



Cornell University  
Operations Research and  
Information Engineering



# Economic Time Series Modeling of U.S. Housing Prices

*Master of Engineering / Financial Engineering Project*

*May 11<sup>th</sup>, 2009*

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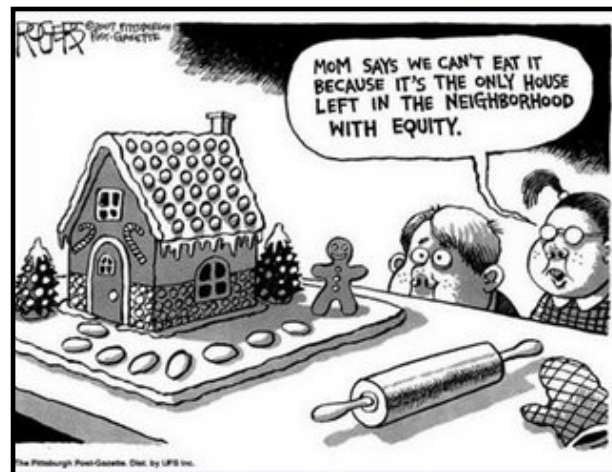
# Agenda

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- I. Introduction
- II. State Results
- III. Modeling Methodology
- IV. Forecasting Methodology
- V. Conclusion



# What Happened?



**Housing Market Decline**

**Mortgage Market Decline**

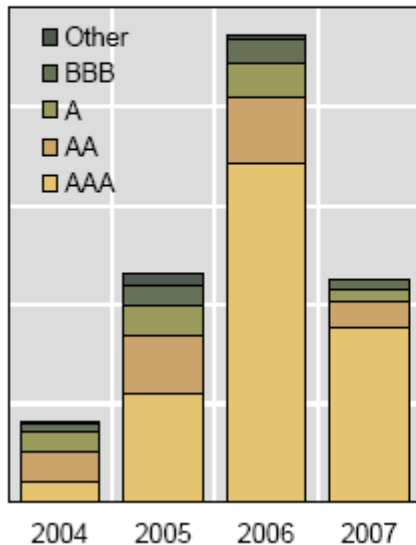
**Broader Economic Meltdown**



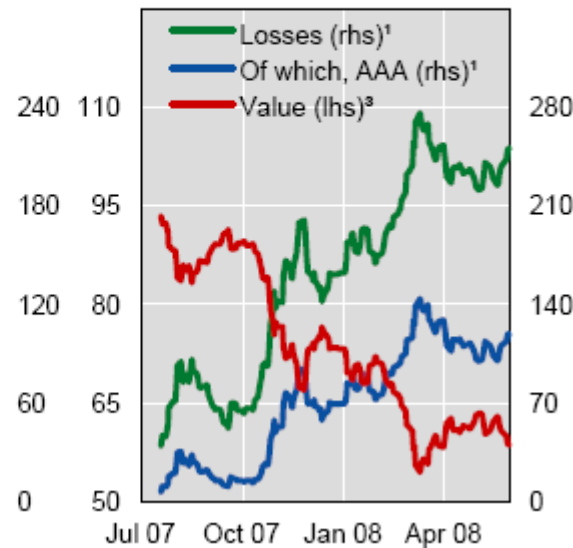
# Purpose and Objectives

## Subprime MBS volumes, implied losses and MBS capital

Outstanding subprime MBS securities<sup>1</sup>



Subprime MBS: ABX-implied value and losses<sup>2</sup>



1 In billions of US dollars. 2 Assumes unrated MBS bonds are written down completely and ABX prices are applied to the respective outstanding MBS volumes. 3 As a percentage of par

Sources: ABSNET.net; JPMorgan Chase; UBS; BIS calculations.

## Purpose

- Housing prices drive Mortgage-Backed Securities (MBS) valuation
- Devise profitable trading strategies

## Objectives

- Develop efficient and robust models to understand the housing price process
- Forecast the evolution of housing prices over medium to long term horizon



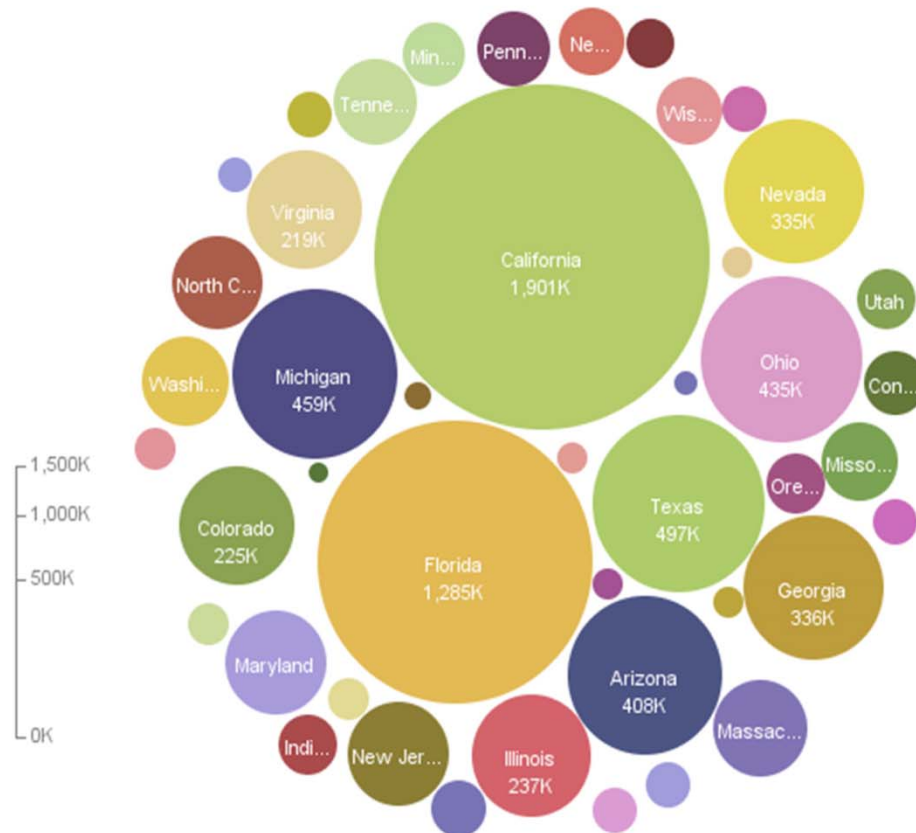
# Housing Price Index (HPI)

- What is it?
  - Measures movement of single-family house prices
  - Quarterly, state-level data from 1975 – 2008
  - Updated based on repeat-transaction methodology
  - Published by the US Office of Federal Housing Enterprise Oversight (OFHEO) based on Fannie / Freddie data
- Advantages
  - Government collected, state-level
  - Publicly available
- Disadvantages
  - Jumbo loans >\$417,000 and risky subprime sales not included
  - Continually updated with every repeat-transaction



# Effect on Americans

## Number of Negative Equity Mortgages by State

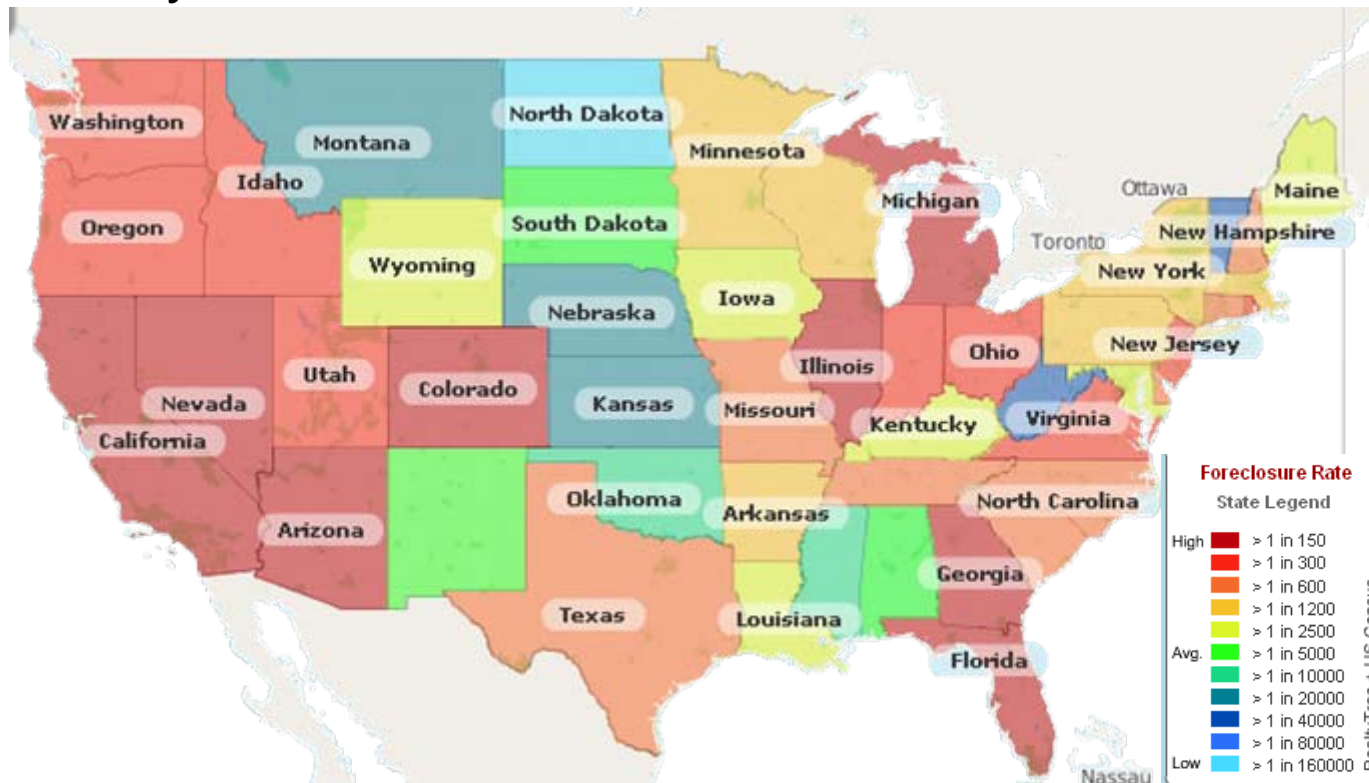






# Distribution of States

- States by foreclosure rate



Source: HotPads.com, 05/09



# Selected States for Discussion

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- High foreclosure rate ( $>1$  in 150)
  - Arizona
  - California
  - Florida
- Mid-level foreclosure rate ( $>1$  in 600)
  - Texas
- Low foreclosure rate ( $>1$  in 20,000)
  - Montana





# Arizona



Phoenix and its suburbs are among the hardest hit by the foreclosure crisis. Avondale, just west of Phoenix, doubled in residents between 2000 and 2005. Now residents are unable to sell their houses except at fire-sale prices. - WSJ



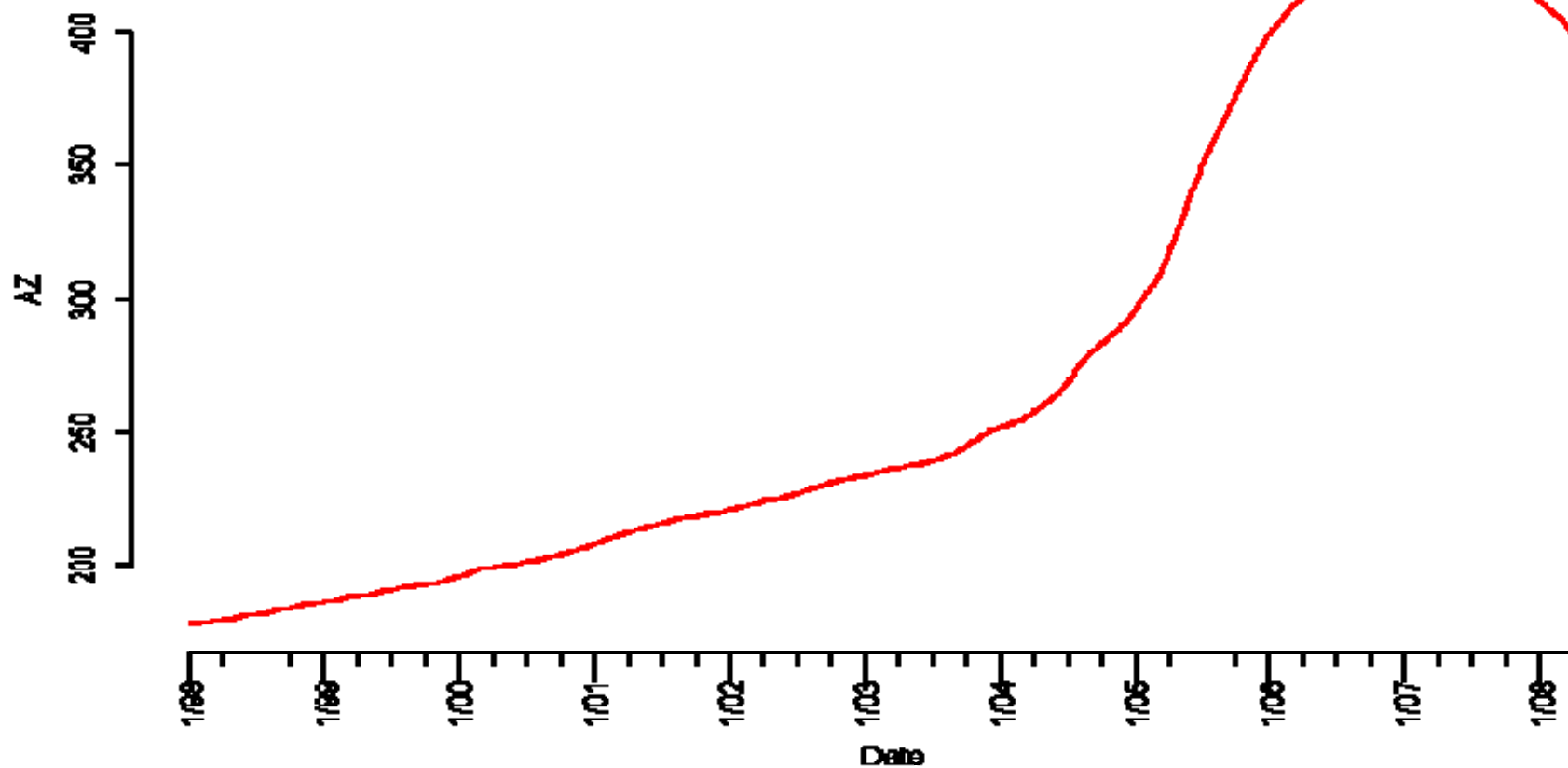
# Arizona



**Appraisers valued the house at \$132,000 for a \$103,000 mortgage before the housing bubble burst. Under foreclosure the house sold for \$18,000. - WSJ**



