A Study of the House Price Dynamics with Bubble: Evidence of U.S. Housing Markets

Vipin Agrawal[a]
Doo Woan Bahng[b]
Su Han Chan[c]
Sae Woon Park[b]
Yun W. Park [a, d]

Abstract
Cycles of boom and bust in the housing market seem to give support to the 'bubble theory' of the house price where the house price is essentially the sum of the fundamental price and the bubble. We test the theory using the cross-sectional time series data of 50 US states from 1985 onwards. We measure the bubble using the percentage changes in median house prices for the 2004:1 to 2006:2 period as well as the deviation from the long run PIR (price-to-income ratios). We find that states with a larger bubble experience a larger subsequent price downfall. Our data suggests that the house price bubble is quite widespread, but geographically confined to 3-4 geographical regions. We document that the excessive liquidity measured by the subprime mortgage and the speculative activity as measured by the variation of house prices explained by the past increases in prices cause the bubble formation and the subsequent burst. Our data also shows that the states with the greater use of subprime mortgages experienced a greater bubble and a greater subsequent bust suggesting that the excessive liquidity that led to excessive subprime mortgage financing contributed to the most recent housing market bubble.

Keywords

bubbles, boom and bust, house price dynamics, speculation, excess liquidity, U.S. housing market, real estate cycles, subprime mortgages, price momentum, price-to-income ratio

[a] Department of Finance, California State University-Fullerton
[b] Department of Business Administration, Changwon National University, South Korea
[c] Department of Real Estate, Zicklin School of Business, Baruch College/CUNY, NY.
[d] Corresponding Author
.

1. Introduction

The US housing market has been subject to two long and sustained cycles of boom and bust in recent years; the first boom in the 1980's and the subsequent crash in the early part of 1990 and the second boom from about the mid-1990's to about 2006 and the corresponding crash still under progress.[1] The boom/bust cycle currently under progress, especially in major metropolitan cities, appears to be the biggest cycle in record both in duration and strength. As shown in Figure 1 the boom/bust cycles appear to be more evident in markets such as California and Florida than others such as Nebraska. The real house prices in California, between 1975-2008 underwent three sustained run-ups and three sustained falls. The most recent house price run-up started in the mid-1990's until it reached the peak around 2006. Then, house prices fell rapidly since 2007. The house prices in Florida, unlike those in California, were relatively stagnant between 1980 and 1996, but they too rose quickly through the middle of the 2000's before they started to decline in 2007. In contrast, house prices in Nebraska rose slowly over the last four decades right up to 2007.

Within the latest boom, America has seen one of the biggest increases in house prices between 2004:1-2006:2 with the average real price growing by 19.3%. In California, Florida, Nevada, Hawaii, Maryland and Washington D.C., they soared by more than 40%. Standard and Poor Composite Home Price Index, which is based on 10 major US cities and has been published monthly since January 1987, peaked in June, 2006. We take the view that we can measure the bubble using this period in which a sudden acceleration of the house price increase occurs within a boom cycle.

[1] Refer to Shiller (2008a) for a thorough discussion of the major booms and busts in the US housing markets.

[Insert Figure 1 about here.]

The booms and busts in house prices observed in the U.S. and abroad have stimulated a great deal of academic research. In particular, Abraham and Hendershott (1996) and Case and Shiller (2003) provide empirical evidence of housing price bubbles in the U.S. Goodman and Thibodeau (2008) show that there was an extreme speculative activity between 2001 and 2005 in the Atlantic coast and California's Pacific coasts. International studies examine bubbles in the UK, Sweden, Spain, China and the OECD countries as a whole among others. There are a number of studies that examine bubbles in the Asian real estate markets as well. An example is Hui and Yue (2006), who examine the recent house price run-ups in Hong Kong, Beijing and Shanghai. Noord (2006) examines the recent house price run-ups in the OECD countries as a whole.

First, since the housing markets in the US are already overheated by the end of 2003, we assume that the subsequent rapid price escalation represents the bubble. Therefore, we measure the bubble using the percentage changes in median house prices for the 2004:1 to 2006:2 period. We find that states with a larger bubble experience a larger subsequent price downfall that occurs between 2006 and 2008.

Next, we assume that house prices are a sum of some multiples of income and a bubble, we measure bubbles using the deviation from equilibrium house price-to-income ratios. We estimate the deviation from the equilibrium house price-to-income ratio at a state level from the first quarter of 1985 to the second quarter of 2006 where we use the US log run average price-to-income ratio and the state long-run price-to-income ratio as the equilibrium house price-to-income ratio. We find that states with a larger bubble experience a larger subsequent price downfall.

Our data suggests that the house price bubble is quite widespread– there are 22 states whose PIR deviation was 15% or higher and 18 states whose deviation was 20% or higher, but geographically confined to 3-4 geographical regions, but the household wealth it impacted is quite large. We document that the excess liquidity measured by the subprime mortgage and the speculative activity as measured by the variation of house prices explained by the past increase in prices influence the size of the bubble. Our data shows that the states with the greater use of subprime mortgages experienced a greater bubble and a greater subsequent bust suggesting that the excess liquidity that caused the rapid growth of the subprime mortgage financing contributed to the current housing market cycle. Overall our results are consistent with the bubble theory of house prices where bubbles grow as house prices rise above the fundamental prices (boom cycle) followed by a collapse of the bubble where house prices revert back to fundamental prices (bust cycle).

The paper is structured as follows. The next section reviews some of the existing studies on house price dynamics, develops the theoretical framework of house price dynamics with bubble and derives econometric models. Section 3 discusses the data. Section 4 tests these models and also evaluates the effect of the speculative activities as well as excess liquidity on the bubble and the subsequent price corrections. Section 5 concludes.

2. Literature Review and Hypothesis Development

The boom and bust phenomena in house prices observed in the U.S. and abroad have stimulated extensive academic research. In particular, Abraham and Hendershott

(1996) and Case and Shiller (2003) provide evidence of housing price bubbles in the U.S. International studies examining bubbles in housing markets include Muellbauer and Murphy (1997) who study the UK housing markets; Bjorklund and Soderburg (1999) who study the Swedish housing markets; and Hui and Shen (2006) who examine the the Chinise housing markets; Fernandez-Kranz and Hon (2006) who study the Spanish housing markets.

Muellbauer and Murphy (1997) examine the economic causes of booms and busts of the UK housing market between 1957 and 1994. Bjorklund and Soderberg (1999) show that the Swedish market for rental properties may have been partly driven by a speculative bubble during the 1980's. Fernandez-Kranz and Hon (2006) examine the house price bubble in Spain between 1998 and 2003. Noord (2006) examines the recent house price run-ups in OECD countries showing that the risk of the housing upswing nearing a peak, even without further interest rate hikes, is found to be high (at or close to 100%) in the United States, and smaller but still significant in France and New Zealand.

Using annual real house prices of 30 metropolitan cities from 1978 to 1992, Abraham and Hendershott find that fundamental variables such as the growth in real income and construction costs and change in the real after-tax interest rate account for about two-fifths of the variation in real house price movements and that non-fundamental variables (lagged real appreciation and the difference between the actual and equilibrium real house price levels) account for about two fifths of the variation and together about three-fifths of the variation. Similarly, Garcia, Giannikos and Guirguts (2007) present evidence that the high growth rates of Spanish house prices can not be fully attributed to fundamentals and that momentum bubbles have a significant impact on real house prices between 1993 and 2004.

More recently, using quarterly housing price time series from 1985 to 2002 for the 50 states of the US, Case and Shiller (2003) report that income alone explains patterns of home price changes since 1985 in all but eight states (Hawaii, Connecticut, New Hampshire, California, Rhode Island, Massachusetts, New Jersey and New York), and in these states the addition of other fundamental variables adds explanatory power. They point out that the pattern of smoothly rising and falling price-to-income ratios and the consistent pattern of under-forecasting of home prices in 2000-2002 suggest that a bubble may exist in these states.

By estimating a probit model of the probability that a peak is nearing in the current situation using the OECD data for the period 1970-2005, van den Noord (2006) finds that an increase in interest rates by 1 to 2 percentage points above then the current historically low interest rates would result in probabilities of a peak nearing 50% or more in the United States, France, Denmark, Ireland, New Zealand, Spain and Sweden. He notes that the subsequent drops in prices in real terms might be large and that the process could be protracted.

Hott and Monnin (2008) propose two alternative models to estimate fundamental prices in real estate markets. They estimate both models for the USA, the UK, Japan, Switzerland and the Netherlands between 1997 and 2005. They find that observed prices deviate substantially and for long periods from their estimated fundamental values. However, they find some evidence that, in the long run, actual prices tend to return to their fundamental values over time.

Shiller (2007) notes that the recent run-up in house prices has occurred, not just in the US., but also in Australia, Canada, China, France, India, Ireland, Italy, Korea, Russia, Spain, and the UK. The coincidence of housing booms across countries would seem to cast doubt on the argument that purely local phenomena, such as supply constraints, could be responsible for house price growth patterns. Moreover, Shiller argues, the boom in the U.S. may be best understood as a series of regional booms, starting at different times. Shiller characterizes the boom in house prices as a classic speculative bubble, driven by extravagant expectations for future price increases, and argues that survey research measuring consumer expectations confirms this description.

Schnabl and Hoffman (2008) using the NAREIT Real Estate Mortgage Index and the NAREIT Real Estate 50 Index argue that in the U.S., the sharp interest cuts in response to the bursting of the dotcom bubble in 2000 led to an overinvestment in the housing market, which in turn led to the most recent boom and bust in the US housing markets.

Stiglitz (1990) provides an intuitive definition of asset bubble: “If the reason that the price is high today is only because investors believe that the selling price is high tomorrow–when fundamental factors do not seem to justify such a price–then a bubble exists.” Moreover, Shiller (2007) also provides a definition of a speculative bubble as a feedback mechanism operating through public observation of price increase and public expectations of future price increases. Thus, a reasonable theoretical framework of house price dynamics with bubble can be based on the idea that bubbles exist if the appreciation of prices is motivated mainly by speculation based on past price increases rather than by market fundamentals.

