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 bubble. Although Phoenix home prices doubled 2004-2006, the relative price of small-to-large homes remained strikingly constant but then fell post-crash by up to 70 percent. We argue that post-crash exit of speculative developers allowed relative prices to diverge while fundamentals of demand and job loss pushed small home relative values down. As speculative developers return relative prices should return to pre-boom levels, consistent with patterns since 2011. Cities should, therefore, be able to reduce post-crash price volatility and mispricing by publicizing 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 January, 2001 to September, 2013.[1] Also apparent in Figure 1a, prices rose at a smooth and modest pace from 2001 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 peaked in late 2005 and then fell by over 50 percent by early 2008. Sales have recovered since 2010 while prices have jumped up nearly 50 percent since mid-2011 (Figure 1a). 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 from January, 2001 to September, 2013 for different home-size segments from the 5th to the 95th size percentiles of the market.[2] 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 notably further than large-home values. As markets began to recover in 2011, two further patterns are noteworthy. Although construction remained depressed (Figure 2b), it is apparent that relative prices across home-size segments exhibit mean reversion with small-home prices rising further than large-home prices (Figure 2a). These patterns are robust to more refined stratifications of the market as will be presented later in the paper.

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[1] The patterns in Figure 1a are precisely estimated. An alternative plot with 95 percent confidence bands is in Figure A-1 of the appendix.

[2] 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.

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 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.[3] 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.[4] 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

[3] 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.

[4] 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 (2014), 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.

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 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. High post-crash turnover rates among smaller homes because of job loss and mortgage default likely then pushed small home prices down relative to larger homes, something we provide suggestive evidence of empirically. We also argue that inelastic demand for smaller homes may further 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 be 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 post-crash price volatility and 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 optimization 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 θ 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 θ units of land while type-2 homes require 1 unit of land.

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

$$\begin{aligned} &Max_{N_1 N_2}[P_1 N_1 - r\theta k N_1] + [P_2 N_2 - rkN_2] \\ &s.t.\ \ N = \theta N_1 + N_2 \end{aligned} \tag{2.1}$$

The first order conditions are:

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

$$\frac{\partial \pi}{\partial N_2} = P_2 - rk - \lambda = 0 \tag{2.2b}$$

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

$$\frac{P_1}{P_2} = \theta \tag{2.3}$$

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 2001-2006. 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 θ 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 2007. By early 2009, housing starts had fallen below 1,000 units per month and have remained below that level through most of 2013. Thus, speculative developers had mostly exited the market by 2009 removing their disciplining effect on relative prices across home-size segments.

It should be emphasized that the post-crash exit of speculative developers does not 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 are obtained from three sources. The first and also our primary source is the Arizona Regional Multiple Listing Service (ARMLS).[5] These data are proprietary and provide information on single family homes listed, sold, or rented from January, 2000 through September, 2013. An important feature of the data is that a home must be listed after January 1, 2000 to appear in the file. For this reason, we report monthly price indexes beginning in January, 2001 as this allows previously listed homes sufficient time to sell and ensures a reasonably thick sample.

[5] 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.

From the ARMLS we use data for Maricopa County which includes all of the Phoenix metropolitan area. There are a total of 1,540,593 home listings over this period prior to cleaning the data; after cleaning we have 1,401,801 observations. For homes listed for sale, each listing contains property address and related identifying codes, sale price, days on the market, original and final listing prices, and more. For homes listed for rent the data provide property address and property identifying codes in addition to rent.[6] Numerous attributes of the properties are also provided including date of construction and various neighborhood and structural attributes. The latter include the square footage of the floor space which we use to stratify the sample into home-size segments.

A limitation of the ARMLS is that it does not include homes for sale by owner (FSBO) and primarily for that reason does not include the entire market of single family homes. For some of the applications to follow it is valuable to have an accurate count of the annual stock of single family homes present in Phoenix and also the amount of new construction. In addition, it is desirable to confirm the accuracy of house price indexes based on the ARMLS given that it does not include FSBO sales. For both reasons we augment the ARMLS data with data from the Maricopa County Assessor's office which includes information on all single family homes throughout the Phoenix metropolitan area.

Two alternative versions of the assessment authority data were obtained. The first was purchased from ION Data Express (http://www.iondataexpress.com/), a company that repackages and sells assessment data. The ION data report sale price, home size and various

[6]See the Arizona realtor website http://www.armls.com/ for additional detail on information provided on each listing by the ARMLS. The ARMLS is one of the largest MLS in the nation in terms of membership.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 ranks 10th (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).

other property characteristics for all real estate transactions in Maricopa County. The ION data do not include information on list price, days on the market, or rents for rental units. In addition, while these data were available beginning in 1988 they only extend to November 2011. Between January 2000 and November 2011, the period over which the ION and ARMLS databases overlap, 1,175,566 single family home sales were recorded in the ION data. This compares to 825,186 sales in the ARMLS database. The ARMLS, therefore, contains roughly 70 percent (825,186/1,175,566) of sales registered with the Assessor's office and reported in the ION data.

To validate the price indexes based on the ARMLS data we estimated separate repeat sale price indexes using both the ARMLS and the ION data. This was done for a variety of home-size segments in the market from July, 2000 through November, 2011 and also for both monthly and annual price indexes. Table A-1 in the appendix reports the correlation between the corresponding price indexes for twenty different home-size segments. The level of correlation is always over 95 percent and in most instances over 98 percent. This confirms that the ARMLS price indexes are reflective of price movements throughout the market for single family homes in Phoenix.

An alternative version of the Maricopa County Assessor office data was obtained through Arizona State University. These data did not contain transaction prices but do allow us to accurately measure the total number of single family homes present in Maricopa County on an annual basis from 2000 through 2012. This allows us to determine the size of the single family housing stock in a given year by home-size segment in the market. In addition, changes in the size of the stock between adjacent years was used to approximate new construction under the assumption that there are few demolitions in Phoenix during our sample period.

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

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

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

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 γ_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,

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

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

$$\log(\frac{Y_{t+\tau,i}}{Y_{t,i}}) = \sum_{t=1}^{\tau_i} \gamma_t D_{t,i} + \omega_{t,i} \qquad \text{for home } i = 1, \ldots, n \tag{3.3}$$

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.[7] Given the identifying assumptions, time invariant house and neighborhood attributes difference away. The γ parameters can then be estimated by regressing the log change in Y between turnover dates on the vector **D**. Provided that **X** and **β** are unchanged between turnover dates, estimates of the **γ**-vector indicate the rate at which Y changes with the passage of time. By substituting in different outcome measures for Y, we 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.

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

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).[8] Bearing this in mind, Figure 3 plots the repeat sale price index as

[7] Rosenthal (2014) 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.

[8] 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

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 present value expression in (4.1) but do 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,[9]

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

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

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

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.

[9] 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.

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:

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

For plausible values of d and g_k, the term dg_k is small so $g_k \approx 0.45d$.[10]

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 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

[10] For example, with $d = 0.02$ and $g = 0.01$, dg is 0.0002 and can be ignored in expression (4.4).

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.[11]

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 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 1 would require extraordinary growth in population and employment to be realized given the extensive degree of developable land surrounding Phoenix.

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 avoids that problem.