# Arizona – HPI





# Arizona – Outlook

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- Town of Maricopa: 75% of all homeowners owe more on their mortgages than the current value of their homes (national estimate of 18%)
- Government will only help you refinance your mortgage if you owe between 80% and 105% of your home's value
  - Arizona is one of the worst hit areas where homes prices have plummeted far below the level of many mortgages
- Federal stimulus plan up to \$8,000 for anyone who hasn't owned a home for at least three years





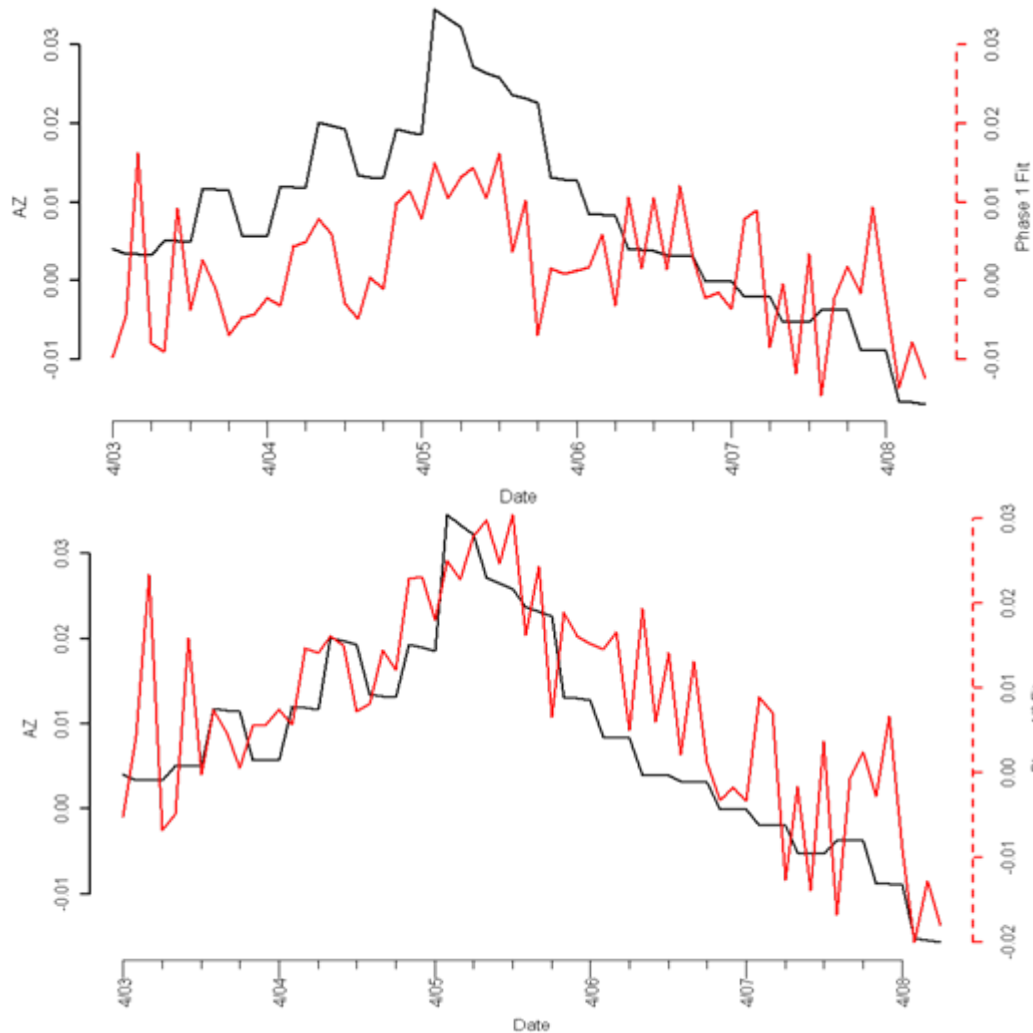
# Arizona – Outlook

- "The foreclosure problem in Arizona is only going to get worse," - Fred Karnas, the new director of the Arizona Department of Housing
  - Currently the state with the nation's third-highest foreclosure rate
- Recent drop in building permits for homes across metropolitan Phoenix
- State Economy has dependence on three industries that led the nation into recession: construction, housing and financial services
- Increase in home prices and sales likely won't happen until 2012

Source: AZCentral.com. Real Estate Outlook



# Arizona Model

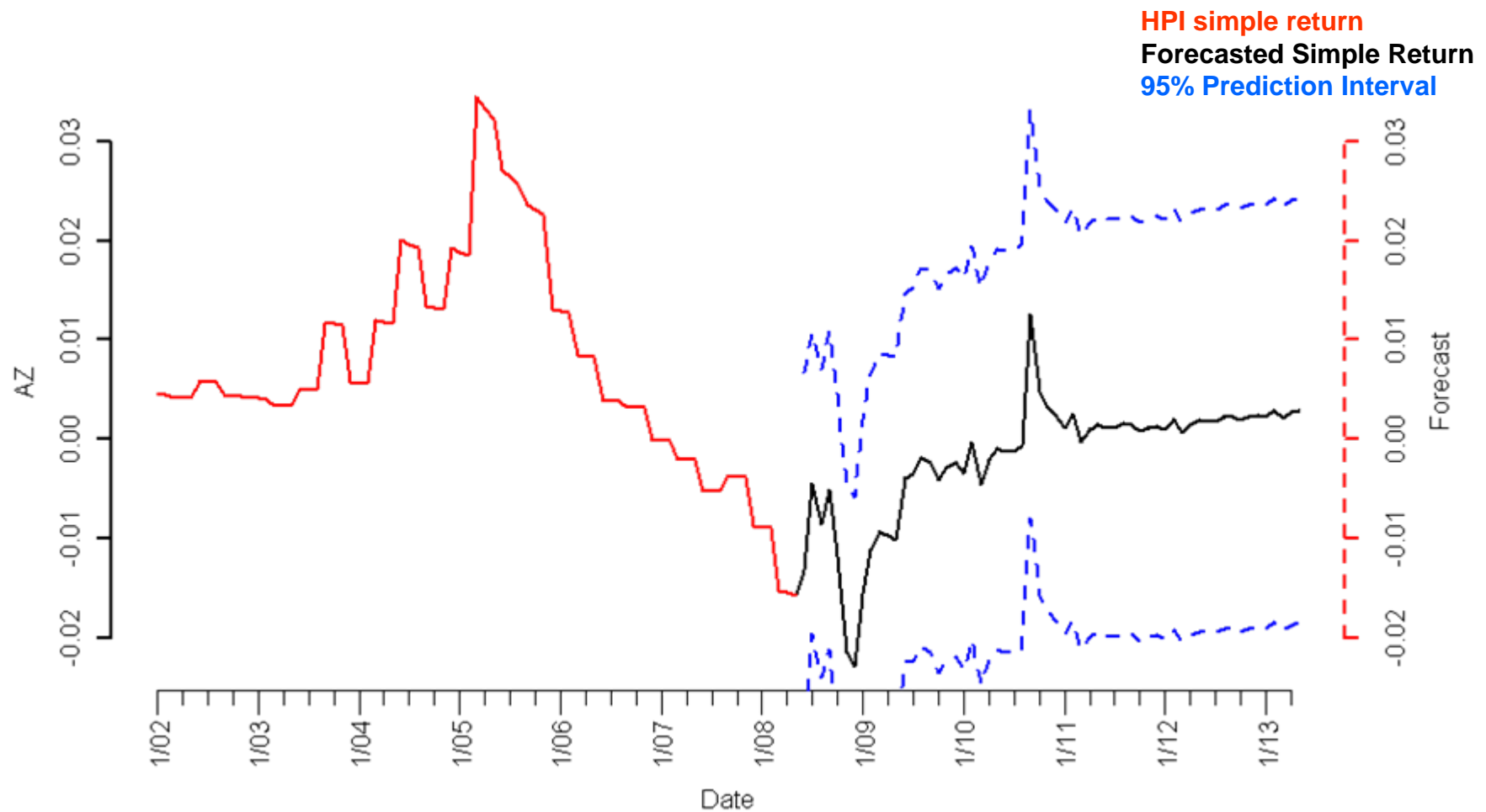


**Forecasts**



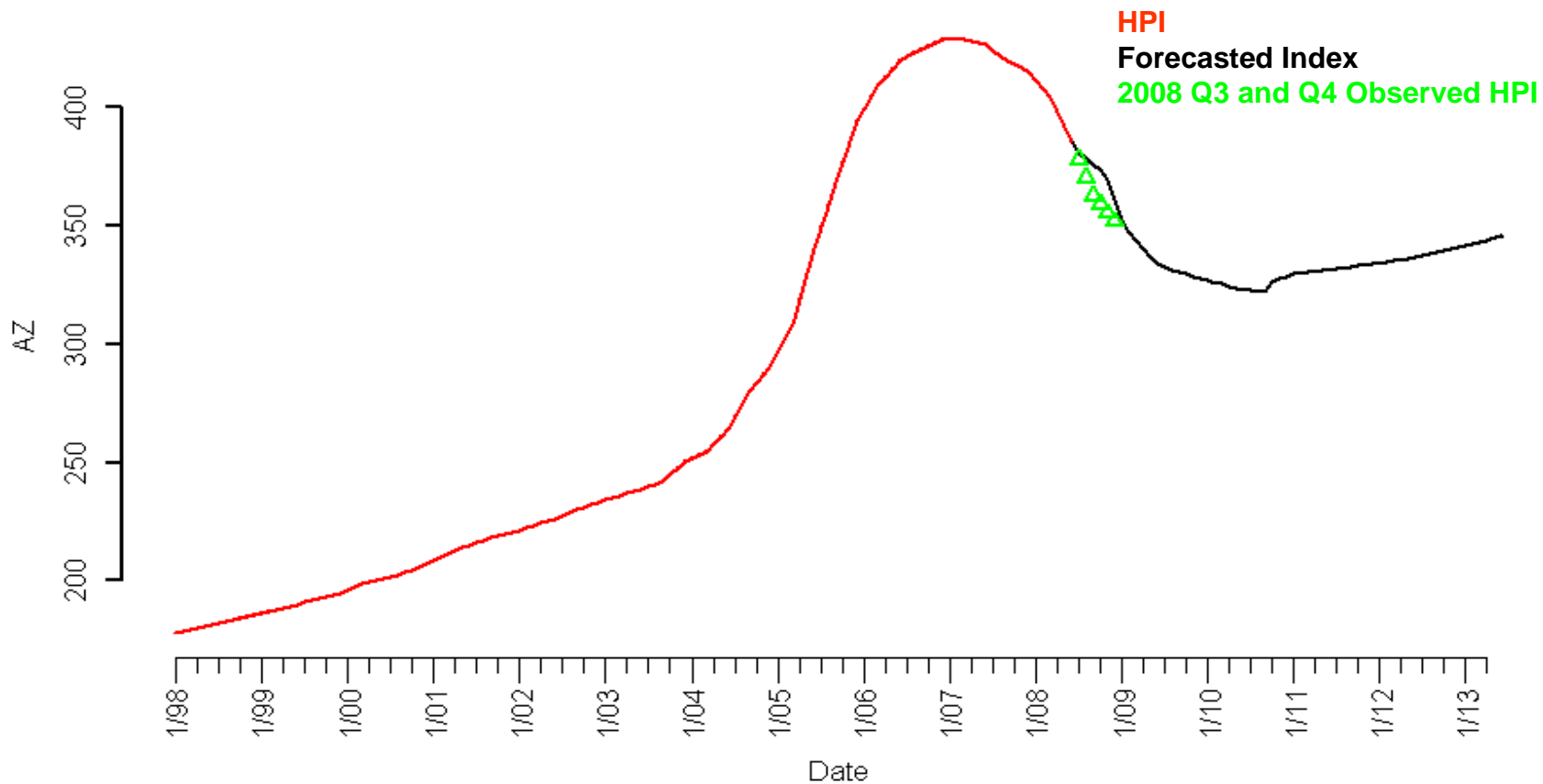


# Arizona – Forecast (Simple Returns)



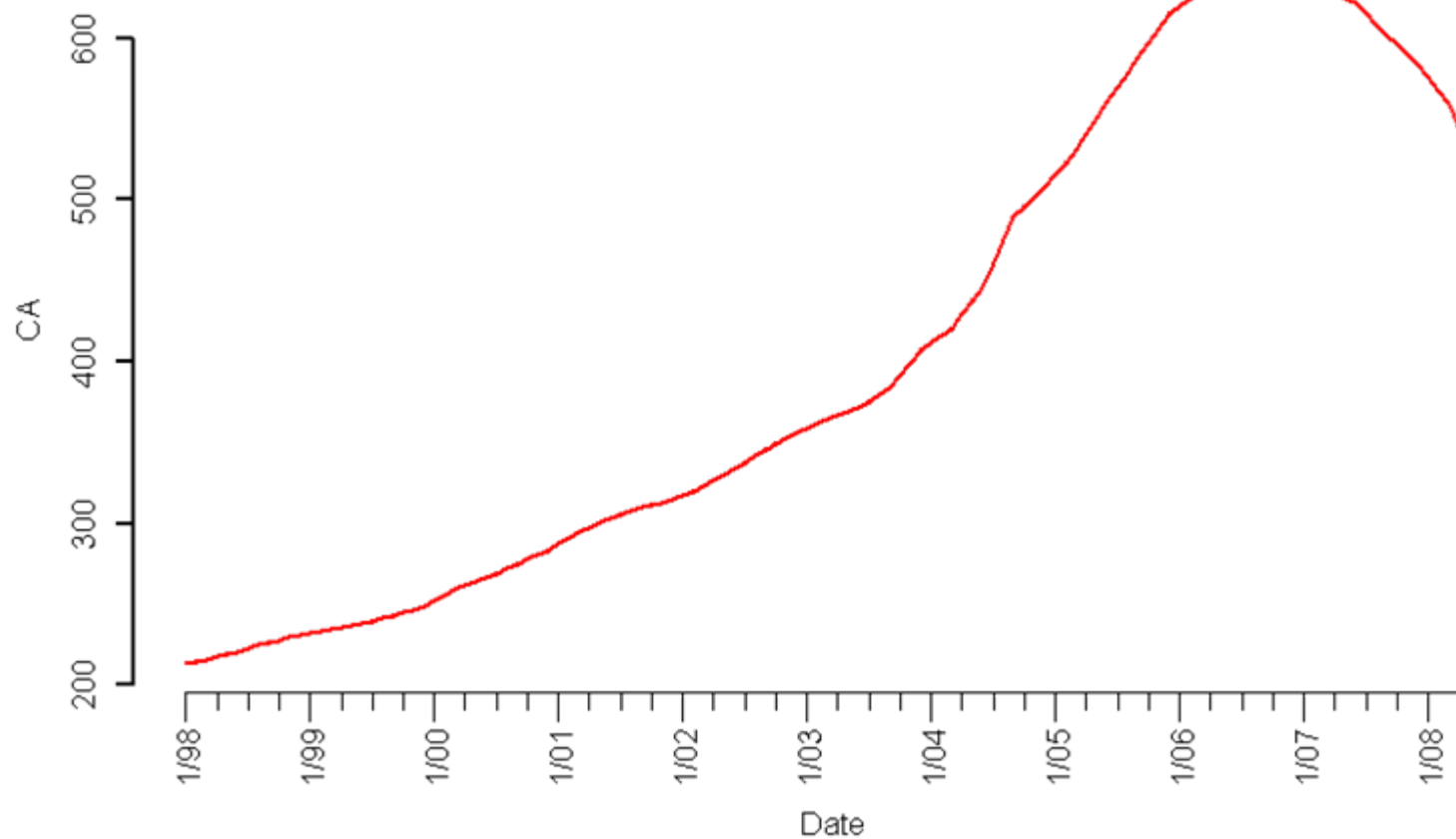


# Arizona - Forecast





# California





# California – Current Climate

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- Poor homeowner quality
  - Bad Sign: Pre-foreclosure notices up 80% in Q1'09
  - Delinquencies on dues to homeowner associations on the rise, some areas as high as 15%
  - Defaults up by ~35% in LA, San Francisco, San Louis Obispo this year
- New home construction at 25-year low
- Economic effects
  - Unemployment 11.2%, one of highest in nation



