Dynamic Relationships among House Price Returns, Mortgage Rates and Default Rates: Study of Recent Mortgage Crisis

Shaun Wang

Department of Risk Management and Insurance

Robinson College of Business

Georgia State University

Xiangjing Wei (Correspondent)

Department of Risk Management and Insurance

Robinson College of Business

Georgia State University

Email: xiangjing.wei@gmail.com

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Abstract

Based on the Granger-Causality test, we apply vector auto regression models (VAR) and simultaneous equations models (SEM) to estimate the dynamic relations among house price returns, mortgage rates and mortgage default rates, using historical data during the time period of 1979 through second quarter 2008. We estimate that, holding all other factors constant, two consecutive 1% increases of default rates can drive house price returns down by about 7%-18%. Conversely, two consecutive 1% decreases of house price returns can drag the current default rate up by 0.04%-0.09%.

We apply our econometric models in making predictions using data up to the second quarter of 2008. The OFHEO's and Case-Shiller's indices exhibit different patterns and thus they yield different predictions as well. The predicted future level of OFHEO's house price returns will remain negative and reach the lowest value in 2010; it may take some years for the house price returns to become positive. However, we get more optimistic forecasts using the Case-Shiller's index, whereas the future house price returns would become positive since 2010, and mortgage default rates will peak by 2010 and decrease thereafter. We add caveats for interpreting these mechanical forecasts: they do not reflect many important dynamics that will strongly impact the housing markets, for instance, the various government mortgage modification programs, and the inventory of excess housing units.

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1. Introduction

The mortgage crisis began with sharp falls after the United States housing boom peaked in 2005-2006 and became apparent in 2007, signaled by a sharp rise in mortgage defaults and foreclosures in the United States. It has affected almost all investments which derive their values from mortgage loans, such as Mortgage-Backed Securities (MBSs) and Collateralized Debt Obligations (CDOs). Up to the middle of 2008, several hundred billion dollars in losses have been reported and written down by the financial institutions which were heavily invested in those products. Much of the capital of the banking system was wiped out. Mortgage insurers and bond insurers were hit hard. Further, the mortgage crisis spread to the general economy.

Many papers discuss the causes and effects of the mortgage crisis. Their analyses focus on many aspects: falling house prices, high-risk mortgage loans and eased lending standards, securitization, roles of credit rating companies, government policies and so on. For example, Crouhy *et al* (2008) examine the players and issues at the heard of this crisis.

When analyzing the possible losses, some studies emphasize the mortgage rate reset. Cagan (2007) projects the amount of default mortgages, including prime mortgages and subprime mortgages, due to mortgage payment reset. Weaver and Reeves (2007) states the impacts on default of Subprime Adjustable Rate Mortgages (ARMs) at the fully indexed rate,

instead of the low introductory rate. Later, the crucial problems in the mortgage market became the concern of most researchers. For example, Foote, *et al* (2008) state that interest-rate resets may not be the main problem in the mortgage market; and higher foreclosure rates stem from falling house prices. They use data from a private firm and focus on the situation in Massachusetts and the rest of New England. One of their concerns is that home prices have a bigger impact on foreclosures than foreclosures have on home prices. Greenlaw, *et al* (2008) and Hatzius (2008) put emphasis on modeling mortgage credit losses, based on the effects of home price declines on foreclosure and mortgage credit losses.

In this paper we utilize a Vector Autoregressive model (VAR) and a Simultaneous Equation model (SEM) to analyze the interactions among house price returns, default rates and mortgage interest rates. We are guided by three central ideas: (1) Fundamental economic factors are the roots of the subprime crisis. Only when these factors improve, will the credit and economic situations revive. Therefore we will not discuss the effects of other factors.[1] This is consistent with the previous papers, which project the mortgage foreclosures and losses based on housing prices. We choose house price returns and mortgage interest rates as the proxies of the fundamental factors. (2) The distinctive feature of this paper is that we focus on the interrelationship among the above three variables. And, based on the observations and our analysis, house prices impact mortgage defaults, and *vice versa*. This could explain why the severity of the crisis is heavier than what we originally expected. (3) By working on a structural model, the dynamic relations among house price returns, mortgage rates and default rates can be investigated better. Holding all other factors constant, two

[1] We admit that the other factors, such as lending standards and credit ratings, have important effects on the subprime roles. However, those are not covered by this paper. Here we only analyze the economic fundamentals and use them to make predictions.

consecutive 1% increases of default rates can drive OFHEO's[2] house price returns down by about 7.64% and Case-Shiller's current house price return down by about 18%. Conversely, two consecutive 1% decreases of OFHEO's or Case-Shiller's house price returns can drag the current default rate up by 0.09 percent or 0.04 percent, respectively. However, the relative high standard errors may render the above estimates fluctuating in a wide range.

We apply our models in making predictions using data up to the second quarter of 2008. The OFHEO's and Case-Shiller's indices exhibit different patterns and thus they yield different predictions as well. Per the data up to the second quarter of 2008, the expected future level of OFHEO's house price returns will remain negative and reach the lowest value in 2010; it may take some years for the house price returns to become positive. However, we get more optimistic forecasts using the Case-Shiller's index: the future house price returns tend positive beyond 2010; and mortgage default rates peak by 2010 and decrease thereafter.

The structure of the rest of this paper is as follows: Section 2 explains the historical dynamics and data. Section 3 shows the Granger-Causality test. Sections 4 and 5 present the VAR process and Simultaneous Equation Model respectively. Section 6 makes predictions based on the models. Section 7 summarizes our conclusions.

2. Historical Observations

2.1. All Mortgage Products are Affected

Although it is generally agreed that this mortgage crisis originated in subprime adjustable rate mortgages (ARM), the mortgage default rates for all the listed types of mortgage products

[2] the Office of Federal Housing Enterprise Oversight. Currently it is called "Federal Housing Finance Agency (FHFA)".

have been increasing since late 2006. Figure 1 shows the percentages of different loans[3] past due 90 days between 1998 and the second quarter of 2008, obtained from the Mortgage Bankers Association. Table 1 displays different mortgage delinquency rates and foreclosure rates in the year end 2005-2007 and the second quarter of 2008, which rose at different rates since 2007, even for Prime mortgages.

Therefore, although some relatively new mortgage products[4] and loose underwriting may be blamed for the mortgage crisis, there indeed exist fundamental economic drivers: the changes in house prices and in mortgage rates. The relationships with the economic fundamentals are what we examine in this paper.

2.2. Interactions prior to the Crisis

Prior to the crisis, the boom in the housing market and low interest rates produced easy credit conditions and encouraged debt-financed consumption. From 1997 through 2006, the national OFHEO's House Price Index (HPI)[5] increased by 67%, while the S&P/Case-Shiller's House Price Index rose by 104%. Between 2000 and 2003, the federal funds rate target maintained by the Federal Reserve dropped from 6.5% to 1.0%[6], hence 30-year fixed mortgage rates fell by 33% (Figure 2). As a result, household debt grew from 60% of disposable personal income at year-end 1974, to 134% of disposable personal income in midyear 2008[7]. At the same time, mortgage default rates and foreclosure rates stayed at a low level.

[3] They include Prime FRM (fixed rate mortgages), Prime ARM (adjustable rate mortgages), Subprime FRM, Subprime ARM and all loans.
[4] such as interest only mortgages and negative amortization mortgages.
[5] Includes data from home sales and appraisals for refinancings.
[6] "Federal Reserve Board: Monetary Policy and Open Market Operations", available at http://www.federalreserve.gov/fomc/fundsrate.htm.
[7] http://en.wikipedia.org/wiki/Subprime_mortgage_crisis

2.3. Interaction since the Crisis

Intuitively speaking, mortgage default will occur if, (i) payments are too large compared with family income, and (ii) there is insufficient equity to enable refinance or sale. Only when the two situations occur simultaneously, will the default rate increase sharply. Therefore the default rate is influenced by both housing equity and affordability. These two variables are basically determined by house prices and mortgage rates, so is mortgage default.

US housing prices experienced a boom for the years from 2002 to 2006. However, the boom housing market enticed the consumers to continue borrowing. At the same time, the Fed funds rate was significantly raised between 2004 and 2006, from 1% to around 5.25%, which contributed to an increase in mortgage rates. 30-year fixed mortgage rates rose by 16% during these three years. The increased mortgage rates make periodic mortgage payments onerous, compared with income. Combined with the deflated house prices, this made it hard to refinance or sell. Therefore mortgage defaults and foreclosure rose dramatically.

On the one hand, as house prices decrease or mortgage rates increase, we expect the default rates to rise. On the other hand, as foreclosures mounted, unsold homes piled up, slowing the pace of home sales. This pushed home prices even lower. In the third quarter of 2007, the national OFHEO's quarter-over-quarter house price return fell below zero, the first negative since 1995. Case-Shiller's quarter-over-quarter house price returns have kept negative since the second quarter of 2006, with a record low return of ─ 6.80 percent in the first quarter of 2008.

In order to keep the economy from slipping into recession, between September 18, 2007 and March 18, 2008, the Federal Reserve slashed its federal funds rate from 5.25% to 2.25%. The effects of lowering market interest rates on mortgage rates are complicated. Lower interest rates tend to pull down the mortgage rates. However, due to the banks' reluctance to

provide credit, they tend to raise the margin (interest spread) in the mortgage rates. These two effects are opposite. Therefore, the 30-year fixed mortgage rates only rose by 10%.

2.4. Data

In this paper, we analyze the dynamic relations among house prices, mortgage rates and default rates. Figure 3 shows the historical data in these variables over time.

We investigate both OFHEO's House Price Index and S&P/ Case-Shiller's House Price Index for house prices.[8] Both of the indices are repeat sales indices. S&P/ Case-Shiller index is value-weighted, based on 10 or 20 metropolitan areas[9], available from 1987. OFHEO's index is unit-weighted, based on the fifty states and Washington D.C., available from 1975. Moreover OFHEO's House Price Index only uses the data based on Fannie Mae and Freddie Mac mortgages. Case-Shiller's House Price Index obtains data from county assessor and recorder offices and therefore covers more houses in the specific areas.

Figure 4 displays the differences between the two indices. Case-Shiller's Index shows larger fluctuations than OFHEO's Index. Between year end 2006 and the second quarter of 2008, OFHEO's house price index had a cumulative decrease of −1.16 percent, while Case-Shiller's house price returns accumulated to a loss of about −20 percent.

As for the mortgage rate, we use the 30-year fixed mortgage rates from the Federal Reserve's website. These should be the most representative mortgage rates.