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

[11] Larger discount rates cause g_k to increase but by an amount that declines as the investor horizon becomes shorter.

market value should be small and stable over time.[12] Figure 4 provides evidence on this point. Figure 4 displays repeat indexes for the sale-to-list price ratio based on the original list price and also the final list price with the indexes normalized to 100 in January, 2003 in both cases.[13] It is worth emphasizing that the sale-to-list price indexes indicate the percentage change in sale-to-list ratios over time but does not say anything about the level of those ratios.[14] For reference, the sale price index is also provided and for all three indexes values are plotted from January, 2001 through December of 2006.

Notice the sharp run-up in sale-to-list price ratios in 2004 regardless of whether one uses the original list price or final list price. Also apparent, in 2004 the sale-to-list index based on original list price is above the index based on final list price while the reverse is true after 2005. This indicates that in 2004 sellers increasingly revised their list prices *upwards* while after 2005 there was an increasing tendency for sellers to revise list price down.[15]

Two competing views of how sellers set list price lead to quite different interpretations of these patterns. 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.[16] Figure 5 presents evidence consistent with that view. The figure plots the median sale-to-final list price

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[12] 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.
[13] 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).
[14] Both sale-to-list price indexes plummet after 2007 and are quite volatile. This presumably reflects that as the crash deepened sellers initially resisted setting their list prices low and the subsequently cut their asking price as their homes did not sell. This is consistent with evidence of possible loss aversion and concerns about regaining lost equity in Genesove and Mayer (2001) and Engelhardt (2003). Downward price stickiness could also occur if sellers are risk-neutral, housing wealth maximizers as in Merlo, Ortalo-Magné, and Rust (2008).
[15] While most revisions to list prices occur when sellers cut their asking price, direct comparison of original and final list prices for individual homes confirms that in 2004 there was an increasing tendency for sellers to revise their asking prices upwards.
[16] 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.

ratio for homes in three size segments (based on square footage of floor space), the 25th-75th percentile, the 95-99th percentile, and above the 99th percentile. The median floor space for these home-size segments was 2,048, 4,623, and 6,784, respectively (see Tables 2a) so these latter two categories are very large homes that trade in thin markets in which there is considerable uncertainty about a given home's market value. For homes in the 25-75th size percentile, the median sale-to-list price ratio is roughly 98 percent over the 2001-2003 pre-boom period when markets were stable. The median sale-to-list price ratios are always notably lower for homes in the 95th to 99th size percentile and lower still for mansions above the 99th size percentile. These patterns reinforce the view that sellers tend to adopt a list-high-sell-low marketing strategy and especially so as uncertainty increases about market value.[17] Under that view the 2004 run-up in sale-to-list ratios implies that seller and buyer expectations of future returns increasingly diverged so that sellers were increasingly surprised by unexpectedly high bids. The increasing tendency for sellers to revise upwards their asking price in 2004 further contributes to this interpretation. Such divergence in seller-buyer expectations of returns, however, should not occur with informed, forward looking agents.

A completely different view of how homes are sold 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

[17] 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.

(e.g. Han and Strange (2011, 2013), Haurin et al (2013).[18] If sellers shifted towards such a strategy as the boom developed that could account for the 2004 spike in sale-to-list ratios in Figure 4.

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 sell in thin markets where sellers face considerable uncertainty about market value.[19] 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, because mansions require considerable effort to market seller-agent contracts include added 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.[20] This suggests that

[18] 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.

[19] 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. 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."

[20] 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

sellers of mansions who set artificially low asking prices risk receiving a single offer at list price and being forced into selling their 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.[21]

Figure 6a presents annual repeat sale price indexes for the core (25-75th size percentile) and mansion segments of the market (95-99th size percentile and > 99th percentile). 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 Phoenix housing market experienced a bubble over the period driven by unrealistic buyer expectations of future returns.[22]

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

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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.

[21] It is also worth noting that prior to 2004 about 10 percent of homes in the core of the market (25-75th size percentile) sold above original list price while for mansions the number was about 5 percent. In 2004, in the core of the market, the share of homes that sold above list jumped to roughly 45 percent while for mansions the number increased to only about 7 percent.

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

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 2001-2006. 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 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 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 additional arguments are required.

We began by assuming that over the pre-boom 2001-2003 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. When the bubble bursts as in 2007, and with durable housing (e.g. Glaeser and Gyourko (2005), Haughout et al (2012)), price falls 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 twenty home-size segments based on the square footage of the floor space in a home for the 0-5 percentile, 5-10 percentile, … and 95-100 percentile.[23] Figure 8 plots annual repeat sale indexes for each home size segment over the period 2001-2013. For each of these indexes, Table 3 tabulates corresponding price index levels by home size segment for the pre-boom index level (P^E) in 2003, the bubble price (P^B) in 2006, and the post-crash price (P^C) in 2009. Also displayed in Table 3 are the differences P^B-P^E, P^B-P^C, and P^C-P^E. Several patterns in Figure 8 and Table 3 are noteworthy. The first is that except for the very largest homes, 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 8 and the second-to-last column of Table 3 (P^C-P^E) reveal a strikingly monotonic ordering of the difference between the pre-boom and post-crash price across home-size segments. That difference is -52 for the 0-5th percentile, -23 for the 50th-55th percentile, and just -6 for the 95th-100 size percentile.

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 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

[23] Tables 2a and 2b provide summary measures for seven size categories that span the market with medians in Table 2a and means in Table 2b. For reference, observe that median home size is roughly 1,000 square feet for the bottom 1st percentile, 2,000 square feet for the 25th to 75th percentiles, and 7,000 square feet for the 99th percentile.

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 is that demand for smaller homes could be more inelastic than demand for larger units which, from Figure 7, would increase the magnitude of the price crash. However, we have no way of testing whether demand for smaller units is more inelastic.[24]

A second alternative mechanism is that large numbers of distressed home sales in the post-crash period may have hit the small-home market segments especially hard causing small-home relative prices to fall. In Table 4a, notice for example that the share of sales classified as "distressed" sales in the ARMLS was roughly 1 percent per year from 2000-2006 but then jumps to a peak of 46 percent in 2009. In Table 4b it is evident that between 2007 and 2012 distressed sales were in fact much more common in smaller home market segments. If speculative developers had remained active throughout the market following the crash, expression (2.3) should have prevailed and the wave of distressed sales would not have caused relative prices to diverge across home-size segments. With speculative developers absent, the jump in distressed sales would have increased the share of existing stock made available for sale and especially so in smaller-home segments. It seems likely that this would have contributed to the fall in small home relative values.

[24] Note 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 could be inelastic relative to demand for existing larger-home units but, as noted above, we are unable to test this possibility.

It is difficult to test the implied causal relationships above because changes in relative prices across home-size segments, differences in building activity, distressed sales and turnover rates are all endogenously determined. Nevertheless, it is illuminating to explore the correlations in the data because if speculative developers are sufficiently active distressed sales and related turnover rates should have little association with changes in relative prices across home-size segments. Bearing this in mind, we treat the 20 size-stratified price indexes as a panel and estimate the following regression:

$$\frac{P_{t,s}}{P_{2003,s}} = d_t + \theta_1 \frac{DissSales_{t,s}}{AllSales_{t,s}} + \theta_2 \frac{Listings_{t,s} / Stock_{t,s}}{Listings_{2003,s} / Stock_{2003,s}}$$

$$+ \theta_3 Log(NewlyBuilt)_{t,s} + \theta_4 Log(NewlyBuilt)_{t,s} \frac{DissSales_{t,s}}{AllSales_{t,s}} \quad (5.1)$$

$$+ \theta_5 Log(NewlyBuilt)_{t,s} \frac{Listings_{t,s} / Stock_{t,s}}{Listings_{2003,s} / Stock_{2003,s}} + e_{t,s}$$

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*(*NewlyBuilt*) is the log of the total number of single family homes built during the year, measured as the difference between the total stock of single family housing between adjacent years. This variable is also interacted with the first two main variables.