# California – Future Outlook

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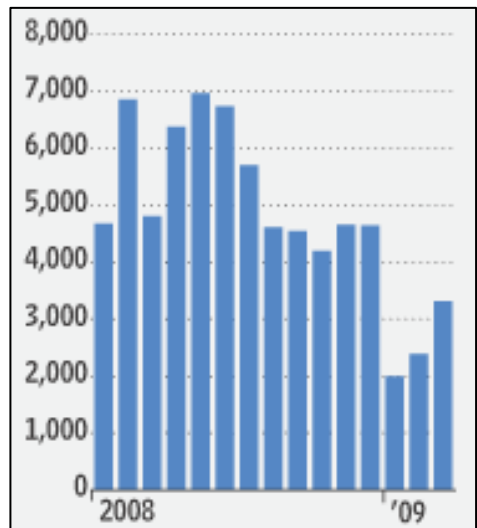
- Signs of recovery slowly
  - 64% increase in sales of single-family homes over prior year
  - Federal stimulus plan of \$8,000 for first-time home buyers
  - State tax credit of \$10,000 to purchase new unoccupied home
  - Homebuilder sales rose around 15% in the West
- Continued concerns
  - Ending of moratoriums on foreclosures by Fannie / Freddie
  - Continued 11.2% unemployment



## California – Future Outlook (cont'd)

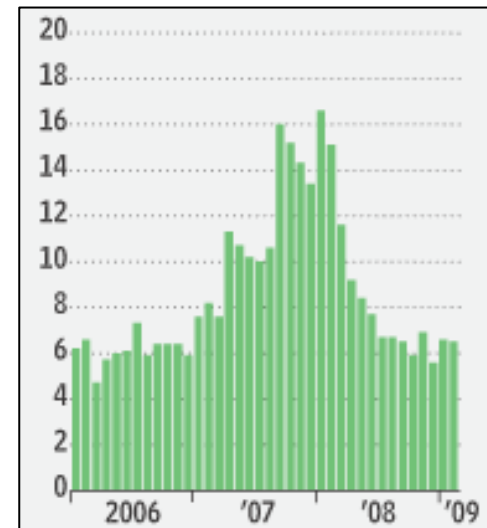
- State tax credit discourages purchase of existing foreclosed homes

**Construction is rising ...**



Total Residential  
Permits in California

**... although housing inventory  
remains stable**



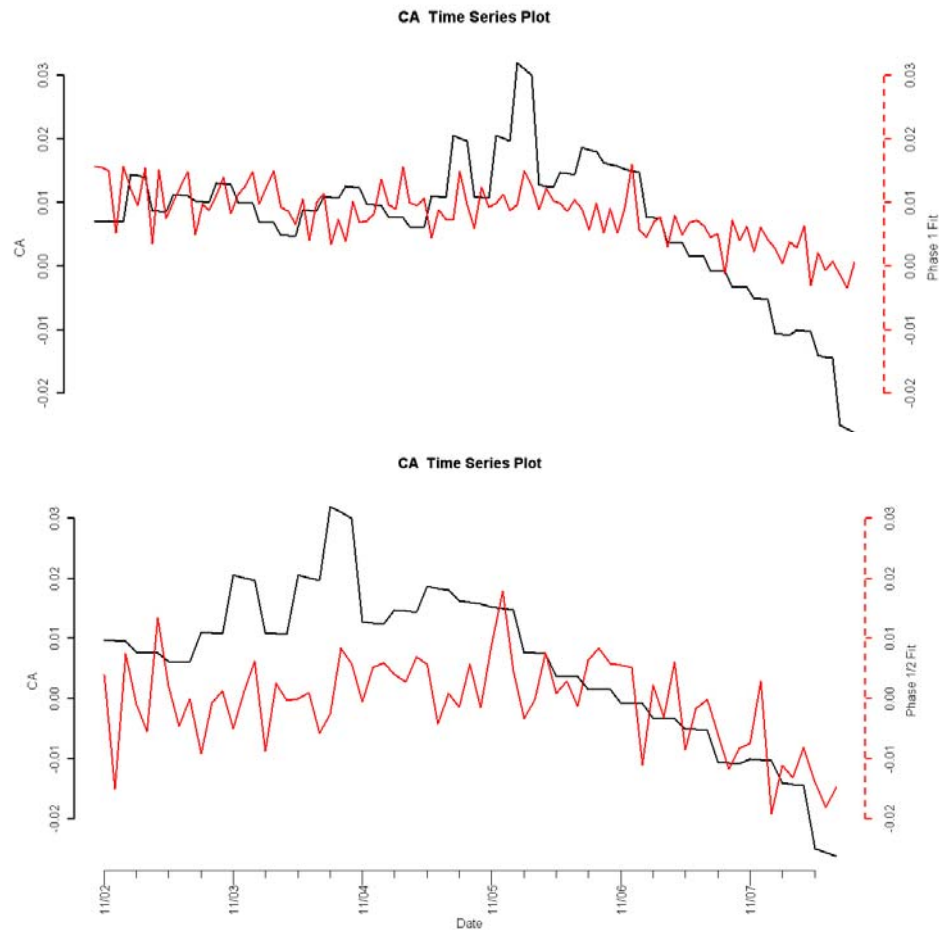
Months Needed to Sell  
Existing Inventory at  
Current Sales Prices

Source: WSJ, 04/24/09.





# California Model

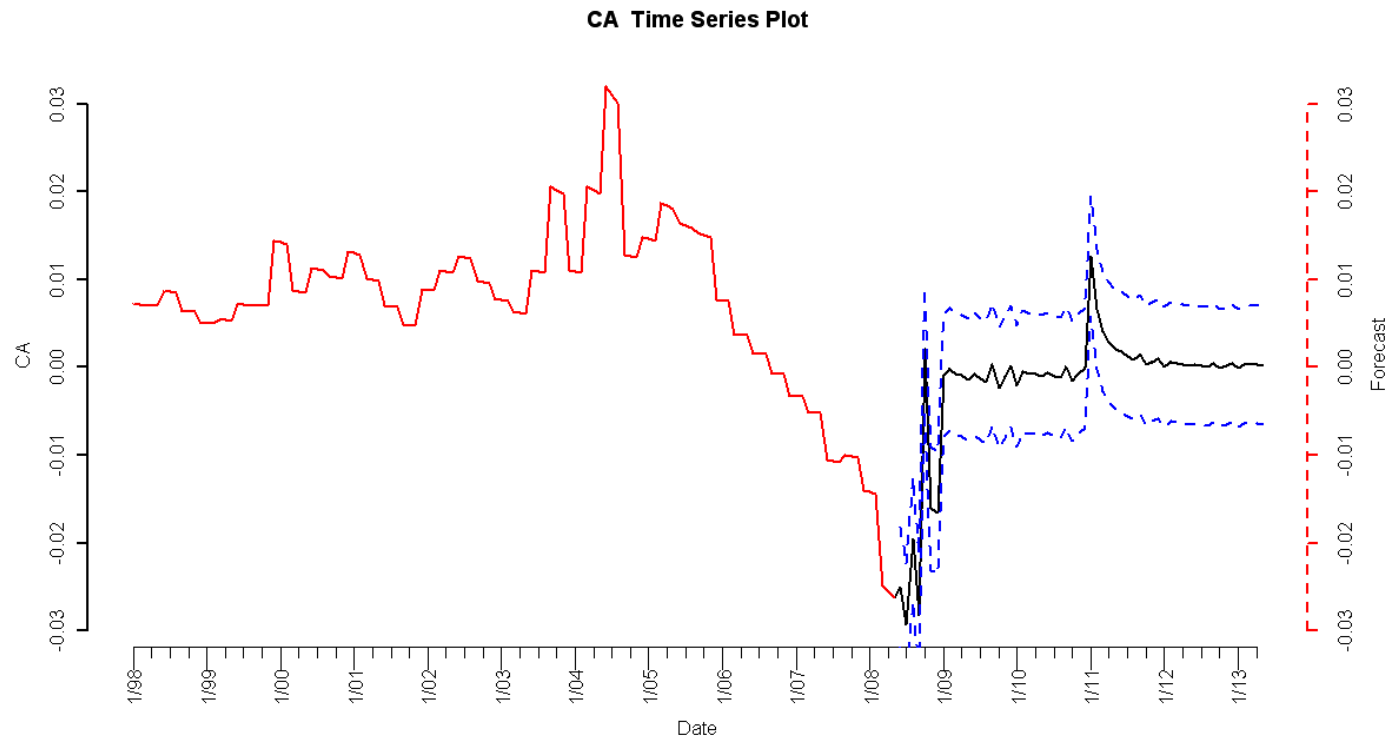


Forecasts



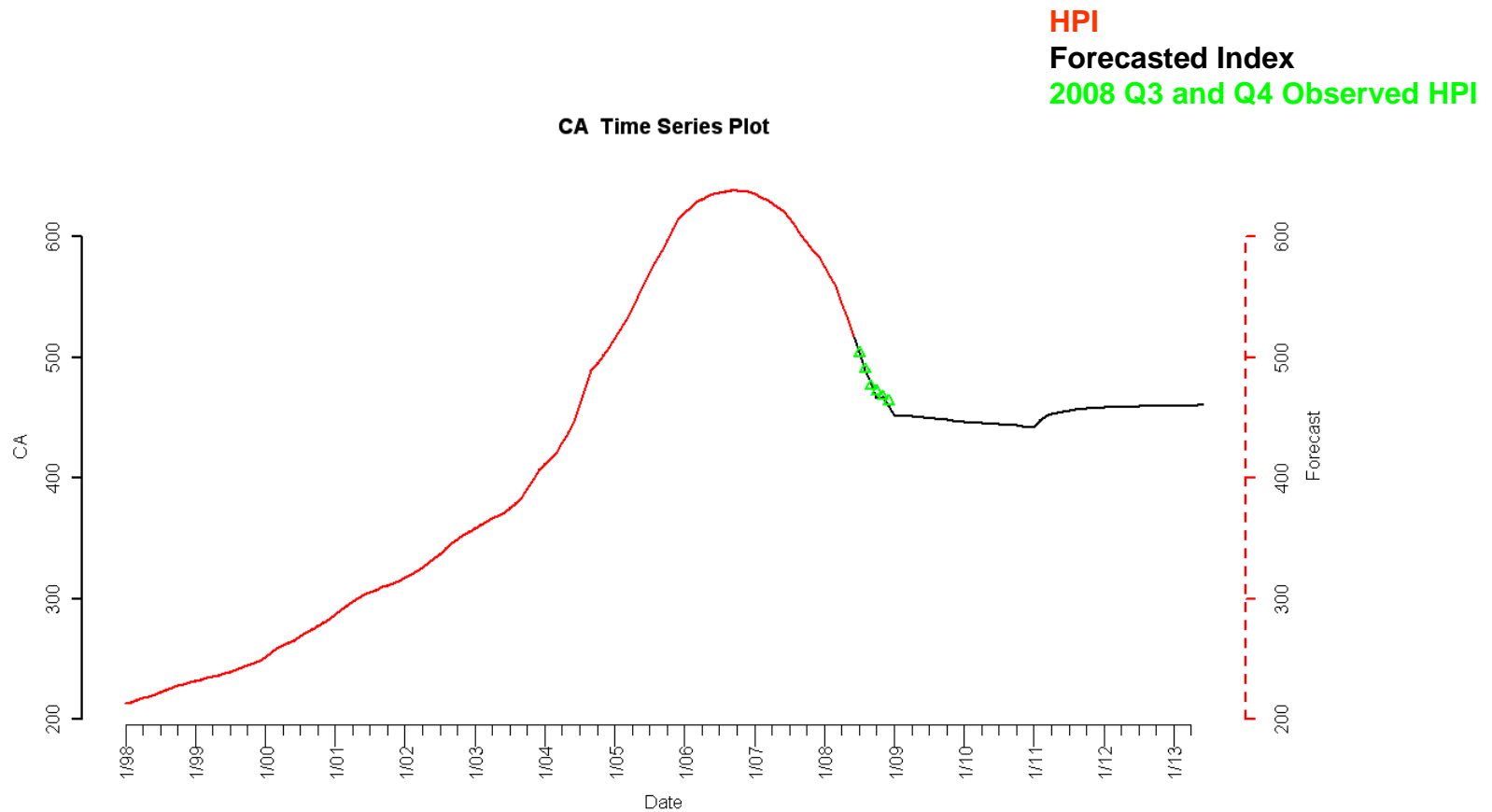
# California – Forecast (simple returns)