[8] Additionally, the current house price series (or indices) used to measure national trends include *the median price of existing homes sold* (published by the National Association of Realtors) and *the median price of new homes sold* (published by the Bureau of the Census of the U.S. Department of Commerce). These two indices are not seasonally adjusted and reflect only recent sales, so they are volatile in the short run.

[9] The 10 metropolitan areas include Boston, Chicago, Denver, Las Vegas, Los Angeles, Miami, New York, San Diego, San Francisco, Washington DC. The 20 metropolitan areas also include Atlanta, Charlotte, Cleveland, Dallas, Detroit, Minneapolis, Phoenix, Portland (Oregon), Seattle, Tampa

We use the percentage of all loans past due 90 days as a proxy for the mortgage default rate[10]. The reasons are: (1) all the mortgage delinquency rates and foreclosure rates are basically cointegrated, so we only need to choose one series; (2) the percentage of all loans past due 90 days is affected less by random noise than the percentages of all loans past due 60 or 30 days; (3) mortgage foreclosure involves a complicated process. Unless analyzing the mortgage credit losses, we do not intend to investigate mortgage foreclosure rates here.

3. Granger Causality test

We first apply the Granger Causality test[11], which examines whether one time series can help forecast another variable, to support the dynamic analysis among house price returns, mortgage rates and default rates.

Suppose we have two terms X and Y, which are time series variables. In the presence of lagged Y, if an F-test on lagged observations of X shows that the X observations provide statistically significant information about future values of Y, then X is said to Granger-cause Y. Therefore, Y is able to be better predicted per the histories of X and Y than only per the history of Y. The VAR model is one simple approach to implementing the Granger Causality test.

Table 2 exhibits the results of the test by using the data through the second quarter of 2008. We obtain similar results for both OFHEO's and Case-Shiller's house price returns. At 10% significance level, house price returns Granger-cause default rates, and vice versa. House price returns Granger-cause mortgage interest rates, but conversely not. There is no apparent

[10] Practically, the differences between mortgage delinquency and mortgage default are based on the number of days of missed installments. Delinquency refers to the non-payment of a mortgage payment due, so it may be defined as a 30-days-and-over delinquency, a 60-days-and-over delinquency or a 90-days-and-over delinquency. Default happens when a borrower fails to pay back 90-days' installment due and the fourth payment is due.
[11] The detailed explanation can be found in the paper "Investigating causal relations by econometric models and cross-spectral methods" by Clive Granger (1969, Econometrica 37, 424-438).

Granger causality between mortgage interest rates and default rates. The reason may be that our test is based on the aggregate level data. However, the results are sufficient for us to investigate the dynamic relationships among the three variables, especially between house price returns and default rates.

4. VAR process

We first utilize a vector autoregressive process VAR(p,d):

$$Y_t = \sum_{i=1}^{p} \Phi_i Y_{t-i} + \varepsilon_t ,$$

where $Y_t = \left(HR_t, D_t, MR_t\right)'$ refers to the endogenous variables and $\varepsilon_t = \left(\varepsilon_{1t}, \varepsilon_{2t}, \varepsilon_{3t}\right)'$ refers to a vector white noise process. Φ_i is a 3×3 matrice. d means the degree of differencing to correct non-stationarity of some variables. HR_t is quarter-over-quarter house price return at time t; MR_t denotes the mortgage rate at time t; D_t refers to the default rate at time t. The mortgage rates and default rates are first-differenced since they are integrated of order one.

According to the Akaike information criterion (AIC)[12] and some other criteria, we choose VAR(7) for OFHEO's house price return and VAR(12) for Case-Shiller's house price return. The lagged periods are chosen based on the significance level of the coefficients.

Since the model is a reduced form and the variables for default rate and mortgage rate are first-differenced, the coefficients may not explain better the dynamic relationships among the three variables. We do not report the coefficients of the VAR model here.

5. Simultaneous Equation Model

[12] Akaike (1974)

5.1. The Model

Case and Shiller (1990) build a forecasting model for house price return, including both lagged house price return and other exogenous variables.

In our paper, since we have more than one endogenous variable, a simultaneous equations model is introduced and some exogenous variables are included. Our model can be represented as

$$\begin{aligned} HR_t &= f_1\left(\sum_{s=0}^{p_2} MR_{t-s}, \sum_{s=0}^{p_3} D_{t-s}, X\right) + \sum_{s=1}^{p_1} a_s HR_{t-s} + \varepsilon_1, \\ MR_t &= f_2\left(\sum_{s=0}^{p_1} HR_{t-s}, \sum_{s=0}^{p_3} D_{t-s}, Y\right) + \sum_{s=1}^{p_2} b_s MR_{t-s} + \varepsilon_2, \\ D_t &= f_3\left(\sum_{s=0}^{p_1} HR_{t-s}, \sum_{s=0}^{p_2} MR_{t-s}, Z\right) + \sum_{s=1}^{p_3} c_s D_{t-s} + \varepsilon_3, \end{aligned} \tag{1}$$

where X, Y and Z refer to vectors of economic variables. The first part of each equation can be regarded as a fundamental value or an intrinsic value of the endogenous variable. The serial correlation part represents the momentum. This model is under a structural framework, so that the relationships among the variables could be more clearly examined.

5.2 Model Specification

The Simultaneous Equation Model can be specified as follows:

$$\begin{aligned} HR_t &= \alpha_0 + \alpha_1 MR_t + \alpha_2 MR_{t-1} + \sum_{s=1}^{p_2} b_s^1 \Delta MR_{t-p_3} + \alpha_3 D_t + \alpha_4 D_{t-1} + \sum_{s=1}^{p_3} c_s^1 \Delta D_{t-p_3} \\ &\quad + \alpha_5 Inf_t + \alpha_6 Inf_{t-1} + \alpha_7 \Delta CC_{t-1} + \alpha_8 \Delta Inc_t + \alpha_9 Unem_t + \alpha_{10} \Delta Unem_t + \alpha_{11} \Delta Tb3m_t \\ &\quad + \sum_{s=1}^{p_1} a_s^1 HR_{t-s} + \varepsilon_1 \end{aligned} \tag{2a}$$

$$MR_t = \beta_0 + \sum_{s=0}^{p_1} a_s^2 HR_{t-s} + \beta_1 D_t + \beta_2 D_{t-1} + \sum_{s=1}^{p_3} c_s^2 \Delta D_{t-s} + \beta_3 Inf_{t-1} + \beta_4 \Delta GDP_t$$

$$+ \beta_5 \Delta TB_t + \beta_6 \Delta TB3m_t + \beta_7 MR_{t-1} + \sum_{s=1}^{p_2} b_s^2 \Delta MR_{t-s} + \varepsilon_2 \quad (2b)$$

$$D_t = \gamma_0 + \sum_{s=0}^{p_1} a_s^3 HR_{t-s} + \gamma_1 MR_t + \gamma_2 MR_{t-1} + \sum_{s=1}^{p_2} b_s^3 \Delta MR_{t-s} + \gamma_3 Inf_{t-1} + \gamma_4 CLTV_t$$

$$+ \gamma_5 \Delta CLTV_t + \gamma_6 \Delta Inc_t + \gamma_7 \Delta TB3m_t + \gamma_8 D_{t-1} + \sum_{s=1}^{p_3} c_s^3 \Delta D_{t-s} + \varepsilon_3 \quad (2c)$$

In the house model (2a), we use *inflation rate (Inf)*[13]*, disposable personal income (Inc)*[14]*, unemployment rate (Unem)*[15]*, construction cost (CC)*[16], and the *3-month Treasury bill rate (TB3m)*[17] as the exogenous variables, as in much of the literature. We choose the *3-month Treasury bill rate* as the indicator of market interest rate.

The mortgage rate equation (2b) includes additional variables, such as *inflation rate (Inf), gross domestic product (GDP)*[18]*, 10-year treasury bond rate (TB), 3-month Treasury bill rate (TB3m)*.

The default rate equation (2c) may contain the *inflation rate (Inf), thecomposite loan-to-value ratio (CLTV)*[19]*, disposable personal income (Inc),* and *the 3-month Treasury bill rate (TB3m)*.

We checked the stationarity of all the variables, using the Augmented Dickey Fuller (ADF) test. Only house price return and inflation rate reject the non-stationary null at 1% significance level. All other variables are integrated of order 1. In order to avoid spurious regression, we correspondingly add the lagged or differenced terms.

[13] from the Consumption Price Index from the U.S. Bureau of Labor Statistics (BLS)
[14] from the Bureau of Economic Analysis' website
[15] from the U.S. Bureau of Labor Statistics (BLS) Household Survey
[16] We use Construction Price Index as the measure of *construction cost*. This index is the price deflator index of new one-family houses under construction from U.S. Census Bureau.
[17] 3-month Treasury bill rate and 10-year Treasury bond rate are available on the Federal Reserve Board's website
[18] from the Bureau of Economic Analysis (BEA)
[19] from the U.S. Federal Housing Finance Board

To detect multicollinearity, we examined *tolerance*[20], *variance inflation factor*[21] and *condition indexes*[22]. The variables currently in equation 2a-2c show no serious multicollinearity.

For the models dealing with OFHEO's house price returns, we use quarterly data from first quarter 1979 through second quarter 2008, with 128 observations in total, due to the data source restrictions of mortgage default rate. For the models dealing with Case-Shiller's house price returns, we use quarterly data from first quarter 1987 through the second quarter of 2008, with 86 observations in total.

5.3 Estimation Results

Using the three-stage-least-squares method, we carry out two regressions for both OFHEO's and Case-Shiller's house price returns. For house price returns, mortgage rates and default rates, one regression contains only one-period-lagged observations, while the other one includes multi-period-lagged or multi-period-changed observations. The results are listed in Table 3. Since for the exogenous variables, the coefficients either have the same signs as we expected or are insignificant, our analysis mainly focuses on the three key variables.

[20] The *tolerance* measures the correlation between one independent variable and all the other independent variables. If we define $R^2_{X,\tilde{X}}$ as the correlation between one dependent variable X and all the other independent variables $\tilde{X}$, then the *tolerance (TOL)* would be $TOL_X = 1 - R^2_{X,\tilde{X}}$. A small value of tolerance means that the variable X is highly correlated with the other variables.

[21] The *variance inflation factor (VIF)* is the inverse of tolerance, $VIF_X = 1 / TOL_X$, showing the degree by which the standard error of the estimator is inflated by multicollinearity. Practically, $TOL < 0.1$ and equivalently $VIF > 10$ indicate a multicollinearity problem.

