital sells for a price,  $r$ . Spec-home developers purchase  $N$  acres of land and then over time construct different combinations of  $H_1$  and  $H_2$  housing on the site to maximize profits treating the land acquisition as a sunk cost. Local development restrictions in Phoenix typically fix the ratio of floor area to lot size for single family developments. Accordingly, and to simplify, type-1 homes are said to require  $\theta$  units of land while type-2 homes require 1 unit of land.

Given these features, the developer's maximization problem is:

$$\begin{aligned} \text{Max}_{N_1, N_2} [P_1 N_1 - r \theta k N_1] + [P_2 N_2 - r k N_2] \\ \text{s.t. } N = \theta N_1 + N_2 \end{aligned} \quad (2.1)$$

The first order conditions are:

$$\frac{\partial \pi}{\partial N_1} = P_1 - r \theta k - \lambda \theta = 0 \quad (2.2a)$$

$$\frac{\partial \pi}{\partial N_2} = P_2 - r k - \lambda = 0 \quad (2.2b)$$

Setting (2.2a) equal to (2.2b), this implies that

$$\frac{P_1}{P_2} = \theta \quad (2.3)$$

Although expression (2.3) is intuitive, it has far reaching implications. It says that when speculative developers are active in the market, the relative price of the two housing types should remain constant provided the technology associated with construction of type-1 and type-2 homes doesn't change. This fits the pattern of house price movements across home-size segments described earlier for 2000-2006. It also suggests that any divergence in relative prices should be temporary, consistent with evidence of mean reversion in relative prices that coincided with the recovery that began in 2011 (see Figure 2a).

A further implication of expression (2.3) is that relative prices could diverge from  $\theta$  if speculative developers are absent. This is especially relevant to the post-crash environment in Phoenix given patterns described in Figure 2b. Housing starts were at 3,000 units per month just prior to the boom, peaked at 6,000 units per month in 2005, and fell back to 3,000 units per month by mid-2008. By early 2009, housing starts had fallen below 1,000 units per month and have remained below that level at least until mid-2013. Thus, speculative developers had largely

exited the market by 2009 removing their disciplining effect on relative prices across home-size segments.

It should be emphasized, however, that the post-crash exit of speculative developers does not necessarily ensure a divergence in relative prices. That is because the model above considers only the supply side of the market and only one component of supply (new construction as opposed to existing stock). To explain the post-crash divergence of relative prices described in the Introduction, it is necessary to allow for the effect of durable stocks of existing housing on supply, turnover rates, and also the nature and influence of demand. These features of the market are considered in the sections to follow.

### **III. Data and repeat-index econometric methodology**

#### *3.1 Data*

Data for the sale of residential real estate inclusive of raw land are obtained from three primary sources. The first source is the Arizona Regional Multiple Listing Service (ARMLS).<sup>4</sup> These data are proprietary and start January, 2000 and end October, 2013. We use data for the Phoenix metropolitan area (Maricopa County). There are a total of 1,540,593 observations over this period prior to our cleaning of the data; after cleaning there are 1,401,801 observations.<sup>5</sup> Each observation in the dataset is a listing of a single family house available for sale. In addition to all sold transactions (849,349), the data also contain listings that did not sell or were withdrawn from the market (552,452). Each listing contains information on property attributes, buyer and seller agent, as well as listing price and days on market. Both the original listing price

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<sup>4</sup>A multiple listing service (MLS) is a private information exchange that includes listing agreements and sale transactions. All real estate agents who agree to share their listing agreements and commissions can use the MLS system. The goal of this sharing arrangement is to find buyers for properties more quickly than agents could on their own. The broker-controlled MLS system has been the primary way that buyers and sellers connect with one another.

<sup>5</sup> Cleaning procedures are outlined in the appendix.

and the final listing price are reported. To see what specific information is included in the listing, the Arizona realtor website <http://www.armls.com/home> provides the latest version of ARMLS forms for residential sales, residential rental, as well as lot and land in addition to market statistics. The ARMLS is one of the largest MLS in the nation in terms of membership.<sup>6</sup>

The second data source includes property records from the Maricopa County Assessor's office. These were obtained in two ways. We initially obtained a subset of the assessment authority database from ION Data Express (<http://www.iondataexpress.com/>), a company that repackages and sells assessment data. Those data contains sales on all real estate in Maricopa County, the most populous county in Arizona, which includes the Phoenix metropolitan area. The database includes the transactions for vacant land and single family houses. The ION data start earlier than the ARMLS in January 1988 but also end in November 2011. There are a total of 2,357,601 transactions over this period. Each observation in this data set contains information on the buyer and seller of the property as well as attributes of the property. Buyers and sellers are categorized as companies, developers, banks / trusts, men, women or couples. In addition to categories, the buyer and seller names are also recorded. The attributes of the properties are both geographic and physical. The city, subdivision and lot number are recorded in the data. Further, the number of bedrooms, number of bathrooms, pool size, heating source, roof quality, square footage of living space and lot square footage is included.

While the ION data contains sales reported in ARMLS as well as for sale by owner (FSBO) transactions, it does not have information on the original list price nor the final list price.

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<sup>6</sup>See [http://en.wikipedia.org/wiki/Multiple\\_listing\\_service](http://en.wikipedia.org/wiki/Multiple_listing_service). The ARMLS service currently has approximately 29,000 subscribers (<http://www.armls.com/about-armls/mission-history>). In terms of membership count of Realtors by state as of 2011, Arizona ranked seventh after California, Florida, Texas, New York, New Jersey and Illinois. Not all realtors belong to the MLS system. (<http://www.realtor.org/sites/default/files/reports/2012/nar-membership-count-by-state-historical.pdf>). Phoenix currently ranks 10<sup>th</sup> (as of May 25, 2013) in terms of the number of total listings by city (<http://www.realtor.com/data-portal/Real-Estate-Statistics.aspx?source=web>).

Besides this, it does not report information on rents, buyer/seller agent and days on the market. The two databases thus complement one another. Over the January 2000 to November 2011 period over which both databases overlap with one another, the number of single family homes that sold in the ION data is 1,175,566 compared to 825,186 sold transactions reported in the ARMLS database. There were 1,369,228 houses that were listed with ARMLS over this period.<sup>7</sup> The ION data includes builder sales to initial homeowners while the ARMLS does not. In total, the ARMLS contains roughly 70% ( $825,186/1,175,566$ ) of sales relative to those registered with the Assessor's office and reported in the ION data.

We also obtained the complete set of property records from the Maricopa County Assessor office broadening our data set to include virtually all properties in the Phoenix MSA, and importantly, extending the data series through July, 2013. These records were obtained from Arizona State University. The records enable us to produce accurate counts of the total stock of housing by size-segment in the market in addition to extending the time horizon of the analysis.

### *3.2 Repeat index methodology*

The empirical analyses to follow evaluate a numbers of series that must first be estimated using the data described above. Those series measure the percent change in key housing market outcome variables holding constant the quality of the underlying housing units. Outcome measures include home sale prices, sale-to-list price ratios, and rents for rental units. For each index, we use the same methodology as for widely used repeat sale indexes that were first developed by Bailey, Muth, and Nourse (1963) and later popularized by Case and Shiller (1989). More precisely, consider two successive times when a home turns over at time  $t$  and  $t+\tau$ ,

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<sup>7</sup> This includes expired listings, listings that were withdrawn, homes listed more than once due to an expired listing.

respectively. For each of these turnovers, the outcome of interest (e.g. sale price) is denoted as  $Y$  and can be written as

$$Y_t = e^{\gamma_t} f(\mathbf{X}_t; \boldsymbol{\beta}_t) , \quad (3.1a)$$

$$Y_{t+\tau} = e^{\gamma_{t+\tau}} f(\mathbf{X}_{t+\tau}; \boldsymbol{\beta}_{t+\tau}) . \quad (3.1b)$$

where  $f(\mathbf{X}; \boldsymbol{\beta})$  is an unknown and possibly non-linear function of the structural and neighborhood characteristics of the home ( $\mathbf{X}$ ) and their corresponding coefficients ( $\boldsymbol{\beta}$ ). The terms  $\gamma_t$  and  $\gamma_{t+\tau}$  are the parameters of interest and reflect the difference in  $Y$  across home turnover dates,  $t$  and  $t + \tau$ .

If  $\mathbf{X}$  and  $\boldsymbol{\beta}$  are unchanged between  $t$  and  $t + \tau$ , taking logs and rearranging gives the log change in  $Y$  between turnovers,

$$\log\left(\frac{Y_{t+\tau}}{Y_t}\right) = \gamma_{t+\tau} - \gamma_t + \omega_{t+\tau} , \quad (3.2)$$

where  $\omega$  is a random error term and  $f(\mathbf{X}; \boldsymbol{\beta})$  drops out of the model. For a sample of properties indexed by  $i$  ( $i = 1, \dots, n$ ) that turnover at various dates, the model in (2) becomes,

$$\log\left(\frac{Y_{t+\tau,i}}{Y_{t,i}}\right) = \sum_{t=1}^{\tau_i} \gamma_t D_{t,i} + \omega_{t,i} \quad \text{for home } i = 1, \dots, n \quad (3.3)$$

where  $D_t$  equals -1, 0 or 1 depending on whether a given property at time  $t$  turns over for the first time, does not turn over, or turns over for the second time, respectively.

Equation (3.3) is the standard repeat sales specification used by Case and Shiller (1989), Harding et al (2007), and many others.<sup>8</sup> Given the identifying assumptions, time invariant house and neighborhood attributes difference away. The  $\gamma$  parameters can then be estimated by regressing the log change in  $Y$  between turnover dates on the vector  $\mathbf{D}$ . Provided that  $\mathbf{X}$  and  $\boldsymbol{\beta}$  are unchanged between turnover dates, estimates of the  $\gamma$ -vector indicate the rate at which  $Y$  changes with the passage of time. By substituting in different outcome measures for  $Y$ , we

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<sup>8</sup> Rosenthal (forthcoming) recently adapted the model to consider changes in the income of arriving occupants across turnover dates. We also extend the model here by applying it to sale-to-list price ratios and rents.

estimate the rate at which house prices change over time, in addition to the rate at which sale-to-list price ratios, and rents also change with the passage of time. In most cases, we estimate these series on a monthly basis from January, 2000 to July, 2013.

## IV. Housing price bubble

### 4.1 Fundamental value

A long tradition in finance has emphasized that with well-functioning, competitive markets, asset price should equal the discounted stream of expected future rents.

$$P_t = \sum_{t=0}^{\infty} E[R_t] / (1 + d)^t \quad (4.1)$$

Nevertheless, direct tests of the present value relationship have proved difficult to defend because of the inherently noisy task of measuring expectations of future returns (e.g. Flood and Hodrick (1990), for example).<sup>9</sup> Bearing this in mind, Figure 3 plots the repeat sale price index as the heavy black line. On the same vertical scale, the repeat rent index is plotted as the black line with yellow (light colored) squares. Comparing the two series, it is obvious that the rent index is flat in comparison to the house price index. However, when the repeat rent index is scaled by a factor of 10 (the dotted line), it is apparent that price movements lead changes in rent and that the two series approximately mirror each other.