**HPI simple return**  
**Forecasted Simple Return**  
**95% Prediction Interval**





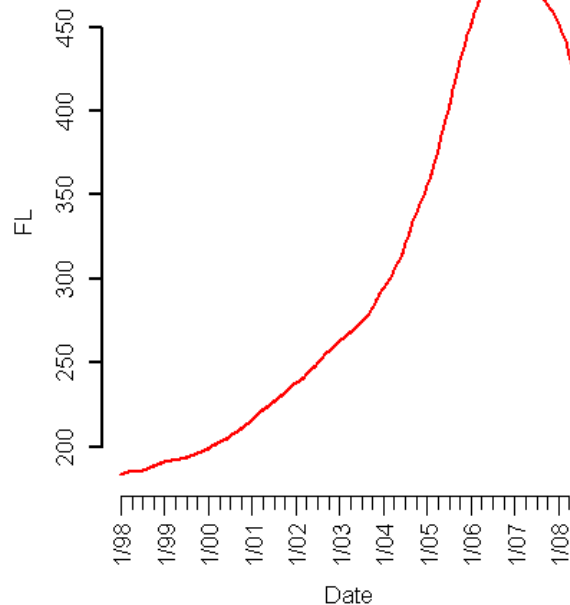
# California – Forecast (HPI)



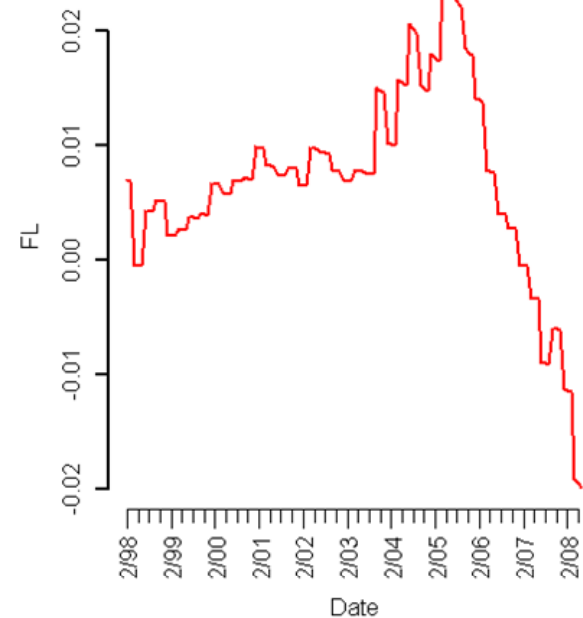


# Florida Housing Market

Florida HPI



Florida HPI Simple Returns





# Florida – “It’s June in Miami!”

- History repeats itself
  - 1920’s housing bubble
- Increasing demand
  - Booming tourism
  - Skyrocketing land prices
  - Exponential population growth
- Plentiful credit and capital
- Speculative investors





## Florida – early 2000's

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- Prices there are up 33% in one year, up 105% over the five years, and 180.7% over the past decade
- Speculative investors craze
- Increasing adjustable-rate mortgages that allow speculative borrowers to delay the cost of their loans





# What's Different About Florida?

## (1) International investors

	% of all international home buying transactions
Florida	26%
California	16%
Texas	10%
Arizona	6%
New York	4%

Source: National Association of Realtors

## (2) Luxury million \$ homes



## (3) Vacation homes

Where people would most like to live – apart from their own state										
	1997	1998	1999	2000	2001	2002	2003	2005	2006	2007
Florida	1	1	1	1	1	2	2	2	3	2
California	3	3	2	5	2	1	1	1	1	1
Hawaii	7	7	9	7	3	3	3	3	2	3
North Carolina	6	4	4	3	7	5	8	8	4	4
Colorado	4	2	3	2	4	4	4	4	7	5

Source: Harris' Annual Poll

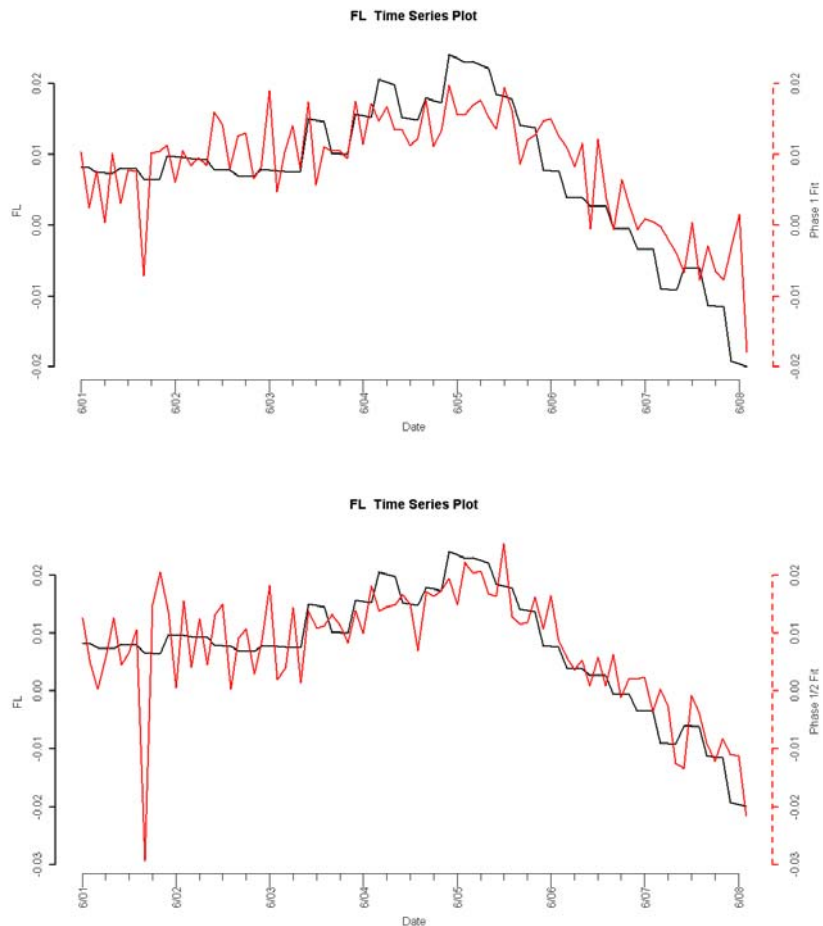


# Florida Outlook – “First In, First Out”

- Population growth
  - By 2010, FL forecasted to be the 3<sup>rd</sup> most populated state in the nation
  - FL’s population expected to increase about 75% by 2030
  - Estimated that 900 people move to FL every day
- Unemployment
  - 4<sup>th</sup> largest labor force
  - Unemployment rate historically below national average for past decade
- Median Income
  - FL no state income tax
  - Extra boost to resident’s income
- Signs of shrinking inventory
  - Although hundreds of foreclosed properties go on the market each month, the inventory of houses for sale is shrinking
  - Current 12-month supply of inventory, down from a peak of 30 months (3-6 months supply is typical of a healthy housing market)
- Investors
  - Steep price declines have encouraged first-time homebuyers with good credit, and lots of investors
  - Cash-rich international investors who are taking advantage of the low prices
  - In recent months, prices have begun to flatten out