[22] *Conditional index* is the ratio of a specific eigenvalue over the maximum of all eigenvalues of the model matrix. As an informal rule, conditional index over 30 may show multicollinearity.

Serial Correlation Term

All the three endogenous variables have highly significantly positive serial correlation coefficients. Obviously, they have a strong tendency to keep their original values.

Interrelationship among the three variables

1) House price return equation (Table 3(1))

Default rates have consistent effects on house price returns for both regressions and both indices. The current default rate has negative coefficients on house price returns, showing that the increased default rate will drive the house price returns down immediately, due to shrunken demand or credit. Combination with the positive estimates of the lagged default rates would reflect a complicated process. Take regression 1 for OFHEO's house price return as an example. The effects of a 1% increase of one-period-lagged default rate on the current house price return are a 9.56% [23] increase. Additionally, if the current default rate also increases by 1%, then the current house price return will decrease by 7.64% (=17.20%-9.56%) finally. Similarly, the two consecutive 1-percent increases in default rates will depress Case-Shiller's current house price return by 18.37%.

As for mortgage rates, the dominant estimates are negatively correlated with the current house price return, meaning that low mortgage rates will drive the housing demand up and so increase the house price returns, and *vice versa*. The two consecutive 1% increases of mortgage rates will depress OFHEO's or Case-Shiller's current house price returns by 0.47% or 0.83% respectively.

[23] In regression 1 for OFHEO's house price return, a 1% increase of one-period-lagged default rate will lead to a 10.77% decrease in one-period-lagged house price returns and correspondingly a 5.82%(=10.77%*0.54) decrease in current house price returns. At the same time, the 1% increase of one-period-lagged default rate will result in a 11.42% increase in current house price returns. Therefore, the net effects of a 1% increase of one-period-lagged default rate on the current house price return would be a 5.60% (=11.42%-5.82%) increase in current house price return.

2) Mortgage rate equation (Table 3(2))

The impact of default rate on mortgage rate is complicated, because mortgage rates may be decomposed into two parts. One is market interest rate and the other is margin, which reflects the willingness of the banks to provide credit. Due to the margin effect, although the market interest rates fell since September 2007, the mortgage rates did not change in the same direction or similar magnitude. The increase in default rates commonly leads to declining market interest rates due to the policymakers' intervention and increased margin due to the unwillingness for the mortgage providers to provide credit. The coefficients on default rates with the two house price indices are different, reflecting the complicated effects.

As for house price returns, the current house price returns are dominant and have negative effects. It means that higher house price return will urge the mortgage providers to provide more credit, and so ease the credit market and lower mortgage rate. For example, the two consecutive 1% increases of OFHEO's or Case-Shiller's current house price returns will depress mortgage rates by 0.61% or 0.07% respectively.

Compared with the change in 3-month Treasury bill rates, the change in 10-year Treasury bond rates positively impacts the mortgage rate more strongly.

3) Default rate equation (Table 3(3))

The negative coefficient on the current house price return shows that the dropped house price return lowers the housing equity and makes it more difficult to pay back the mortgage by refinancing, which drives the default rate up.

Again take Regression 1 as example. Two consecutive 1% decreases of OFHEO's house price returns will push the current default rate up by 0.09 percent. And two consecutive 1%

decreases of Case-Shiller's house price returns will push the current default rate up by 0.04 percent.

In terms of mortgage rates, for the new mortgagors, the augmented fixed mortgage rates make it more difficult for buyers with lower affordability to get a mortgage loan, which causes lower default rate. At the same time, the current mortgagors have comparatively lower contract rates and tend to keep their contracts and not to default. The results may not be consistent with the intuition that the risen mortgage rates drive up default rates. The reasons may be that (1) we are analyzing at the aggregate level; (2) by using 30-year fixed mortgage rate, we exclude the adjustment of the mortgage rates in the current contracts.

6. Model Predictions

In this part, we first try to make some prediction performance comparisons among different models. Second, we use the data up to the fourth quarter of 2007, in order to compare the predicted values with the actual data for the first two quarters of 2008. Third, we use the data up to the second quarter of 2008 to make more predictions.

6.1. Prediction Performance Comparison

Generally, different models are specified for different purposes and are used to predict over various horizons. We do not want to jump to a conclusion as to which model is better. We conduct the comparisons, based on the quarterly predictions of the AR model, the VAR model, the one-period lagged SEM and the multi-period lagged SEM, for the two periods: (1) from first quarter 2005 through second quarter 2008; (2) from the first quarter of 2007, the beginning period of the mortgage crisis, through second quarter 2008.

For the period from first quarter 2005 through second quarter 2008, we compare eight-quarter-ahead predictions by a rolling window analysis. For example, we first employ the data through fourth quarter 2004 to estimate, and make predictions for first quarter 2005 through fourth quarter 2006, based on the estimates. Then we estimate via the data through first quarter 2005 and predict for second quarter 2005 through first quarter 2007. Since the data used in this paper are only through second quarter 2008, when observations are not available for the latest or future periods, the prediction results are dropped from the comparison sample. The predictions for SEM's are conditional predictions, so we use the actual observations for exogenous variables.

For the period from first quarter 2007 through second quarter 2008, we compare four-quarter-ahead predictions by a rolling window analysis.

The measure of prediction accuracy is the root mean squared error (RMSE). Then for *s*-quarter-ahead prediction performance, the formula is

$$RMSE = \left[\frac{1}{T} \sum_{t=1}^{T} \left(Y_t - {}_s\hat{Y}_t \right) \right]^{1/2},$$

where Y_t is the actual observation at time t for house price return, mortgage interest rate or default rate, ${}_s\hat{Y}_t$ is the prediction made *s* quarters earlier, and T is the total numbers of the predictions made *s* quarters earlier during the above specified period.

Table 4 exhibits the prediction comparison results using OFHEO's house price returns or Case-Shiller's house price returns, measured by RMSE, for the period from first quarter 2005 through second quarter 2008. Table 5 exhibits the prediction comparison results for the period from first quarter 2007 through second quarter 2008.

We have to admit that the samples we explored during the test periods are small, especially in the second period, which may somewhat affect the results. However, a few

results are still clear. In forecasting house price returns and default rates, the VAR model and SEM models produce better predictions results than the AR model. These results are also consistent with the Granger-causality test. One important factor which affects the results may be that our comparison periods are near or in the subprime crisis, when the increased mortgage default rates have heavier impacts on house prices than boom periods.

6.2. Testing of Predictive Performance using data through the end of 2007

Prediction via VAR model

We first examine relationships between 3-month Treasury bill rates, the 30-year fixed mortgage rate, and mortgage rate spreads (as the differences between 30-year fixed mortgage rates and 3-month Treasury bill rates). Although the 3-month Treasury bill rates can come down to near zero during some periods of Fed easing, the mortgage rate spreads tend to move upward during these economic periods (See Figure 5). This opposite movement of mortgage spreads will keep 30-year fixed mortgage rates above a certain level. In fact, the historical 30-year mortgage rates have never come below 5%. Accordingly, in our econometric modeling of future mortgage rates, we put a constraint on future 30-year fixed mortgage rates and they will always be no less than 4 percent.

For both house price indices, we make 3-year forecasts via VAR, using historical data up to the fourth quarter of 2007. By comparison, we also make forecasts via Auto-Regressive models (AR). We employ Monte-Carlo simulations to estimate confidence intervals for the predictions.

The actual quarter-over-quarter OFHEO's house price returns for the first two quarters in 2008 have continuously deteriorated. The return is -0.23% in the first quarter and -1.45% in the second quarter of 2008, which is the worst quarter-over-quarter return since 1975. Figure

6 displays the predicted values of OFHEO's house price returns for the next three years from first quarter 2008 through fourth quarter 2010. The mean values of predicted house price returns per the AR model are always positive over time since 2008, which deviates from the actual data. On the contrary, the mean values of predicted house price returns per VAR models are mainly negative. The predictions based on VAR reach the lowest point in tthird quarter 2009. Additionally, although the confidence intervals per both AR and VAR fail to exactly catch the huge deterioration in the second quarter of 2008, the 90% confidence limit from VAR is relatively close to the actual data.

The actual quarter-over-quarter Case-Shiller's house price returns for the first two quarters in 2008 show a different trend. The return is -6.79% in the first quarter, which is lowest since 1987, and -4.29% in the second quarter of 2008, which is better than the previous one. Figure 7 displays the predicted values of Case-Shiller's house price returns for the next three years from first quarter 2008 through fourth quarter 2010. The 90% confidence limits catch the huge deterioration in the first quarter of 2008. The mean values of predicted Case-Shiller's house price returns per the VAR model are recovered a little bit quicker than the ones per the AR model.

The actual national default rates for the first two quarters in 2008 have deteriorated further, with 1.63% in first quarter 2008 and 1.83% in second quarter 2008 the highest since 1979. Figure 8 shows the expected predictions of national default rates by the AR model, the VAR model with OFHEO's house price returns, and the VAR model with Case-Shiller's house price returns. The three models roughly catch the trends during the first two quarters of 2008. While the default rates per the AR model or the VAR model with OFHEO's house price returns display a continuously increasing trend, the expected predictions per the VAR model with Case-Shiller's house price returns reach the highest in 2009.

When investigating the predicted mortgage rate, the results from the three models diverge, displaying complicated relationships with the other variables.

These above results clearly show the impacts of mortgage default on the housing market, no matter which house price index we use.

Prediction per SEM

Based on the known values of the exogenous variables in the first two quarters of 2008, we calculate conditional predictions[24] per SEM. The expected results per the model with OFHEO's house price returns and Case-Shiller's house price returns are shown in Table 6 and 7 respectively.

The multi-period-lagged SEM obtains the predicted OFHEO house price returns with the means of -0.24% and -0.83% (-0.89% if predicted dynamically) and with the confidence intervals of [-1.31%, 0.81] and [-1.91%, 0.29%] ([-2.07% 0.33%] if predicted dynamically) in the first two quarters of 2008. Similarly, for default rates and mortgage rates, the predicted means from the multi-period-lagged SEM are quite close to the actual values.

For the model with Case-Shiller's house price returns, the main exception is the predicted result for Case-Shiller's house price return in the second quarter of 2008, which deviates substantially from the actual value.

6.3. Model Predictions Using Data through 2008Q2

We re-estimate the VAR model using the data through second quarter 2008 and make predictions. And the prediction results are graphed in Figure 10 with OFHEO's house price returns and in Figure 11 with Case-Shiller's house price returns.

[24] The unconditional predictions do not show much improvement, compared with the results from VAR. We do not present the results here.