To clarify these patterns, suppose that expected real rents are constant so that (4.1) simplifies to  $P = R/d$ . Holding  $d$  constant, temporal variation in  $R$  scaled by  $1/d$  should be similar to changes in  $P$ . The patterns in Figure 3, therefore, provide partial support for the

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<sup>9</sup> Shiller (1981) was among the first of the present value studies and showed that stock prices displayed excess volatility relative to dividends. In much of the following literature, a common practice when estimating (4.1) has been to use ex post measures of rent to proxy for ex ante investor expectations. Meese and Wallace (1994) is an example of this in the real estate area.

present value expression in (4.1). Nevertheless, this does not preclude the presence of a price bubble for reasons to follow.

#### 4.2 Expectations of future rent growth

Consider now the following question. By how much would investor expectations of future real annual rent growth have to increase to support a doubling of price from January 2004 to January 2006? To address this question, expression (4.1) is re-written imposing the assumption that real rents grow at a constant annual rate  $g$  such that  $R_{t+1} = (1+g)R_t$ , and that the discount rate remains fixed at  $d$  with for  $g < d$ . For the initial period 0, (4.1) simplifies to,<sup>10</sup>

$$P_0 = R_0 \sum_{t=0}^{\infty} \left[ \frac{1+g}{1+d} \right]^t \quad . \quad (4.2)$$

A doubling of price between periods 0 and  $k$  can be written as,

$$2 = P_k / P_0 = \frac{R_k}{R_0} \left[ \frac{1+g_k}{1+g_0} \right] \left[ \frac{d-g_0}{d-g_k} \right] \quad . \quad (4.3)$$

From Figure 3, the ratio,  $R_{2006}/R_{2004}$  based on beginning of year (January) values is 106/96 or 1.1.

We impose that value on (4.3) and normalize  $g_0$  to zero so that  $g_k$  measures the change in anticipated growth rates as of period  $k$  relative to period 0. Solving for  $g_k$  then yields:

$$1.82 = \left[ \frac{d+dg_k}{d-g_k} \right] \rightarrow g_k = 0.45d - \frac{dg_k}{1.82} \quad . \quad (4.4)$$

For plausible values of  $d$  and  $g_k$ , the term  $dg_k$  is small so  $g_k \approx 0.45d$ .<sup>11</sup>

Expression (4.4) implicitly assumes that investors have an infinite horizon, consistent with an efficient market. In contrast, in Table 1 we highlight the change in  $g$  necessary to

<sup>10</sup> From (4.2),  $g$  must be less than  $d$  so that  $(1+g)/(1+d) < 1$  which is necessary for  $P_0$  to be finite.

<sup>11</sup> For example, with  $d = 0.02$  and  $g = 0.01$ ,  $dg$  is 0.0002 and can be ignored in expression (4.4).

support a doubling of price between 2004-2006 for investor horizons of infinity, 100 years, 50 years, and 25 years. To simplify, we set  $R_{2006}/R_{2004}$  to 1, roughly consistent with the patterns in Figure 3, and normalize the year-2004 value for  $g_0$  to be zero so that  $g_k$  reflects the change in  $g$  between 2004 and 2006 that would be necessary to support a doubling of price. For each investor horizon, we calculate  $g_k$  for a pre-specified real annual discount rate.

The primary challenge in conducting this sort of “what-if” analysis is to select an appropriate discount rate. Some guidance can be gained by considering historical real rates of return on stocks and U.S. government securities. Using data from 1926-2006, Siegel (2008) calculates that the real (constant dollar) annualized return on stocks was 6.8 percent per year based on geometric averaging. For 10-year US Treasury bonds Siegel reports an analogous return of 2.4 percent and for 3-month Treasury bills 0.7 percent (see Siegel (2008), pages 13 and 15). We believe that most investors would perceive real estate to be a riskier investment than short and long term U.S. government securities but safer than a balanced portfolio of stocks. This suggests that a credible real discount rate for real estate investments could be in the neighborhood of 3 percent. In Table 1 we experiment with discounts rates from 2.0 to 5.0 percent in 0.5 percentage point increments.<sup>12</sup>

In Table 1, observe that with an infinite investor horizon, the change in  $g$  necessary to support a doubling of price between 2004 and 2006 varies from 1 to 2.5 percentage points for discount rates from 2 to 5 percent, respectively. Even with a 2 percent discount rate, which strikes us as conservative,  $g_k$  is quite large when one considers the compounding effect on real rents over an infinite horizon. For shorter horizons, as with 50 or 25 years, the values for  $g_k$  are even larger. As an example, with a 3 percent real discount rate,  $g_k$  equals 3.12 percentage points

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<sup>12</sup> Larger discount rates cause  $g_k$  to increase but by an amount that declines as the investor horizon becomes shorter.

for a 50 year horizon and 5.53 percentage points for a 25 year horizon. At these rates, real rents in Phoenix twenty-five years in the future would be 2.15 and 3.84 times higher than at present, respectively. Even if one assumes a very low real discount rate and a very long investor horizon, the values for  $g_k$  in Table 2 would require extraordinary growth in population and employment to be realized given the extensive degree of developable land surrounding Phoenix. These patterns suggest that the doubling in price between 2004 and 2006 was a bubble that was driven by factors other than forward looking investor behavior. This view is reinforced in the next section.

#### *4.3 Sale-to-list price ratios*

Although the analysis above is suggestive that the 2004-2006 price boom was a bubble, it suffers from the limitation that we do not actually know the rate at which future anticipated returns should be discounted. This section adopts a different modeling strategy that is also suggestive that the 2004-2006 boom was a bubble.

With efficient markets, all investors should have access to the same publicly available information and should have similar expectations of future rents in expression (4.1), on average. This implies that any difference between seller versus buyer assessment of a property's current market value should be small and stable over time.<sup>13</sup> Figures 4a and 4b provide evidence on this point. Figure 4a displays repeat indexes for sale-to-list price ratios based on both the original list price and the final list price with both indexes normalized to 100 in year-2000.<sup>14</sup> It is worth emphasizing that the indexes indicate percentage changes in sale-to-list ratios over time but do not say anything about the level of those ratios.

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<sup>13</sup> Although we have no particular reason to think that buyers and sellers have different discount rates, our arguments below only require that any difference in buyer/seller discount rates is stable over time.

<sup>14</sup> The indexes were estimated as described in section 3 with the sale-to-list price ratio for a given home turnover substituted for  $Y_t$  in expression (3.3).

Notice first that both indexes largely move together until markets crashed after which sale-to-list price ratios based on original list price fell notably further relative to ratios based on the final list price (see Figure 4a). The resulting spread is suggestive that as the crash deepened, sellers initially resisted setting their list prices low relative to the boom years but eventually cut their asking prices when their homes did not sell (recall that few homes sold in 2007).<sup>15</sup> Such behavior is consistent with evidence from Genesove and Mayer (2001) and Engelhardt (2003) who argue that loss aversion and credit concerns discourage sellers from setting list prices below market values that prevailed just a few years earlier. While striking, these patterns are not central to our assessment of what drove the 2004-2006 boom.

Focus now on the spike in sale-to-list price ratios in 2004 and recall that prices were rising at this time (see Figure 4b). For that reason, loss aversion and credit concerns are largely not relevant. On the other hand, two competing views of how sellers set list price lead to quite different interpretations of the jump in sale-to-list price ratios. Under the “conventional” view, sellers set list price above anticipated selling price by an amount that increases with uncertainty about a home’s market value.<sup>16</sup> Consistent with that view, in Figure 5a notice that the median sale-to-list price ratio among homes between the 25<sup>th</sup> and 75<sup>th</sup> size percentile (based on floor space) was roughly 98 percent over the 2000-2003 pre-boom period when markets were stable. Moreover, over the entire sample horizon, sale-to-list price ratios were notably lower for mansions (the top 1 percent size percentile) which trade in thin markets and for which there is

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<sup>15</sup> It is worth noting that downward price stickiness could also occur if sellers are risk-neutral, housing wealth maximizers as in Merlo, Ortalo-Magné, and Rust (2008).

<sup>16</sup> This view is reinforced by seller agent contract provisions that typically oblige sellers to compensate the agent if a bid is received without contingencies at or above asking price irrespective of whether a sale occurs. Han and Strange (2013) note this feature of the seller-agent contract as well in explaining why the list price is relevant. Partly for these reasons, the seller’s list price is often perceived as an implicit promise to sell the home if a bid comes in at or above asking price.

considerable uncertainty about a given home's market value.<sup>17</sup> A completely different view of how sellers set list price is that as markets heat up, sellers increasingly adopt a “bidding war” marketing strategy in which they intentionally set list price below perceived market values. The intent in pursuing such a strategy is to generate excitement, multiple simultaneous bids, and a pseudo auction that results in a quicker sale at a higher price (e.g. Han and Strange (2011, 2013), Haurin (2013)).<sup>18</sup>

Under the conventional view of how a home is marketed, the increase in sale-to-list ratio implies that seller and buyer expectations of future returns increasingly diverged. Absent other considerations, that should not occur with informed, forward looking agents and would be suggestive of mispricing in the Phoenix housing market and the possible formation of a price bubble. If instead, sellers in 2004 shifted towards a bidding war strategy to market their homes then the spike in sale-to-list price ratio would not necessarily be indicative of inefficiency and the formation of a price bubble.

The market for mansions provides an opportunity to control for confounding effects of seller marketing strategies. For a variety of conceptual and institutional reasons, sellers of mansions never adopt a bidding war strategy. Mansions have highly idiosyncratic features and

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<sup>17</sup> Sass (1988), Glower, Haurin and Hendershott (1998), and Haurin, et al (2010) all find that sellers of unusual homes set higher list prices relative to sale price in comparison to homes with more common attributes and which sell in thicker markets. Additional support for this view is provided by Zuehlke (1987) and Haurin (1988) who show that common style homes and those sold in thicker markets sell more quickly, consistent with lower asking prices. See also Yavas and Yang (1995), Knight (2002), Anglin, Rutherford and Springer (2003), Merlo and Ortalo-Magne (2004), and Allen, Rutherford and Thomson (2009) among others for related evidence.