The preceding literature review suggests that house prices are a sum of fundamental prices and speculative components and that the behavior of the speculative component then gives rise to boom/bust cycles. Variations in the fundamental component of house prices are a result of demand and supply imbalance. Assuming that house prices are some combinations of fundamental factors such as income and a bubble, we can measure bubbles using the deviation of house prices from some fundamental prices. If prices and income are cointegrated, then the gap between the two may be a useful indicator of when house prices are above or below their equilibrium values (Abraham and Hendershott, 1996; Capozza et al., 2002 ; Malpezzi, 2002; Meen, 2002, Gallin, 2003).

Therefore, we measure the size of bubbles using the house price run-up as well as the deviation of PIR (price-to-income ratios) from the long run PIR. We measure speculation by the influence of house price momentum among others. We then measure the size of the bubble burst by the price correction that occurs following the bubble. For example, we measure the size of the most recent bubble burst by the price drop between 2006:2 and 2008:3.

3. Data Discussion

The study period comprises 1985:1 to 2008:3 for 50 states, from which we use the sample period from 1985:1 to 2006:2, a total of 86 quarterly observations, to estimate the bubble size and we use the sample period from 2006:2 o 2008:3 to estimate the size of the bubble burst.[2] We use the OFHEO (Office of Federal Housing Enterprise Oversight) quarterly house price index, which uses data on conventional conforming mortgage transactions on single detached properties obtained from the Federal Home Loan

[22] The main findings of the paper do not change even when we include Washington D.C. in the sample.

Mortgage Corporation (Freddie Mac) and the Federal National Mortgage Association (Fannie Mae). The house price indexes (HPI) published by the OFHEO are based on a modified version of the weighted repeat sales (WRS) methodology proposed by Case and Shiller (1989).[3]

Since we do not have the actual median house prices for the states, we estimate the state median house prices from the OFHEO house price index for each state. First, we estimate the median house prices in 1975:1 by dividing the 2000 state median house prices by the state house price indices in 2000:1.[4] We choose to show the median house price indices in 1975:1 because the OFHEO state house price indices start in 1975:1. Then, we multiply the 1975:1 median house prices by the 2006:2 house price index to calculate the median house prices in 2006:2. Similarly, we multiply the 1975:1 median house prices by the 2008:3 house price index to calculate the median house prices in 2008:3.

The data for house price determinants are obtained over the same period as our quarterly house price index. They come from various sources and precise definitions and sources are shown in the Appendix 1. We use quarterly total personal income time series. However, when the total personal income is available only on an annual basis, we interpolate it to generate quarterly observations using the cubic method.[5] For monthly data such as the interest rates on 30-year conventional mortgage loans, we use March, June, September and December observations.[6] Those variables measured in nominal

[3] Calhoun (1996) provides the background and a technical description of the data and statistical methods used to estimate the HPI.
[4] State-level median house prices in 2000 are based on owner estimates found in the 2000 census.
[5] We use the cubic spline interpolation, which involves joining segments of third degree (cubic) polynomial curves.
[6] When we use monthly average interest rates to produce quarterly observations, we get similar results.

terms (such as house price index, total personal income and construction cost index) are deflated by the consumer price index of the corresponding state. For the regression results in the tables, we do not adjust for the possible seasonality in housing price index.[7] All the variables, with the exception of interest rates, are converted to natural logarithms. Subprime originations as a share of housing units in 2005 by states are from the 2006 Mortgage Market Statistical Annual.

4. Empirical Results and Discussion

Next, we use the price increases that occur after 2003 to measure the size of the bubble. That is, we measure the bubble as the price increase over 2004:1 to 2006:2 where we assume that prices in 2003:4 are fundamental prices and price increases over 2004:1 to 2006:2 are bubbles. Prices which began rising from the second half of 1990s appear to peak in 2003. Then as the real federal funds rates turn negative in 2004, house prices rise even more sharply. Therefore, one can argue that price increases from 2004 till 2006 are speculative bubbles caused by excessively low or negative real interest rates. Assuming that bubbles start in 2004:1 and burst in 2006:2 we measure the size of the bubble as rates of changes in house prices for the 2004:1 to 2006:2 period. The state level results are shown in Appendix 2 and the decile summaries are shown in Table 1.

[Insert Table 1 about here.]

Appendix 1 shows the median house prices in 2004:1, the median house prices in 2006:2, the median house prices in 2008:3, the percentage changes in median house prices for the 2004:1 to 2006:2 period and the percentage changes in median house prices

[7] However, when the housing price index is seasonally adjusted using the 11th district seasonal adjustment method, we get essentially similar results.

for the 2006:2 to 2008:3 period for all 50 states. The 50 states are ranked by the percentage changes in median house prices for the 2004:1 to 2006:2 period, then grouped into 10 deciles where the decile 1 corresponds to the states with the highest price run-up and the decile 10, the lowest price run-up. The corresponding decile figures are shown in Panel A of Table 1. In column (A) of Panel A of Table 1 we show the decile median house prices in 2004:1. In column (B) we show the decile median house prices in 2006:2. In column (C) we show the decile median house prices in 2008:3. Assuming that bubbles start in 2004:1 and burst in 2006:2 we measure the size of the bubble as percentage changes in median house prices for the 2004:1 to 2006:2 period as shown in column (D). We find that the bust is concentrated in the decile 1 states where the price run-up of 58.86% is followed by the price fall of 16.78%. In contrast, the price fall is relatively modest in deciles 2 through 10.

Shiller (2008) indicates that the rate of US housing appreciation slowed after 2005 and suggests that sometime after mid-2006 prices began declining. Schnabl and Hoffman (2008) indicate that the recent speculative bubble in the US housing market burst in summer of 2007 suggesting that prices reached the peak about 2007:1. Therefore, we, albeit somewhat arbitrarily, consider the state median house prices in 2006:2 to be the peak prices, which we show in column (B) of Appendix 2.[8]

We regress the percentage changes in house prices for 2006:2/2008:3 on those for 2004:2/2006:2 and show the OLS regression analysis in Panel B. The regression coefficient is negative (-0.26) and significant (p-value < 1%) suggesting that the bubble formed during the boom causes the bust in the aftermath. We conduct non-parametric

[8] Even if we move up the peak up to four quarters beyond 2006:2, the main conclusions of the paper are not affected.

tests of the correlation between the percentage changes in house prices for 2004:2-2006:2 and those for 2006:2-2008:3 and find that they are strongly negatively correlated. Kendal's tau is -0.822 and Spearman's rho is -0.915, which are significant at 1%, respectively. The non-parametric correlation test result suggests that the bubble formed during the boom is closely associated with the bust in the aftermath.

We also measure the size of the bubble in residential house prices in each state by calculating the deviation from the long run state average PIR. After ranking the states by the PIR deviations, which are shown in Appendix 3, we form 10 deciles where the decile 1 corresponds to the states with the highest PIR deviation and the decile 10, those states with the lowest PIR deviation. Panel A of Table 2 shows the size of the bubble and the corresponding size of the bubble burst for the deciles. Column A shows the state average PIR; column B, the state 2006:2 PIR; column C, the deviation from the state average PIR; and column D, the deviation from the US average PIR. Column E shows the percentage changes in median house prices for 2006:2-2008:3. We find a clear correlation between the PIR deviation and the house price drop.

[Insert Table 2 about here.]

In Panel B, we regress the size of the bubble burst on the size of the bubble formed (the deviation from the state average and the U.S. average) using the ordinary least squares method. The results reported in the panel show that the regression coefficient of the bubble formed is highly significant and negative. We conduct non-parametric tests of the correlation between the two measures (the deviation from the state average PIR and the subsequent price drop) and find that they are strongly negatively correlated as shown in Panel C. Kendal's tau is -0.764 and Spearman's rho is -0.894, which are significant at 1%, respectively. Our results in Panels B and C imply that the states with a larger bubble experience a larger subsequent price correction. They also suggest that the rise in the house price above the fundamental price (bubble formation) is followed by a collapse of the bubble where the house price reverts back to the fundamental price (bubble burst).

In Figure 2, we show on the US map the largest PIR deviation states (the deciles 1 and 2 states), which are Hawaii (HI), California (CA), Washington (WA), Arizona (AZ), Nevada (NV), Oregon (OR), Rhode Island (RI), Washington D.C. (DC), Florida (FL) and New Jersey (NJ). The largest PIR deviation states are indicated with the horizontal lines. States which experienced the largest subsequent house price drops from 2006:2 to 2008:3 (the deciles 1 and 2 states) are indicated with vertical lines. These states are California (CA), Nevada (NV), Florida (FL), Arizona (AZ), Rhode Island (RI), Michigan (MI), Massachusetts (MA), New Hampshire (NH), Montana (MN) and New Jersey (NJ). The states which experienced the largest PIR deviation, then, the largest price drop are California (CA), Nevada (NV), Arizona (AZ), Florida (FL), New Jersey (NJ) and Rhode Island (RI) and they are indicated by meshed lines.

Notice that most of the states that show a large bubble formation belong to the northern part of the east coast, west coast (including Hawaii), and states with a warm climate such as Nevada, Arizona, and Florida. This is consistent with the anecdotal observation that the bubble in the recent real estate boom concentrated on the northeastern states, states along the west coast and states with a warm climate. This is also consistent with the findings of Goodman and Thibodeau (2008) who show that there was an extreme speculative activity between 2001 and 2005 in the Atlantic coast and California's Pacific coasts.

Our data suggests that the speculation is quite widespread– there are 22 states whose PIR deviation was 15% or higher and 18 states whose deviation was 20% or higher, but geographically confined to 3-4 geographical regions, but the household wealth it impacted is quite large.

[Insert Figure 2 about here.]

We next analyze the rate of change in real house prices as a function of fundamental variables and the house price momentum for the 50 U.S. states for the 1985:1 to 2006:2 period.[9] We choose this time frame (and not 1975:1 to 2006:2) to focus on the current bubble. As fundamental variables we use the natural logarithm of the total household income, mortgage rates, and the rate of change in construction costs which is measured by the first difference in the natural logarithm of construction costs in real dollars. As momentum variables, which are measures of the speculative component of house prices we use the lagged rate of change in the real house price up to four quarters.