The prediction results show great differences due to the different trends for the two indices. As we mentioned, OFHEO's house price returns reach the lowest value in second quarter 2008, while Case-Shiller's house price returns have the lowest value in first quarter 2008 and are somewhat higher in second quarter 2008. Additionally, from the end of 2006 through second quarter 2008, OFHEO's house price index only decreased by about 1 percent, while Case-Shiller's index dropped down by around 20 percent. The gaps between the two indices may come from the differences in their data sources and calculation methods, which is beyond our paper's scope.

On an expected value basis, the future level of OFHEO's house price returns will remain negative and reach the lowest value in 2010 and increase slowly thereafter, although it may take quite a few years for the house price returns to become positive. Based on the 90% confidence limits, if predicting optimistically, the house price returns may become positive again after 2010.

The expected Case-Shiller house price returns tend to become positive after 2010. Figure 11 shows that default rates reach the highest value in 2010 and decrease slowly thereafter.

If we combine these two sets of results, we could say that, considering only the internal relationships among house price returns, mortgage rates and default rates, ignoring the effects of external factors, the year 2010 is an important turning point for house price returns and default rates.

7. Conclusion

Based on the Granger-Causality test, we present VAR and SEM models to describe the dynamic relations of house price returns, mortgage rates and default rates. With their structural form, simultaneous equation models can explain the relationships more clearly. By investigating both OFHEO's and Case-Shiller's house price returns, we find the interactive

negative relationship between house price returns and default rates. For example, holding all other factors constant, two consecutive 1% increases in default rates can drive OFHEO's house price returns down by about 7.64% and Case-Shiller's current house price return down by about 18%. Conversely, two consecutive 1% decreases of OFHEO's or Case-Shiller's house price returns can push the current default rate up by 0.09 percent or 0.04 percent, respectively. The effects of mortgage rates show different results for models with the two different house price indices, reflecting complicated relationships.

When making predictions using data through second quarter 2008, we observe that mortgage default rates have large impacts on house price returns, and vice versa. So the unfolding mortgage default experience can affect the recovery of the housing market. According to the VAR model, only considering the inter-relationships among house price returns, mortgage rates and default rates, the year 2010 will probably be an important turning point for both house price returns and mortgage default rates. We add caveats for interpreting these mechanical forecasts: they do not reflect many important dynamical factors that will strongly affect the housing markets, for instance, the various government mortgage modification programs, and the inventory of excess housing units.

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Table 1: Mortgage Delinquency Rates

The default rates of all types of mortgages have increased in different degrees, especially the adjustable rate mortgages (ARM).

		2005Q4	Increased*	2006Q4	Increased*	2007Q4	Increased*	2008Q2	Increased**
All loans	Loans Past Due 30 Days	2.85%	2.89%	3.08%	8.07%	3.20%	3.90%	3.30%	3.13%
	Loans Past Due 60 Days	0.83%	10.67%	0.90%	8.43%	1.15%	27.78%	1.28%	11.30%
	Loans Past Due 90 Days	1.02%	18.60%	0.96%	-5.88%	1.48%	54.17%	1.83%	23.65%
	Loans in Foreclosure	0.42%	-8.70%	0.54%	28.57%	0.83%	53.70%	1.19%	43.37%
Prime FRM Loans	Loans Past Due 30 Days	1.49%	0.00%	1.64%	10.07%	1.72%	4.88%	1.90%	10.47%
	Loans Past Due 60 Days	0.35%	12.90%	0.34%	-2.86%	0.44%	29.41%	0.57%	29.55%
	Loans Past Due 90 Days	0.37%	48.00%	0.29%	-21.62%	0.40%	37.93%	0.60%	50.00%
	Loans in Foreclosure	0.15%	-11.76%	0.16%	6.67%	0.22%	37.50%	0.37%	68.18%
Prime ARM Loans	Loans Past Due 30 Days	1.76%	13.55%	2.30%	30.68%	2.89%	25.65%	3.24%	12.11%
	Loans Past Due 60 Days	0.44%	33.33%	0.63%	43.18%	1.20%	90.48%	1.56%	30.00%
	Loans Past Due 90 Days	0.34%	47.83%	0.47%	38.24%	1.41%	200.00%	2.70%	91.49%
	Loans in Foreclosure	0.20%	5.26%	0.41%	105.00%	1.06%	158.54%	1.93%	82.08%
Subprime FRM Loans	Loans Past Due 30 Days	5.06%	1.00%	5.57%	10.08%	7.17%	28.73%	8.05%	12.27%
	Loans Past Due 60 Days	1.60%	1.27%	1.73%	8.12%	2.54%	46.82%	3.14%	23.62%
	Loans Past Due 90 Days	3.04%	-2.88%	2.78%	-8.55%	4.29%	54.32%	4.84%	12.82%
	Loans in Foreclosure	1.05%	-23.36%	1.09%	3.81%	1.52%	39.45%	2.28%	50.00%
Subprime ARM Loans	Loans Past Due 30 Days	6.74%	13.66%	7.93%	17.66%	8.80%	10.97%	8.68%	-1.36%
	Loans Past Due 60 Days	2.35%	23.68%	3.13%	33.19%	4.58%	46.33%	4.80%	4.80%
	Loans Past Due 90 Days	2.53%	25.87%	3.38%	33.60%	6.64%	96.45%	7.55%	13.70%
	Loans in Foreclosure	1.55%	3.33%	2.70%	74.19%	5.29%	95.93%	7.09%	34.03%

Sources: Mortgage Bankers Association
*: Increased percentage compared with one year ago
**: Increased percentage compared with the end of 2007

Table 2: Granger Causality Test for house price returns, default rates and mortgage rates[25]

The table shows whether group 2 variable Granger-causes group 1 variable. The null hypothesis of the test is that group 2 variable does not Granger-cause group 1 variable.

We obtain similar results for both OFHEO's and Case-Shiller's house price returns. At the 10% significance level, house price returns Granger-cause default rates, and vice versa. House price returns Granger-cause mortgage interest rates, but conversely not. There is no Granger causality between mortgage interest rates and default rates.

Granger Causality Test				
Test	Group 1 Variable	Group 2 Variable	Chi-Square	Prob>Chisq
1	OFHEO House Price Return	First-differenced Default Rate	11.38	0.0226
2	OFHEO House Price Return	First-differenced Mortgage Rate	5.19	0.2683
3	First-differenced Default Rate	OFHEO House Price Return	8.41	0.0775
4	First-differenced Default Rate	First-differenced Mortgage Rate	0.79	0.9395
5	First-differenced Mortgage Rate	OFHEO House Price Return	10.39	0.0343
6	First-differenced Mortgage Rate	First-differenced Default Rate	0.59	0.9636
Test	Group 1 Variable	Group 2 Variable	Chi-Square	Prob>Chisq
1	Case-Shiller's House Price Return	First-differenced Default Rate	41.06	<.0001
2	Case-Shiller's House Price Return	First-differenced Mortgage Rate	8.38	0.3005
3	First-differenced Default Rate	Case-Shiller's House Price Return	18.37	0.0104
4	First-differenced Default Rate	First-differenced Mortgage Rate	5.97	0.5438
5	First-differenced Mortgage Rate	Case-Shiller's House Price Return	12.31	0.0907
6	First-differenced Mortgage Rate	First-differenced Default Rate	2.7	0.9112

[25] Mortgage interest rates and default rates are first-differenced for stationarity.

Table 3 (1): regression results for SEM –house price return equation

This table exhibits the regression results of three-stage least square for the **house price return equation.** The part (1) is from the **model with OFHEO's house price returns**. The part (2) is from the **model with Case-Shiller's house price returns**. The data are centered at the mean.

Equation: House Price Return	**With OFHEO's House Price Return (1)**		**With Case-Shiller's House Price Return(2)**	
Variable	Regression 1	Regression 2	Regression 1	Regression 2
Intercept	0.026 (0.200)	0.076 (0.310)	-0.642 (0.658)	-0.503 (0.336)
1-period-lagged house price return	0.504** (0.104)	0.402** (0.228)	0.707** (0.272)	1.088** (0.175)
2-period-lagged house price return		0.112 (0.257)		-0.523** (0.272)
3-period-lagged house price return		0.114 (0.328)		0.360* (0.252)
4-period-lagged house price return	-- 	-- 		-0.288* (0.216)
30-year fixed mortgage rate	-0.772** (0.240)	-0.856** (0.418)	-0.527 (1.249)	-0.338 (0.497)
1-period-lagged 30-year fixed mortgage rate	0.688** (0.226)	0.767** (0.400)	0.066 (0.837)	0.001 (0.404)
1-period-lagged change of 30-year fixed mortgage rate		-0.094 (0.343)		-0.509* (0.382)
2-period-lagged change of 30-year fixed mortgage rate		0.271 (0.369)		-0.213 (0.309)
3-period-lagged change of 30-year fixed mortgage rate		0.016 (0.262)		0.278 (0.334)
default rate	-17.201** (7.037)	-18.255 (18.530)	-25.596 (33.181)	-23.263** (12.027)
1-period-lagged default rate	18.232** (7.705)	18.383 (19.578)	25.173 (34.236)	23.627** (13.190)
1-period-lagged change of default rate		4.543 (4.630)		1.413 (2.872)
2-period-lagged change of default rate		0.539 (2.718)		-2.296 (2.969)
3-period-lagged change of default rate		4.413 (6.371)		4.070* (2.881)
inflation rate	-0.044 (0.103)	0.014 (0.109)	-0.008 (0.343)	-0.343 (0.269)
lagged inflation rate	0.593* (0.225)	0.462 (0.514)	0.944 (1.767)	0.807 (0.647)
change in income	6.648 (9.777)	-1.842 (11.418)	25.028 (38.340)	6.725 (15.026)
change of 3-month Treasury bill rate	0.069 (0.121)	0.096 (0.230)	-0.462 (0.569)	0.469 (0.424)
change in construction cost	0.044 (8.021)	2.617 (9.579)	6.727 (34.194)	2.129 (16.539)
unemployment rate	-0.003 (0.047)	0.030 (0.104)	0.069 (0.374)	-0.273 (0.323)
change in unemployment rate	0.069 (0.384)	-0.186 (0.657)	-0.389 (1.815)	1.401 (1.096)

Note: *20%, *10% indicate the corresponding significance levels. The numbers in parentheses refer to the standard errors of the coefficients.

Table 3(2): regression results for Model 2—Mortgage Rate Equation

This table exhibits the regression results of three-stage least squares for **the mortgage rate equation**. Part (1) is from the **model with OFHEO's house price returns**. Part (2) is from the **model with Case-Shiller's house price returns**. The data are centered at the mean.