<sup>18</sup> Han and Strange (2011, 2013) provide the most careful assessment of the frequency of bidding wars and also have formalized conceptual arguments that help characterize conditions under which sellers may adopt a bidding war strategy, and related, the role of the list price. At the national level, they show that in the 1980s and 1990s, bidding wars – proxied by instances in which homes sold above list price – accounted for roughly 3-5 percent of sales. That number grew to 20 percent in 2000 and has since dropped back to roughly 10 percent. Han and Strange (2011) further show that bidding wars are more common in thick markets with many potential home buyers and large numbers of sales. Haurin et al (2013) recently examined the Columbus, Ohio housing market and concluded that seller marketing strategy must be based at least in part on an auction-like process. See Horowitz (1992), Chen and Rosenthal (1996), Arnold (1999), Knight (2002), Haurin et al. (2010), and Carrillo (forthcoming) for related discussion.

sell in very thin markets where sellers face considerable uncertainty about market value.<sup>19</sup> This greatly increases the risk that multiple bids on a mansion would not arrive at the same time even with list price set well below expected sale price (see Han and Strange (2013) for related discussion). Moreover, mansions require considerable effort to market and take much longer to sell, all of which increases the seller-agent's effort. Seller-agent contracts for mansions recognize this by including additional provisions to ensure that the agent is compensated even if a seller withdraws after a contingent-free bid at or above list price is received.<sup>20</sup> This suggests that sellers of mansions who set artificially low asking prices are at risk of receiving a single offer at list price and being forced into a situation in which they sell the home at a discount. For these reasons, sellers of mansions virtually *never* adopt a bidding war strategy in which they intentionally set list price low relative to expected value.<sup>21</sup>

Figure 5b provides additional context by plotting the percentage of sales with sale-to-list price ratios above 1 for the core of the market (the 25-75<sup>th</sup> size percentile) and mansions based on the original list price. As with Han and Strange (2011), this provides evidence on the

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<sup>19</sup> A Walt Danley newsletter (<http://waltdanley.com/blog/why-zillow-com-zestimates-are-wrong-luxury-homes/>) explains why automated valuation models as used by Zillow.com do not work well for luxury homes in contrast to production homes (tract homes). Danley emphasizes that this is because luxury homes have many idiosyncratic features and amenities and also trade in thin markets.

<sup>20</sup> The duration of the seller-agent contract for mansions is longer (at least one year) than typical contracts as mansions take longer to sell and are often advertised well beyond the immediate metropolitan area. Mansions are shown only by appointment and potential buyers must first go through a prequalification process in which their financial status is documented before an invitation to view the property is extended. Upon placing a bid on the home, prospective buyers of mansions typically are obliged to put down a deposit ("earnest money") of roughly 3-5 percent of the asking price. Additional earnest money must be put down after the appraisal and loan approval are completed. The broker is entitled to 50 percent of the earnest money or commission specified in the contract, whichever is less if the deal fails to occur. Arizona law states that the buyer can cancel a deal for ANY reason within 10 days of signing the purchase contract. Brokers, therefore, have strong incentives to ensure that buyers are qualified and serious about their offer. This increases broker effort and risk.

<sup>21</sup> Buyers of multi-million dollar mansions may also view the list price as a signal of the home's quality and be deterred by a low list price. This sentiment is echoed in Donald Trump's book, the Art of the Deal on page 122. "Mr. Trump," she said, "we're in trouble. Museum Tower just announced its prices and they're much lower than ours." I thought for a minute, and I realized that actually the opposite was true: Museum Tower had just done itself damage. The sort of wealthy people we were competing for don't look for bargains in apartments. They may want bargains in everything else, but when it comes to a home, they want the best, not the best buy. By pricing its apartments lower than ours, Museum Tower had just announced that it was not as good as Trump Tower."

frequency of bidding wars. Notice that prior to 2004 about 10 percent of homes in the core of the market sold above original list price while for mansions the number was about 3 percent. Beginning with the boom in 2004, in the core of the market, the share of homes that sold above list jumped to roughly 45 percent and then crashed beginning in early 2005. Mansions also experienced a rise in the share of homes sold above list but to a much lesser degree.

Figure 6a presents repeat sale price indexes for the core and mansion segments of the market. The plots confirm that mansion prices boomed along with the rest of the market. Moreover, Figure 6b shows that mansion repeat sale-to-list price ratios display the same jump in 2004 as for the rest of the market. Given that mansions are not marketed through a bidding war strategy, we view this as evidence that buyer-seller assessments of market value in the mansion market increasingly diverged in 2004, consistent with mispricing and market inefficiency. With such behavior in the mansion market, and given the weight of the other evidence previously discussed, it seems likely that the entire housing market experienced a bubble over the period driven by unrealistic buyer expectations of future returns.<sup>22</sup>

## **V. Post-crash price dynamics**

Section 2 highlighted the influence of speculative developers on relative prices across home-size segments. The model yielded the important result that relative prices should remain constant when the housing market is growing and speculative developers are building new homes. As noted earlier, that result is consistent with pre-crash patterns in Figure 2a for 2000-2006. The model also implies that any post-crash divergence in relative prices should disappear as markets begin to recover and speculative developers return to the market. That result is also

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<sup>22</sup> Foote, Gerardi, and Willen (2012) also argue that homebuyers acted on overly optimistic beliefs regarding house prices during the recent housing boom.

consistent with evidence in Figure 2a that smaller-home prices rose sharply relative to large-home values as house prices rose 2011-2013. Nevertheless, post-crash exit of speculative developers is not sufficient to ensure divergence in relative prices across home-size segments or the other patterns in Figure 2a that were highlighted earlier. Those patterns include: (i) post-crash prices fell below pre-boom levels, (ii) post-crash prices fell notably further for smaller-home market segments, and (iii) between 2011-2013, construction remained depressed even though prices jumped roughly fifty percent. To explain these patterns we consider additional features of supply and demand.

We began by assuming that over the pre-boom 2000-2003 period prices were determined solely by the underlying fundamentals of supply and demand: no bubble was present at this time. In Figure 7, the pre-boom price corresponds to  $P^E$  at the intersection of supply and demand. Given evidence from the previous section, we assume that the 2004-2006 boom was a bubble in the sense that price rose above levels that could be sustained given underlying fundamentals of demand. In Figure 7, this is illustrated by an increase in price to  $P^B$ . That leads to an expansion of the housing stock from  $H^E$  to  $H^B$  as developers build additional housing but without sustainable demand support. For that reason, we draw the figure without an outward shift in demand to point B. When the bubble bursts as in 2007, and with durable housing (e.g. Glaeser and Gyourko (2005), Houghout et al (2012)), price falls all the way back to  $P^C$  on the demand curve where markets clear. This corresponds to the leveling off of price in 2009 in Figure 2a.

An implication of the model in Figure 7 is that with durable housing (e.g. Glaeser and Gyourko (2005) and Houghout et al (2012)) and downward sloping market demand, price must fall below pre-boom levels following the collapse of a bubble. This is consistent with the patterns noted in Figures 1a and 2a. In Figure 7 it is equivalent to the condition that  $P^C - P^E < 0$ .

To further verify this prediction, we stratify the housing market into seven size segments based on the bottom 1<sup>st</sup> size percentile, the 1-5 percentile, 5-25 percentile, 25-75 percentile, 75-95 percentile, 95-99 percentile, and top 1 percentile. Tables 2a and 2b provide summary measures for each home size category for sample medians (Table 2a) and means (Table 2b). The summary measures include square footage of the floor space, price, sale-to-list price ratios, and days on the market. For reference, median home size is roughly 1,000 square feet for the bottom 1<sup>st</sup> percentile, 2,000 square feet for the 25<sup>th</sup> to 75<sup>th</sup> percentiles, and 7,000 square feet for the 99<sup>th</sup> percentile.

Figure 8a plots separate repeat sale indexes for each home size segment over the period 2000-2010, while Table 3 tabulates corresponding price index levels by home size segment for the pre-boom index level ( $P^E$ ), the bubble price ( $P^B$ ), and the post-crash price ( $P^C$ ). Also displayed in Table 3 are the differences  $P^B - P^E$ ,  $P^B - P^C$ , and  $P^C - P^E$ .<sup>23</sup> Two patterns are especially noteworthy. The first is that except for the very largest homes, the post-crash price index levels fall well below pre-boom levels. This is consistent with the arguments above and provides further support for the view that the price boom was a bubble. Second, Figure 8a and the final column of Table 3 reveal a strikingly monotonic ordering of the difference between the pre-boom and post-crash price ( $P^C - P^E$ ) across home-size segments. That difference is -71 for the bottom 1<sup>st</sup> percentile, -31 for the 25<sup>th</sup>-75<sup>th</sup> percentile, and positive 16 for the top 1 percentile.<sup>24</sup>

Given the similarity of the price boom ( $P^B - P^E$ ) across market segments, one cannot appeal to the size of the bubble to explain the monotonic ordering of  $P^C - P^E$ . A different possibility is that long run supply is more inelastic for larger home-size segments as that would

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<sup>23</sup> Pre-boom, boom, and post-crash values were based on index values from December 2003, January 2006, and January 2009, respectively.

<sup>24</sup> Only the 95<sup>th</sup> to 99<sup>th</sup> percentile and top 1 percentile exhibit (small) positive values for  $P^C - P^E$ . For these market segments, this suggests that there was some net increase in demand between 2004 and 2009 and/or a scaling back of the share of existing stock made available for sale. This latter possibility is discussed further below.

imply less overbuilding in response to the price boom and a smaller spread between  $P^C$  and  $P^E$ . It is true that mansions are only built in select neighborhoods and in principle that could contribute to inelasticity of new supply at the very top of the market. Nevertheless, differences in long run elasticity of supply across home-size segments do not seem to offer a plausible explanation for the market-wide monotonic pattern evident in the last column of Table 3. The technology to build a 2,000 square foot home, for example, is certainly essentially identical to that used to build 1,500 and 2,500 square foot homes. Two alternative mechanisms seem more likely to account for the monotonic increase in post-crash drop in price among smaller home segments. The first considers the influence of turnover in the market on supply while the second recognizes possible differences in the elasticity of demand across home-size segments. We begin with the former.

The model in Figure 7 implicitly treats the entire stock of housing at the depth of the crash as available for sale. In practice, this is not correct as existing homeowners only occasionally put their homes on the market. Turnover rates also differ across home-size segments as do days on the market when a home is being sold. Evidence of the latter is provided in the summary measures reported in Tables 2a and 2b (larger homes take longer to sell). Finally, it is well known that job loss and mortgage defaults both shot up in Phoenix following the 2007 crash. Job loss would have contributed to the sharp increase in mortgage defaults (see Gyourko and Tracy (2014), for example), distressed sales, and turnover as many families were forced out of their homes. If speculative developers were active, expression (2.3) would prevail and even widespread job loss would not have caused prices to diverge across size segments of the market. But with speculative developers absent, the sharp increase in distressed sales and related turnover of stock in the market would have been equivalent to an outward shift in

segment BC of the supply function in Figure 7 creating a disproportionate downward pressure on small-home prices.

To test the arguments above, we further refine our stratification of the market into 20 size categories in five percentile increments from the 0-5 percentile, 5-10 percentile, ... 95-100 percentile. Annual repeat sale indexes for these twenty size categories were estimated and are displayed in Figure 8b. The qualitative patterns for the indexes are as before.