Table 5 presents estimates based on (5.1) for the full sample horizon 2000-2012, the pre-crash period 2000-2006, and the post-crash period 2007-2012. The first three columns include only the year fixed effects and the log of the number of newly built homes in a given home-size segment. The second three columns include all of the controls described above.

In column (2), notice that the elasticity with respect to new construction is just 1.5 percent with a t-ratio of 0.85 and a within R-square of just 3.1. In column three, which focuses on the post-crash period, the corresponding elasticity is 18.4 percent with a t-ratio of 8.95 and a within R-square of 55.8 percent. These patterns are consistent with the argument that relative prices are unrelated to building activity when speculative developers are active. That message is reinforced in the more fully specified models in columns 4-6. Notice that the within R-square in column five is 18 percent while its analogue in column six is 73.7 percent. Observe also in column 6 that the coefficient on list-to-stock ratio is negative and significant while its interaction with the number of units built is positive and significant. This is also suggestive that when building activity is sufficiently present variation in turnover rates has less influence on relative prices. The coefficient on distressed sales and its interaction with building activity are not significant, consistent with the view that distressed sales influences relative home values through their influence on turnover rates.

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. Figure 2b provides evidence consistent with these predictions in that it documents a 50 percent increase in price since late 2011 despite continued depressed levels of construction. The plots in Figure 8 and the final column of Table 3 also confirm that relative prices across home-size segments have exhibited a dramatic degree of mean reversion since 2011, with small home prices rising further than larger home values. As a result, much of the price dispersion evident in 2009 has disappeared, presumably because forward looking investors recognize the impending return of speculative development to the market.

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 70 percent relative to the largest homes.

Regression results confirm the essential role of speculative developers. Results also 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.

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Table 1
Increase in Real Annual Rent Growth Rate in Percentage Points Necessary to Support a Doubling in Price from 2004 to 2006[a]

	Investor Horizon (Years)			
Real Annual Discount Rate	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

[a]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
July 2000 through September 2013 Based on AMLS Data[a]

		Home Size Category Based on Square Footage of Homes Sold						
	ALL SALES	< 1%	1 - 5%	5 - 25%	25 - 75%	75 - 95%	95 - 99%	> 99%
Observations	849,349	52,000	74,787	230,156	374,301	98,424	16,185	3,496
Median Sale Price	183,916	103,301	127,093	152,260	213,048	387,903	779,087	1,912,609
Median Final List Price	187,708	105,057	129,038	154,450	218,136	401,318	818,512	2,109,597
Median Original List Price	192,597	107,663	131,585	157,891	223,909	416,857	869,686	2,298,040
Median Year Built	1995	1972	1983	1993	1997	2001	2002	2002
Median Days on Market	41	34	34	35	43	57	80	133
Median Square Feet	1,790	1,016	1,223	1,495	2,048	3,226	4,623	6,784
Median Original Sale-to-List	0.972	0.984	0.985	0.981	0.970	0.955	0.927	0.870
Median Final Sale-to-List	0.985	0.993	0.993	0.990	0.983	0.974	0.955	0.916

Table 2b
Mean Values for Single Family Detached Homes Sold
July 2000 through September 2013 Based on AMLS Data[a]

		Home Size Category Based on Square Footage of Homes Sold						
	ALL SALES	< 1%	1 - 5%	5 - 25%	25 - 75%	75 - 95%	95 - 99%	> 99%
Observations	849,349	52,000	74,787	230,156	374,301	98,424	16,185	3,496
Mean Sale Price	244,062	103,311	128,854	159,302	236,478	451,735	922,138	2,208,299
Mean Final List Price	252,597	105,257	131,011	162,203	242,922	470,835	990,308	2,472,663
Mean Original List Price	263,967	110,085	135,751	168,148	252,656	491,579	1,058,499	2,728,538
Mean Year Built	1989	1971	1981	1987	1992	1998	1998	1999
Mean Days on Market	64	53	53	56	65	84	116	172
Mean Square Feet	1,996	984	1,215	1,485	2,093	3,312	4,749	7,314
Mean Original Sale-to-List	0.957	0.959	0.967	0.966	0.957	0.941	0.911	0.879
Mean Final Sale-to-List	0.979	0.985	0.987	0.985	0.978	0.967	0.945	0.908

[a]All dollar values are in January, 2010 dollars.

Table 3: Sale Price Index Boom and Bust by Home Size Category
2000 through 2013 Based on AMLS Data

Home Size Percentile	2003 Pre-Boom Price (P^E)	2006 Bubble Price (P^B)	2009 Post-Crash Price (P^C)	2013 Recovery Price (P^R)	$P^B - P^E$	$P^B - P^C$	$P^C - P^E$	$P^R - P^E$
0 to 5	100	152	48	82	52	104	-52	-18
5 to 10	100	153	58	93	53	94	-42	-7
10 to 15	100	151	61	95	51	90	-39	-5
15 to 20	100	149	64	98	49	85	-36	-2
20 to 25	100	151	67	101	51	85	-33	1
25 to 30	100	149	68	101	49	81	-32	1
30 to 35	100	151	69	103	51	81	-31	3
35 to 40	100	151	73	104	51	78	-27	4
40 to 45	100	151	73	107	51	78	-27	7
45 to 50	100	150	75	106	50	75	-25	6
50 to 55	100	149	77	106	49	72	-23	6
55 to 60	100	150	77	108	50	74	-23	8
60 to 65	100	149	79	109	49	70	-21	9
65 to 70	100	152	83	111	52	69	-17	11
70 to 75	100	151	82	110	51	69	-18	10
75 to 80	100	147	84	110	47	62	-16	10
80 to 85	100	150	86	109	50	64	-14	9
85 to 90	100	149	85	110	49	63	-15	10
90 to 95	100	147	86	109	47	61	-14	9
95 to 100	100	150	94	114	50	56	-6	14

[a] Pre-boom, bubble, and post-crash prices were measured based on annual sales price index values over the respective years 2003, 2006, and 2009. For each size category the year 2003 index value is normalized to 100.