Here we adopt the simple version of the fundamental house price equation as proposed by Hendry (1984) among others where the real house price is expressed in terms of the total personal income, construction costs, and interest rate.[10] To this simple model of house prices where house price determinants are fundamental factors of house prices, we add the influence of the past house prices to model the speculative component of house prices. The explanatory power of the past house increases on the current price increases in a given state can measure the speculative activity in the housing market.

[9] The exact starting date of the time series varies depending on the number of lags used in the model.
[10] Total personal income is the product of the number of households and per capita income.

Table 3 reports the regression estimates for two selected states: California (a bubble state) and Nebraska (a non-bubble state). The fundamental variables have the expected signs for California and Nebraska. The coefficient of the rate of change in total personal income is positive suggesting that increases in real income raise real house prices. The coefficient of the rate of change in construction costs is also positive suggesting that increases in construction costs push up real house prices. The negative coefficient associated with mortgage rates suggests that a drop in the mortgage rate leads to increases in real house prices.

[Insert Table 3 about here.]

We document that house prices show a strong momentum in relation to past price changes and the previous period mispricing only in California. For the Nebraska sample, the influence of the past four quarter returns on housing is limited at most. House prices in non-bubble states like Nebraska have been falling from the beginning of the sample period (1975) to about mid-90s monotonically. We conclude that speculative activities are unlikely to be present in states like Nebraska and speculative activities are likely to be present in states like California.

We forecast the ‘fundamental house prices’ from 2004:1 to 2008:3 using the in-sample forecasting method. The house price equation uses the fundamental variables only. Using the model estimates for 1985:1-2003:4, we forecast house prices for 2004:1-2008:3. We plot the actual housing prices vs. forecasted house prices in Figure 3. We find that in California the observed house prices overshoot the forecasted prices by a wide margin (19%) for 2004:1-2006:2 then they fall quite rapidly toward the ‘fundamental prices’ thereafter while in Nebraska the actual house prices are only slightly higher than the fundamental prices (3%) through the entire period of 2004:1-2008:3. This is consistent with the hypothesis that a large bubble was formed in the California house price prior to the bubble burst that followed.

[Insert Figure 3 about here.]

We extend this analysis to all 50 states. We find that the ten states with the greatest overshooting of the actual house prices over the forecasted prices in 2006Q2 are Nevada with 22% of overshooting; California, 19% ; Florida, 16%; Hawaii, 14%,….

When we can add the housing supply variable, which is measured by the new housing units, as a fundamental variable to the house price equation, we find qualitatively the same results as before. When we use the federal fund rates, prime lending rates and yields on 10-year treasury notes instead of interest rates on the 30-year conventional mortgage loans, we find qualitatively the same results as before. To control for the substitution effect of the stock market, we add the changes in the NYSE-Amex-NASDAQ weighted average stock price index as an explanatory variable. We obtain qualitatively the same results as before.

A number of studies have indicated that the public expectation of future house prices affects the current house prices. In particular, Abraham and Hendershott (1996) and Case and Shiller (2003) use the explanatory power of the past prices as a measure of speculation. Similarly, we measure the level of speculation using the R^2 of the past four quarter prices. First, we estimate the regression models for each of the 50 states. Then, we measure the level of speculation using the R^2 of the price momentum variables for each of the 50 states. Next, we divide the states into deciles based on the R^2 of the momentum variables. The results are reported in Table 4. We present, for each decile, the R^2 of the overall variables, the R^2 of the fundamental variables, the R^2 of the momentum variables and the percentage changes in house prices. A casual observation reveals a strong negative correlation between the R^2 of the momentum variables and the percentage changes in house prices during the bust phase.

[Insert Table 4 about here.]

We compare the current bubble with the previous bubble in order to present a more dynamic picture of bubble formation and see if bubbles are becoming more extensive and larger over time suggesting that the next bubble will be even more extensive and larger. We measure bubbles using the PIR deviation from the "equilibrium" PIR, which we estimate by subtracting the US average PIR from the PIR peak for each state for both the 1975:1-1998:2 period and the 1998:3-2008:3 period. We then calculate the percent PIR deviations for each period. The PIR deviation and the percent PIR deviation are shown in Table 5. We find that the number of bubble states has increased from 2 to 14 states using the 50% PIR deviation as the threshold of bubble. The number of bubble states has increased from 10 to 26 states using 20% PIR deviation as the threshold of bubble. Bubbles in bubble states have become larger and some non-bubble states such as Arizona and Florida and Maryland have become bubble states in the current cycle. Clearly, the current bubble is far more extensive than the previous one. The size of the bubble is much greater than the previous bubble for most of bubble states. In particular, the increase in the bubble size in the top four bubble states (Hawaii, California, Nevada and Arizona) is in excess of 60%. Therefore, we conclude that the extent and the intensity of bubble has increased from the previous bubble to the current bubble.

[Insert Table 5 about here.]

The cause of the housing bubble in the 2000's has been the focus of significant policy and academic research. In particular, we examine the effect of the excess liquidity on the bubble and the subsequent burst. We measure the excess liquidity using the subprime loan origination to the extent that an excessive amount of subprime loans were made because of the excess liquidity as pointed out by Coleman IV, LaCour-Little and Vandell (2008), Mayer and Pense (2008), Mian and Sufi (2008), Schnabl and Hoffman (2008), Shiller (2008b), Sherland (2008) and Wheanton and Nechayev (2008) among others.

Schnabl and Hoffman (2008) using the NAREIT Real Estate Mortgage Index and the NAREIT Real Estate 50 Index argue that in the U.S., the sharp interest cuts in response to the bursting of the dotcom bubble in 2000 led to an overinvestment in the housing market, which in turn led to the most recent boom and bust in the US housing markets. Coleman, LaCour-Little and Vandell (2008) show that the dramatic increase in subprime lending during this period is in part responsible for these market dynamics.[11] Mian and Sufi (2008) demonstrate that a rapid expansion in the supply of mortgages driven by disintermediation explains a large fraction of recent U.S. house price appreciation and subsequent mortgage defaults.

In order to examine the possible effect of subprime origination on the bubble dynamics, we conduct a two-stage regression. First, we use the ratio of subprime originations per housing units as independent variable and the deviation from period state average PIR of 2006:2 as dependent variable in the regression estimation. We obtain

[11] Average combined loan –to-value (CLTV) ration on subprime variable-rate mortgages rose from less than 80 percent in 2000 to over 85 percent in 2005-2006. (Sherlund 2008)

fitted values of the deviation from period state average PIR of 2006:2, which we use as the independent variable in the regression estimation of the price change over 2006:2-2008:3.

In Table 5, we report the two-stage regression where we use the subprime lending as one of the causes of the bubble in the first regression. The first-stage regression where the deviation from the state average PIR is the dependent variable indicates that the deviation from the state average PIR is related positively to the subprime lending. Therefore, the subprime lending seems to have influenced the bubble growth measured by the deviation from the state average PIR. The second-stage regression where the house price change between 2006:2 and 2008:3 is the dependent variable indicates that the house price change between 2006:2 and 2008:3 is related negatively to the deviation from the state average PIR showing that a larger bubble leads to a greater price correction.

[Insert Table 6 about here.]

Next, we examine the role of supply elasticity. It is possible that states with low elasticity had bigger bubbles but states with high elasticity had smaller/no bubbles. In addition, the states where the magnitude of the bubbles this period were worse than those in previous periods could be because of worsening supply elasticity (which would again suggest that absent some regulatory changes, the bubbles next period will be worse since supply elasticity will continue to deteriorate).

We estimate the supply elasticity using a two-stage regression as in Goodman and Thibodeau (2008). In the first stage they derive house price estimates using a regression analysis similar to that in Table 3. Then, in the second stage, the predicted real house price estimates are used as an explanatory variable in the supply regression (change in (log) supply = a*change in (log) real prices + b*change in (log) incomes +c*change in (log) construction costs + d*change in (log) population + e*change in (log) unemployment + f*change in (log) interest rate). The supply elasticity will be given by the coefficient of change in (log) real prices ("a").

There is one issue with measuring supply elasticity which may be relevant. When prices decline in a state, supply elasticity is negative because housing stock is not destroyed in declining markets. Obviously this negative number is meaningless – in fact since supply increases in falling markets, one can argue that supply is highly elastic. Therefore, we use the boom period only for the estimation.

[Insert Table 7 about here.]

We conduct a series of robustness checks on our results using alternative measures of the size of bust. Instead of using the 2006:3-2008:3 to measure the bubble burst, we use 2007:1-2008:3 instead since a number of states show the peak price in the latter half of 2006 as measured by the OFHEO index. We obtain qualitatively the same results. We also measure the size of the bubble burst from the quarter after the peak quarter to 2008:3 for each state. We obtain qualitatively the same results. Finally, we use the Case-Shiller house price index instead of the OHFEO index since the OHFEO index is based on conforming loan data, which would exclude expensive houses.[12] We also obtain qualitatively the same results as before.

5. Conclusion

[12] Conforming mortgage loans are mortgage loans which qualify for the Fannie Mae and Freddie Mac mortgage loan purchase programs.

Cycles of boom and bust in the housing market seem to give support to the 'bubble theory' of the house price where the house price is essentially the sum of the fundamental price and the bubble. We examine the bubble dynamics in the 50 states in the most recent house price cycle, which started around the second half of 1990s and peaked around 2006.

Assuming that house prices are some combinations of fundamental factors such as income and a bubble, we measure bubbles using the deviation of house prices from some fundamental prices. Specifically, we measure the size of bubbles using the percentage changes in the median house prices between 2004:1 and 2006:2 as well as the deviation of price-to-income ratios from the long run price-to-income ratios. We then measure the size of the bubble burst by the price correction that occurred between 2006:2 and 2008:3, specifically the percentage changes in the median house prices between 2006:2 and 2008:3.

We estimate the size of the bust as well as the size of the bubble for all 50 states. We also form deciles based on the measures of the bubble. A visual inspection of the deciles shows a clear correlation between the proposed measures of the bubble and the bubble burst.