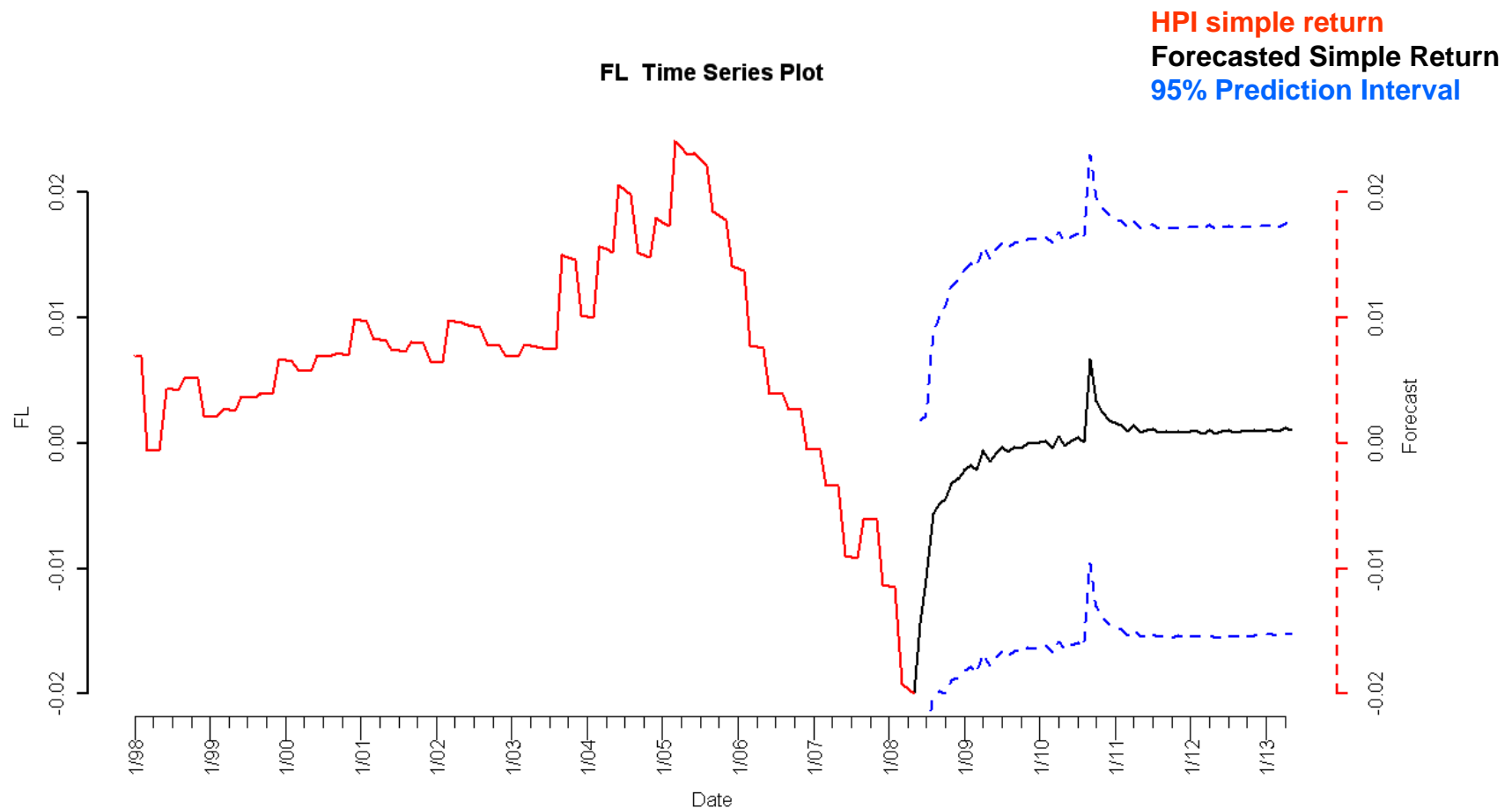
# Florida Model



Forecasts

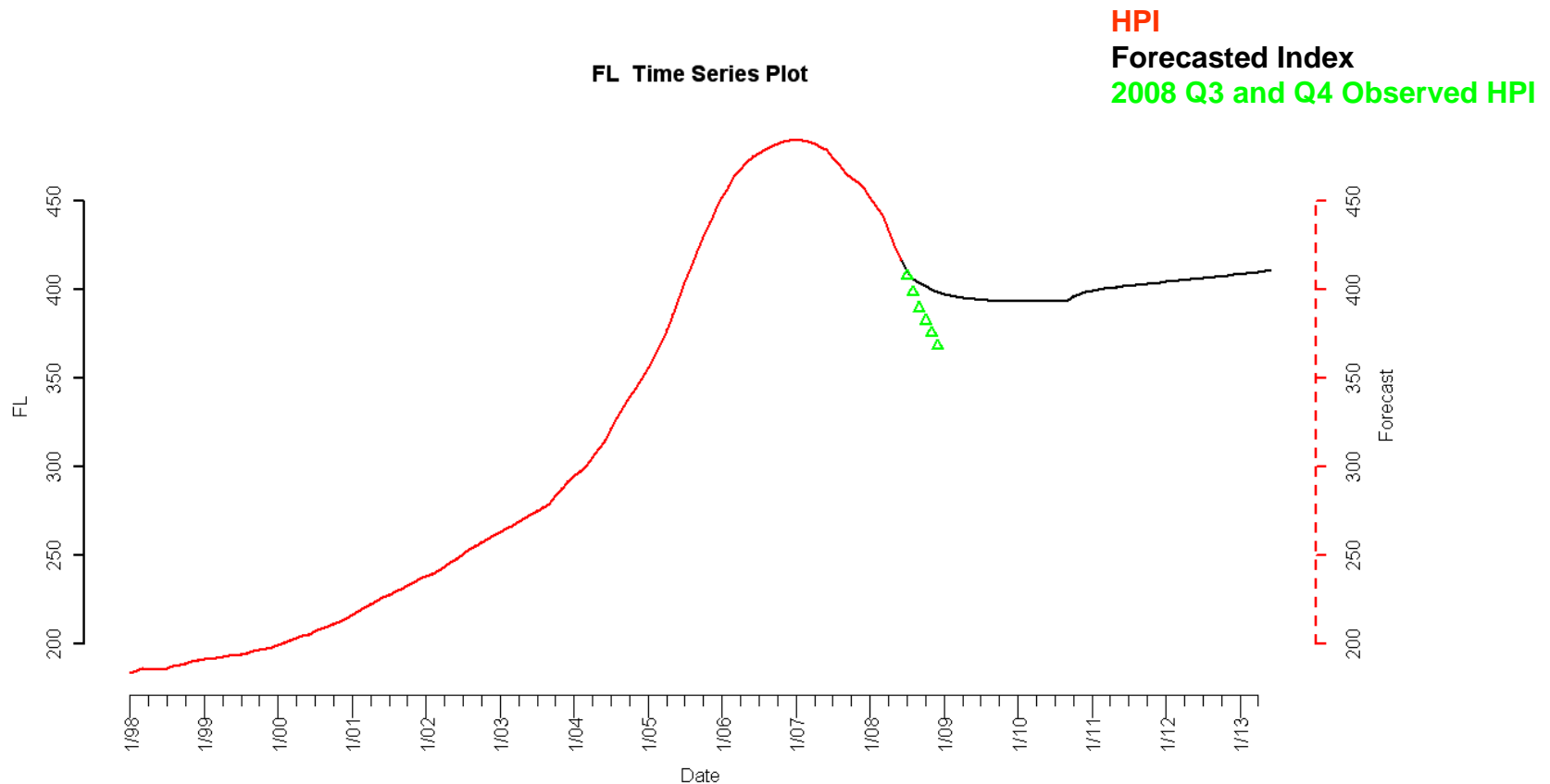


# Florida – Forecast (simple returns)





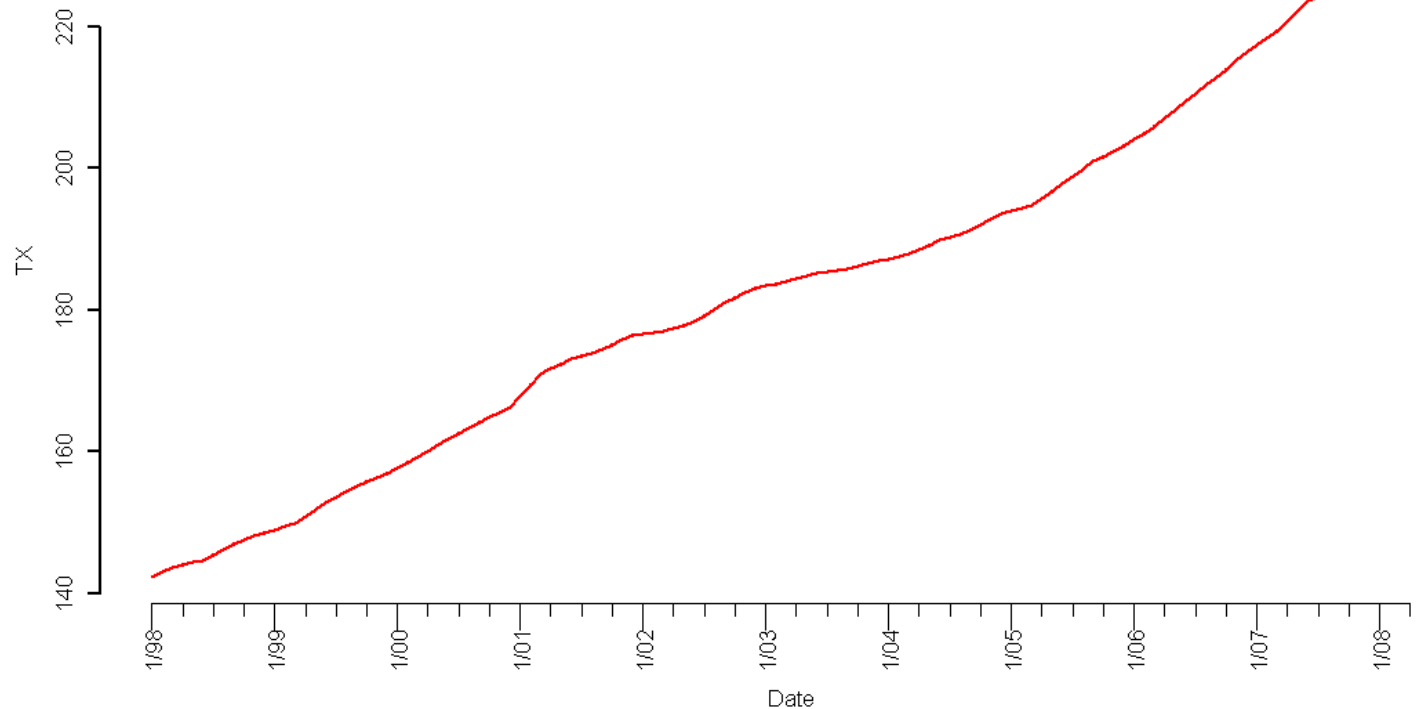
# Florida – Forecast (HPI)





# Texas

**Texas HPI**



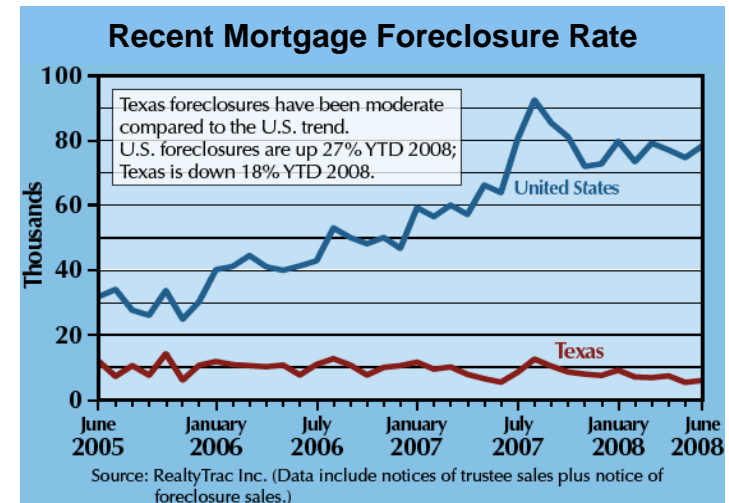
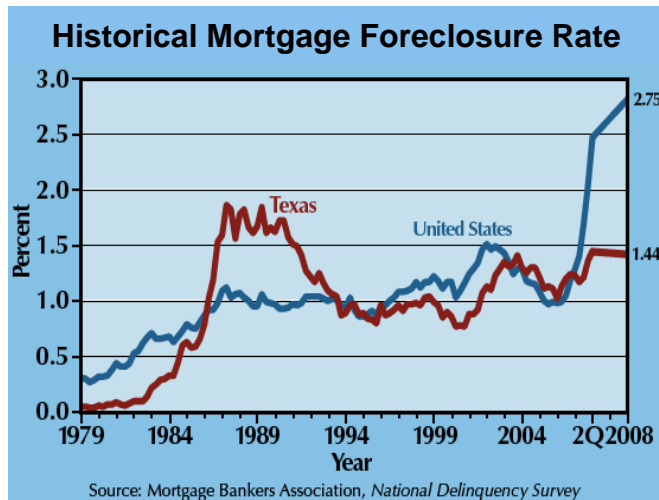
*"Don't Mess With Texas"*





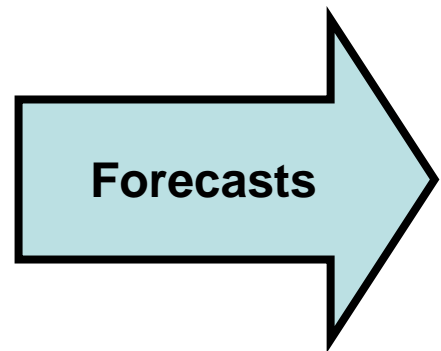
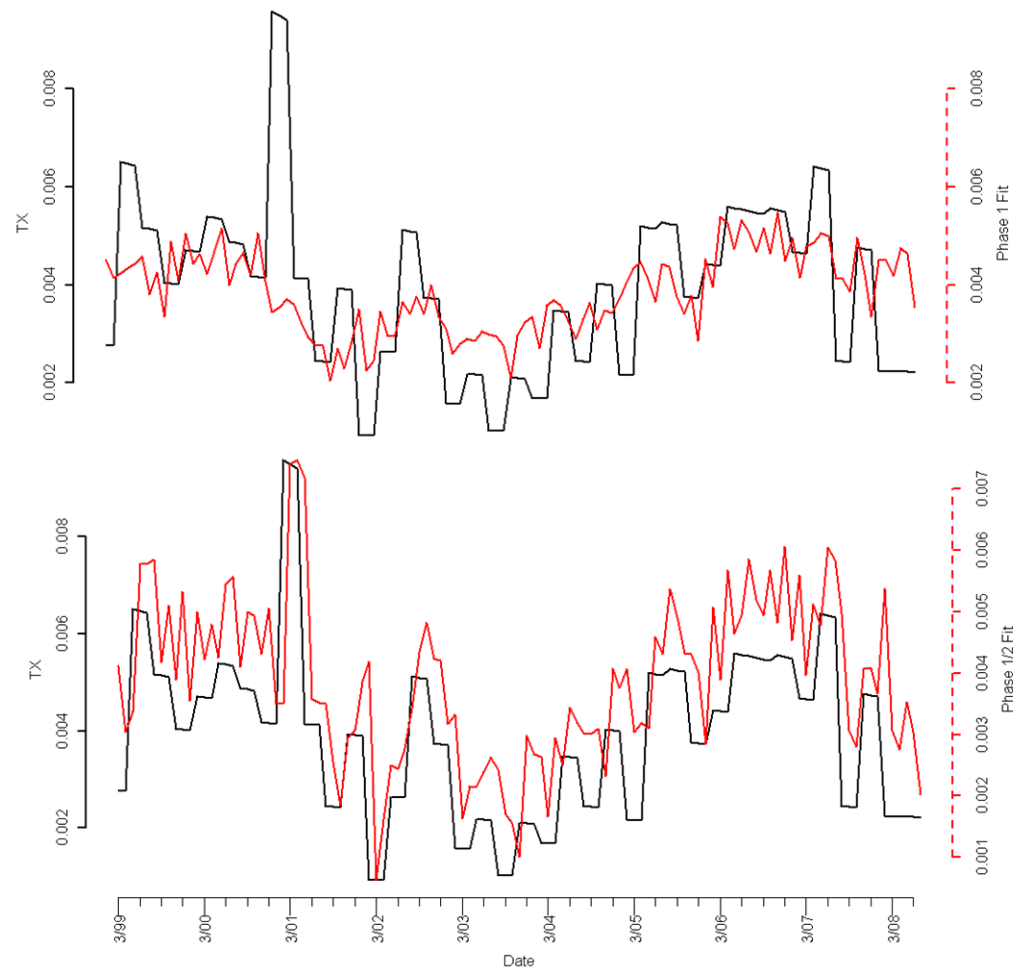
# Texas

- Texas Learned Their Lesson
- “Flatland” vs. “Zoned Zone”
  - “The Two Americas” Paul Krugman