Table 4a: Construction and Distressed Sales by Year

Year	Units Built	Build/Stock	Number Distressed Sales	Distressed/All-Sales
2000	1,569	0.056	15	0.0086
2001	1,646	0.057	21	0.0095
2002	1,710	0.055	35	0.0124
2003	1,766	0.055	51	0.0149
2004	2,270	0.068	52	0.0116
2005	2,014	0.059	38	0.0072
2006	1,699	0.048	9	0.0051
2007	1,084	0.029	88	0.0517
2008	659	0.017	879	0.3435
2009	326	0.008	1,886	0.4637
2010	310	0.008	1,583	0.4150
2011	285	0.007	1,340	0.3159
2012	380	0.009	1,045	0.2731

Table 4b: Construction and Distressed Sales by Home Size Segment

	Pre-Crash: 2000 to 2006			Post-Crash: 2007 to 2012		
Home Size Percentile	Number Units Built	Build/Stock	Number Distressed Sales	Number Units Built	Build/Stock	Number Distressed Sales
0 to 5	1,734	0.011	157	201	0.001	3,187
5 to 10	1,771	0.027	65	317	0.004	1,749
10 to 15	1,538	0.026	47	381	0.006	1,577
15 to 20	1,795	0.037	39	393	0.007	1,365
20 to 25	1,681	0.035	40	393	0.007	1,347
25 to 30	1,738	0.038	31	478	0.009	1,247
30 to 35	1,776	0.037	35	581	0.011	1,205
35 to 40	1,890	0.051	25	479	0.011	1,045
40 to 45	1,725	0.042	24	469	0.010	1,091
45 to 50	1,907	0.047	23	618	0.013	1,078
50 to 55	1,866	0.065	18	469	0.013	901
55 to 60	1,794	0.062	20	500	0.014	954
60 to 65	1,778	0.054	19	545	0.013	945
65 to 70	1,941	0.066	17	527	0.014	858
70 to 75	1,924	0.067	14	564	0.015	834
75 to 80	2,025	0.082	13	602	0.018	743
80 to 85	1,871	0.083	11	597	0.019	753
85 to 90	1,911	0.091	13	618	0.021	697
90 to 95	1,871	0.108	12	619	0.024	662
95 to 100	1,673	0.107	11	799	0.033	501

Table 5
Change in Annual House Price Index in Year-*t* Relative to 2003
For 5-percentile Increment Home-Size Segments From 2000 to 2012[a,b]
(Dependent Variable P_t/P_{2003})[a,b]

	2000-2012	2000-2006	2007-2012	2000-2012	2000-2006	2007-2012
Log number of newly built homes	0.1359	0.0153	0.1847	-0.1302	-0.0577	-0.0465
	(4.67)	(0.85)	(8.95)	(-4.01)	(-1.96)	(-0.57)
Distressed Sales/Total Sales (X1)	-	-	-	-2.4847	7.1975	-1.4349
	-	-	-	(-3.87)	(0.40)	(-1.05)
Listings/Stock in year-*t*/year-2003 (X2)	-	-	-	-1.6269	-0.8169	-1.5294
	-	-	-	(-4.31)	(-2.47)	(-5.32)
Log number of newly built homes * X1	-	-	-	0.2512	-1.0794	0.0981
	-	-	-	(2.76)	(-0.43)	(0.51)
Log number of newly built homes * X2	-	-	-	0.2251	0.1277	0.1873
	-	-	-	(4.71)	(3.13)	(4.52)
Observations	260	140	120	260	140	120
Year Fixed Effects	13	7	6	13	7	6
R-sq within	0.405	0.031	0.558	0.697	0.181	0.737
R-sq between	0.421	0.247	0.837	0.398	0.057	0.821
R-sq overall	0.412	0.065	0.734	0.411	0.050	0.802

[a] Dependent variable equals P_t/P_{2003} where t indexes year (from 2000 to 2012) and P_{2003} is the price index in year 2003. *t*-ratios in parentheses based on standard errors clustered at the year-level.
[b] AMLS data were used to measure the number of distressed sales, homes listed, and spec-home development for each of the 20 home-size categories on an annual basis based on listing and sales from January,, 2000 to September, 2013. The stock of single family homes was determined using Maricopa assessment authority data obtained through Arizona State University. Newly built homes are measured as the change in stock between years. The number of single family homes listed, sales of single family homes, and the number of distressed sales of single family homes were determined using the AMLS data.