We model the size of the bust as a function of the size of the bubble. We estimate the model using the cross-sectional regressions. We find that larger bubbles cause larger bubble busts. We confirm the statistical significance of this relationship using the non-parametric tests. Overall our results are consistent with the basic notion of the 'bubble theory' of house prices where bubbles grow as house prices rise above the fundamental prices (boom cycle) followed by a collapse of the bubble where house prices revert back to fundamental prices (bust cycle).

Our data suggests that the house price bubble is quite widespread, but geographically confined to 3-4 geographical regions. Furthermore, the household wealth it impacted is quite large. Most of the states that show a large bubble formation belong to the northern part of the east coast, the west coast (including Hawaii), and states with a warm climate such as Nevada, Arizona, and Florida. This is consistent with the anecdotal observation that the bubble in the recent real estate booms is concentrated on the northeastern states, states along the west coast and states with a warm climate.

We document that the speculative activity as measured by the variation of house prices explained by the past increases in prices influence the size of the bubble. We also document that the excess liquidity measured by the use of subprime mortgage loans also has a positive effect on the size of the bubble. Our data shows that the states with the greater use of subprime mortgages experienced a greater bubble and a greater subsequent bust suggesting that the excess liquidity as manifested through excessive subprime mortgage lending contributed to the most recent housing market bubble.

There is much debate on whether using the PIR to detect a bubble is appropriate. While a few other measures of bubble were proposed in the literature, there is no universally accepted measure of bubble as yet. However, if there is a large deviation of the PIR from the long-run average PIR in a region, the possibility of a bubble exists. Using the deviation from the long-run average PIR, steps can be taken to minimize the negative consequences resulting from the eventual bust. Measuring a bubble using many variables require a great deal of time and effort to make necessary observations of regression variables and to determine the size of the bubble. Therefore, it may take excessive amount of time for the government to intervene in a timely manner. In contrast, the use of a simple measure such as the PIR allows a rather straightforward monitoring of a bubble enabling the government to make policy decisions in a timely manner.

Shiller (2008b) attributes the US economy's two most recent bubbles- one in the stock markets in the 1990s and the other in the housing markets in the 2000s-to the irrational exuberance. The lesson of the subprime crisis is that the government should not allow an irrational exuberance to drive the housing markets. Given the havoc an extensive bubble in the housing markets can cause, the early detection of the bubble is critical. The deviation from the long run average PIR is a simple and intuitive measure of bubble based on the household's ability to pay for the housing costs allowing policy advisors to make timely decisions.

References

Abraham, J. M. and Hendershott, P. H. (1996), Bubbles in metropolitan markets, Journal of Housing Research, **7**, 191-207.

Bjorklaud, K. and Soderberg, B. (1999), Property cycles, speculative bubbles and the gross income multiplier, Journal of Real Estate Research, 18, 151-174.

Capozza, D.R., Hendershott, P.H. , Mark, C. and Mayer, C.J. (2002), Determinants of real house price dynamics, NBER Working Paper No. 9262.

Calhoun, C. A. (1996), OFHEO house price indexes: HPI technical description, Office of Federal Housing Enterprise Oversight.

Case, K. E. and Shiller, R. J. (2003), Is there a bubble in the housing market. Brookings Papers on Economic Activity, 2, 299-362.

Coleman IV. M. , LaCourt-Little, M. and Vandell, K.D. (2008), Subprime lending and the housing bubble: Tail wags dog?, Journal of Housing Economics 17, 272-290.

Fernandez-Kranz. D. and Hon, M. T. (2006), A cross-section analysis of the income elasticity of housing demand in Spain: Is there a real estate bubble?, Journal of Real Estate Finance and Economics 32, 449-470.

Gallin, J. (2003), The long-run relationship between house prices and income: Evidence from local housing markers, Finance and Economic Discussion Series, Federal Reserve Board Working Paper No. 2003-17.

Goodman, A.C. and Thibodeau, T.G. (2008), Where are the speculative bubbles in US housing markets?, Journal of Housing Economics, 17, 117-137.

Hendry, D. F. (1984), Econometric modeling of house prices in the UK, Econometrics and Quantitative Economics, Hendry, D. F. and Wallis, K. F. (eds) Basil Blackwell, Oxford.

Himmelberg, C., Mayer, C. and Sinai, T (2005), Assessing high house prices: Bubbles, fundamentals and misperceptions, Journal of Economic Perspectives 19, 67-92.

Hui, E.C. and Yue, S. (2006), Housing price bubbles in Hong Kong, Beijing and Shanghai: A comparative study, Journal of Real Estate Finance and Economics, 33, 299-327.

Inside Mortgage Finance Publication, Inc. (2007), The 2006 Mortgage Market Statistical Annual.

Malpezzi, S. (1999), A simple error correction model of house prices, Journal of Housing Economics 8, 27-62.

Mayer, C.J. and Pence, K. (2008), Subprime mortgages: What, where, and whom?, NBER Working Paper No. 14083.

Meen, G. (2002), The time-series behavior of house prices: A transatlantic divide?, Journal of Housing Economics 11, 1-23.

Mian, A. and Sufi, A. (2008), The consequences of mortgage credit expansion: Evidence from the 2007 mortgage default crisis, NBER Working Paper No. 13936.

Muellbauer, J. and Murphy, A. (1997), Booms and busts in the UK housing market, The Economic Journal, 107, 1701-1727.

Schnabl, G and Hoffmann, A (2008), Monetary policy, vagabonding liquidity and bursting bubbles in new and emerging markets: An overinvestment view, The World Economy 31, 1226-1252.

Shiller, R.J. (2008a), Historic turning points in real estate, Eastern Economic Journal 34, 1-13.

Shiller, R.J. (2008b), The subprime solution: How today's global financial crisis happened, and what to do about it, Princeton University Press.

Sherland, S.M. (2008), The past, present, and future of subprime mortgages, Finance and Economics Discussion Series, Division of Research & Statistics and Monetary Affairs, Federal Reserve Board, Washington, D.C., Working Paper No. 2008-03.

Stiglitz, J.E. (1990), Symposium on bubbles, Journal of Economic Perspectives 4, 13-18.

van den Noord, P. (2006), Are house prices nearing a peak? A probit analysis for 17 OECD countries, OECD Economics Department Working Papers, No. 488, OECD Publishing

Wheanton, W. C. and Nechayev (2008), The 1998-2005 housing "bubble" and the current "correction ": what's different…, Journal of Real Estate Research 30, 1-26.

Table 1. The relationship between percentage changes in median house prices for the subperiod 2004:1-2006:2 and those for the subperiod 2006:2-2008:3

Panel A. Deciles of percentage changes in median house prices for 2004:1-2006:2

	(A)	(B)	(C)	(D)	(E)
	median house prices, 2004:1	median house prices, 2006:2	median house prices, 2008:3	percentage changes in house prices for 2004:1-2006:2	percentage changes in house prices for 2006:2-2008:3
decile 1	251,153	396,304	336,341	58.86	-16.78
decile 2	193,667	285,859	284,155	46.59	0.11
decile 3	185,622	252,803	257,881	35.70	2.87
decile 4	175,213	229,372	231,797	30.93	3.52
decile 5	174,857	220,775	221,144	26.41	1.01
decile 6	111,451	135,059	141,230	21.18	5.11
decile 7	138,356	163,600	162,367	18.22	2.92
decile 8	123,013	143,935	147,663	16.96	3.63
decile 9	125,802	141,962	146,229	12.98	4.05
decile 10	111,226	121,516	119,004	9.49	-1.43

Panel B. The OLS model estimation of the house price changes of the 50 US states for the subperiod 2006:2–2008:3 as a function of those for the subperiod 2004:1–2006:2

variables	percentage changes in the median house prices (2006:2–2008:3)	
constant	7.46	(3.17) [a]
percentage changes in the median house prices (2004:1–2006:2)	-0.26	(-3.39) [a]
R^2	0.19	
adjusted R^2	0.17	

The dependent variable is the percentage changes in the median house prices between 2006:2–2008:3. The explanatory variable is the percentage changes of the median house prices between 2004:1–2006:2.
[a] denotes significance at the 1% level.

Percentage changes in median house prices for the 2004:1 to 2006:2 period are calculated for all 50 states. The 50 states are ranked by the percentage changes in median house prices for the 2004:1 to 2006:2 period, then grouped into 10 deciles where the decile 1 corresponds to the states with the highest price run-up and the decile 10, the lowest price run-up.

Table 2. Bubble measured by the deviation from the state average PIR (price-to-income ratios)

Panel A. Deciles of the PIR deviation from the state average PIR

	(A)	(B)	(C)	(D)	(E)
	period average PIR	2006:2 PIR	deviation from state average PIR	deviation from US average PIR	percentage changes in house prices between 2006:2 and 2008:3
decile 1	6.84	11.07	4.23	6.39	-13.54
decile 2	5.30	7.72	2.42	3.04	-5.31
decile 3	5.11	6.91	1.80	2.23	-3.20
decile 4	4.91	5.96	1.06	1.28	3.07
decile 5	5.16	5.96	0.80	1.28	1.34
decile 6	4.61	5.09	0.48	0.41	-0.77
decile 7	4.45	4.41	-0.04	-0.27	2.22
decile 8	3.95	3.68	-0.27	-1.00	7.93
decile 9	3.94	3.53	-0.41	-1.15	2.06
decile 10	4.18	3.52	-0.66	-1.16	9.10

Panel B. The OLS model of the subsequent price drop (bubble burst) as a function of the deviation of the PIR (bubble) using 50 US States

	Model 1		Model 2	
deviation from state average PIR	-0.12	(-3.30) [a]		
deviation from US average PIR			-0.06	(-2.81) [a]
constant	0.19	(2.91) [a]	0.15	(2.37) [b]
R-squared	0.18		0.14	
adj R-squared	0.16		0.12	

Period average price-to-income ratios are calculated over the 1975:1 to 2006:2 period. The dependant variable is the percentage changes in house prices between 2006:2 and 2008:3. The t-statistics are shown in parentheses.

[a] denotes significance at the 1% level.

[b] denotes significance at the 5% level.