Equation: Mortgage Rate	**With OFHEO's house price return (1)**		**With Case-Shiller's house price return (2)**	
Variable	Regression 1	Regression 2	Regression 1	Regression 2
Intercept	-0.002	0.008	-0.157**	-0.103
	(0.102)	(0.108)	(0.065)	(0.068)
1-period-lagged 30-year fixed mortgage rate	0.963**	0.957**	0.992**	0.998**
	(0.014)	(0.018)	(0.021)	(0.019)
1-period-lagged change of 30-year fixed mortgage rate		0.075		0.018
		(0.100)		(0.054)
2-period-lagged change of 30-year fixed mortgage rate		0.084		-0.007
		(0.100)		(0.053)
3-period-lagged change of 30-year fixed mortgage rate		-0.045		0.031
		(0.073)		(0.050)
default rate	-3.807*	-7.617**	1.360*	1.123
	(2.586)	(3.934)	(1.071)	(0.896)
1-period-lagged default rate	3.832*	7.595**	-1.566*	-1.319*
	(2.793)	(4.057)	(1.081)	(0.910)
1-period-lagged change of default rate		2.180**		0.592*
		(1.197)		(0.418)
2-period-lagged change of default rate		-0.218		0.240
		(0.855)		(0.406)
3-period-lagged change of default rate		1.299		0.111
		(1.455)		(0.433)
house price return	-0.477**	-0.616**	-0.064	-0.028
	(0.149)	(0.179)	(0.073)	(0.058)
1-period-lagged house price return	0.325**	0.367**	0.059	0.051
	(0.084)	(0.086)	(0.063)	(0.069)
2-period-lagged house price return		0.003		-0.025
		(0.081)		(0.046)
3-period-lagged house price return		0.088		0.024
		(0.084)		(0.043)
4-period-lagged house price return	--	--		-0.026
				(0.027)
lagged inflation rate	0.241**	0.245**	-0.011	0.023
	(0.087)	(0.115)	(0.062)	(0.060)
Change of nominal GDP	0.917	0.955	8.867**	6.784*
	(5.440)	(5.718)	(4.091)	(4.327)
Change of 10-year Treasury bond rate	0.567**	0.443**	0.820**	0.825**
	(0.096)	(0.111)	(0.052)	(0.053)
change of 3-month Treasury bill rate	-0.027	0.009	0.063*	0.071
	(0.055)	(0.066)	(0.047)	(0.059)

Note: *20%, *10% indicate the corresponding significance levels. The numbers in parentheses refer to the standard errors of the coefficients.

Table 3 (3): regression results for Model 2—Default Rate Equation

This table exhibits the regression results of three-stage least squares for **the default rate equation**. Part (1) is from the **model with OFHEO's house price returns**. Part (2) is from the **model with Case-Shiller's house price returns**. The data are centered at the mean.

Equation: Default Rate	**With OFHEO's house price return (1)**		**With Case-Shiller's house price return(2)**	
Variable	Regression 1	Regression 2	Regression 1	Regression 2
Intercept	0.002 (0.011)	0.006 (0.009)	-0.023* (0.015)	-0.015 (0.016)
1-period-lagged default rate	1.059** (0.034)	1.019** (0.038)	0.994** (0.054)	1.056** (0.099)
1-period-lagged change of default rate		0.238** (0.117)		0.074 (0.165)
2-period-lagged change of default rate		0.023 (0.114)		-0.070 (0.145)
3-period-lagged change of default rate		0.257** (0.126)		0.202* (0.143)
30-year fixed mortgage rate	-0.046** (0.017)	-0.040** (0.016)	-0.022 (0.022)	-0.019 (0.023)
1-period-lagged 30-year fixed mortgage rate	0.041** (0.016)	0.036** (0.016)	0.005 (0.021)	0.007 (0.023)
1-period-lagged change of 30-year fixed mortgage rate		-0.007 (0.012)		-0.014 (0.019)
2-period-lagged change of 30-year fixed mortgage rate		0.014* (0.011)		0.006 (0.021)
3-period-lagged change of 30-year fixed mortgage rate		-0.001 (0.010)		0.004 (0.020)
house price return	-0.058** (0.019)	-0.043** (0.016)	-0.033* (0.025)	-0.006 (0.032)
1-period-lagged house price return	0.029** (0.012)	0.017* (0.012)	0.022 (0.022)	0.005 (0.034)
2-period-lagged house price return		0.006 (0.010)		-0.005 (0.019)
3-period-lagged house price return		0.002 (0.011)		0.004 (0.018)
4-period-lagged house price return		--		0.000 (0.012)
lagged inflation rate	0.034** (0.009)	0.026** (0.011)	0.039 (0.020)	0.053** (0.022)
composite loan-to-value ratio	-0.002 (0.215)	0.045 (0.173)	0.038 (0.219)	0.552 (0.465)
Change of composite loan-to-value ratio	0.001 (0.226)	0.047 (0.159)	0.009 (0.223)	0.109 (0.536)
change in income	0.372 (0.565)	-0.074 (0.481)	0.933 (0.793)	0.873 (0.807)
change of 3-month Treasury bill rate	0.004 (0.007)	0.006 (0.007)	-0.015 (0.019)	-0.027 (0.032)

Note: *20%, *10% indicate the corresponding significance levels. The numbers in parentheses refer to the standard errors of the coefficients.

Table 4: Prediction Performance Comparison, Root Mean Squared Error, 2005Q1—2008Q2

The left side of this table exhibits the results using OFHEO's house price returns; the right side of the table displays the results using Case-Shiller's house price returns.

	OFHEO's House Price Return				Case-Shiller's House Price Return			
Prediction Horizon	AR	VAR	one-period lagged SEM	multi-period lagged SEM	AR	VAR	one-period lagged SEM	multi-period lagged SEM
1	0.899	0.757	0.758	0.776	1.304	1.065	1.168	1.221
2	1.177	1.065	0.98	0.859	2.039	1.685	2.196	2.327
3	1.268	1.194	1.004	0.858	2.411	2.091	2.597	2.499
4	1.302	1.393	1.044	1.212	3.074	2.837	3.578	3.438
5	1.506	1.692	0.966	1.34	3.574	3.400	4.201	4.011
6	1.648	1.896	0.976	1.481	4.811	4.145	5.133	4.529
7	1.771	2.104	1.012	1.78	5.356	4.924	6.142	5.323
8	1.875	2.266	1.092	1.967	5.862	5.839	7.506	6.324
	Mortgage Interest Rate				Mortgage Interest Rate			
Prediction Horizon	AR	VAR	one-period lagged SEM	multi-period lagged SEM	AR	VAR	one-period lagged SEM	multi-period lagged SEM
1	0.251	0.313	0.127	0.273	0.251	0.408	0.129	0.133
2	0.438	0.521	0.144	0.32	0.438	0.845	0.197	0.194
3	0.533	0.507	0.262	0.346	0.533	1.032	0.315	0.267
4	0.635	0.53	0.461	0.451	0.635	1.312	0.419	0.360
5	0.735	0.593	0.666	0.578	0.735	1.570	0.452	0.423
6	0.885	0.589	0.752	0.646	0.885	1.722	0.535	0.499
7	0.961	0.391	0.827	0.616	0.961	1.875	0.638	0.532
8	1.004	0.341	0.898	0.705	1.004	2.040	0.825	0.567
	Mortgage Default Rate				Mortgage Default Rate			
Prediction Horizon	AR	VAR	one-period lagged SEM	multi-period lagged SEM	AR	VAR	one-period lagged SEM	multi-period lagged SEM
1	0.103	0.103	0.106	0.098	0.103	0.111	0.079	0.090
2	0.194	0.194	0.201	0.184	0.194	0.168	0.137	0.159
3	0.283	0.285	0.317	0.278	0.283	0.239	0.203	0.237
4	0.396	0.402	0.426	0.389	0.396	0.345	0.279	0.339
5	0.469	0.481	0.501	0.461	0.469	0.403	0.353	0.434
6	0.533	0.55	0.537	0.49	0.533	0.455	0.386	0.488
7	0.574	0.591	0.574	0.504	0.574	0.462	0.397	0.509
8	0.605	0.617	0.618	0.521	0.605	0.406	0.368	0.527

Table 5: Prediction Performance Comparison, Root Mean Squared Error, 2007Q1—2008Q2

The left side of this table exhibits the results using OFHEO's house price returns; the right side of the table displays the results using Case-Shiller's house price returns.

	OFHEO's House Price Return				Case-Shiller's House Price Return			
Prediction Horizon	AR	VAR	one-period lagged SEM	multi-period lagged SEM	AR	VAR	one-period lagged SEM	multi-period lagged SEM
1	1.418	0.852	0.765	0.623	2.950	0.722	0.487	0.741
2	2.589	1.822	1.181	0.506	8.109	0.999	5.710	6.971
3	3.39	2.585	1.563	0.455	7.269	0.762	5.259	5.662
4	4.102	3.752	2.301	1.109	3.732	1.120	15.716	16.767
	Mortgage Interest Rate				Mortgage Interest Rate			
Prediction Horizon	AR	VAR	one-period lagged SEM	multi-period lagged SEM	AR	VAR	one-period lagged SEM	multi-period lagged SEM
1	0.062	0.148	0.027	0.075	0.062	0.192	0.031	0.013
2	0.221	0.549	0.048	0.129	0.221	0.952	0.086	0.050
3	0.201	0.593	0.137	0.192	0.201	0.578	0.217	0.104
4	0.063	0.644	0.536	0.443	0.063	0.224	0.377	0.134
	Mortgage Default Rate				Mortgage Default Rate			
Prediction Horizon	AR	VAR	one-period lagged SEM	multi-period lagged SEM	AR	VAR	one-period lagged SEM	multi-period lagged SEM
1	0.017	0.016	0.019	0.015	0.017	0.021	0.011	0.014
2	0.073	0.07	0.087	0.068	0.073	0.05	0.046	0.057
3	0.182	0.181	0.267	0.195	0.182	0.121	0.143	0.141
4	0.42	0.424	0.553	0.458	0.42	0.312	0.33	0.361