Figure 1a: Repeat Sale Price Index Using AMLS 2001:1 – 2013:9

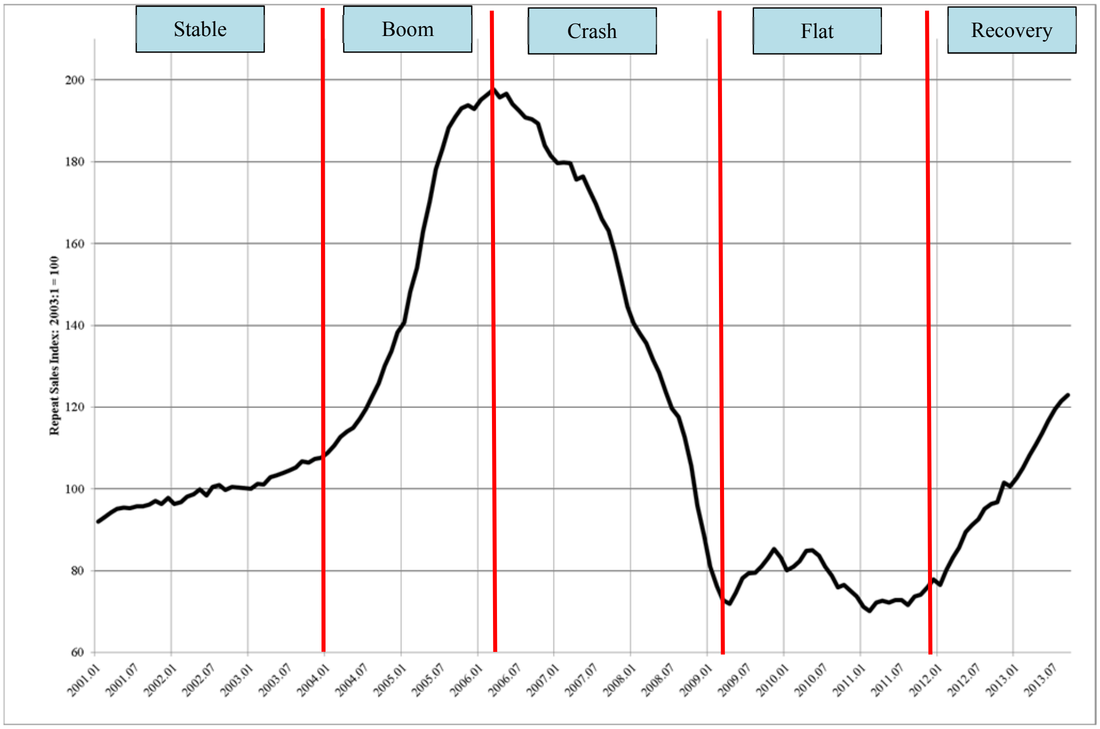


Figure 1b: Number of Homes Sold Using AMLS 2001:1 – 2013:9

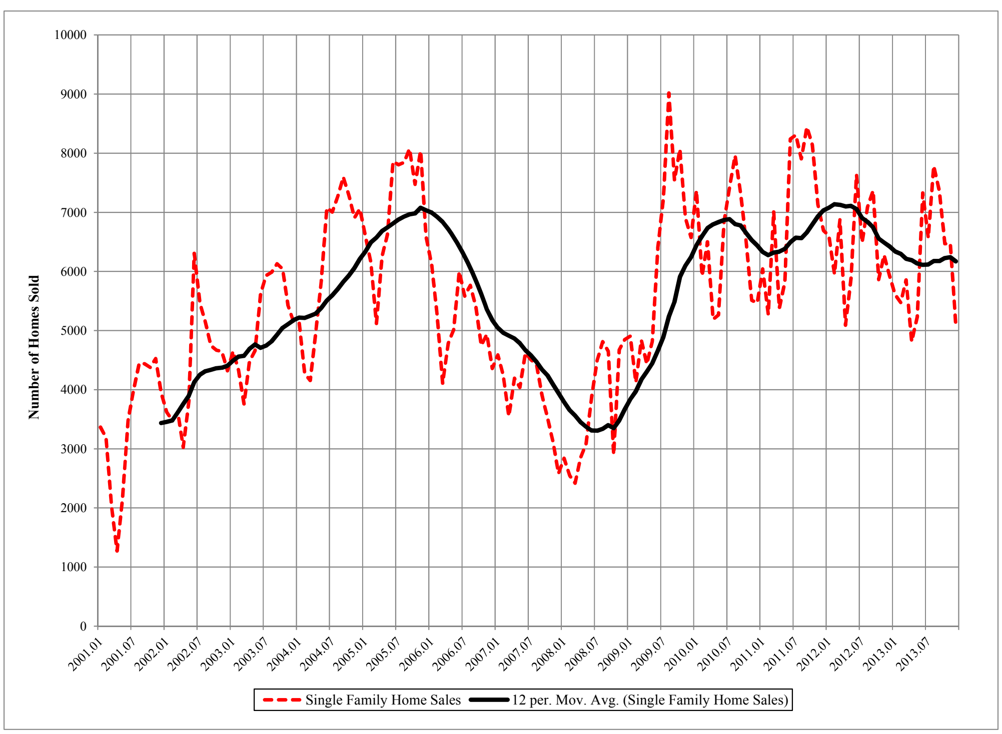


Figure 2a: Repeat Sales Indexes Using AMLS by Home Size Segment 2001:1 – 2013:9

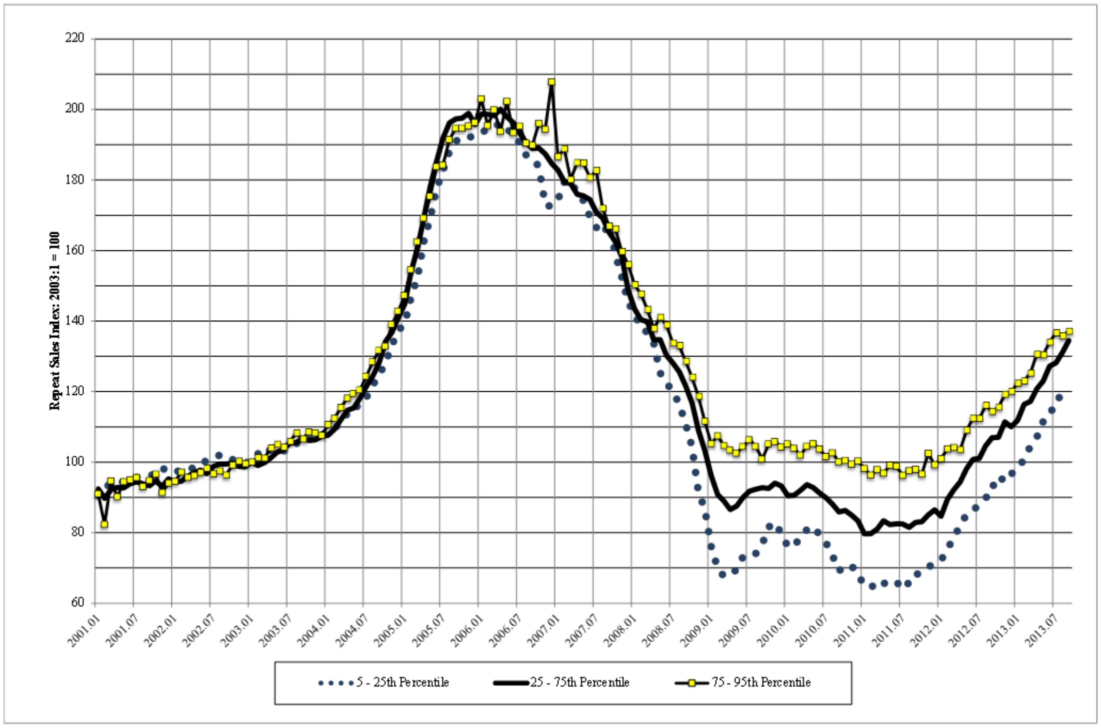


Figure 2b: Single Family Housing Starts and Repeat Sale Index 1989:1 to 2013:12 Based on FRED Data at the Saint Louis Federal Reserve Bank