Panel C. Non-parametric test of correlation between the size of the bubble burst and the deviation from the historical average PIR using 50 US States

Kendall's tau	-0.764[a]
Spearman's rho	-0.894 [a]

The correlation variables are the deviation from the state average PIR and the percentage changes in house prices between 2006:2 and 2008:3 by deciles

[a] denotes significance at the 1% level.

[b] denotes significance at the 5% level.

Table 3. OLS models of percentage changes in real house prices as a function of fundamental variables and house price momentum variables

Panel A. California

variables	parameter estimates		explained squares	R^2
constant	-0.003	(-0.726)		
Δlog(income)	0.238	(1.502)	0.0019	0.049
Δ (mortgage rate)	-0.614	(-1.936)[c]	0.0004	0.011
Δlog (construction cost)	0.382	(1.738)[c]	0.0025	0.065
Δlog (population)	1.046	(0.956)	0.0035	0.093
Δlog (unemployment)	-0.022	(-1.050)[b]	0.0000	0.001
R^2 of fundamental variables				0.219
Δlog (house price(-1))	0.530	(4.646)[a]	0.0161	0.424
Δlog (house price (-2))	-0.005	(-0.039)	0.0005	0.013
Δlog (house price (-3))	0.426	(3.483)[a]	0.0016	0.043
Δlog (house price (-4))	-0.151	(-1.359)	0.0003	0.008
R^2 of momentum variables				0.488
total sum of squares			0.03797	
R^2 of overall variables				0.707

Panel B. Nebraska

variables	parameter estimates		explained squares	R^2
constant	-0.003	(-1.932)[c]		
Δlog(income)	0.213	(3.187)[a]	0.0010	0.149
Δ (mortgage rate)	-0.345	(-2.023)[b]	0.0002	0.029
Δlog (construction cost)	0.273	(3.603)[a]	0.0010	0.153
Δlog (population)	2.068	(2.281)[b]	0.0004	0.064
Δlog (unemployment)	-0.013	(-2.176)[b]	0.0003	0.041
R^2 of fundamental variables				0.436
Δlog (house price(-1))	0.052	(0.549)	0.0000	0.005
Δlog (house price (-2))	-0.018	(-0.198)	0.0000	0.000
Δlog (house price (-3))	0.168	(1.829)[c]	0.0002	0.033
Δlog (house price (-4))	0.155	(1.558)	0.0001	0.017
R^2 of momentum variables				0.055
total sum of squares			0.0067	
R^2 of overall variables				0.491

The dependent variable is the rate of nominal house price between 1985:1-2006:2.
The explanatory variables are the rate of change in total real household income, mortgage rates, the rate of change in real construction costs and four lags of the real house price. Δlog indicates the first difference in the natural logarithm. The t-statistics are shown in parentheses.

[a] denotes significance at the 1% level.
[b] denotes significance at the 5% level.
[c] denotes significance at the 10% level.

Table 4. The relation between the house price momentum and the subsequent price change

Panel A. Deciles of the R^2 of the house price momentum variables

	1985:1-2006:2	1985:1-2006:2	1985:1-2006:2	2006:2-2008:3
	R^2 of overall variables	R^2 of fundamental variables	R^2 of momentum variables	percentage changes in house price
decile 1	0.689	0.140	0.549	-11.157
decile 2	0.624	0.173	0.451	-0.824
decile 3	0.567	0.178	0.388	-2.134
decile 4	0.564	0.253	0.310	-4.183
decile 5	0.496	0.225	0.271	3.002
decile 6	0.487	0.267	0.220	3.084
decile 7	0.503	0.328	0.174	2.404
decile 8	0.439	0.312	0.127	4.798
decile 9	0.335	0.260	0.075	3.633
decile 10	0.326	0.286	0.040	5.078

We estimate the regression models of the percentage changes in house prices as a function of fundamental variables as well as house price momentum variables (house price changes in the previous four quarters) for each of the 50 US states. Then, we measure the level of speculation using the R^2 of the price momentum variables for each of the 50 U.S. states. Next, we divide the states into deciles based on the R^2 of the momentum variables.

Panel B. The OLS model of the subsequent house price changes as a function of the R^2 of the house price momentum across the 50 U.S. states

	Model 1		Model 2	
R^2 of price momentum variables (1985:1-2006:2)	-17.147	(-2.23) [b]		
R^2 of fundamental variables (1985:1-2006:2)			1.377	(0.120)
constant	5.033	(2.110) [b]	0.142	(0.050)
R^2	0.092		0.000	
adjusted R^2	0.073		-0.020	

The dependent variable is the percentage change in the house price between 2006:2-2008:3.
The explanatory variable of Model 1 is the R^2 of the momentum variables (1985:1-2006:2).
The explanatory variable of Model 2 is the R^2 of the fundamental variables (1985:1-2006:2).
t- statistics are shown in parenthesis.
[a] denotes significance at the 1% level.
[b] denotes significance at the 5% level.

Table 5. Comparison of bubble sizes between the 1975:1-1998:2 period and the 1998:3-2008:Q3 period

	Peak-US Average		% Deviation	
State	1975:1-1998:2	1998:3-2008:Q3	1975:1-1998:2	1998:3-2008:Q3
Hawaii	8.93	12.96	190.71	276.97
California	4.08	8.98	87.24	191.79
Nevada	0.93	3.84	19.96	82.01
Arizona	0.26	3.61	5.51	77.05
Oregon	1.05	3.56	22.41	75.96
Rhode Island	1.81	3.31	38.68	70.81
Louisiana	-0.89	3.25	-19.04	69.34
Washington	1.08	3.24	23.10	69.25
Utah	2.08	3.24	44.51	69.21
New Jersey	1.70	3.01	36.37	64.23
Massachusetts	1.81	2.90	38.61	61.92
Maryland	0.84	2.73	17.84	58.23
Washington DC	0.36	2.67	7.69	57.03
Florida	-0.48	2.36	-10.30	50.49
New York	0.93	2.23	19.85	47.54
Virginia	0.43	1.85	9.23	39.51
Delaware	0.67	1.78	14.34	37.93
New Hampshire	1.20	1.74	25.71	37.20
Alaska	0.45	1.71	9.57	36.52
Connecticut	1.74	1.43	37.14	30.53
Colorado	0.40	1.40	8.48	29.83
Vermont	0.83	1.33	17.74	28.50
New Mexico	0.81	1.33	17.39	28.38
Idaho	0.24	1.27	5.17	27.09
Maine	0.49	1.00	10.56	21.28
Montana	0.04	0.94	0.75	20.09
Minnesota	-0.73	0.66	-15.56	14.06
Illinois	-0.19	0.62	-4.02	13.18
Georgia	-0.15	0.21	-3.23	4.53
Wisconsin	-0.57	0.07	-12.18	1.45
North Carolina	-0.22	0.05	-4.76	1.11
South Carolina	-0.40	-0.07	-8.61	-1.52
Michigan	-0.82	-0.18	-17.44	-3.82
Pennsylvania	-0.42	-0.20	-9.06	-4.21
Ohio	-0.79	-0.62	-16.88	-13.16

Wyoming	-0.69	-0.62	-14.72	-13.25
Tennessee	-0.71	-0.65	-15.11	-13.85
Missouri	-0.99	-0.72	-21.15	-15.30
Alabama	-0.73	-0.75	-15.68	-16.05
Kentucky	-0.88	-0.76	-18.70	-16.22
West Virginia	-1.04	-0.80	-22.29	-17.14
Mississippi	-0.75	-0.87	-15.94	-18.50
Indiana	-0.93	-0.96	-19.91	-20.53
Arkansas	-1.01	-1.01	-21.54	-21.52
South Dakota	-1.21	-1.21	-25.92	-25.81
North Dakota	-1.16	-1.24	-24.70	-26.56
Nebraska	-1.36	-1.34	-29.04	-28.53
Iowa	-1.36	-1.34	-28.97	-28.59
Texas	-1.02	-1.38	-21.71	-29.47
Kansas	-1.44	-1.42	-30.83	-30.43
Oklahoma	-1.50	-1.56	-32.12	-33.33

Table 6. The effect of the subprime mortgages on the house price bubble using the two- stage least squares analysis.

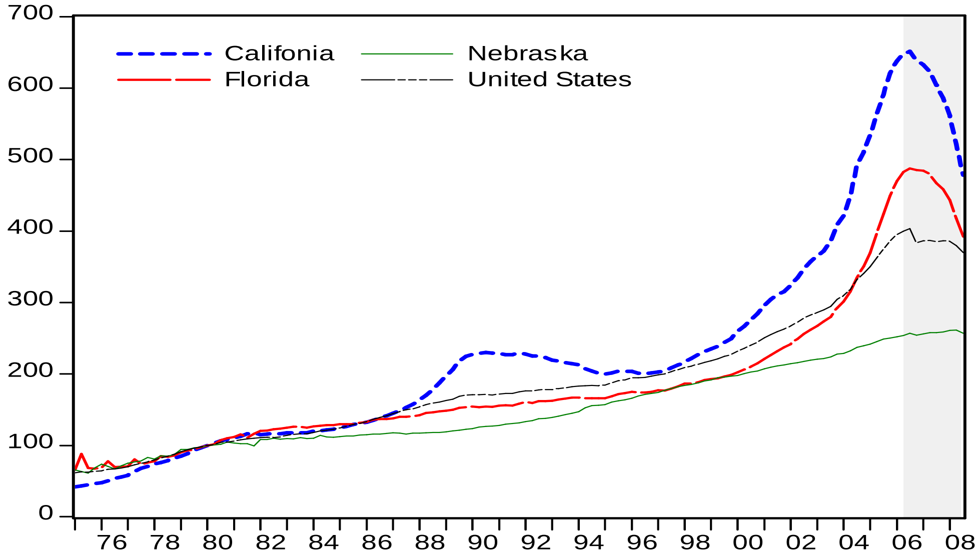
variables	first equation		second equation	
constant	-1.03	(-3.72) [a]	5.82	(5.50) [a]
ratio of the subprime originations to all mortgage loans	55.25	(7.51) [a]		
fitted deviation from the state average PIR			-6.96	(-8.36) [a]
R^2	0.55		0.59	
adjusted R^2	0.54		0.58	

[a] denotes significance at the 1% level.
[b] denotes significance at the 5% level.