We next treat the 20 home size segments as a cross section and evaluate annual changes in their relative price index levels by constructing a balanced panel from 2000 to 2013. Drawing on that sample, Table 4 presents regression results based on the following estimating equation:

$$\begin{aligned} \frac{P_{t,s}}{P_{2003,s}} = & d_t + \theta_1 \frac{DissSales_{t,s}}{AllSales_{t,s}} + \theta_2 \frac{Listings_{t,s}/Stock_{t,s}}{Listings_{2003,s}/Stock_{2003,s}} \\ & + \theta_3 Log(SpecSales)_{t,s} + \theta_4 Log(SpecSales)_{t,s} \frac{DissSales_{t,s}}{AllSales_{t,s}} \quad (5.1) \\ & + \theta_5 Log(SpecSales)_{t,s} \frac{Listings_{t,s}/Stock_{t,s}}{Listings_{2003,s}/Stock_{2003,s}} + e_{t,s} \end{aligned}$$

In this expression, we treat the pre-boom year-2003 as the base year. Accordingly, the dependent variable is the percent difference in quality adjusted house price between year  $t$  and 2003 for a given size segment  $s$ . The vector  $d_t$  are year fixed effects. The variable  $DissSales/AllSales$  is the share of distressed sales from among all sales in the MLS data in year  $t$  and size-segment  $s$ . The variable  $Listings/Stock$  is the share of the total stock that is listed for sale in  $t$  and  $s$ . This variable is always normalized by its year-2003 value to allow for “normal” differences in turnover rates and time on the market that differ across home-size segments. The variable  $Log(SpecSales)$  is the log of the total number of sales of newly constructed homes built on spec in  $t$  and  $s$ . This variable is also interacted with the first two main variables.

Three sets of estimates of (5.1) are presented in Table 4. The first column uses the entire sample from 2000-2013. The second column restricts the sample to the pre-crash period, 2000-2006. The third column focuses only on the post-crash period, 2007-2013. The primary story is in the last two columns. Observe that for the 2000-2006 period, the model controls have almost no explanatory power. The overall R-square based on pre-differenced data is effectively zero. On the other hand, for the post-crash 2007-2013 period, the overall R-square is roughly 80 percent. Also evident in the table, none of the coefficients in the middle column (2000-2006) are significant but this is not true for the third (2007-2013) column. For the 2007-2013 period an increase in the share of stock currently listed (relative to 2003) has a strong negative influence on price index level. That effect, however, is sharply reduced when there are a larger number of spec-home sales in the market.

The patterns in Table 4 are consistent with the various conceptual arguments outlined above. As suggested in Section 2, post-crash exit of speculative developers allows for the possibility that price index levels may diverge. As implied by Figure 7, a disproportionate increase in turnover rates among smaller homes would shift supply out and put downward pressure on small home values relative to larger homes. However, as spec-home developers return to the market that effect should moderate and price index levels should revert back to pre-boom levels.

Although the regression model in Table 4 explains 80 percent of the variation in post-crash relative prices across home-size segments, a question remains: what drives the remaining 20 percent? Figure 7 suggests a possible answer. Consider that occupants of large homes typically have the financial ability to substitute towards smaller dwellings but the reverse is less true for occupants of smaller homes. In addition, the extra square footage associated with a very

large home is a luxury purchase as opposed to a necessity. For both reasons, demand for existing smaller-home units is likely inelastic relative to demand for existing larger-home units. In Figure 7, that would amplify the magnitude of the crash in price in the small-home segment of the market relative to larger homes, causing small-home relative prices to drop. Although we cannot test this possibility directly, the model in Figure 7 makes clear that differences in the elasticity of demand across home-size segments would also contribute to post-crash divergence in relative prices.

A final implication of Figure 7 pertains to dynamics that arise as markets begin to recover. With continuing increase in population as has occurred in Phoenix, housing demand gradually shifts out and up the inelastic portion of the supply function in Figure 7 along segment BC. This continues until markets return to the elastic portion of the long run supply function at point B. During this time, price should increase sharply (up segment BC) but with little new construction. Only once the market has returned to the long run supply function at point B should price increases moderate and construction levels return to levels more characteristic of the pre-boom period. Figures 2a, 2b, and 8b provide evidence consistent with these predictions.

## **VI. Conclusion**

The boom and bust in U.S. house prices of the previous decade triggered a near financial meltdown and the great recession. This also brought new appreciation for the need to understand house price dynamics and contributed to a host of recent studies on the cause and consequences of housing price booms. This paper extends that literature by documenting and explaining previously unrecognized post-crash dynamics that reveal missing information in the housing market and point to feasible policy measures that can reduce mispricing.

Our study draws on single family housing transactions in Phoenix from 2000 to 2013. Based on three different sets of evidence we argue that the doubling of price between 2004 and 2006 was a bubble driven by unrealistic buyer expectations of future returns. We then stratify the market into home-size segments from very small homes up to mansions. Results show that relative prices across home size segments were virtually constant prior to the crash, a pattern we attribute to the presence of speculative developers. With collapse of the bubble, house prices fell below pre-boom levels because of unwarranted construction during the boom. Moreover, with the post-crash exit of speculative developers, increased turnover associated with post-crash job loss pushed small-home values down by up to 80 percent relative to the largest homes.

Regression results confirm the essential role of speculative developers and turnover associated with post-crash job loss and mortgage default. These factors explain roughly eighty percent of post-crash variation in relative prices across home-size segments within individual years. Related results confirm that as speculative developers return to the market, relative prices revert back to pre-boom levels. The implicit forecast that post-crash small-home investments should yield higher returns than investment in larger homes implies arbitrage opportunities and mispricing of homes. We believe this is possible because post-crash exit of spec-home developers removed an essential disciplining effect from the market and that housing market participants are likely largely unaware of possible divergence in relative prices across home-size segments. Cities can address this absence of information and reduce mispricing by publishing size-stratified repeat sale indexes.

The patterns uncovered in this paper likely apply to other metropolitan areas that are subject to volatile housing markets. They also suggest that real estate bubbles set off a sequence of dynamic effects that continue well past the initial formation and collapse of the bubble.

## References

- Allen, M., R. Rutherford and T. Thomson. 2009. "Residential Asking Rents and Time on the Market." *Journal of Real Estate Finance and Economics* 38: 351-365.
- Anglin, P., R. Rutherford, and T. Springer. 2003. "The Trade-off Between the Selling Price of Residential Properties and Time-on-the-Market: The Impact of Price Setting." *Journal of Real Estate Finance and Economics* 26: 95-111.
- Arnold, M. 1999. "Search, Bargaining and Optimal Asking Prices." *Real Estate Economics* 27: 453-481.
- Bailey, Martin J., Richard F. Muth, and H. O. Nourse. 1963. "A Regression Model for Real Estate Price Index Construction." *Journal of the American Statistical Association* 58, 933-942.
- Carrillo, Paul (forthcoming). "To Sell or Not to Sell: Measuring the Heat of the Housing Market." *Real Estate Economics*.
- Case, Karl and Robert Shiller J. 1989. "The Efficiency of the Market for Single Family Homes," *American Economic Review*, 79(1): 125-137.
- Case, Karl and Robert Shiller J. 2003. "Is There a Bubble in the Housing Market?" *Brookings Papers on Economic Activity*, 2, 1-44.
- Chen, Y., and Robert Rosenthal. 1996a. "Asking Prices as Commitment Devices." *International Economic Review* 37: 129-55.
- Chen, Y., and Robert Rosenthal. 1996b. "On the Use of Ceiling-Price Commitments by Monopolists." *RAND Journal of Economics* 27: 207-20.
- Engelhardt, Gary, V. 2003. "Nominal loss aversion, housing equity constraints, and household mobility: evidence from the United States." *Journal of Urban Economics* 53: 171-19.
- Flood, Robert P. and Robert J. Hodrick. 1990. "On Testing for Speculative Bubbles." *The Journal of Economic Perspectives*, 4:2, 85-101.
- Foote, Christopher, Kris S. Gerardi, and Paul S. Willen. 2012. "Why Did So Many People Make So Many Ex Post Bad Decisions? The Causes of the Foreclosure Crisis," Public Policy Discussion Paper Series No. 12-2, Federal Reserve Bank of Boston, [www.bos.frb.org/economic/ppdp/2012/ppdp1202.pdf](http://www.bos.frb.org/economic/ppdp/2012/ppdp1202.pdf)
- Genesove, David and Lu Han. 2012. "Measuring the Thinness of Real Estate Markets." Working paper, Rotman School of Management, University of Toronto.

- Genesove, David and Christopher Mayer. 2001. "Loss aversion and selling behavior: evidence from the housing market." *Quarterly Journal of Economics* 116: 1233-1260.
- Glaeser, Edward L., Joseph Gyourko, and Albert Saiz. 2008. "Housing Supply and Housing Bubbles." *Journal of Urban Economics* 64: 198-217.
- Glomer, M., Donald R. Haurin and Patrick H. Hendershott. 1998. "Selling Price and Selling Time: The Impact of Seller Motivation." *Real Estate Economics* 26: 719-740.
- Gyourko, Joseph and Joseph Tracy. 2014. "Reconciling theory and empirics on the role of unemployment in mortgage default." *Journal of Urban Economics*, 80: 87-96.
- Han, Lu and William. Strange. 2011. "Bidding Wars for Houses." *Real Estate Economics*.
- Han, Lu and William Strange. 2013. "What is the Role of the Asking Price for a House?" working paper.
- Harding, John, Stuart S. Rosenthal, and C.F. Sirmans. 2007. "Depreciation of Housing Capital, Maintenance, and House Price Inflation: Estimates from a Repeat Sales Model." *Journal of Urban Economics*, 61: 193-217.
- Harding, John, Stuart S. Rosenthal, and C.F. Sirmans. 2003. "Estimating Bargaining Power in the Market for Existing Homes." *The Review of Economics and Statistics*, 85(1): 178-188.
- Haurin, Donald. 1988. "The Duration of Marketing Time of Residential Housing." *AREUEA Journal* 16: 396-410.
- Haurin, Donald., J. Haurin, T. Nadauld and Anthony Sanders. 2010. "List Prices, Sale Prices and Marketing Time: An Application to U.S. Housing Markets." *Real Estate Economics* 38: 659-685.
- Haurin, Donald, Stanley McGreal, Alastair Adair, Louise Brown, and James R. Webb, 2013. "List price and sales prices of residential properties during booms and busts." *Journal of Housing Economics* 22(1): 1-10.
- Himmelberg, Charles, Christopher Mayer, and Todd Sinai. 2005. "Assessing High House Prices: Bubbles, Fundamentals, and Misperceptions," *Journal of Economic Perspectives*, 19(4): 67-92.
- Horowitz, J., 1992. "The Role of the List Price in Housing Markets: Theory and an Econometric Model." *Journal of Applied Econometrics* 2: 115-129.
- Haughwout, Andrew, Richard W. Peach, J. Sporn, and Joseph Tracy. 2012. "The Supply Side of the Housing Boom and Bust of the 2000s." Federal Reserve Bank of New York *Working Paper* (<http://www.nber.org/chapters/c12620.pdf>) .