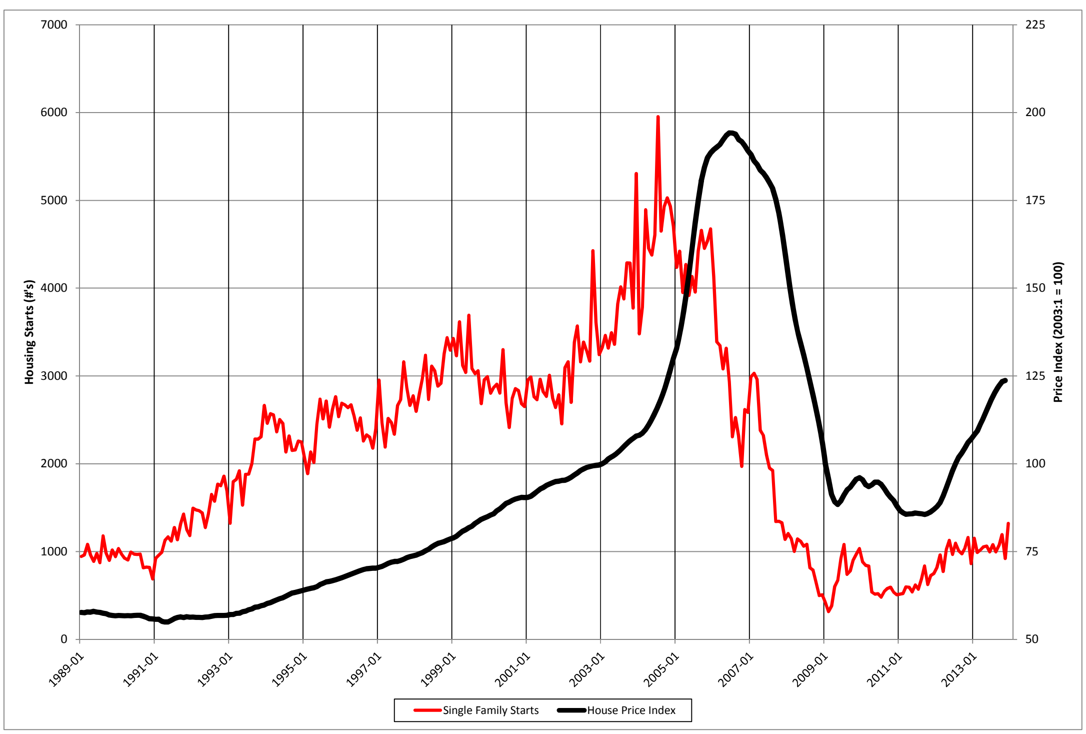


Figure 3: Repeat Sales and Repeat Rent Indexes Using AMLS Data 2001:1 – 2013:9

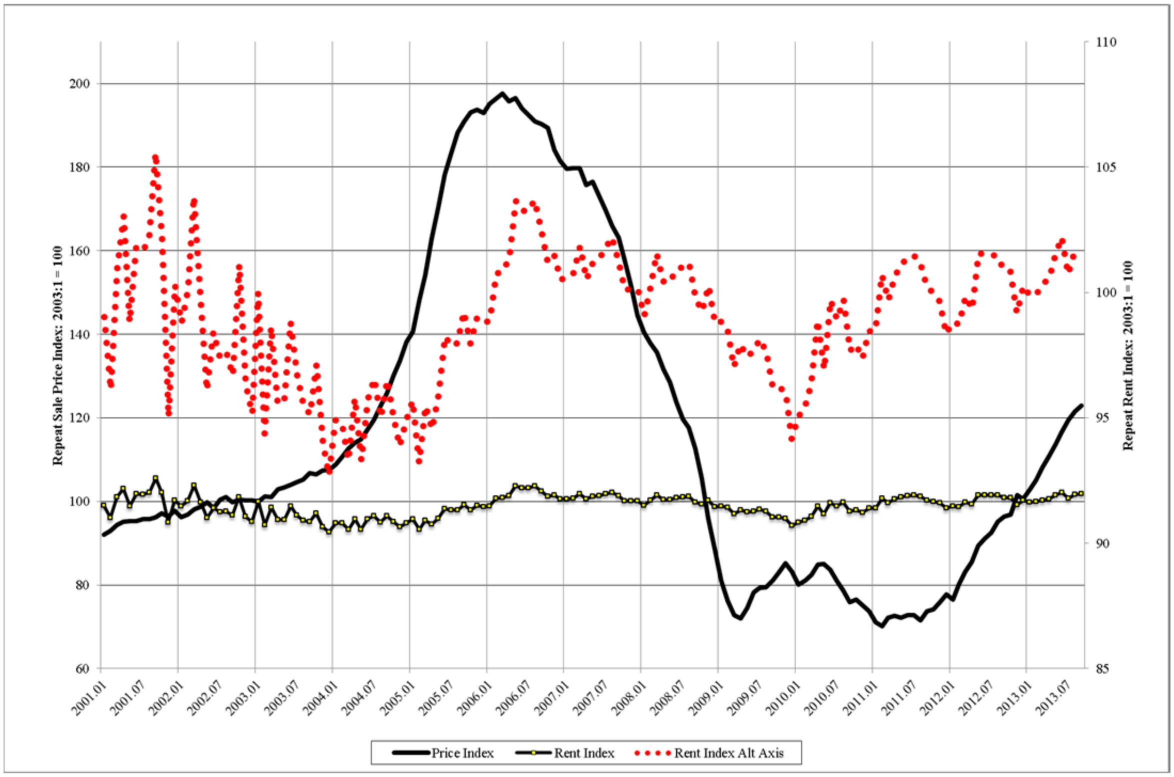


Figure 4: Repeat Sale-to-List and Sale Price Indexes Using AMLS Data 2001:1 – 2013:9

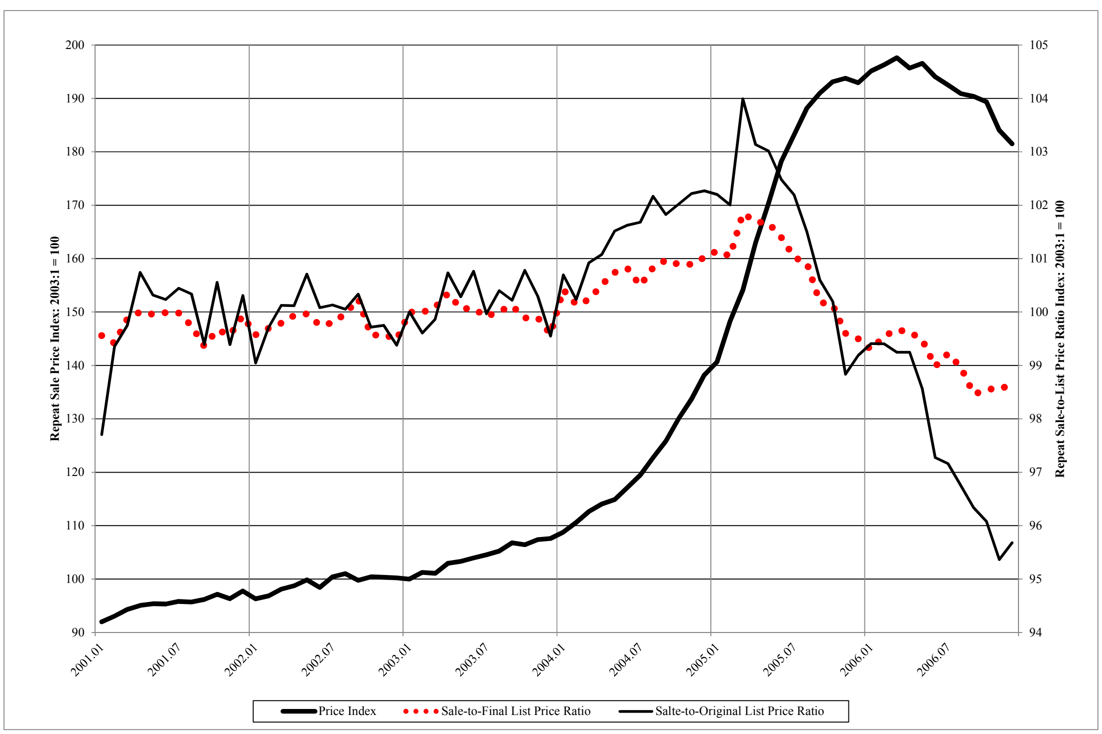


Figure 5: Median Sale-to-List Price Using AMLS Data 2001 - 2013 by Home Size Segment (Based on Final List Price)