The deviation from the period state average PIR is estimated in the first stage and the estimated values are used to estimate the house price change between 2006:2 and 2008:3 in the second stage. Instrument variable is the ratio of subprime originations per housing units by state in 2005. Hawaii and Alaska are excluded in the sample because we can not get the ratio of subprime originations per housing units. The t-statistics are shown in parentheses.

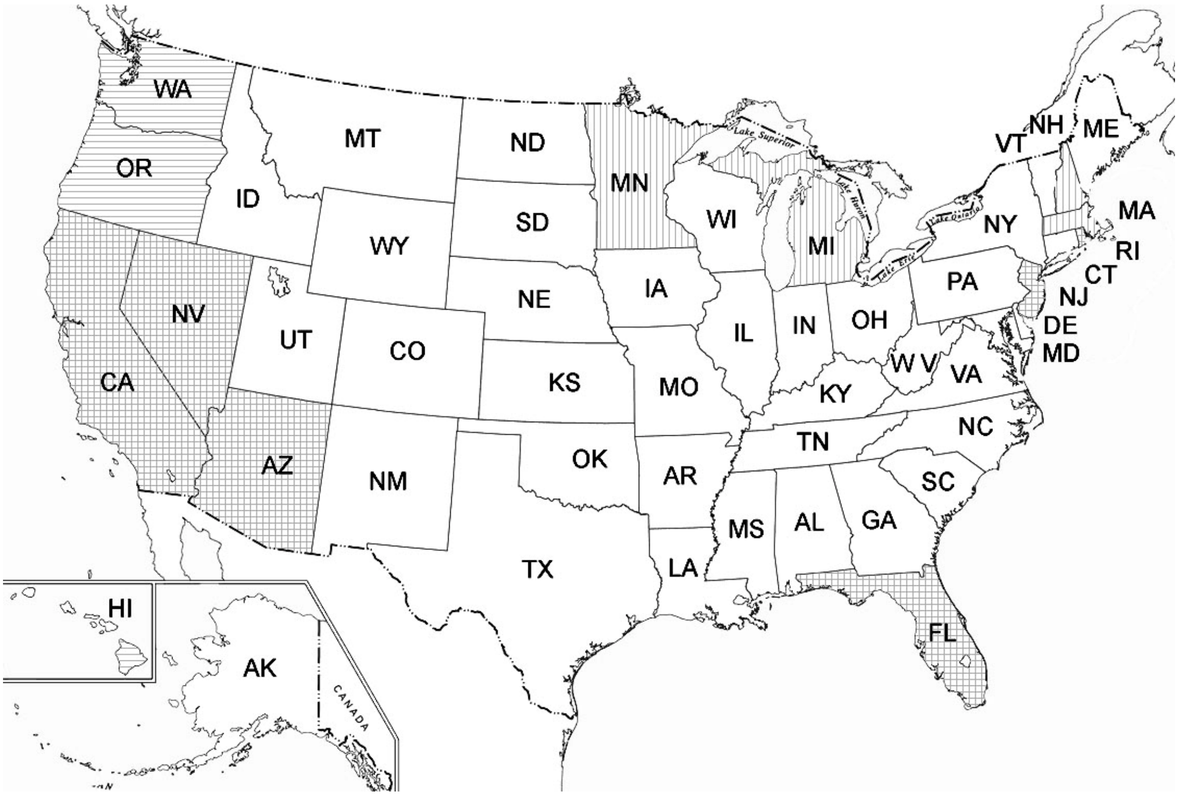
Table 7. The estimation of price elasticity of bubble states

Figure 1. Cycles in the US house price.



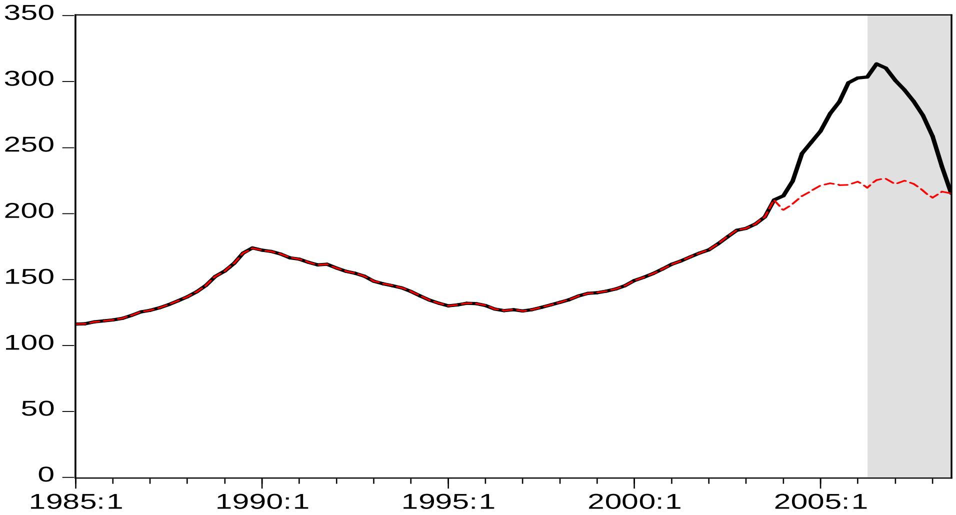
The shaded area is from 2006:2 to 2008:3.

Figure 2. Bubble states

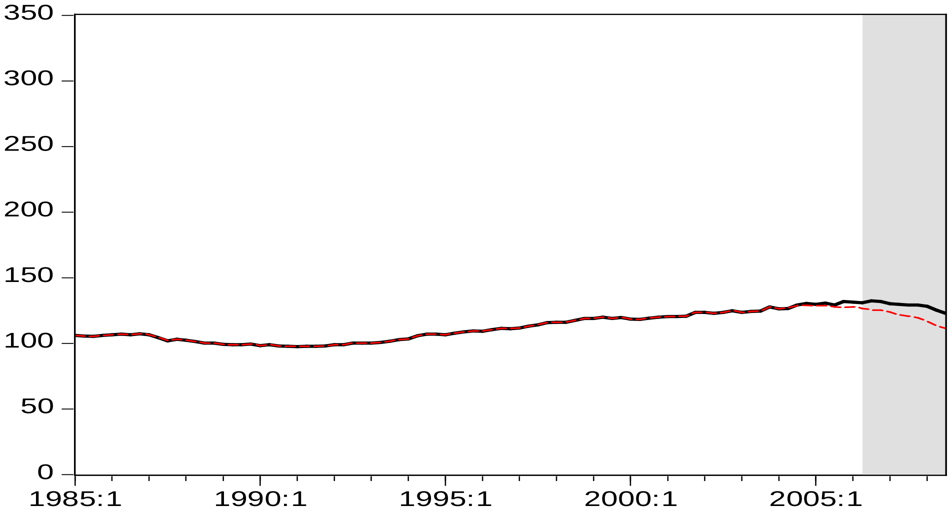


The largest PIR deviation states are Hawaii (HI), California (CA), Washington (WA), Arizona (AZ), Nevada (NV), Oregon (OR), Rhode Island (RI), Washington D.C. (DC), Florida (FL), New Jersey (NJ), which are indicated with the horizontal lines. States which experienced the largest subsequent house price drops from 2006:2 to 2008:3 are California (CA), Nevada (NV), Florida (FL), Arizona (AZ), Rhode Island (RI), Michigan (MI), Massachusetts (MA), New Hampshire (NH), Montana (MN), New Jersey (NJ), are indicated with vertical lines. The states which experienced the largest PIR deviation, then, the largest price drop are California (CA), Nevada (NV), Arizona (AZ), Florida (FL), New Jersey (NJ) and Rhode Island (RI) and they are indicated by meshed lines.

Figure 3. Actual prices vs. forecasted prices



(A) California



(B) Nebraska

Solid line: actual housing prices ; dotted line: forecasted house prices; vertical line is 2006:2. We use in-sample forecasting method. The house price equation is the one used in Table 2. Using the model estimates for 1985:1-2003:4, we forecast house prices for 2004:1-2008:3.

Appendix 1. Data descriptions and sources

variables	explanations	sources
house price index (HPI)	the OFHEO house price index for the U.S. and all states from OFHEO	OFHEO (www.ofheo.gov)
consumer price index (CPI)	all states from the US Census Bureau	US Census Bureau (census.gov)
total household income (TPY)	all states from Bureau of Economic Analysis	Bureau of Economic Analysis (ea.gov)
population (POP)	all states from Bureau of Economic Analysis	Bureau of Economic Analysis (bea.gov)
construction cost index (CC)		Means Construction Cost index by RS Means Company (constructionbook.com)
new housing units	all states from the US Census Bureau	US Census Bureau (census.gov)
employment rate	all states from the Bureau of Labor Statistics	Bureau of Labor Statistics (data.bls.gov)
unemployment rate	all states from the Bureau of Labor Statistics	Bureau of Labor Statistics (data.bls.gov)
federal funds rates		CRSP
prime lending rates		CRSP
Treasury notes rates	yields on 10-year treasury notes	CRSP
S&P/Case-Shiller Home Price Indices	Case-Shiller Home Price Indices (from January, 1987 to September, 2008)	Case-Shiller Home Price Indices (homepricr. standardandpoors.com)
mortgage rates	30-year conforming fixed mortgage rates from Freddie Mae	Freddie Mae (freddiemac.com)
stock market valuation	NYSE-Amex-NASDAQ value weighted price index from CRSP	CRSP
volume of subprime mortgage loans	originations as a share of housing units by State, 2005	2006 Mortgage Market Statistical Annual (www.imfpubs.com)

Appendix 2. The percentage changes in the median house prices for the 2004:1-2006:2 period and the 2006:2-2008:3 period for the 50 U.S. states