- Knight, John. 2002. "Listing Price, Time on Market, and Ultimate Selling Price: Causes and Effects of Listing Price Changes." *Real Estate Economics* 30: 213-237.
- Leventis, Andrew. 2012. "Home Price Indexes for Homes in Different Price Tiers: Biases and Corrections," Federal Housing Finance Agency Working Paper 12-1.
- Linneman, Peter. 1986. "An Empirical Test of the Efficiency of the Housing Market." *Journal of Urban Economics* 20, 140-154.
- Mayer, Christopher. 2011. "Housing Bubbles: A Survey." *Annual Review of Economics* 3:559–77.
- McManus, Douglas. 2013. "House Price Tiers in Repeat Sales Estimation." Freddie Mac, mimeo.
- McMillen, Daniel. 2013. "Local Quantile House Price Indices." University of Illinois, mimeo.
- Meese, Richard and Nancy Wallace. 1994. "Testing the Present Value Relation for Housing Prices: Should I leave My House in San Francisco?" *Journal of Urban Economics*, 35, 245-266.
- Merlo, Antonio, Francois Ortalo-Magne, and John Rust, 2008. "The home selling problem: Theory and evidence." Working Paper, University of Maryland.
- Merlo, Antonio and Francois Ortalo-Magne. 2004. "Bargaining over residential real estate: evidence from England." *Journal of Urban Economics*. 56, 192-216.
- Rosen, Harvey. 1979. "Housing Decisions and the U.S. Income Tax : An Econometric Analysis." *Journal of Public Economics*. 11:1,1-23.
- Rosenthal, Stuart. 1999. "Residential Buildings and the Cost of Construction: New Evidence on the Efficiency of the Housing Market," *Review of Economics and Statistics*, 81(2): 288-302.
- Rosenthal, Stuart S. (forthcoming). "Are Private Markets and Filtering a Viable Source of Low-Income Housing? Estimates from a "Repeat Income" Model," *American Economic Review*.
- Sas, Timothy. 1988. "A Note on Optimal Price Cutting Behavior Under Demand Uncertainty," *Review of Economics and Statistics*, 2, 336-339.
- Siegel, Jeremy J. 2008. Stocks for the Long Run, 4<sup>th</sup> edition, McGraw-Hill, New York, NY.,
- 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.
- Trump, Donald J. and T. Schwartz. 1988. Trump: The Art of the Deal. Random House, New York.

Yavas, Abdullah and S. Yang. 1995. "The Strategic Role of Listing Price in Marketing Real Estate: Theory and Evidence." *Real Estate Economics* 23: 347-368.

Zuehlke, Thomas. 1987. "Duration Dependence in the Housing Market," *Review of Economics and Statistics*, 69, 701-709.

**Table 1**  
**Increase in Real Annual Rent Growth Rate in Percentage Points**  
**Necessary to Support a Doubling in Price from 2004 to 2006<sup>a</sup>**

Real Annual Discount Rate	Investor Horizon (Years)			
	Infinite	100	50	25
0.020	0.0100	0.0169	0.0289	0.0534
0.025	0.0125	0.0183	0.0300	0.0543
0.030	0.0150	0.0199	0.0312	0.0553
0.035	0.0175	0.0215	0.0324	0.0564
0.040	0.0200	0.0232	0.0337	0.0574
0.045	0.0225	0.0250	0.0350	0.0585
0.050	0.0250	0.0269	0.0364	0.0596

<sup>a</sup>All values based on annuity expressions with an initial zero rate of anticipated annual rent growth and  $R_k/R_0 = 1$  in expression (7).

**Table 2a**  
**Median Values for Single Family Detached Homes Sold January 1, 2000 to December 31, 2010**

	ALL SALES	Home Size Category Based on Square Footage of Homes Sold						
		< 1%	1 - 5%	5 - 25%	25 - 75%	75 - 95%	95 - 99%	> 99%
Observations	687,133	43,194	61,743	191,090	303,113	74,627	11,275	2,091
Median Sale Price	\$182,500	\$98,000	\$119,900	\$144,700	\$213,000	\$400,000	\$845,000	\$2,200,000
Median Final List Price	\$185,000	\$99,000	\$120,000	\$145,000	\$218,000	\$414,900	\$889,950	\$2,400,000
Median Original List Price	\$189,900	\$99,900	\$123,500	\$149,500	\$224,900	\$429,900	\$939,900	\$2,550,000
Median Year Built	1995	1972	1983	1992	1996	2000	2001	2002
Median Days on Market	43	35	35	38	46	61	88	140
Median Square Feet	1764	1012	1217	1489	2045	3,267	4,751	7,096
Median Final Sale-to-List	0.991	1.000	1.000	1.000	0.988	0.979	0.959	0.925
Median Original Sale-to-List	0.976	0.989	0.988	0.984	0.973	0.958	0.929	0.881

**Table 2b**  
**Mean Values for Single Family Detached Homes Sold January 1, 2000 to December 31, 2010**

	ALL SALES	Home Size Category Based on Square Footage of Homes Sold						
		< 1%	1 - 5%	5 - 25%	25 - 75%	75 - 95%	95 - 99%	> 99%
Observations	687,133	43,194	61,743	191,090	303,113	74,627	11,275	2,091
Mean Sale Price	\$241,228	\$103,887	\$128,963	\$157,935	\$236,924	\$467,967	\$1,002,214	\$2,433,558
Mean Final List Price	\$248,408	\$105,531	\$130,700	\$160,270	\$242,456	\$485,677	\$1,070,311	\$2,693,051
Mean Original List Price	\$260,237	\$110,153	\$135,875	\$166,569	\$252,914	\$508,521	\$1,150,408	\$2,993,137
Mean Year Built	1988.43	1970.38	1980.37	1986.38	1991.39	1997.11	1997.92	1998.10
Mean Days on Market	65.583	53.26	53.14	56.43	67.20	88.07	122.34	181.23
Mean Square Feet	1,974.18	980.91	1,209.59	1,480.60	2,093.98	3,356.41	4,901.84	7,689.94
Mean Final Sale-to-List	0.982	0.985	0.989	0.988	0.982	0.971	0.948	0.917
Mean Original Sale-to-List	0.958	0.958	0.966	0.965	0.957	0.944	0.908	0.948

**Table 3: Price Adjustments (in percent) by Home Size Category**

Size Percentile	Pre-Boom		Post-Crash			
	Price (P <sup>E</sup> )	Bubble Price (P <sup>B</sup> )	Price (P <sup>C</sup> )	P <sup>B</sup> - P <sup>E</sup>	P <sup>B</sup> - P <sup>C</sup>	P <sup>C</sup> - P <sup>E</sup>
< 1 <sup>st</sup>	121	202	50	81	152	-71
1 <sup>st</sup> to 5 <sup>th</sup>	115	216	70	100	146	-45
5 <sup>th</sup> to 25 <sup>th</sup>	119	211	80	92	131	-39
25 <sup>th</sup> to 75 <sup>th</sup>	121	216	90	95	126	-31
75 <sup>th</sup> to 95 <sup>th</sup>	124	226	110	102	116	-14
95 <sup>th</sup> to 99 <sup>th</sup>	125	216	130	91	86	5
> 99 <sup>th</sup>	134	236	150	103	86	16

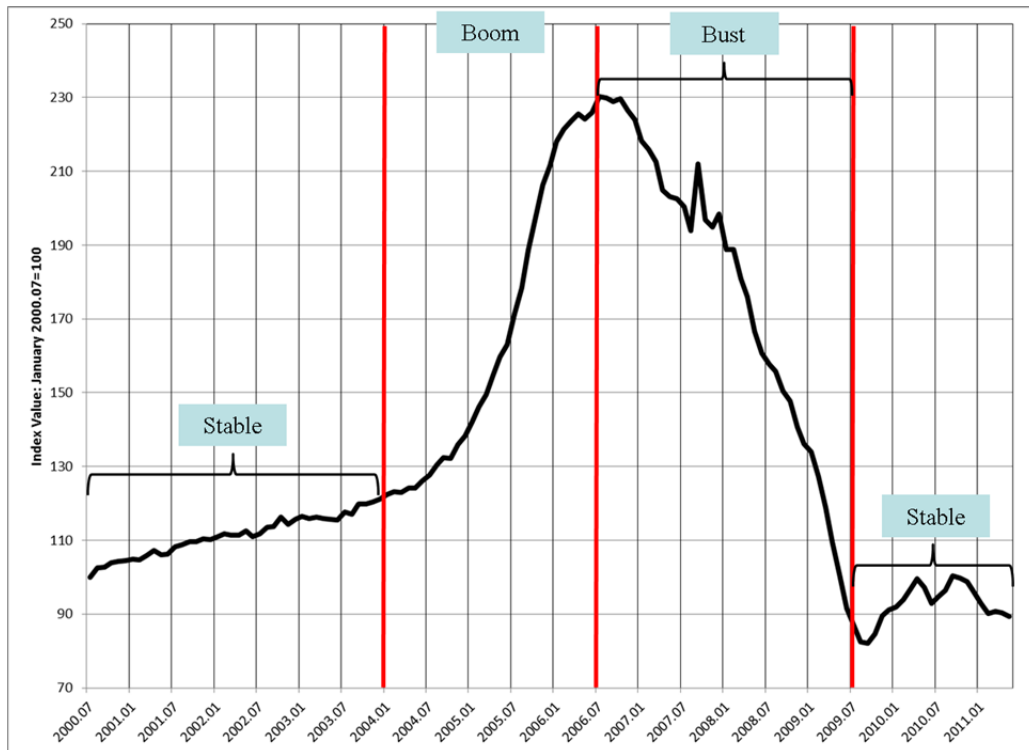
<sup>a</sup> Pre-boom, bubble, and post-crash prices were measured in December 2003, January 2006, and January 2009 for each size segment in the market based on price index values displayed in Figure 8a.