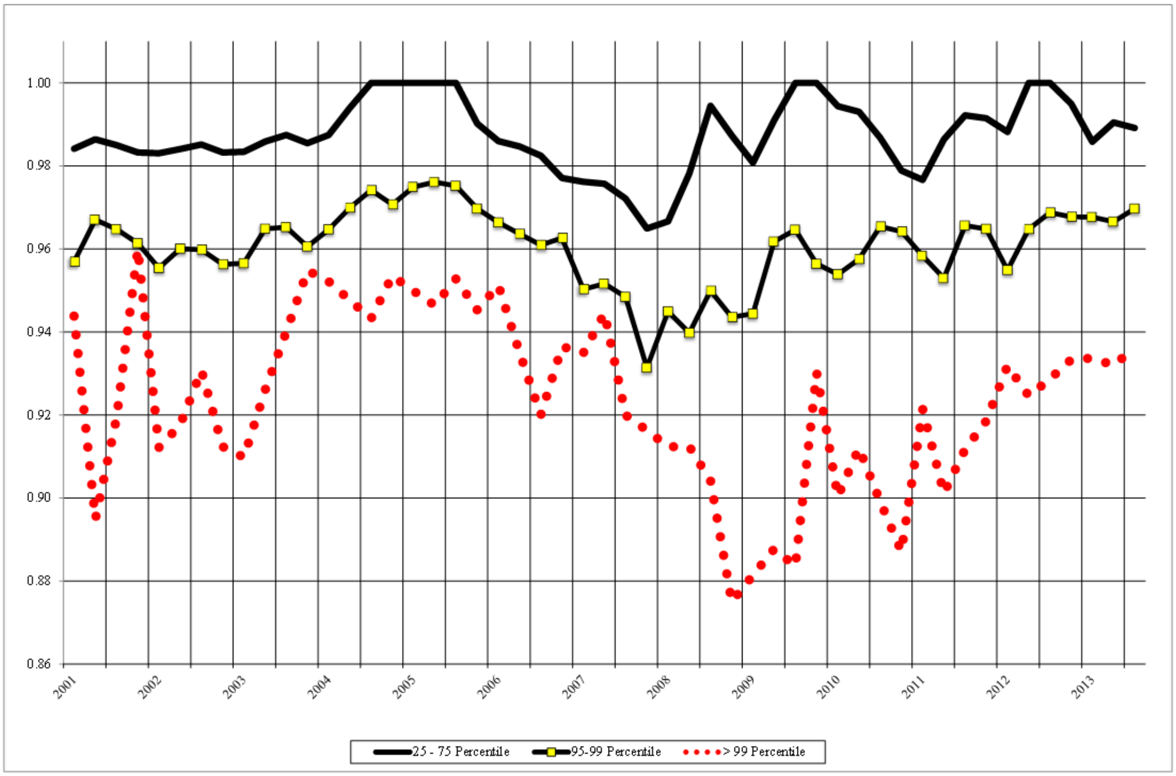


Figure 6a: Repeat Sale Price Index (Annual) Using AMLS Data 2001-2013
Mansions Versus the Core of the Market

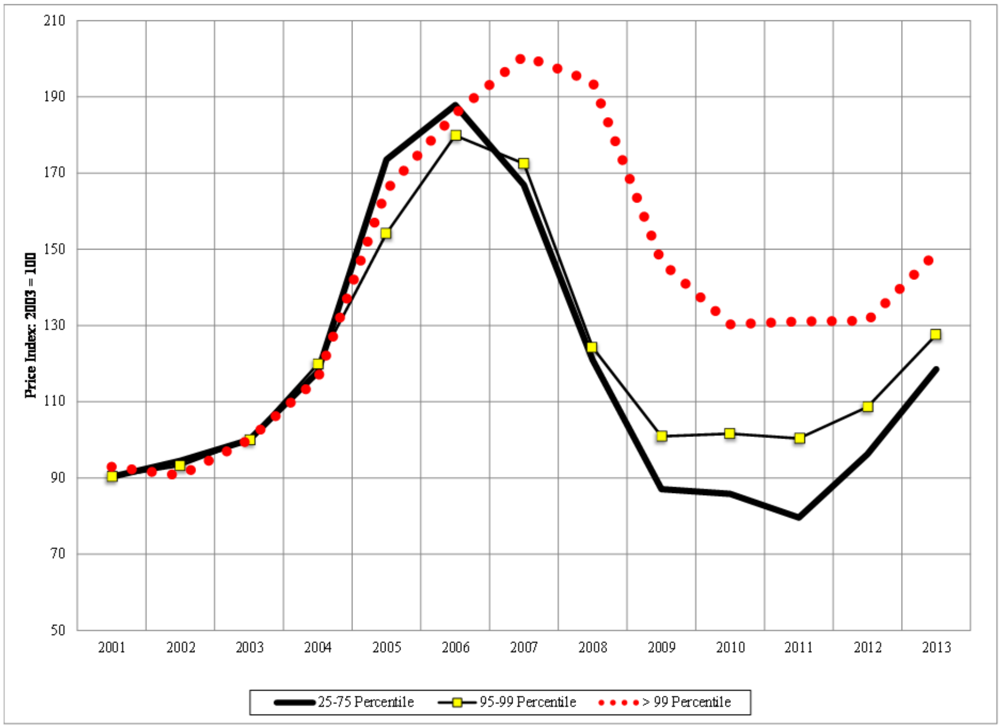


Figure 6b: Repeat Sale-to-Final List Price Ratio (Annual)
Using AMLS Data 2001-2013
Mansions Versus the Core of the Market