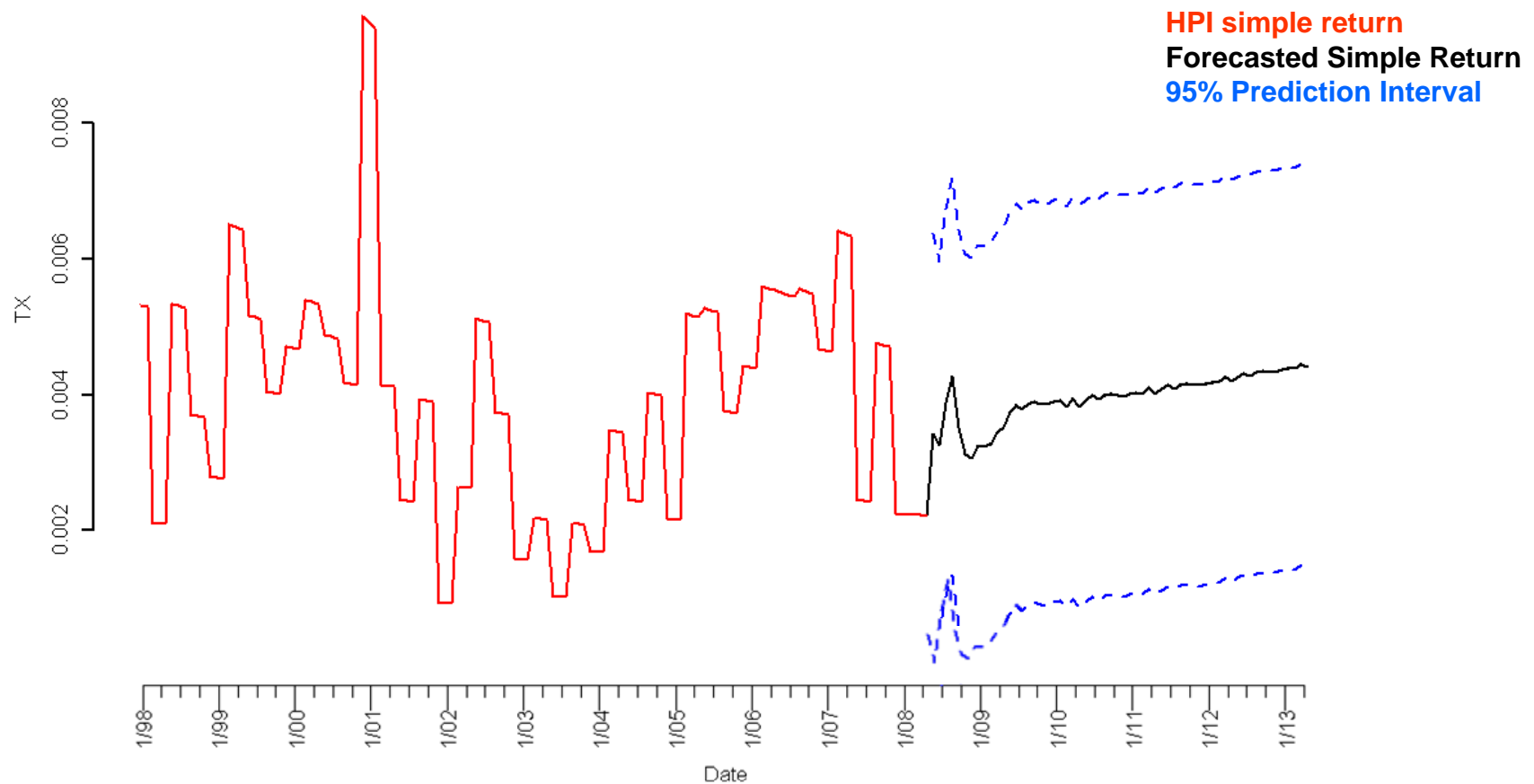


# Texas Model



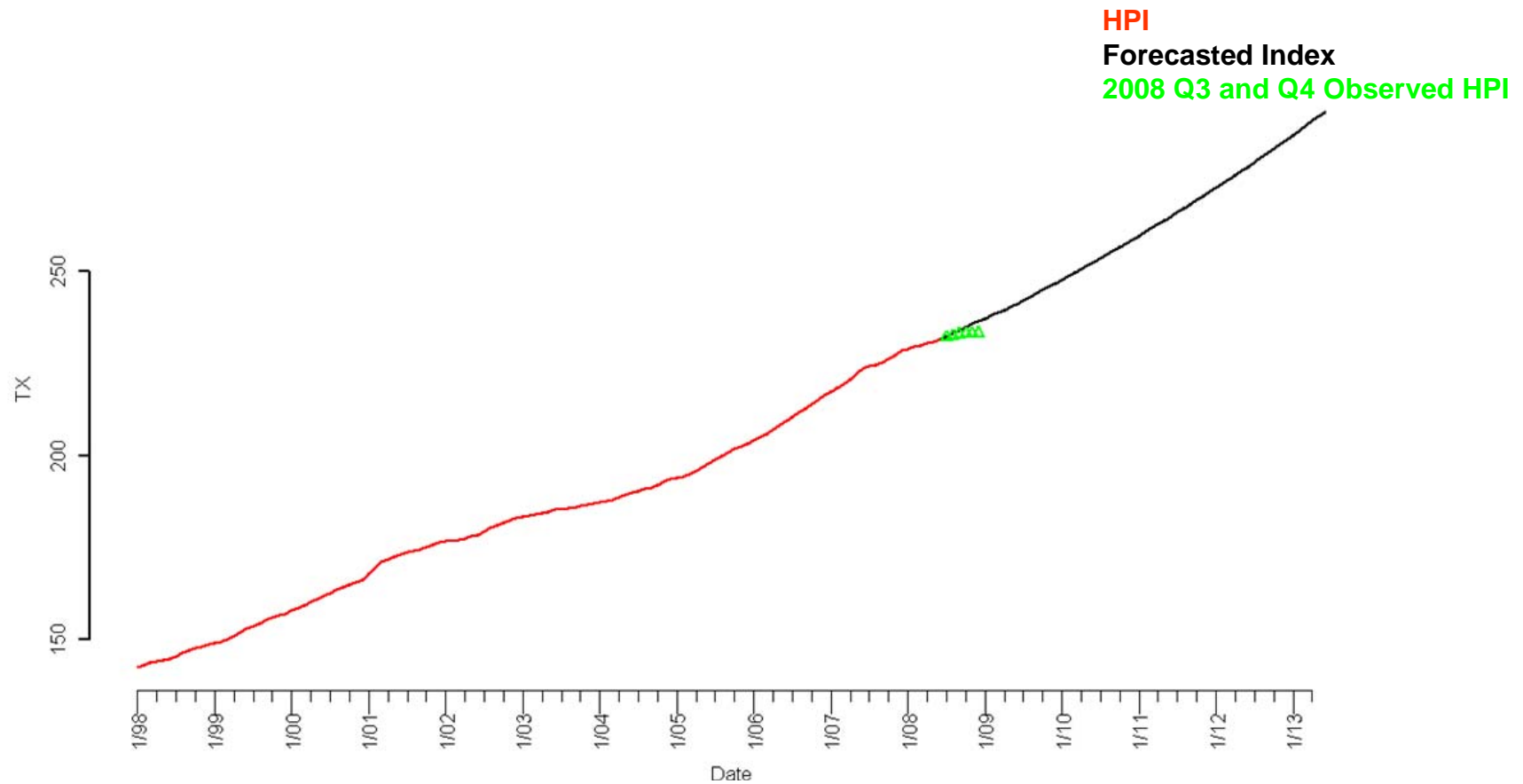


# Texas Forecasts





# Texas Forecast





# Montana



Montana Leads 2009 Top Housing Market Forecast



# Montana – Outlook

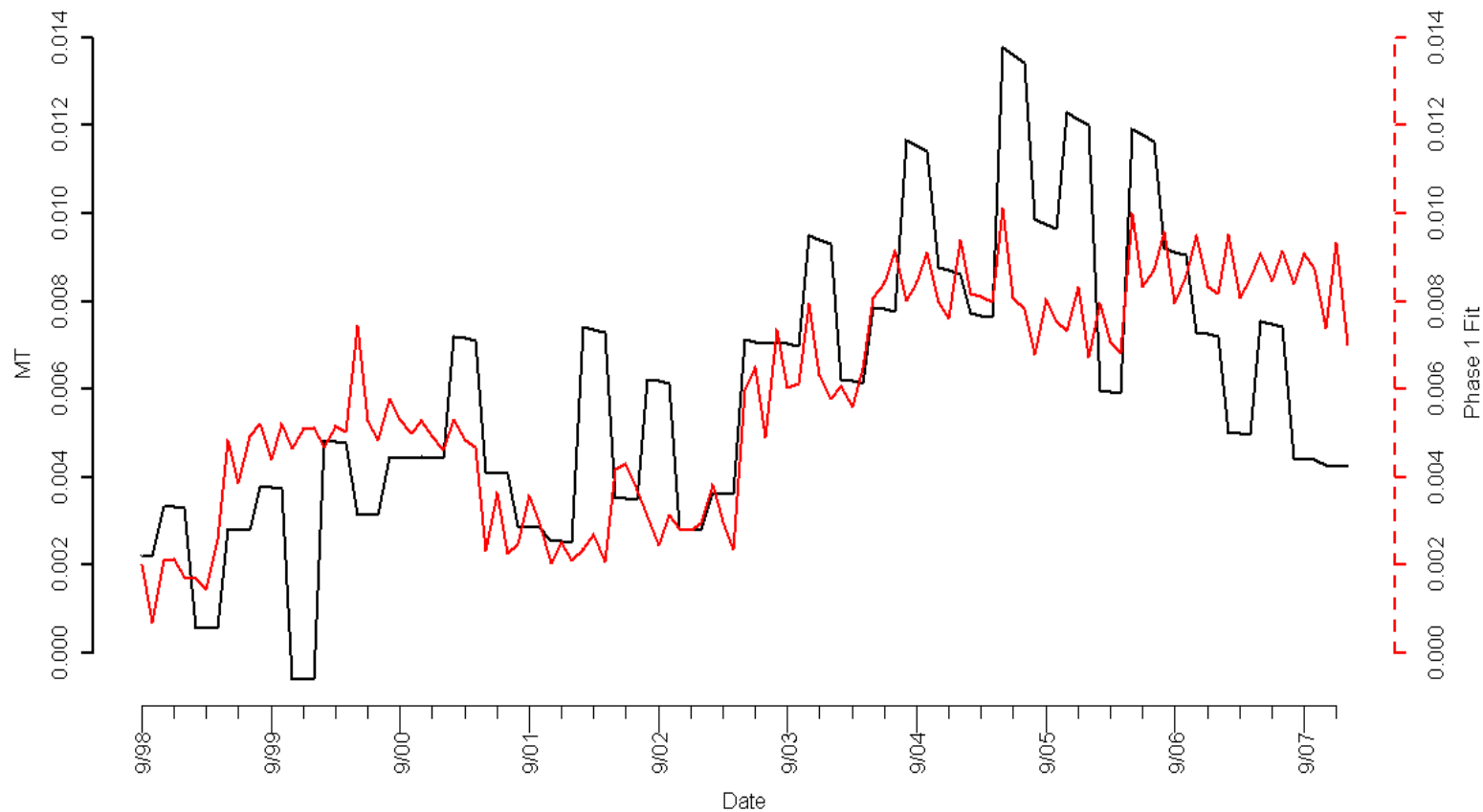
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- Has one of the highest employment rates in the nation due to growth in the energy industry.
- Most of Montana have seen a growing population and is now forecast to deflate a marginal 3.7% in 2009 .
- Unemployment rate is 5.6% in January, which is well below January's national average of 7.6%.
- Bozeman has one of the highest numbers of home businesses in the country.