**Table 4**  
**Change in Annual House Price Index in Year- $t$  Relative to 2003**  
**For 5-percentile Increment Home-Size Segments**  
**(Dependent Variable  $P_t/P_{2003}$ )<sup>a,b</sup>**

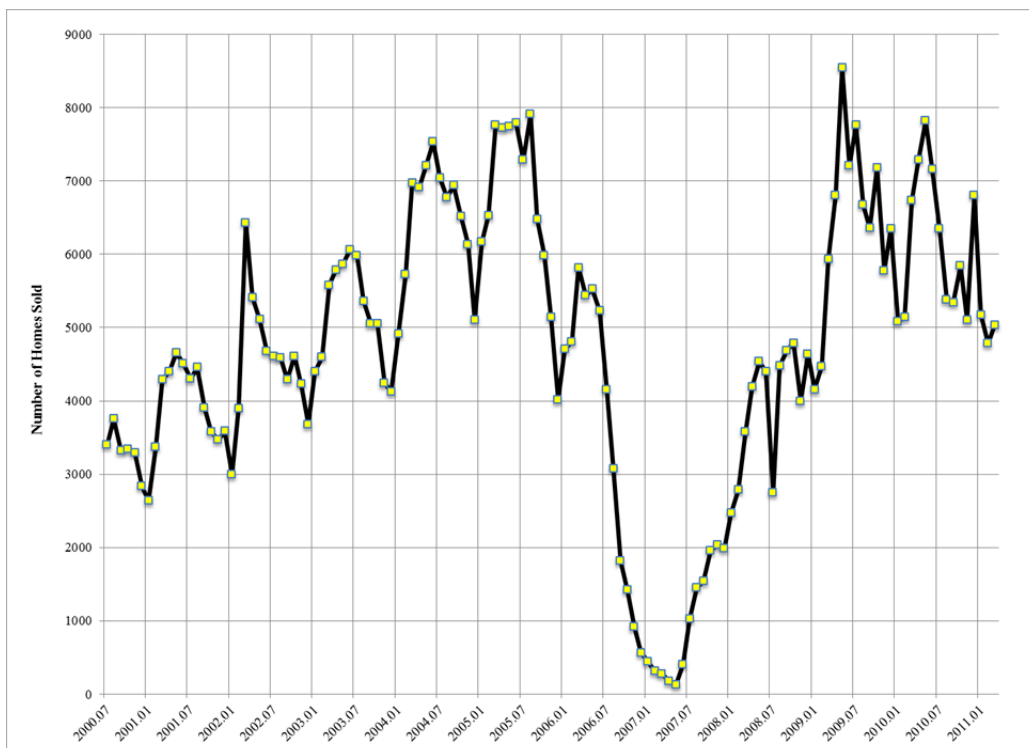
	2000-2013	2000-2006	2007-2013
Distressed Sales/Total Sales (X1)	-2.758 (-5.66)	9.422 (0.94)	-1.021 (-1.14)
Listings/Stock in year- $t$ /year-2003 (X2)	-0.9185 (-2.02)	-0.2044 (-0.76)	-1.088 (-3.19)
Log number of spec-home sales	-0.0779 (-1.43)	-0.0258 (-0.81)	0.2283 (0.47)
Log number of spec-home sales * X1	0.348 (3.73)	-1.892 (-1.05)	0.0929 (0.64)
Log number of spec-home sales * X2	0.1314 (1.92)	0.0500 (1.18)	0.1152 (2.74)
Observations	280	140	140
Year Fixed Effects	14	7	7
R-sq within	0.644	0.166	0.731
R-sq between	0.431	0.001	0.820
R-sq overall	0.442	0.000	0.799

<sup>a</sup>  $t$ -ratios in parentheses based on standard errors clustered at the year-level.

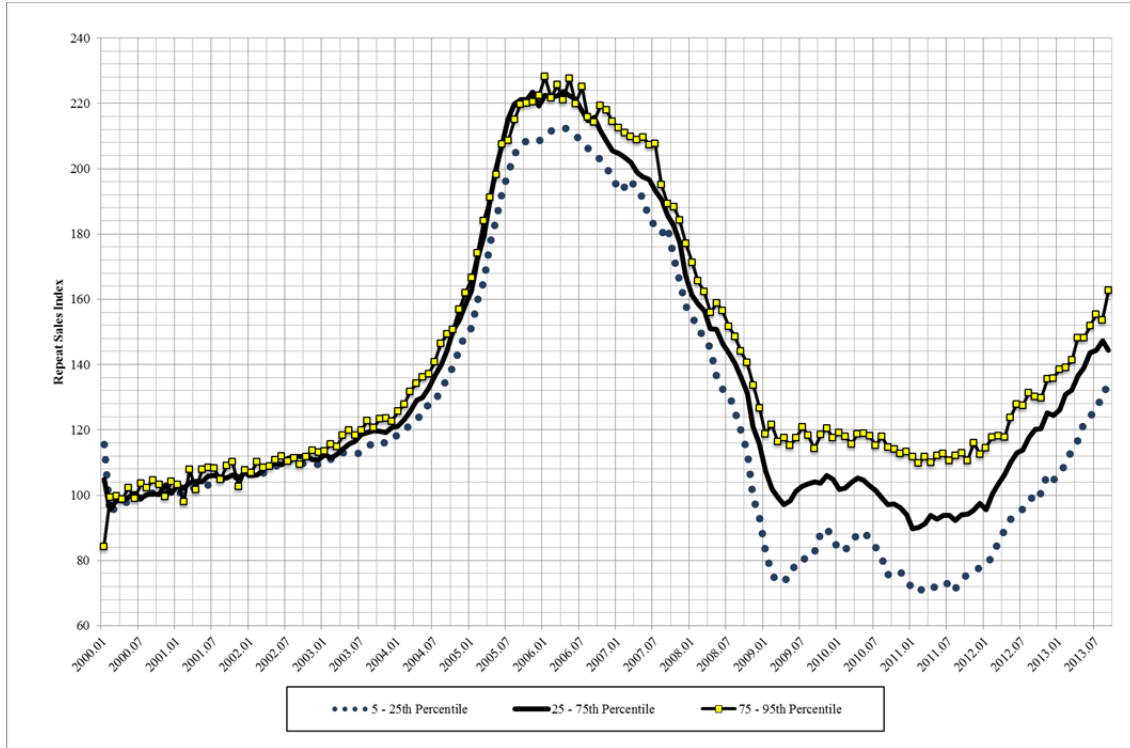
**Figure 1a: Repeat Sale Price Index (Normalized to 100 for 2000:07)**