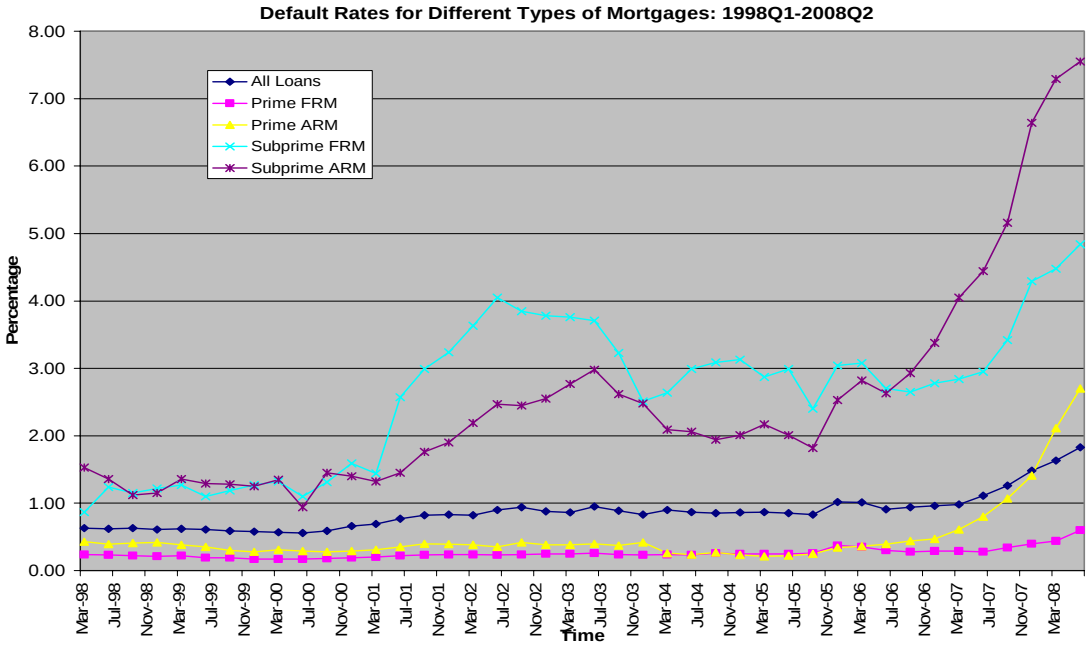
Table 6: Conditional Predictions of OFHEO's House Price Returns, Mortgage Rates and Default Rates

OFHEO's House Price Returns (%)											
	actual	VAR		1-period lag SEM				multi-period lag SEM			
			90% Conf Interval	one step forecast	90% Conf Interval	dynamic forecast	90% Conf Interval	one step forecast	90% Conf Interval	dynamic forecast	90% Conf Interval
3/31/2008	-0.23	0.25	[-0.65 1.19]	0.24	[-0.79 1.34]			-0.24	[-1.31 0.81]		
6/30/2008	-1.45	-0.04	[-1.02 0.96]	0.04	[-1.01 1.10]	0.27	[-0.87 1.43]	-0.83	[-1.91 0.29]	-0.89	[-2.07 0.33]
Default Rate (%)											
	actual	VAR		1-period lag SEM				multi-period lag SEM			
			90% Conf Interval	one step forecast	90% Conf Interval	dynamic forecast	90% Conf Interval	one step forecast	90% Conf Interval	dynamic forecast	90% Conf Interval
3/31/2008	1.63	1.56	[1.48 1.63]	1.59	[1.51 1.67]			1.66	[1.57 1.74]		
6/30/2008	1.83	1.64	[1.52 1.76]	1.73	[1.65 1.81]	1.68	[1.56 1.81]	1.79	[1.71 1.87]	1.82	[1.69 1.94]
Mortgage Rate (%)											
	actual	VAR		1-period lag SEM				multi-period lag SEM			
			90% Conf Interval	one step forecast	90% Conf Interval	dynamic forecast	90% Conf Interval	one step forecast	90% Conf Interval	dynamic forecast	90% Conf Interval
3/31/2008	5.88	5.76	[5.01 6.53]	6.00	[5.45 6.57]			5.96	[5.33 6.57]		
6/30/2008	6.09	5.33	[4.00 6.68]	6.11	[5.52 6.67]	6.28	[5.49 7.10]	6.12	[5.49 6.77]	6.19	[5.10 7.35]

Table 7: Conditional Predictions of Case-Shiller's House Price Returns, Mortgage Rates and Default Rates

Case-Shiller's House Price Returns (%)											
	actual	VAR		1-period lag SEM				multi-period lag SEM			
			90% Conf Interval	one step forecast	90% Conf Interval	dynamic forecast	90% Conf Interval	one step forecast	90% Conf Interval	dynamic forecast	90% Conf Interval
3/31/2008	-6.79	-6.14	[-7.74 -4.55]	-6.21	[-8.74 -3.65]			-6.46	[-8.30 -4.63]		
6/30/2008	-4.30	-5.36	[-7.65 -3.08]	-7.28	[-9.73 -4.69]	-6.97	[-9.97 -3.81]	-7.00	[-8.94 -5.06]	-6.62	[-9.11 -4.18]
Default Rate (%)											
	actual	VAR		1-period lag SEM				multi-period lag SEM			
			90% Conf Interval	one step forecast	90% Conf Interval	dynamic forecast	90% Conf Interval	one step forecast	90% Conf Interval	dynamic forecast	90% Conf Interval
3/31/2008	1.63	1.61	[1.52 1.69]	1.68	[1.60 1.77]			1.62	[1.52 1.73]		
6/30/2008	1.83	1.86	[1.74 1.98]	1.82	[1.74 1.91]	1.87	[1.76 1.98]	1.82	[1.71 1.93]	1.81	[1.66 1.95]
Mortgage Rate (%)											
	actual	VAR		1-period lag SEM				multi-period lag SEM			
			90% Conf Interval	one step forecast	90% Conf Interval	dynamic forecast	90% Conf Interval	one step forecast	90% Conf Interval	dynamic forecast	90% Conf Interval
3/31/2008	5.88	5.81	[5.30 6.31]	5.74	[5.50 5.99]			5.95	[5.65 6.25]		
6/30/2008	6.09	4.98	[4.27 5.71]	6.16	[5.92 6.41]	6.00	[5.67 6.35]	6.42	[6.12 6.73]	6.48	[5.99 6.92]

Figure 1: default rates for all types of mortgage loans



Source: Mortgage Bankers Association

Figure 2: Fed funds rates vs. 30-year fixed mortgage interest rates

Between 2000 and 2003, the Federal funds rate target dropped from 6.5% to 1.0%, whence the 30-year fixed mortgage rates dropped by 33%.

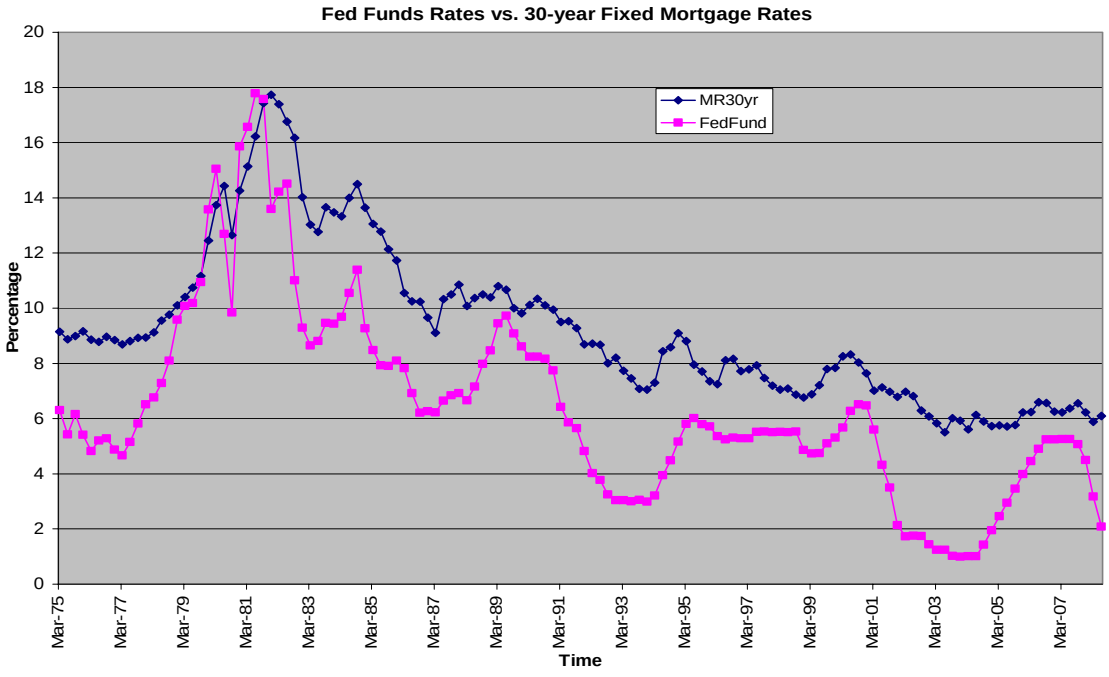


Figure 3: house price returns, mortgage rates and default rates

This figure displays the historical quarterly data of house price returns, mortgage rates and default rates from first quarter 1979 to second quarter 2008. The left-side y-axis is for house price return and default rate. The right-side y-axis is for mortgage rate. The default rates are multiplied by 2 in this graph to keep them in the same range as the house price returns.