# Montana Model

MT Time Series Plot



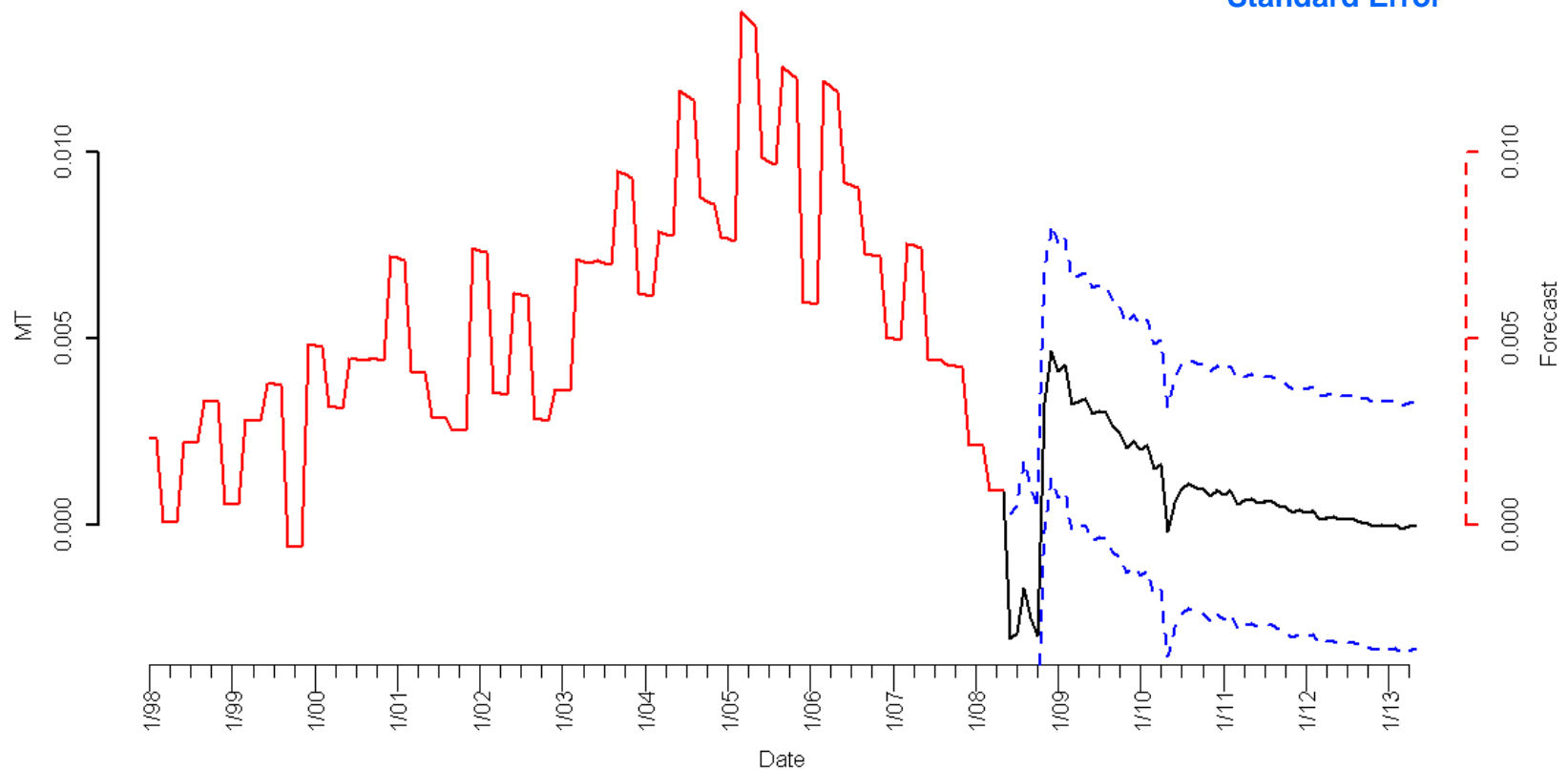




# Montana Forecasts

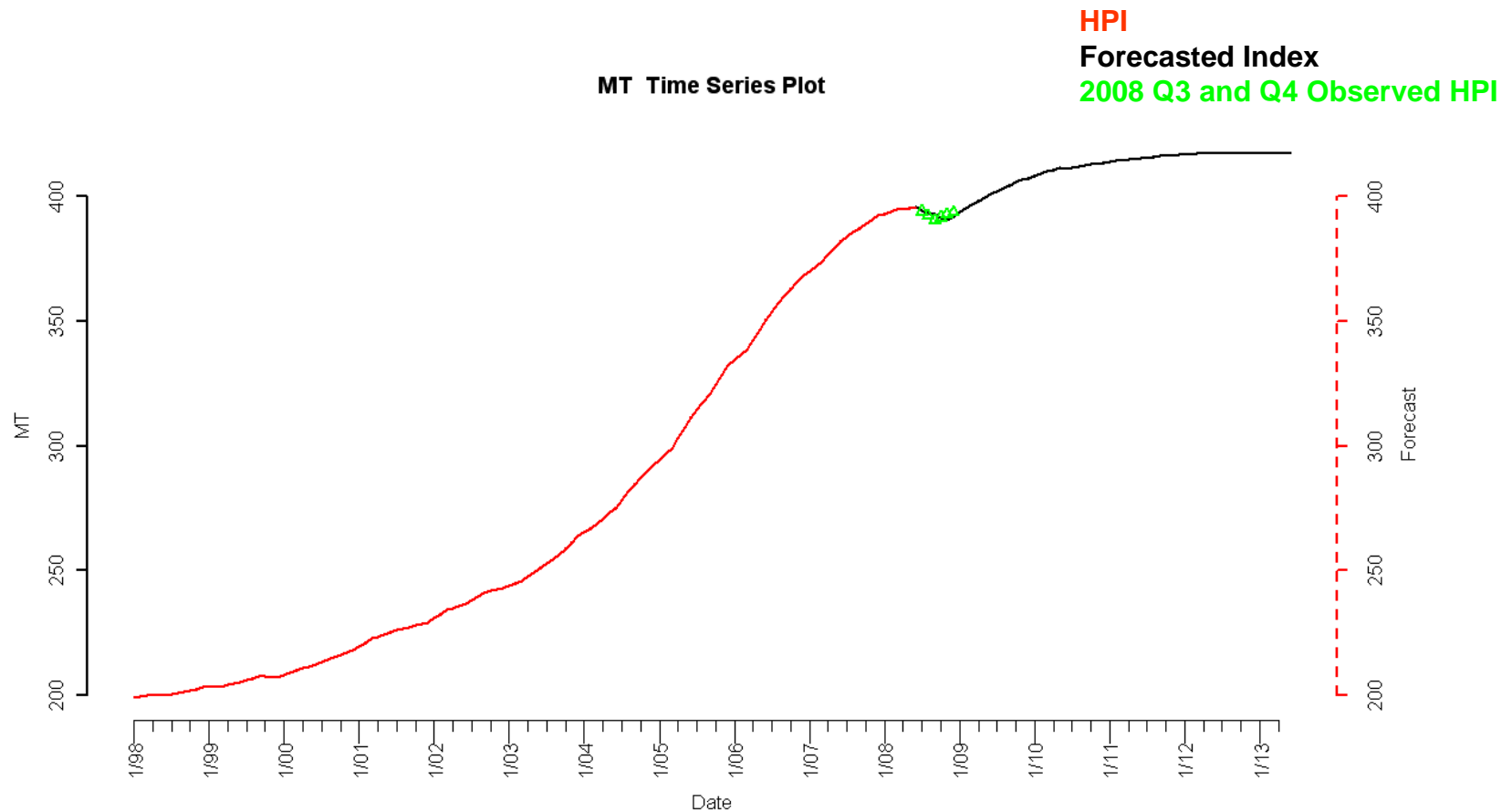
MT Time Series Plot

HPI simple return  
Forecasted Simple Return  
Standard Error



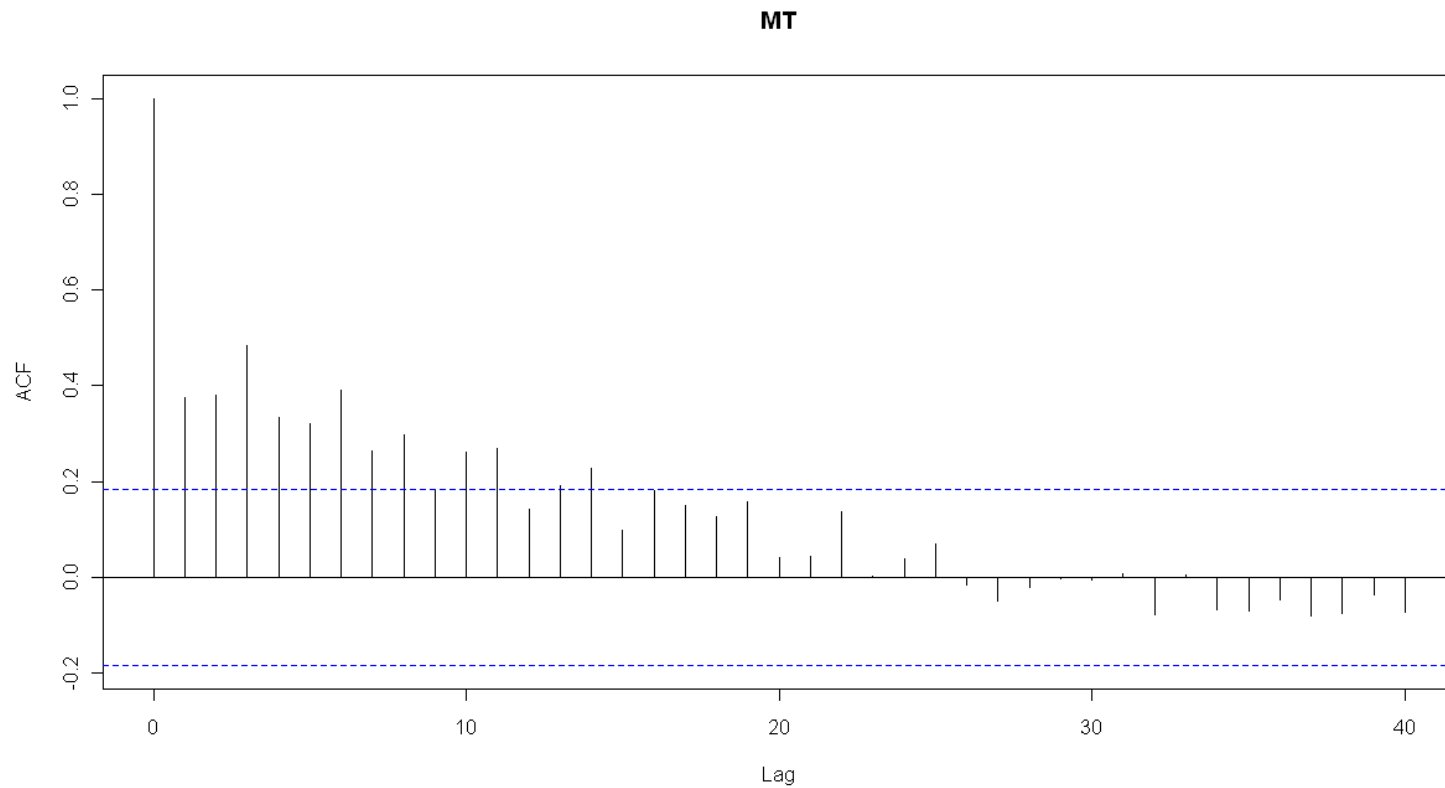


# Montana Forecasts (cont'd)



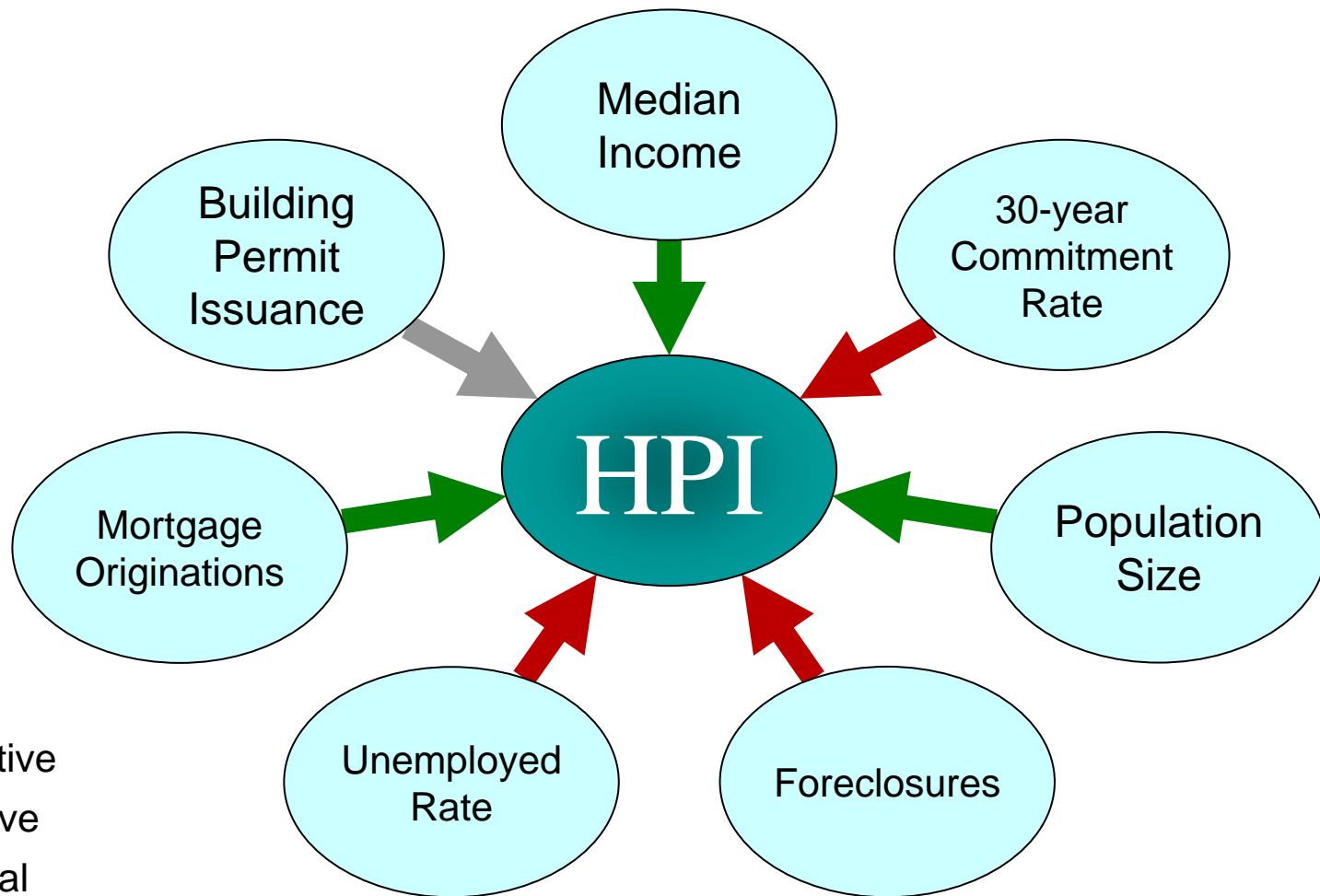


# Montana (ACF of Residuals)





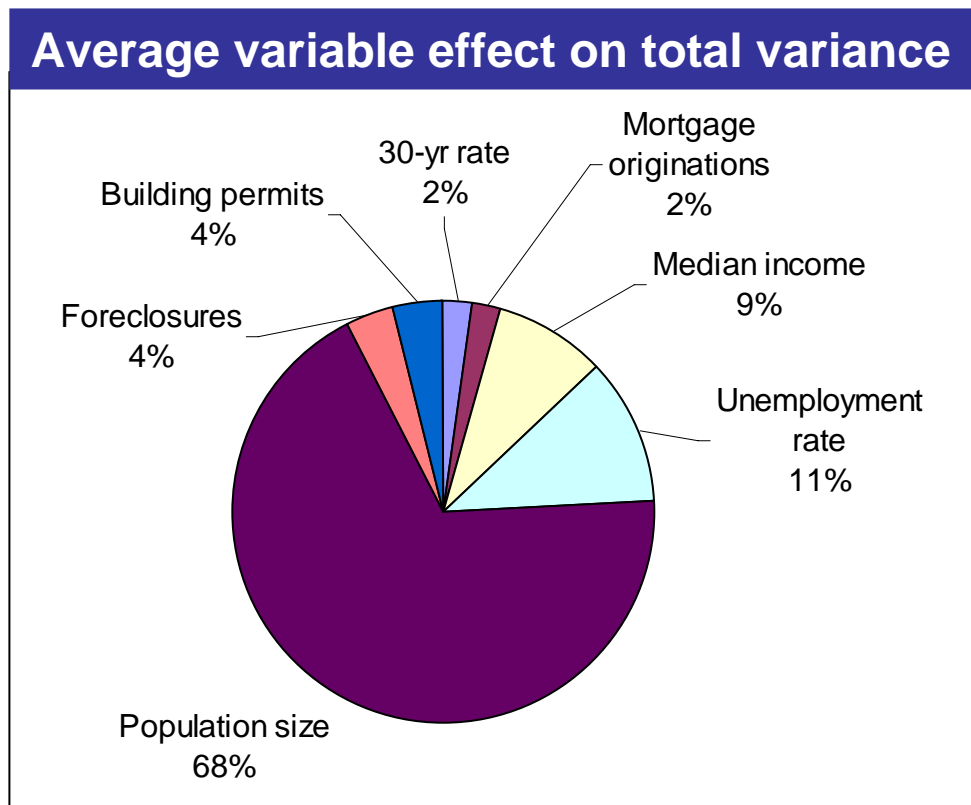
# Variable Relationships





# Aggregate Empirical Results

- Strength of variable relationships across states



Direction of relationships consistent with theoretical values



# Modeling Approach

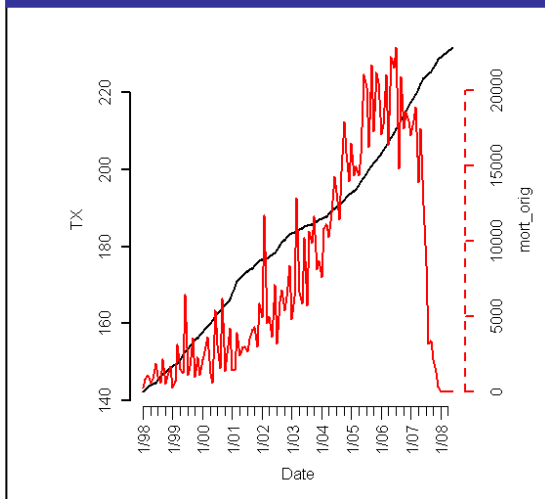
- Drift Model
  - Multiple linear regression
  - Predictors: Macroeconomic factors on both the supply and demand side
  - Response: Housing Price Index (HPI)
  - Requirements: Unit-root stationarity of the residuals
  - Equation:  $Y_t = \beta X_{t-l} + r_t$
- Volatility Model
  - Model autocorrelation of residuals
  - Time series modeling using ARFIMA / GARCH
  - Equations:  $(1 + B)^d (\Phi(B))r_t = (\Theta(B))a_t$

$$a_t = \left( \sum_i \alpha_i a_{t-i}^2 \right) + \left( \sum_i \beta_i \sigma_{t-i}^2 \right) + \omega \quad a_t = \sigma_t \varepsilon_t \quad \varepsilon_t \sim N(0,1)$$

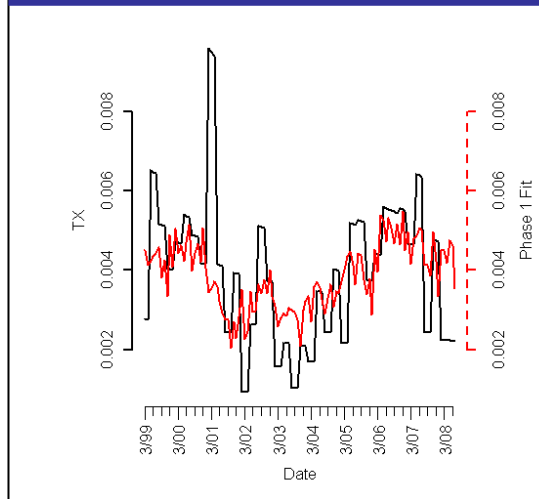


# Drift Modeling

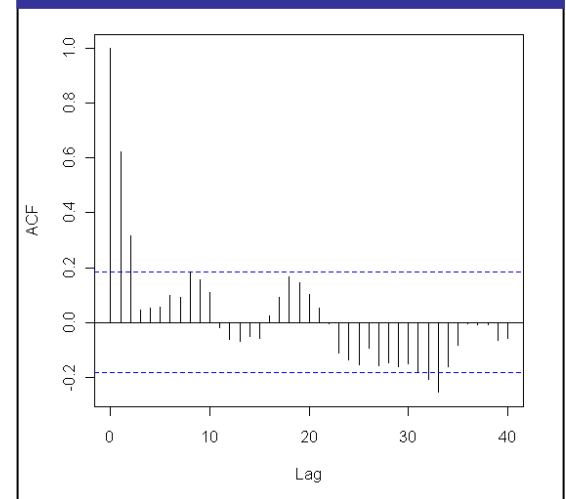
Step 1



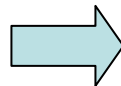
Step 2



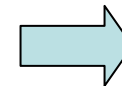
Step 3



**Determine lags of predictor variables**



**Robust multiple linear regression**



**Stationarity & autocorrelation of residuals**





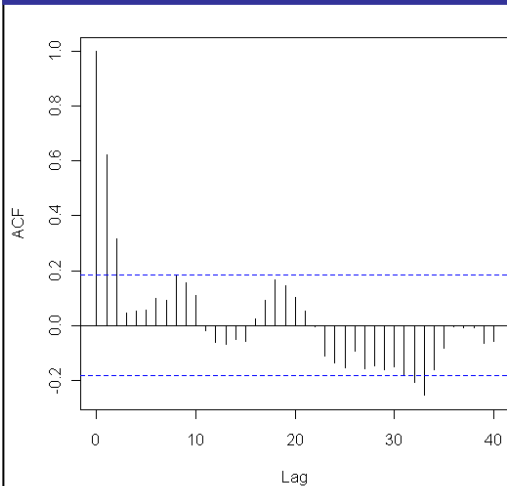
# Volatility Modeling

- Purpose
  - To model serial autocorrelations in residuals
  - To stabilize variance and volatility clustering from drift model
  - Original residuals should already be stationary
- Univariate Time Series Modeling
  - Auto-Regressive, Moving Average (ARMA)
  - General Auto-Regressive Conditional Heteroscedasticity (GARCH)