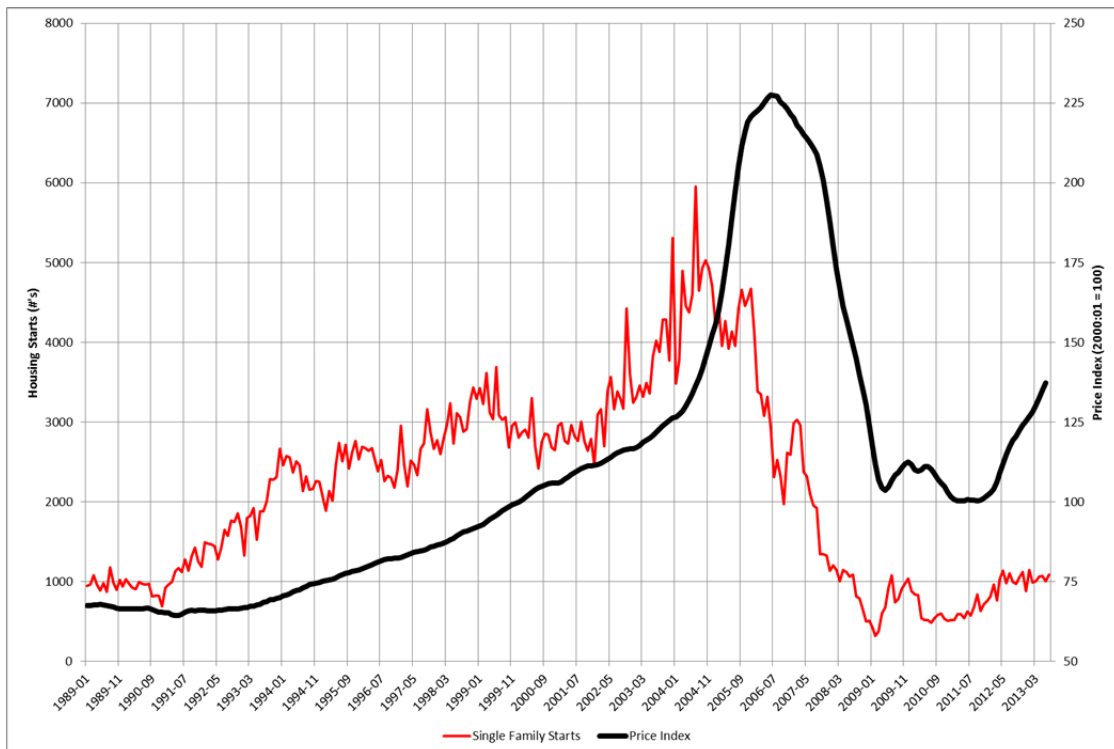
**Figure 1b: Number of Homes Sold**



**Figure 2a: Repeat Sales Indexes by Home Size Segment 2000-2013**



**Figure 2b: Single Family Housing Starts 1989:1 to 2013:7**



**Figure 3: Repeat Sales and Repeat Rent Indexes**

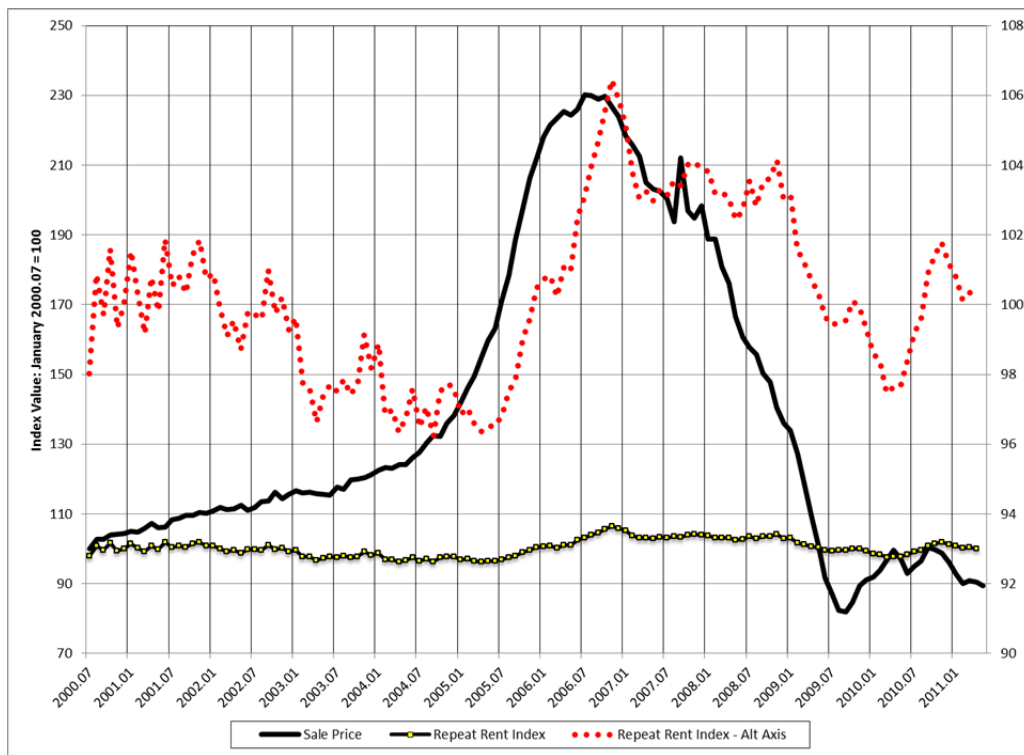


Figure 4a: Repeat Sale-to-List Price Indexes

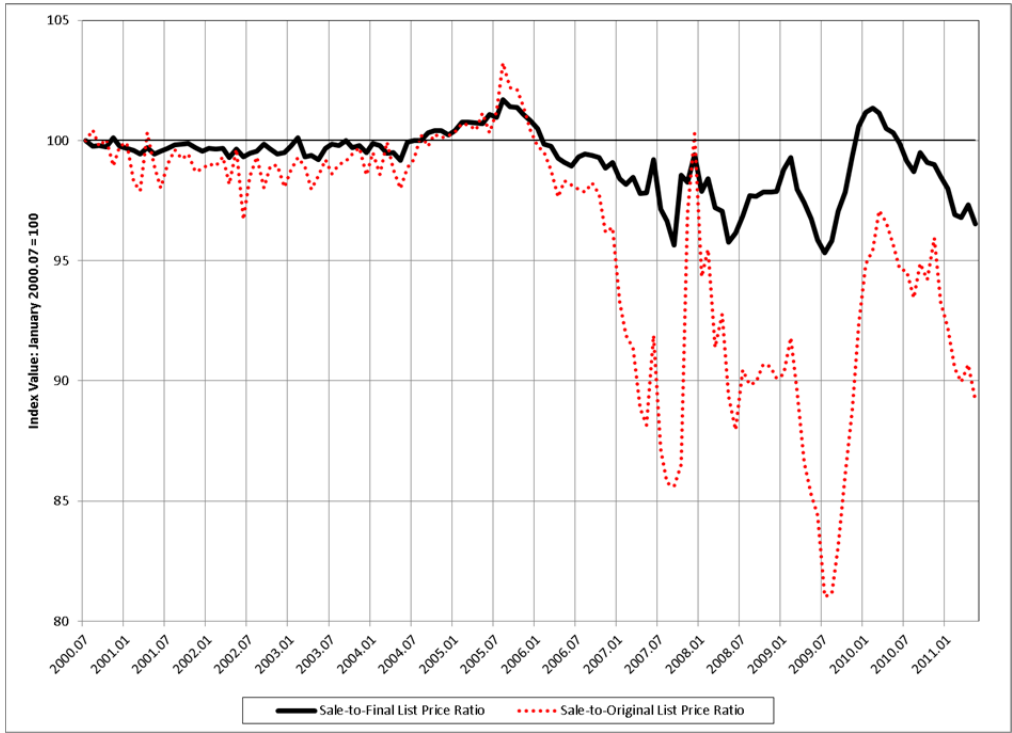
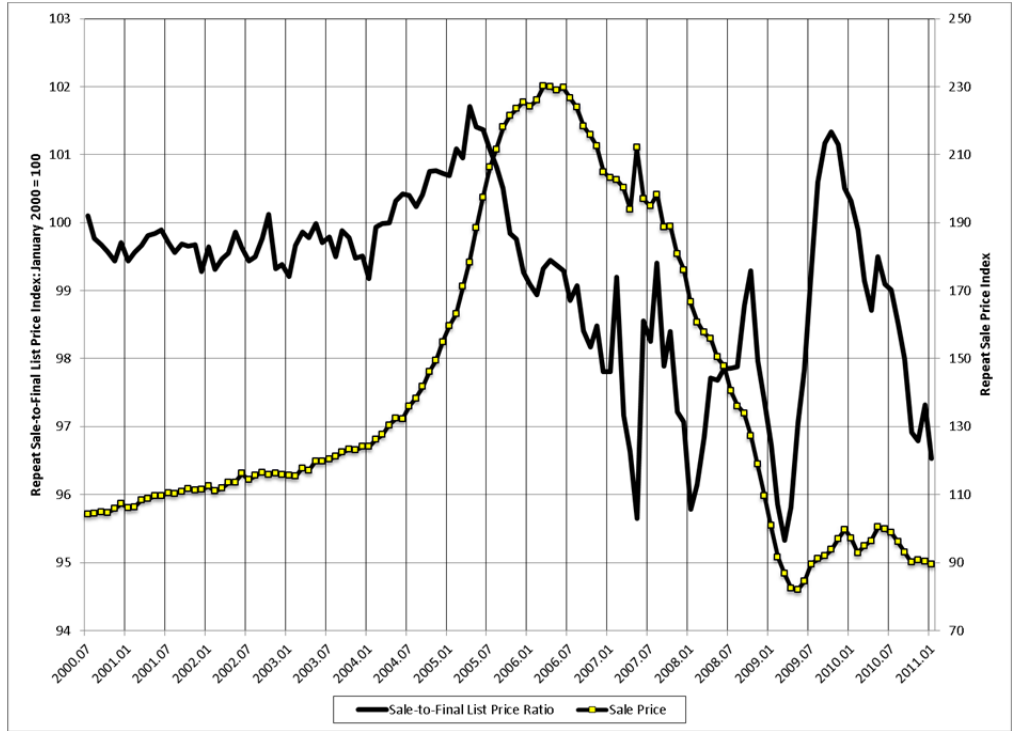
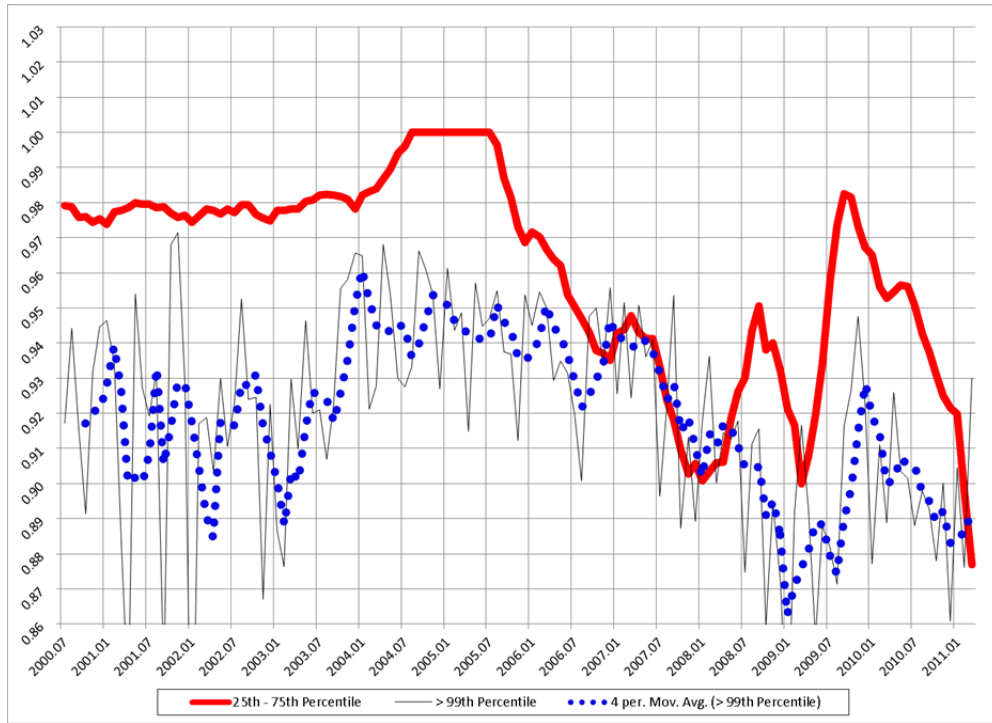


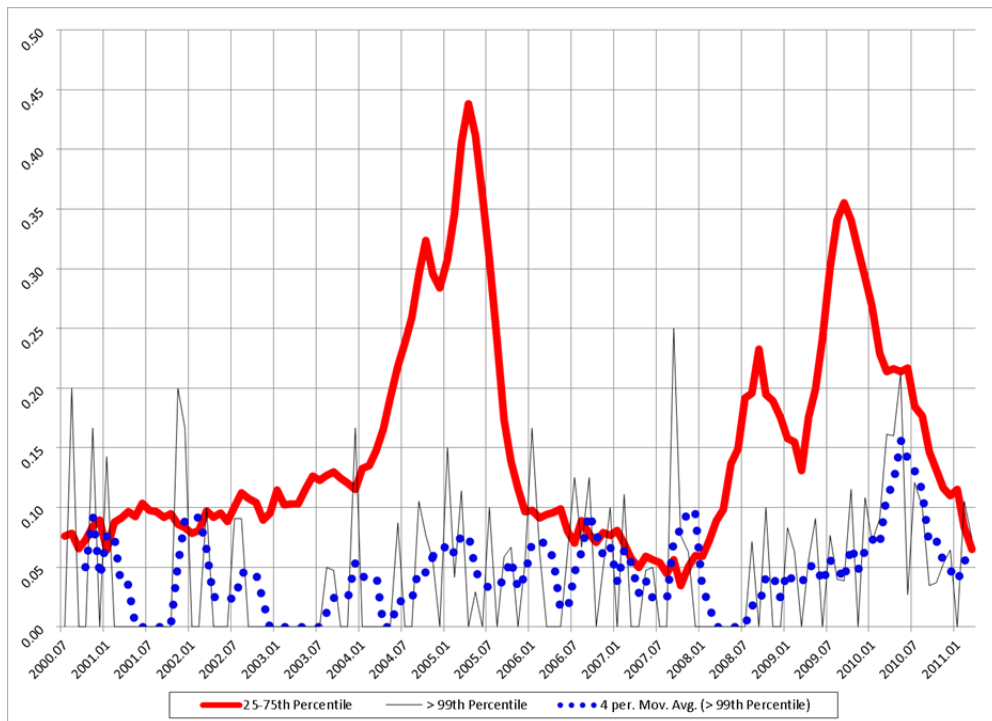
Figure 4b: Repeat Sale-to-List and Sale Price Indexes