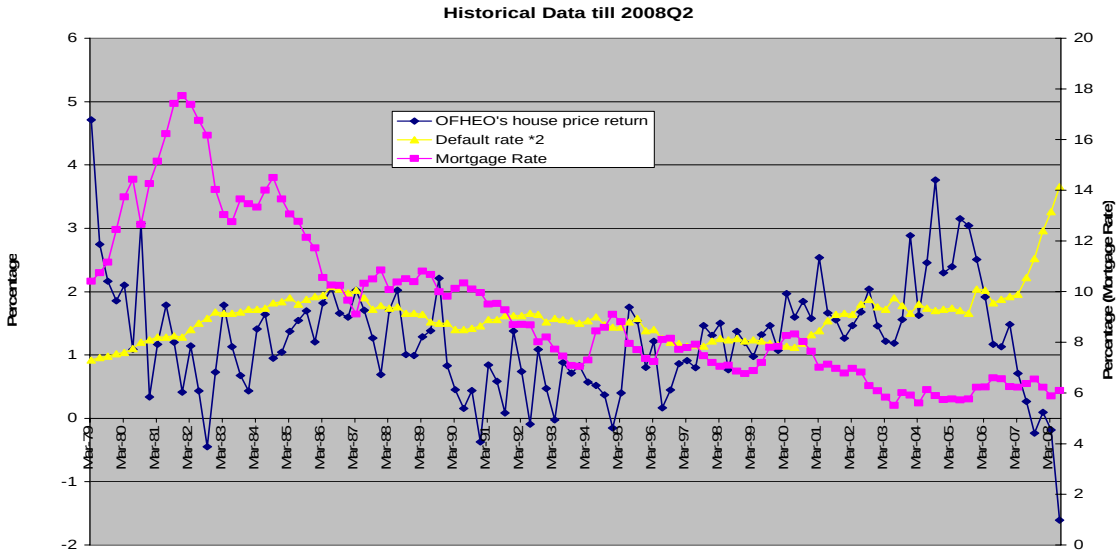


Figure 4: quarter-over-quarter OFHEO's vs. Case-Shiller's house price returns to 2008Q2

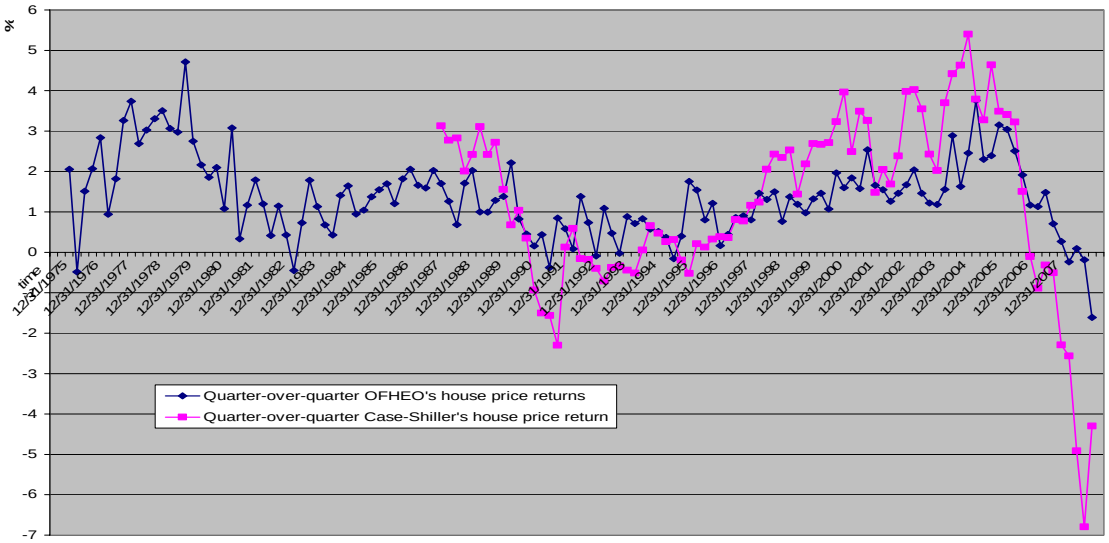


Figure 5: Comparison between 3-month Treasury bill rates and mortgage spreads

Mortgage spreads are the differences between 30-year fixed mortgage rates and the 3-month Treasury bill. Although the 3-month Treasury bill rates can come down to near zero during some time periods of Fed easing, the mortgage rate spreads tend to move upward during these economic periods, keeping 30-year fixed mortgage rates above a certain level .

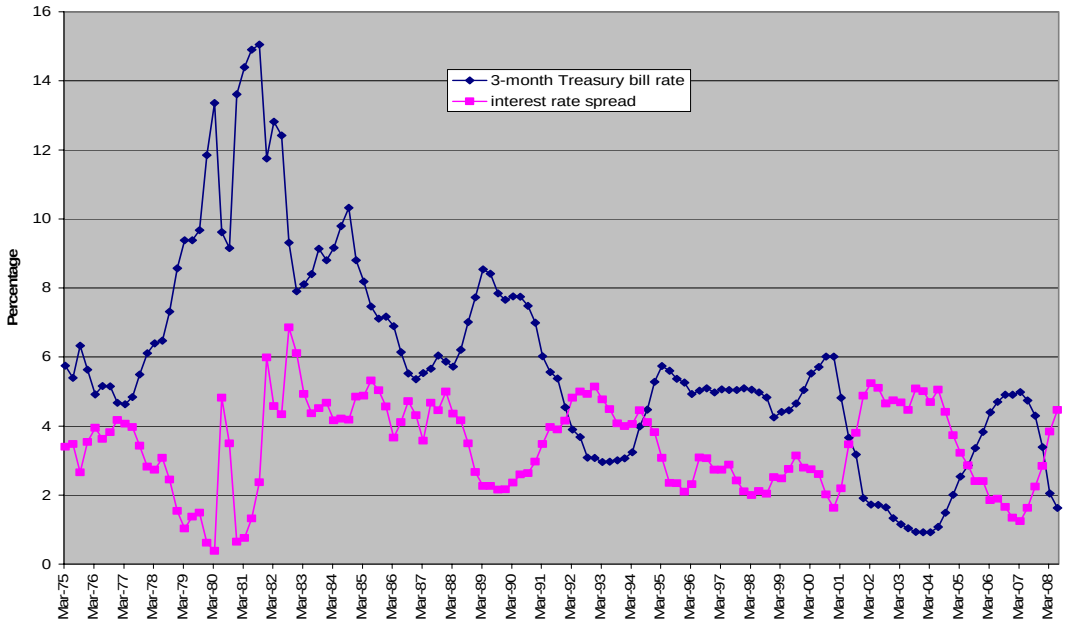


Figure 6: Actual vs Predicted OFHEO's House Price Returns

The house price returns are from OFHEO's index. The models use the data through the end of 2007 and there are 3-year predictions through fourth quarter 2010.

Figure 6a: Predictions based on AR model.

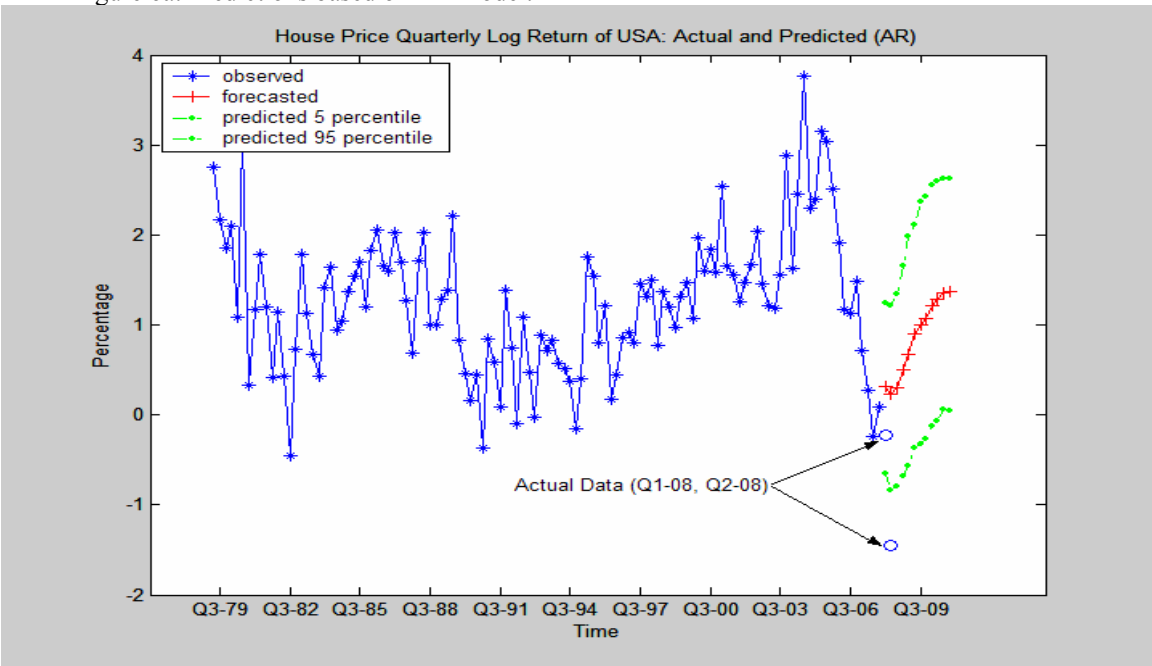


Figure 6b: Predictions based on VAR model.

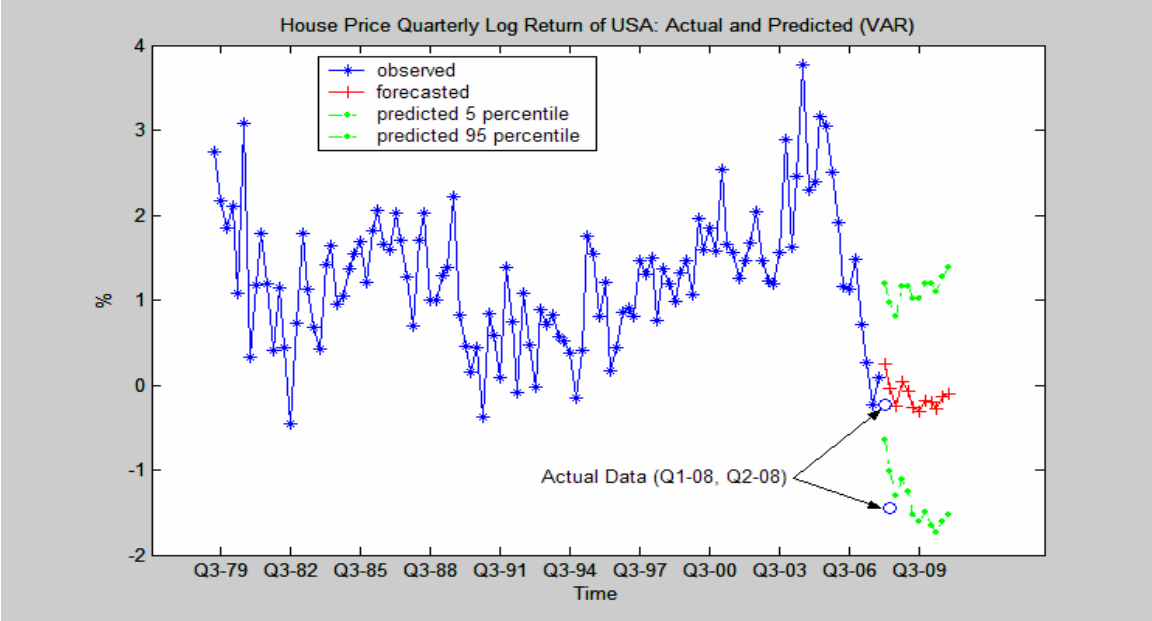


Figure 7: Actual vs Predicted Case-Shiller's House Price Returns

The house price returns are from Case-Shiller's index. The models use the data through the end of 2007 and there are 3-year predictions through fourth quarter 2010.

Figure 7a: Predictions based on AR model.