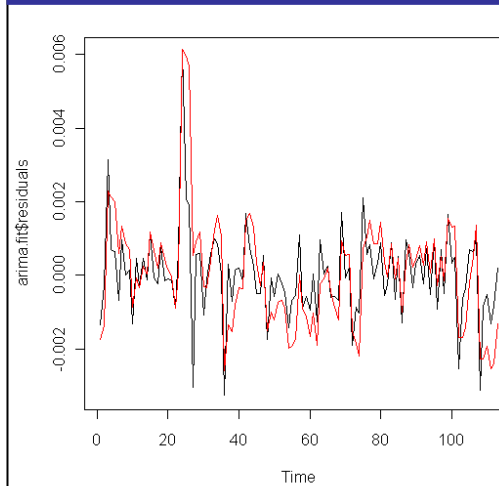


# Volatility Modeling

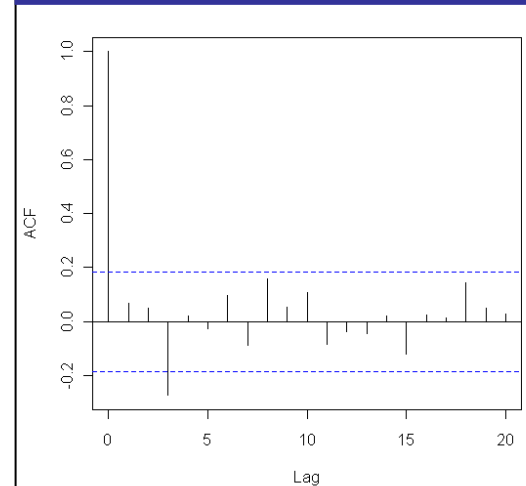
Step 1



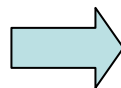
Step 2



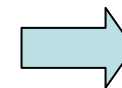
Step 3



**Correlated residuals**



**Fit ARFIMA/GARCH models**



**Residuals are uncorrelated**



# Modeling Challenges

- Data
  - Influential observations in the pre-1990 HPI Data
    - Accuracy of the data in this time period is questionable
    - Hindered stationarity of residuals
    - Removed using the Grubb's test for influential data points
  - Frequency and Temporal Relationships
    - Linear interpolation used to obtain monthly estimates
    - Multiple “lags” of each variable tested
- Regression Coefficients
  - T statistic may not be accurate indicator of statistical significance
  - Predictor may still explain a substantial amount of variation in the HPI



# Modeling Challenges (cont'd)

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- Constraints
  - Parsimonious model: single lag for each predictor variable
  - Coefficients make economic sense
- Stationarity of residuals



# Forecasting HPI

- Drift Forecasting
  - Examine trends in each of 7 macroeconomic variables
  - Determine key assumptions for each variable
  - Project out to 60 months
  - Assume relationships are the same as before
- Volatility Forecasting
  - Based on ARMA/GARCH models built
  - Explains additional model volatility

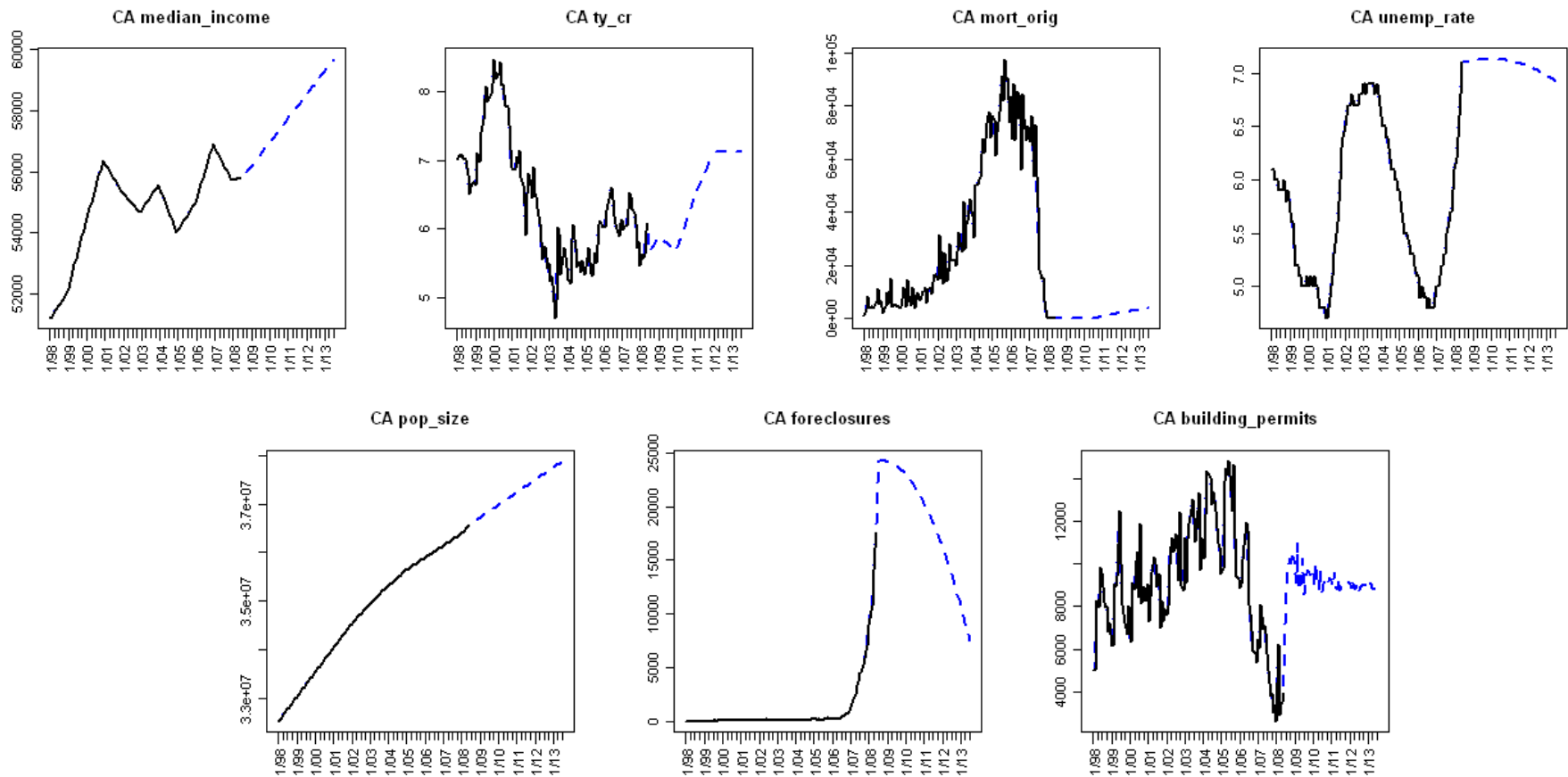


# Variable Forecasts / Assumptions

	Variable		Assumption
Demand	Unemployment Rate	→	Periodic trend
	Population Size	→	Linear growth
	Median Income	→	Grows at long term inflation
	Mortgage Originations	→	Zero for 24 months
	30-Year Commitment Rate	→	Analyst forecasts (Global Insight)
Supply	Building Permits	→	Move about pre-bubble mean
	Foreclosure	→	Based on total foreclosures (CSFB)



# Sample Forecasts - California







# Conclusion

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- Drivers of housing prices – summary
- The bigger they are, the harder they fall



# Acknowledgements

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- Sponsor: Dr. Paul Thurston
- Advisors
  - Dr. David Matteson
  - Dr. David Ruppert
- Program
  - Dr. Kathryn Caggiano
  - Victoria Averbukh
  - Selene Cammer



Cornell University



# Questions

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# Appendix I: Model Coefficients

Arizona		California		Florida	
Variable	Value	Variable	Value	Variable	Value
median_income-Lag12	1.2492	median_income-Lag0	0.2131	pop_size-Lag-6	7.1020
ty_cr-Lag8	-0.0125	ty_cr-Lag4	0.0076	median_income-Lag0	0.6452
mort_orig-Lag2	0.0142	mort_orig-Lag6	0.0144	ty_cr-Lag3	-0.0016
unemp_rate-Lag9	-0.2443	unemp_rate-Lag8	-0.3727	mort_orig-Lag2	0.0032
foreclosures-Lag12	-0.0049	foreclosures-Lag6	-0.0106	unemp_rate-Lag3	-0.0260
building_permits-Lag13	0.0152	building_permits-Lag8	0.0067	foreclosures-Lag2	-0.0151
				building_permits-Lag3	0.0138

Montana		Texas	
Variable	Value	Variable	Value
ty_cr-Lag-6	0.0046	pop_size-Lag0	2.4587
mort_orig-Lag-2	0.0002	median_income-Lag12	0.0947
median_income-Lag6	-0.0882	ty_cr-Lag3	-0.0039
unemp_rate-Lag6	-0.0457	mort_orig-Lag7	0.0000
pop_size-Lag3	9.3867	unemp_rate-Lag4	-0.0314
foreclosures-Lag1	-0.0001	foreclosures-Lag10	-0.0005
building_permits-Lag1	0.0011	building_permits-Lag3	0.0006



## Appendix II: HPI - OFHEO vs. Case-Shiller

### OFHEO

- Purchase Price and Refinance Appraisals
- Mortgage data from Fannie Mae and Freddie Mac
- Equally weights all prices
- Covers all states; important when some areas are growing rapidly

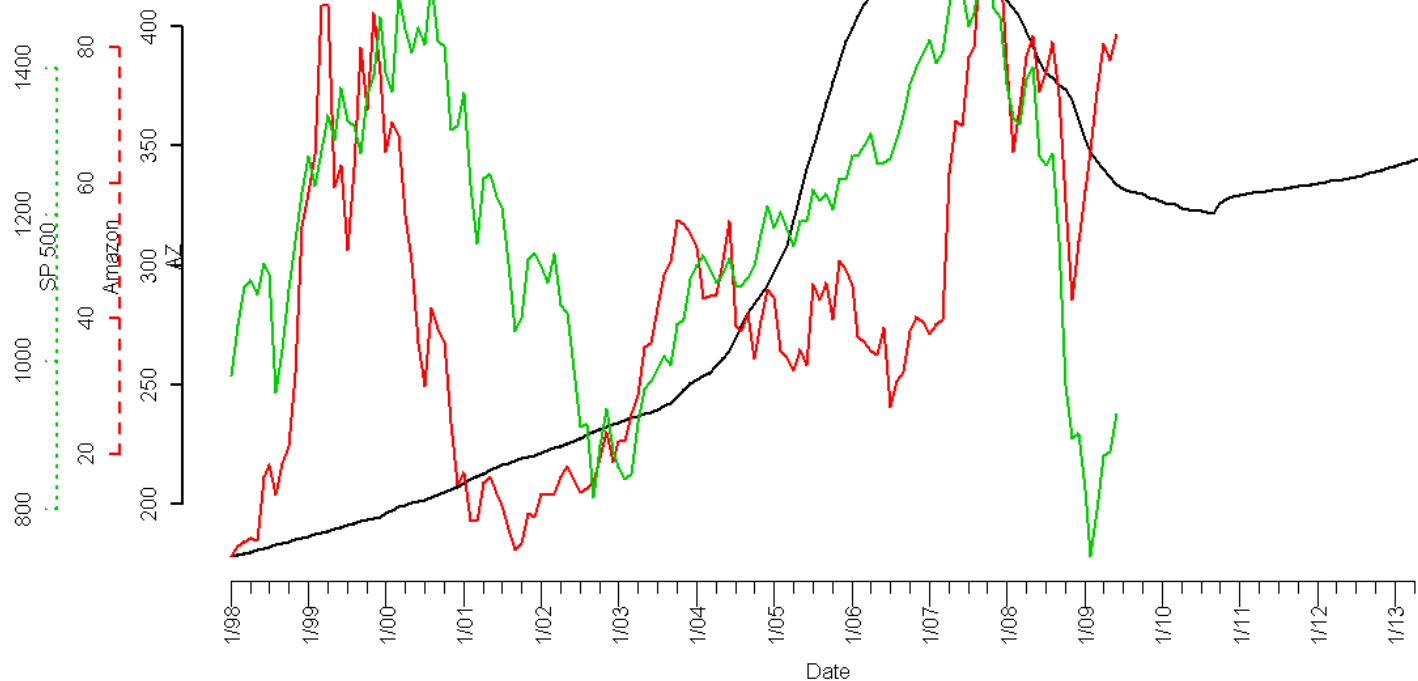
### Case-Shiller

- Purchase Price
- Mortgage data comes from county records
- Value-weighted, giving more weight to higher priced homes
- No data from 13 states



# Appendix III: HPI with S&P500

AZ Time Series Plot





# Appendix IV: Sources

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## FOR CALIFORNIA

[http://www.dre.ca.gov/pdf\\_docs/Op\\_Ed\\_New\\_Home\\_Credit\\_%202\\_26\\_09.pdf](http://www.dre.ca.gov/pdf_docs/Op_Ed_New_Home_Credit_%202_26_09.pdf)

<http://blogs.wsj.com/developments/2009/05/06/another-sign-of-foreclosure-trouble-in-california/?ref=patrick.net>

<http://blogs.wsj.com/developments/2009/04/24/foreclosures-set-to-soar-in-california/>

<http://online.wsj.com/article/SB124087905185761701.html>

[http://online.wsj.com/article/SB124061719457055061.html?ru=yahoo&mod=yahoo\\_hs#articleTabs%3Darticle](http://online.wsj.com/article/SB124061719457055061.html?ru=yahoo&mod=yahoo_hs#articleTabs%3Darticle)

## FOR Jumbo Mortgages

<http://online.wsj.com/article/SB123543726577454673-search.html>

## FOR Pictures

<http://online.wsj.com/article/SB123543721679054667.html>

<http://online.wsj.com/video/bank-decides-to-demolish-new-homes/509981D0-7AAF-4A29-AE46-A490D7FE2A93.html>