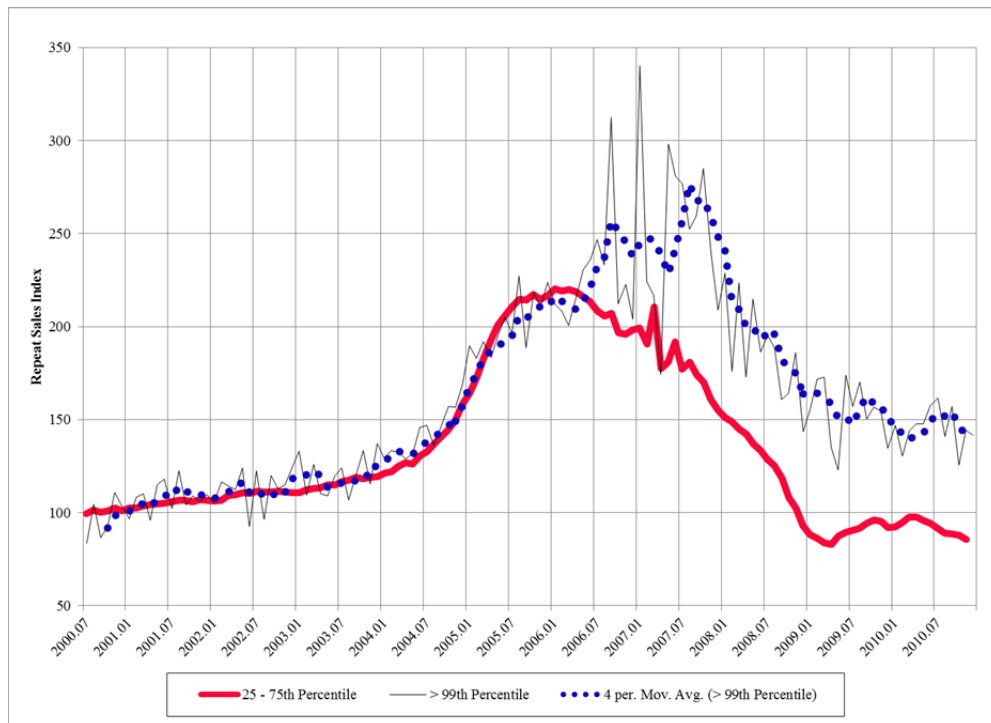
**Figure 5a: Median Sale-to-List Price  
by Home Size Segment (Based on Original List Price)**



**Figure 5b: Percent of Sales with Sale-to-List Price Ratio Above 1  
by Home Size Segment (Based on Original List Price)**



**Figure 6a: Repeat Sale Price Index for the 99<sup>th</sup> and 25<sup>th</sup>-75<sup>th</sup> House Size Percentiles as Measured by Square Footage of the Floor Space of Homes Sold 2000-2011**



**Figure 6b: Repeat Sale-to-List Price for the 99<sup>th</sup> and 25<sup>th</sup>-75<sup>th</sup> House Size Percentiles Based on Square Footage of Floor Space for Homes Sold: 2000:07 to 2006:01**

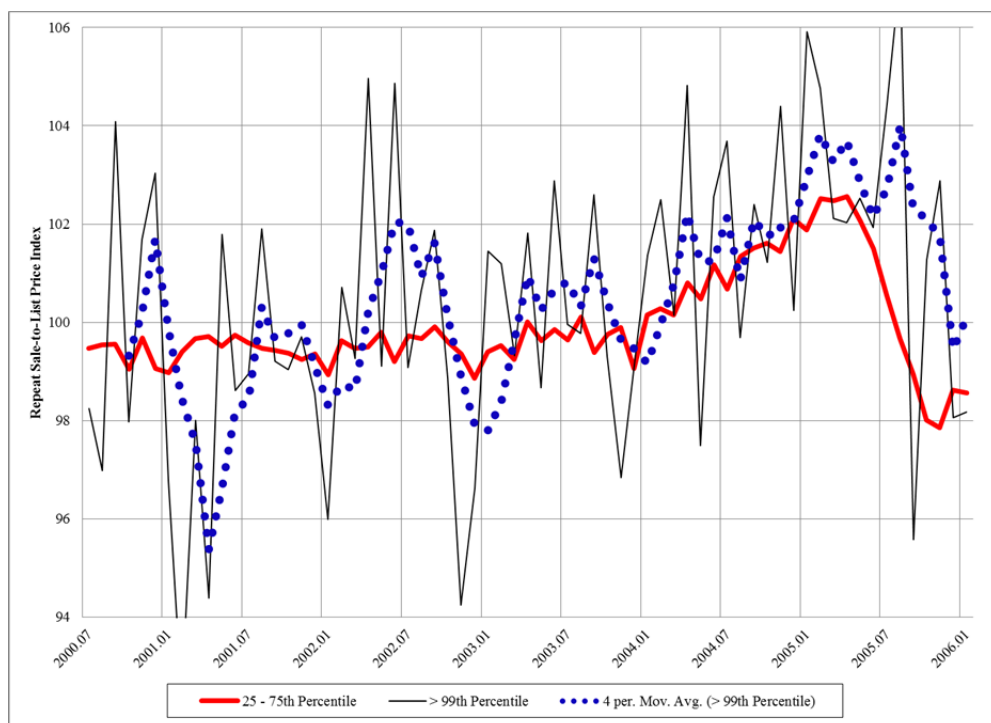
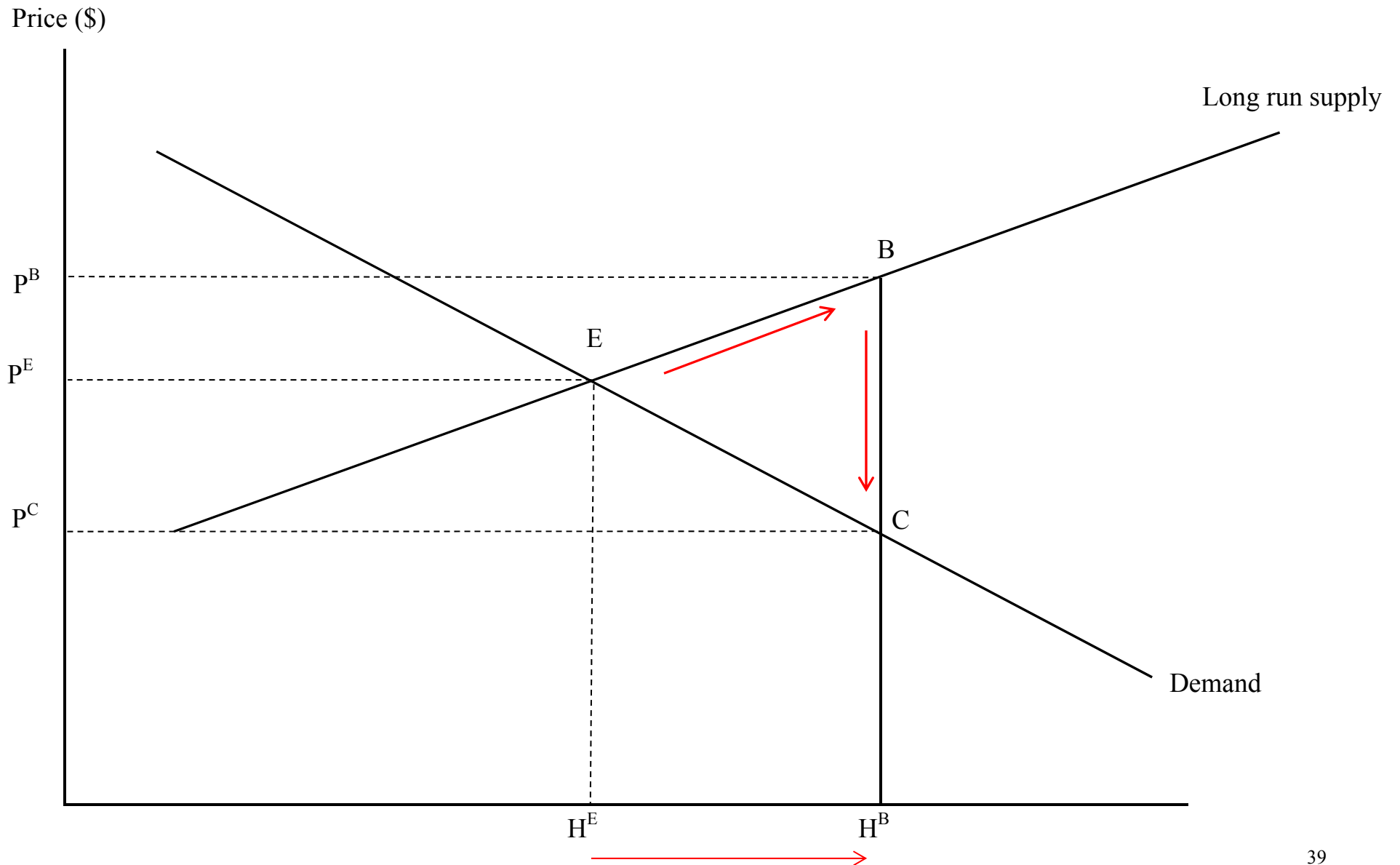
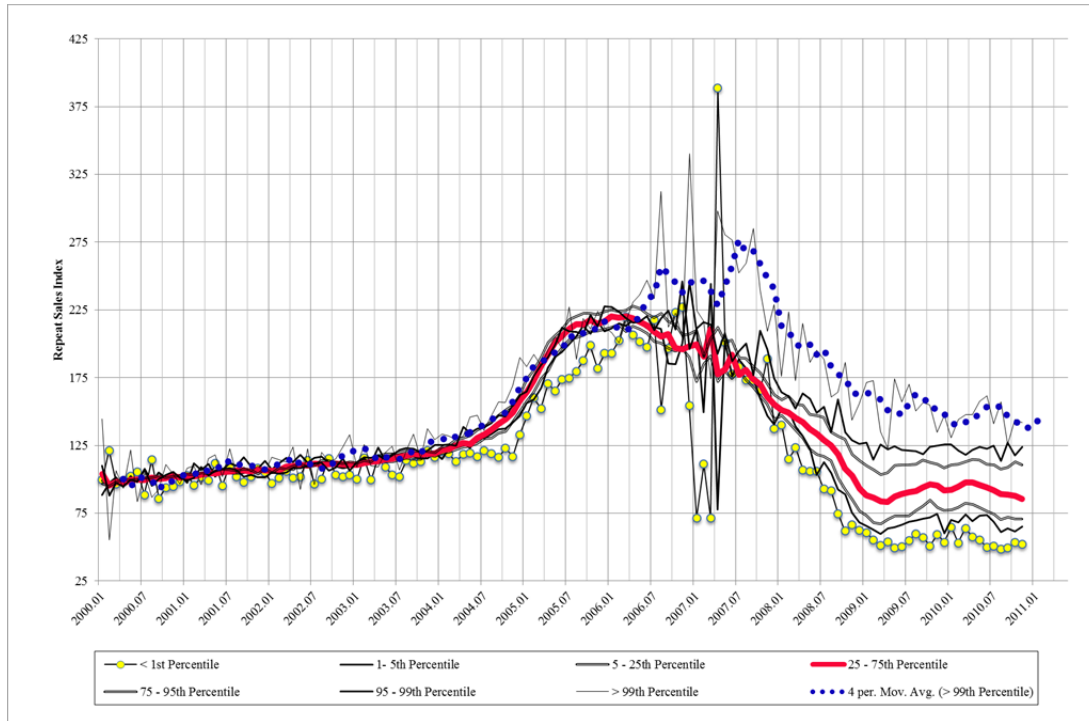


Figure 7: Post-Crash Dynamics Following a Housing Market Bubble



**Figure 8a: Repeat Sales Indexes1 by Seven House Size Categories**



**Figure 8b: Annual House Price Indexes Stratified by 20 Home-Size Segments**