	(A)	(B)	(C)	(D)	(E)
	median house price in 2004:1	median house price in 2006:2	median house price in 2008:3	percentage changes between 2004:1 and 2006:2	percentage changes between 2006:2 and 2008:3
Alabama	99,794	118,375	130,186	18.62	9.98
Alaska	178,193	233,944	250,612	31.29	7.12
Arizona	155,174	258,010	221,327	66.27	-14.22
Arkansas	86,297	102,207	105,781	18.44	3.50
California	342,931	526,724	389,239	53.59	-26.10
Colorado	208,543	233,548	233,528	11.99	-0.01
Connecticut	237,474	303,299	289,582	27.72	-4.52
Delaware	181,380	244,405	249,757	34.75	2.19
Florida	156,921	251,365	204,281	60.19	-18.73
Georgia	136,639	155,576	155,124	13.86	-0.29
Hawaii	400,873	632,970	631,233	57.90	-0.27
Idaho	124,343	175,626	183,760	41.24	4.63
Illinois	165,545	201,334	201,312	21.62	-0.01
Indiana	108,223	117,111	118,564	8.21	1.24
Iowa	97,644	109,039	112,249	11.67	2.94
Kansas	99,327	110,801	114,152	11.55	3.02
Kentucky	101,910	114,828	119,134	12.68	3.75
Louisiana	101,985	124,728	134,042	22.30	7.47
Maine	144,633	179,952	182,364	24.42	1.34
Maryland	214,479	323,426	310,437	50.80	-4.02
Massachusetts	285,670	337,827	306,170	18.26	-9.37
Michigan	138,640	148,071	128,952	6.80	-12.91
Minnesota	173,427	203,678	190,988	17.44	-6.23
Mississippi	82,669	97,202	107,557	17.58	10.65
Missouri	111,204	128,774	129,778	15.80	0.78
Montana	127,243	167,217	183,689	31.42	9.85
Nebraska	101,631	112,877	114,254	11.06	1.22
Nevada	199,866	312,448	235,622	56.33	-24.59
New Hampshire	204,916	251,060	234,275	22.52	-6.69
New Jersey	259,981	355,775	337,086	36.85	-5.25
New Mexico	128,590	170,046	182,135	32.24	7.11
New York	222,639	290,035	280,886	30.27	-3.15
North Carolina	126,820	148,690	160,037	17.25	7.63
North Dakota	89,899	109,750	120,422	22.08	9.72
Ohio	121,888	131,199	125,854	7.64	-4.07
Oklahoma	84,420	95,787	102,300	13.47	6.80
Oregon	185,527	266,454	277,314	43.62	4.08
Pennsylvania	126,260	163,056	166,506	29.14	2.12
Rhode Island	225,257	295,472	256,409	31.17	-13.22
South Carolina	112,979	134,637	144,168	19.17	7.08
South Dakota	95,942	112,305	121,744	17.05	8.40

Tennessee	107,671	126,228	135,768	17.23	7.56
Texas	97,498	110,073	121,061	12.90	9.98
Utah	161,003	206,509	232,992	28.26	12.82
Vermont	151,809	203,158	210,724	33.82	3.72
Virginia	176,388	254,700	250,562	44.40	-1.62
Washington	206,350	290,631	309,703	40.84	6.56
West Virginia	86,847	104,846	106,206	20.72	1.30
Wisconsin	137,348	162,387	162,143	18.23	-0.15
Wyoming	122,732	160,191	187,389	30.52	16.98
mean	158,098	207,401	203,099		
median	137,348	170,046	183,689		
min	82,669	95,787	102,300		
max	400,873	632,970	631,233		
range	318,205	537,183	528,934		
SD	68,244	110,555	98,101		

Appendix 3. Deviation from the state average PIR as a measure of bubble for the 50 U.S. states

	(A)	(B)	(C)	(D)	(E)
	state average PIR	2006:2 PIR	deviation from the state average PIR (C)=(B)-(A)	deviation from the US average PIR (D)= (B)-US average	Percentage house price changes between 2006:2 and 2008:3
Alabama	4.39	3.81	-0.58	-0.87	9.98
Alaska	5.33	6.30	0.97	1.62	7.12
Arizona	5.57	8.29	2.72	3.61	-14.22
Arkansas	4.14	3.67	-0.47	-1.01	3.50
California	7.44	13.66	6.22	8.98	-26.10
Colorado	5.36	6.07	0.71	1.39	-0.01
Connecticut	5.27	6.11	0.83	1.43	-4.52
Delaware	4.89	6.34	1.45	1.66	2.19
Florida	4.74	7.04	2.30	2.36	-18.73
Georgia	4.82	4.89	0.07	0.21	-0.29
Hawaii	10.81	17.64	6.83	12.96	-0.27
Idaho	5.15	5.89	0.74	1.21	4.63
Illinois	4.57	5.28	0.72	0.60	-0.01
Indiana	4.01	3.62	-0.39	-1.06	1.24
Iowa	3.55	3.27	-0.29	-1.41	2.94
Kansas	3.60	3.21	-0.39	-1.47	3.02
Kentucky	4.10	3.92	-0.18	-0.76	3.75
Louisiana	4.54	4.04	-0.50	-0.64	7.47
Maine	4.50	5.57	1.06	0.89	1.34
Maryland	5.25	7.36	2.11	2.68	-4.02
Massachusetts	5.48	7.40	1.92	2.72	-9.37
Michigan	3.89	4.39	0.50	-0.29	-12.91
Minnesota	4.45	5.28	0.83	0.60	-6.23
Mississippi	4.39	3.68	-0.71	-1.00	10.65
Missouri	3.90	3.94	0.04	-0.74	0.78
Montana	4.58	5.55	0.97	0.87	9.85
Nebraska	3.69	3.29	-0.40	-1.39	1.22
Nevada	5.83	8.46	2.63	3.78	-24.59
New Hampshire	5.08	6.38	1.30	1.70	-6.69
New Jersey	5.46	7.69	2.22	3.01	-5.25
New Mexico	5.60	5.80	0.19	1.12	7.11
New York	4.93	6.91	1.98	2.23	-3.15
North Carolina	4.78	4.67	-0.11	-0.01	7.63
North Dakota	3.89	3.37	-0.52	-1.31	9.72
Ohio	4.10	3.96	-0.14	-0.72	-4.07
Oklahoma	3.81	3.00	-0.81	-1.68	6.80
Oregon	5.40	8.01	2.61	3.33	4.08
Pennsylvania	3.94	4.48	0.54	-0.20	2.12
Rhode Island	5.43	7.93	2.50	3.25	-13.22
South Carolina	4.65	4.59	-0.06	-0.09	7.08
South Dakota	3.67	3.32	-0.35	-1.36	8.40
Tennessee	4.26	3.91	-0.35	-0.77	7.56

Texas	4.07	3.24	-0.83	-1.44	9.98
Utah	6.34	7.21	0.88	2.53	12.82
Vermont	5.03	6.01	0.98	1.33	3.72
Virginia	5.00	6.53	1.53	1.85	-1.62
Washington	5.46	7.92	2.46	3.24	6.56
West Virginia	4.25	3.84	-0.40	-0.84	1.30
Wisconsin	4.26	4.70	0.44	0.02	-0.15
Wyoming	4.17	3.98	-0.19	-0.70	16.98

Column (A) shows the state average PIR, column (B) shows 2006:2 state PIR and column (C) shows the size of the bubble using the 2006:2 deviation from the state average PIR and column (D) shows the 2006:2 deviation from the US average PIR. Column (E) shows the percentage changes in median house prices for 2006:2-2008:3.

Appendix 4. Explanatory power of momentum variables for house price changes using the 1985:1-2006:2 data for the 50 U.S. States

	1985:1-2006:2	1985:1-2006:2	1985:1-2006:2	2006:2-2008:3
	R^2 of overall variables	R^2 of fundamental variables	R^2 of house price momentum variables	Percentage changes in house prices
Alabama	0.520	0.468	0.052	9.98
Alaska	0.046	0.018	0.027	7.12
Arizona	0.575	0.269	0.307	-14.22
Arkansas	0.416	0.358	0.057	3.50
California	0.697	0.124	0.572	-26.10
Colorado	0.552	0.149	0.403	-0.01
Connecticut	0.688	0.153	0.534	-4.52
Delaware	0.614	0.214	0.401	2.19
Florida	0.668	0.413	0.256	-18.73
Georgia	0.556	0.393	0.163	-0.29
Hawaii	0.616	0.186	0.430	-0.27
Idaho	0.393	0.219	0.174	4.63
Illinois	0.449	0.264	0.185	-0.01
Indiana	0.372	0.324	0.049	1.24
Iowa	0.176	0.081	0.095	2.94
Kansas	0.460	0.306	0.155	3.02
Kentucky	0.395	0.378	0.017	3.75
Louisiana	0.509	0.318	0.191	7.47
Maine	0.524	0.207	0.317	1.34
Maryland	0.682	0.288	0.394	-4.02
Massachusetts	0.724	0.228	0.496	-9.37
Michigan	0.507	0.180	0.326	-12.91
Minnesota	0.534	0.356	0.178	-6.23
Mississippi	0.301	0.234	0.067	10.65
Missouri	0.511	0.260	0.252	0.78
Montana	0.231	0.106	0.125	9.85
Nebraska	0.427	0.331	0.095	1.22
Nevada	0.577	0.270	0.307	-24.59
New Hampshire	0.685	0.171	0.514	-6.69

New Jersey	0.687	0.106	0.581	-5.25
New Mexico	0.545	0.362	0.183	7.11
New York	0.653	0.199	0.454	-3.15
North Carolina	0.499	0.388	0.110	7.63
North Dakota	0.454	0.229	0.225	9.72
Ohio	0.477	0.379	0.098	-4.07
Oklahoma	0.486	0.312	0.174	6.80
Oregon	0.478	0.060	0.418	4.08
Pennsylvania	0.613	0.193	0.420	2.12
Rhode Island	0.690	0.146	0.544	-13.22
South Carolina	0.423	0.366	0.057	7.08
South Dakota	0.321	0.063	0.258	8.40
Tennessee	0.528	0.383	0.146	7.56
Texas	0.453	0.165	0.288	9.98
Utah	0.568	0.271	0.297	12.82
Vermont	0.573	0.250	0.323	3.72
Virginia	0.712	0.435	0.278	-1.62
Washington	0.515	0.060	0.455	6.56
West Virginia	0.201	0.161	0.040	1.30
Wisconsin	0.357	0.296	0.061	-0.15
Wyoming	0.327	0.050	0.277	16.98

Appendix 5. Deviation from mean price-to-income ratios as a measure of bubble.