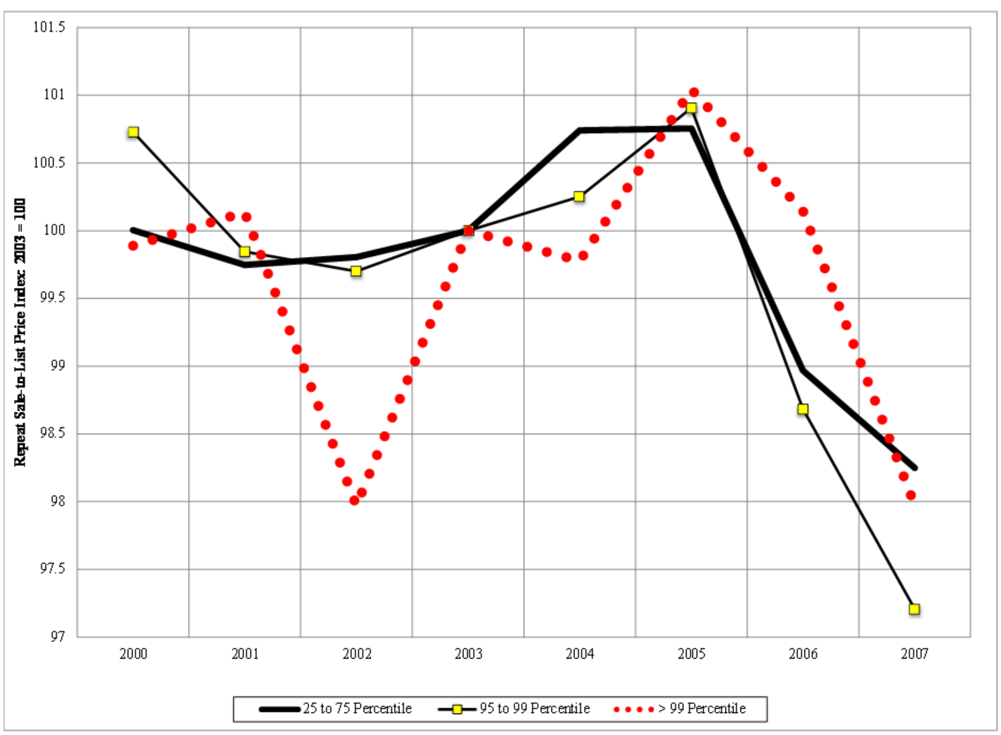


Figure 7: Post-Crash Dynamics When All Homes Implicitly Turn Over Each Period

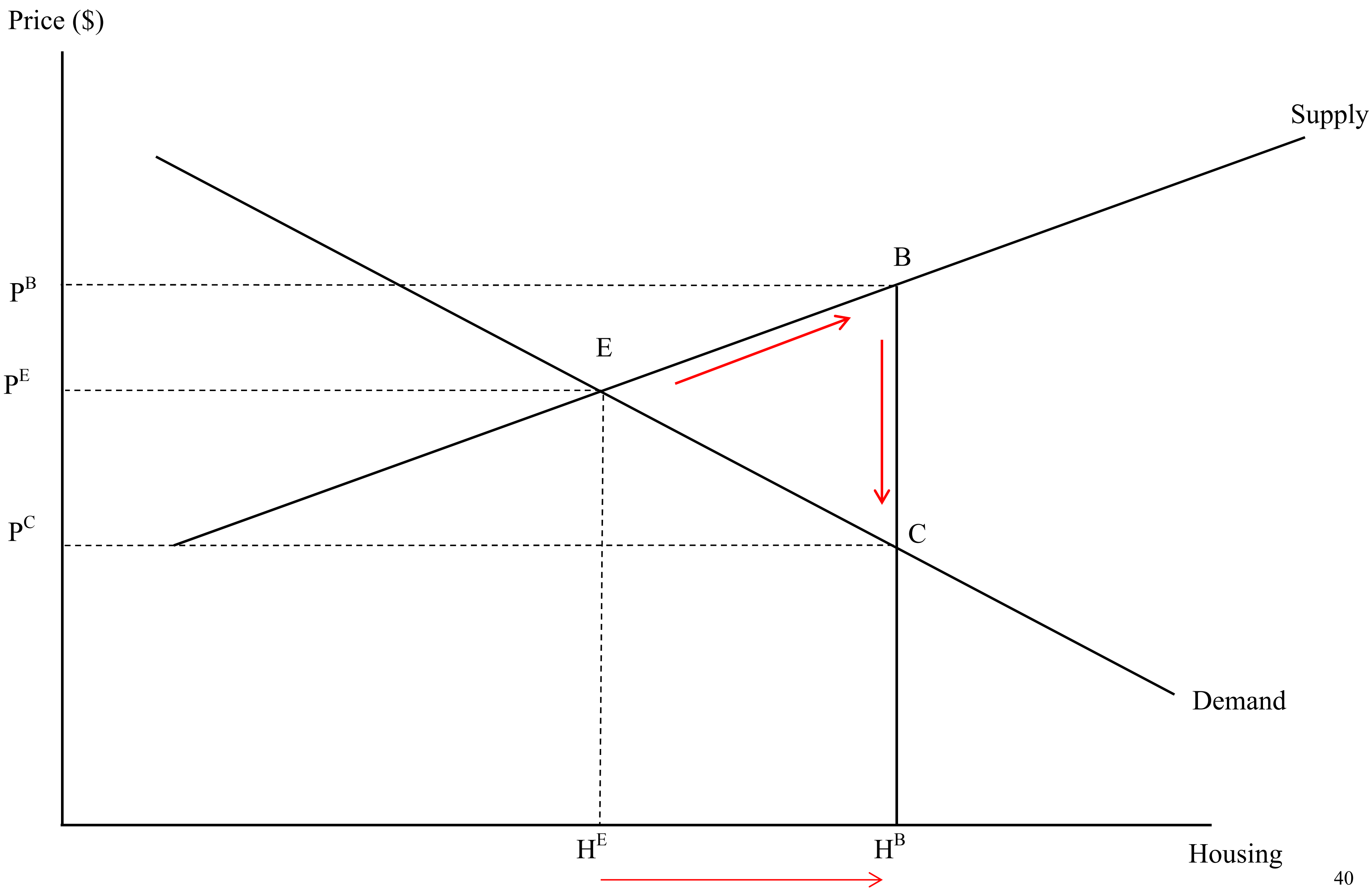
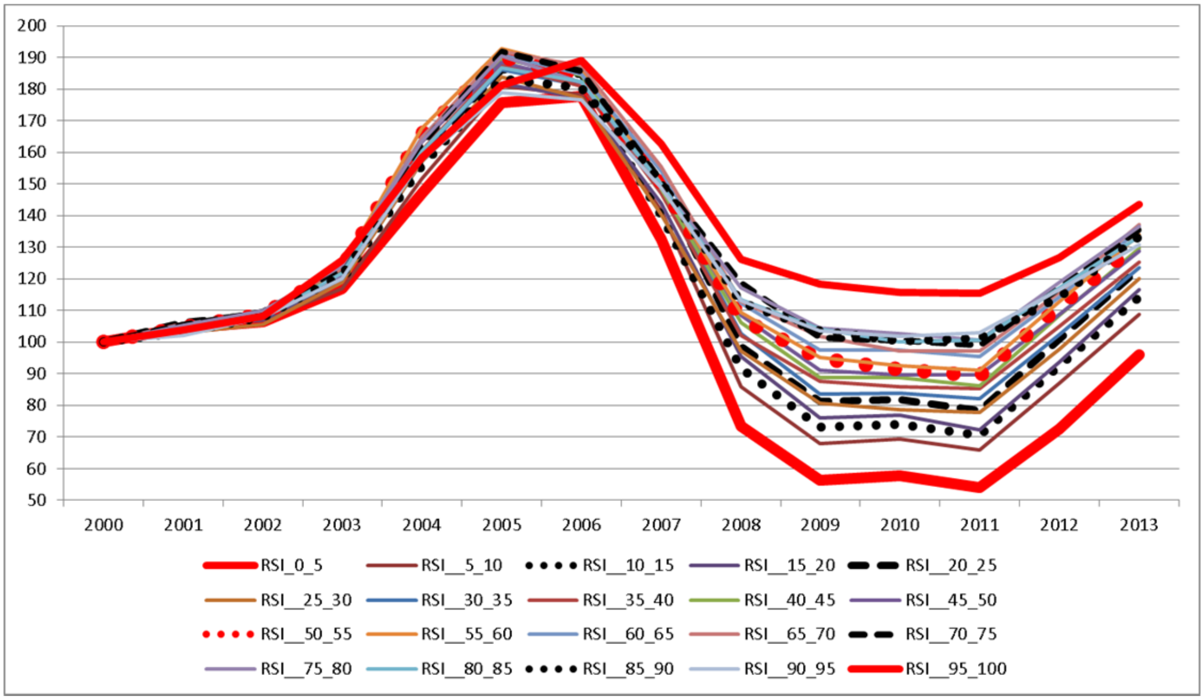


Figure 8: Annual House Price Indexes Using AMLS Data for 20 Home-Size Segments



Appendix A
Supplemental Tables and Figures

Table A-1
Correlation Coefficients Between AMLS and Assessment Authority Repeat Sale Indexes
July 2000 to December 2011

Home Size Percentile	Monthly Indexes	Annual Indexes	Home Size Percentile	Monthly Indexes	Annual Indexes
0 to 5	0.989	0.993	50 to 55	0.986	0.997
5 to 10	0.987	0.995	55 to 60	0.983	0.995
10 to 15	0.989	0.995	60 to 65	0.987	0.991
15 to 20	0.980	0.995	65 to 70	0.973	0.996
20 to 25	0.986	0.995	70 to 75	0.978	0.990
25 to 30	0.984	0.996	75 to 80	0.965	0.985
30 to 35	0.985	0.993	80 to 85	0.961	0.994
35 to 40	0.985	0.994	85 to 90	0.983	0.990
40 to 45	0.989	0.996	90 to 95	0.967	0.984
45 to 50	0.988	0.997	95 to 100	0.945	0.981

[a] Values are the correlation between two alternate sets of home price indexes. The set of indexes was calculated using AMLS data which does not include FISBO ("for sale by owner") sales. The second was calculated using Maricopa County assessment authority data and was obtained from ION corporation. Those data are available from 2000 through 2011. Both data sets include only single family homes sold during the 2000-2011 period.

Figure A-1: Repeat Sale Price Index Using AMLS 2001:1 – 2013:9 With Confidence Bands