Panel A. Sub Period(1975:1-1998:2)

	(A)	(B)	(C)	(D)	(E)	(F)
	Trough	Peak	Average	Peak-US Average	% Deviation	Quarter of Peak
Alabama	3.66	3.95	3.80	-0.73	-15.68	1989:4
Alaska	3.75	5.13	4.44	0.45	9.57	1996:4
Arizona	4.70	4.94	4.82	0.26	5.51	1996:1
Arkansas	3.36	3.67	3.52	-1.01	-21.54	1989:4
California	6.34	8.76	7.55	4.08	87.24	1989:4
Colorado	4.23	5.08	4.65	0.40	8.48	1995:4
Connecticut	4.13	6.42	5.27	1.74	37.14	1989:4
Delaware	4.31	5.35	4.83	0.67	14.34	1990:1
Washington DC	3.60	5.04	4.32	0.36	7.69	1989:4
Florida	3.76	4.20	3.98	-0.48	-10.30	1989:4
Georgia	3.93	4.53	4.23	-0.15	-3.23	1991:2
Hawaii	10.54	13.61	12.07	8.93	190.71	1995:3
Idaho	4.14	4.92	4.53	0.24	5.17	1994:1
Illinois	4.13	4.49	4.31	-0.19	-4.02	1991:1
Indiana	3.58	3.75	3.67	-0.93	-19.91	1993:3
Iowa	3.01	3.32	3.17	-1.36	-28.97	1989:4
Kansas	2.91	3.24	3.08	-1.44	-30.83	1989:4
Kentucky	3.57	3.81	3.69	-0.88	-18.70	1989:4
Louisiana	3.51	3.79	3.65	-0.89	-19.04	1989:4
Maine	3.78	5.17	4.48	0.49	10.56	1989:4
Maryland	4.53	5.52	5.02	0.84	17.84	1989:4
Massachusetts	4.70	6.49	5.59	1.81	38.61	1997:4
Michigan	3.43	3.86	3.65	-0.82	-17.44	1993:3
Minnesota	3.66	3.95	3.81	-0.73	-15.56	1990:1
Mississippi	3.46	3.93	3.70	-0.75	-15.94	1989:4
Missouri	3.32	3.69	3.50	-0.99	-21.15	1996:1
Montana	3.58	4.72	4.15	0.04	0.75	1994:3
Nebraska	3.10	3.32	3.21	-1.36	-29.04	1991:4
Nevada	4.96	5.61	5.29	0.93	19.96	1989:4
New Hampshire	3.88	5.88	4.88	1.20	25.71	1989:4
New Jersey	4.54	6.38	5.46	1.70	36.37	1995:4
New Mexico	4.83	5.49	5.16	0.81	17.39	1989:4
New York	4.22	5.61	4.91	0.93	19.85	1989:4
North Carolina	4.12	4.46	4.29	-0.22	-4.76	1989:4
North Dakota	3.14	3.52	3.33	-1.16	-24.70	1996:1
Ohio	3.67	3.89	3.78	-0.79	-16.88	1995:4
Oklahoma	3.02	3.18	3.10	-1.50	-32.12	1997:4
Oregon	4.15	5.73	4.94	1.05	22.41	1989:4
Pennsylvania	3.45	4.26	3.85	-0.42	-9.06	1989:4
Rhode Island	4.52	6.49	5.51	1.81	38.68	1989:4
South Carolina	3.93	4.28	4.10	-0.40	-8.61	1995:2
South Dakota	3.05	3.47	3.26	-1.21	-25.92	1989:4
Tennessee	3.55	3.97	3.76	-0.71	-15.11	1989:4

Texas	3.00	3.66	3.33	-1.02	-21.71	1997:4
Utah	4.89	6.76	5.83	2.08	44.51	1989:4
Vermont	4.17	5.51	4.84	0.83	17.74	1989:4
Virginia	4.20	5.11	4.66	0.43	9.23	1995:4
Washington	5.07	5.76	5.42	1.08	23.10	1990:1
West Virginia	3.44	3.64	3.54	-1.04	-22.29	1995:3
Wisconsin	3.71	4.11	3.91	-0.57	-12.18	1995:4
Wyoming	3.08	3.99	3.54	-0.69	-14.72	1996:1

Panel B. Sub Period(1998:3-2008:3)

	(A)	(B)	(C)	(D)	(E)	(F)
	Trough	Peak	Average	Peak-US Average	% Deviation	Quarter of Peak
Alabama	3.60	3.93	3.74	-0.75	-16.05	2007:1
Alaska	4.81	6.39	5.49	1.71	36.52	2007:2
Arizona	4.75	8.29	6.06	3.61	77.05	2006:2
Arkansas	3.35	3.67	3.46	-1.01	-21.52	2006:2
California	6.48	13.66	9.62	8.98	191.79	2006:2
Colorado	5.01	6.08	5.67	1.40	29.83	2005:4
Connecticut	4.10	6.11	5.06	1.43	30.53	2006:2
Delaware	4.29	6.46	5.26	1.78	37.93	2007:1
Washington DC	3.70	7.35	5.35	2.67	57.03	2006:3
Florida	3.76	7.04	5.07	2.36	50.49	2006:2
Georgia	4.01	4.89	4.49	0.21	4.53	2006:2
Hawaii	9.73	17.64	13.09	12.96	276.97	2006:2
Idaho	4.42	5.95	5.03	1.27	27.09	2006:3
Illinois	4.11	5.30	4.71	0.62	13.18	2007:1
Indiana	3.46	3.72	3.63	-0.96	-20.53	2001:4
Iowa	3.07	3.34	3.24	-1.34	-28.59	2003:1
Kansas	2.99	3.26	3.16	-1.42	-30.43	2003:2
Kentucky	3.59	3.92	3.78	-0.76	-16.22	2006:2
Louisiana	3.60	7.93	3.89	3.25	69.34	2005:3
Maine	3.77	5.68	4.74	1.00	21.28	2005:4
Maryland	4.35	7.41	5.65	2.73	58.23	2007:1
Massachusetts	4.76	7.58	6.31	2.90	61.92	2005:4
Michigan	3.64	4.50	4.21	-0.18	-3.82	2005:1
Minnesota	3.70	5.34	4.62	0.66	14.06	2005:4
Mississippi	3.43	3.81	3.56	-0.87	-18.50	2007:1
Missouri	3.31	3.96	3.67	-0.72	-15.30	2006:1
Montana	4.34	5.62	4.85	0.94	20.09	2006:3
Nebraska	3.03	3.35	3.25	-1.34	-28.53	2005:3
Nevada	4.72	8.52	6.20	3.84	82.01	2006:1
New Hampshire	3.90	6.42	5.31	1.74	37.20	2005:4
New Jersey	4.52	7.69	6.06	3.01	64.23	2006:2
New Mexico	4.72	6.01	5.24	1.33	28.38	2007:3
New York	4.19	6.91	5.56	2.23	47.54	2006:2
North Carolina	4.07	4.73	4.40	0.05	1.11	2008:2
North Dakota	2.98	3.44	3.17	-1.24	-26.56	2007:1
Ohio	3.52	4.06	3.88	-0.62	-13.16	2005:3
Oklahoma	2.76	3.12	2.99	-1.56	-33.33	2003:1

Oregon	5.46	8.24	6.56	3.56	75.96	2007:2
Pennsylvania	3.32	4.48	3.86	-0.20	-4.21	2006:2
Rhode Island	4.51	7.99	6.20	3.31	70.81	2006:1
South Carolina	3.93	4.61	4.28	-0.07	-1.52	2008:2
South Dakota	3.12	3.47	3.24	-1.21	-25.81	2007:1
Tennessee	3.60	4.03	3.78	-0.65	-13.85	2007:4
Texas	2.97	3.30	3.15	-1.38	-29.47	2003:1
Utah	6.14	7.92	6.70	3.24	69.21	2007:4
Vermont	4.08	6.01	4.91	1.33	28.50	2006:2
Virginia	4.11	6.53	5.16	1.85	39.51	2006:2
Washington	5.25	7.92	6.41	3.24	69.25	2006:2
West Virginia	3.34	3.88	3.56	-0.80	-17.14	2005:4
Wisconsin	3.88	4.75	4.31	0.07	1.45	2005:4
Wyoming	3.39	4.06	3.68	-0.62	-13.25	2006:3

Panel C. Deciles of Sub Period(1975:1-1998:2)

	Trough	Peak	Average	Difference	Change
decile 1	5.685	7.941	6.634	1.307	-0.296
decile 2	4.207	5.794	4.884	0.910	-0.274
decile 3	4.079	5.283	4.742	0.541	-0.227
decile 4	3.843	4.674	4.268	0.406	-0.179
decile 5	4.000	4.767	4.417	0.350	-0.162
decile 6	3.516	3.995	3.727	0.268	-0.118
decile 7	3.713	4.102	3.889	0.213	-0.096
decile 8	3.633	4.011	3.824	0.188	-0.092
decile 9	3.564	3.849	3.712	0.136	-0.074
decile 10	3.683	3.878	3.786	0.091	-0.050

Panel D. Deciles of Sub Period(1998:3-2008:3)

	Trough	Peak	Average	Difference	Change
decile 1	5.496	10.563	7.368	5.067	-0.482
decile 2	4.381	7.541	5.856	3.160	-0.420
decile 3	4.583	7.202	5.798	2.620	-0.366
decile 4	4.476	6.435	5.334	1.958	-0.309
decile 5	4.396	5.860	5.046	1.464	-0.251
decile 6	4.065	5.099	4.607	1.034	-0.204
decile 7	3.670	4.373	4.045	0.703	-0.161
decile 8	3.374	3.845	3.591	0.471	-0.123
decile 9	3.208	3.549	3.380	0.340	-0.097
decile 10	3.179	3.467	3.349	0.288	-0.083