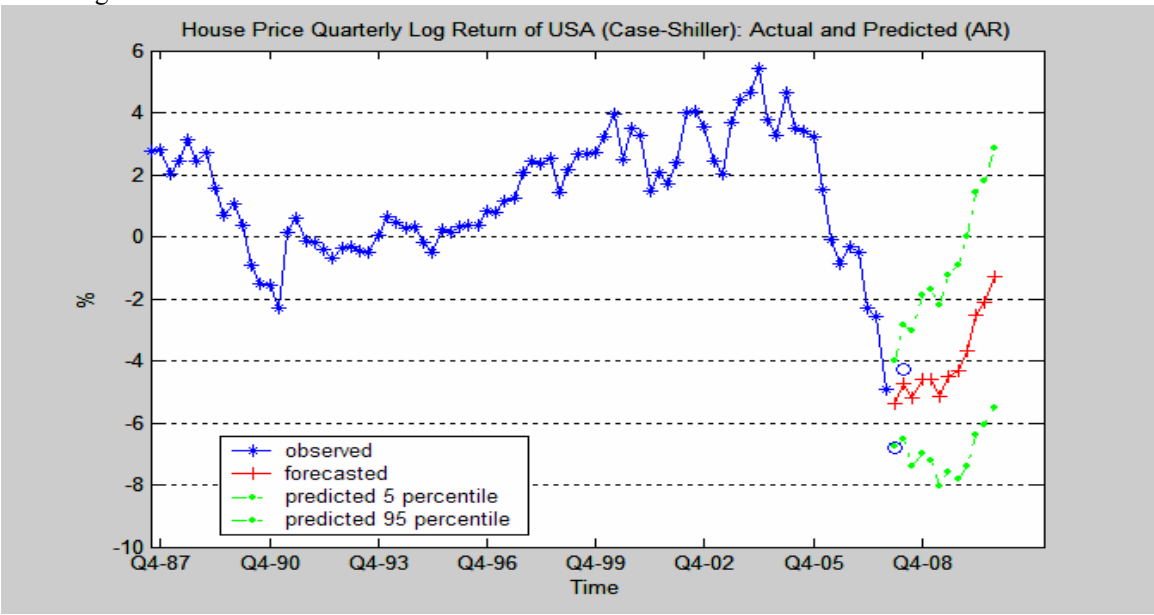


Figure 7b: Predictions based on VAR model.

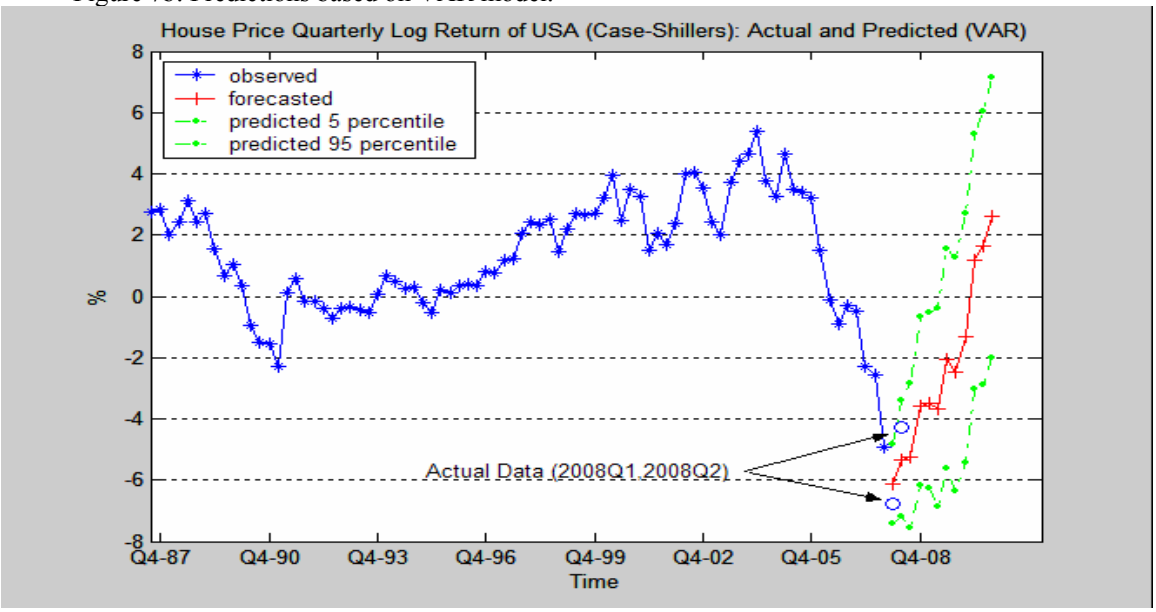


Figure 8: Actual vs Predicted National Default Rates

The models use the data through the end of 2007 and there are 3-year predictions through fourth quarter 2010.

Figure 8a: Predictions based on AR model

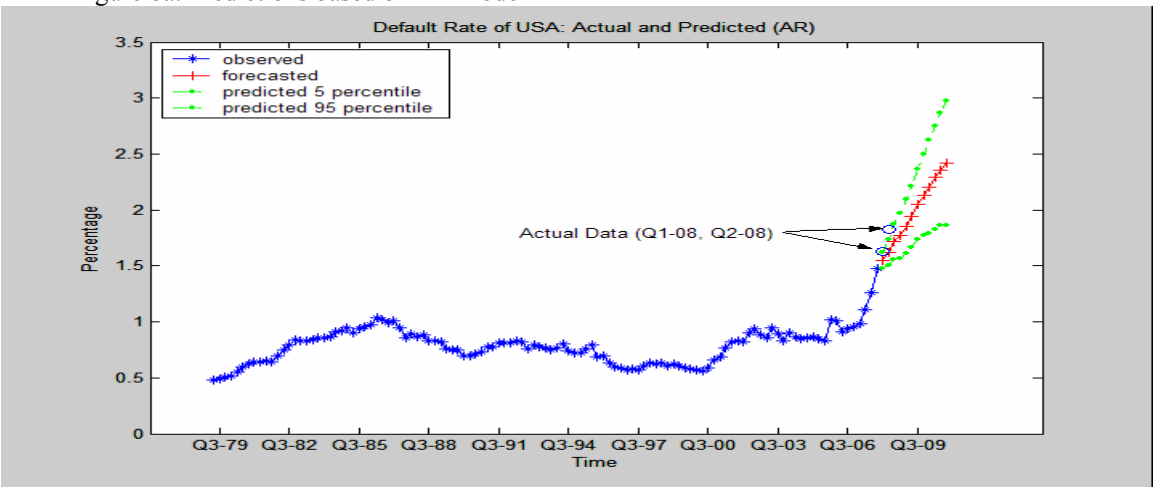


Figure 8b: Predictions based on VAR model with OFHEO's House Price Returns

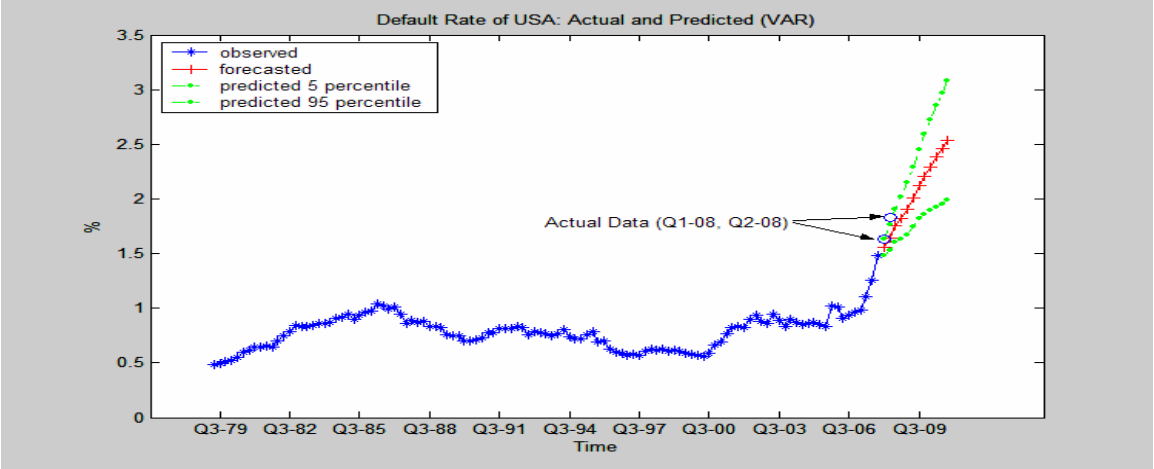


Figure 8c: Predictions based on VAR model with Case-Shiller's House Price Returns

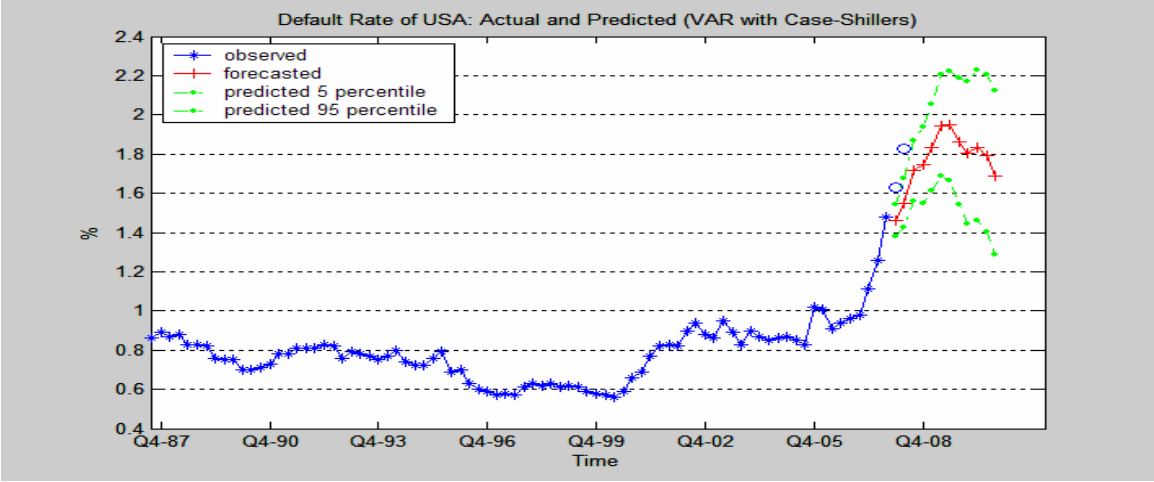


Figure 9: Actual vs. Predicted National Mortgage Rates

The models use the data through the end of 2007 and there are 3-year predictions through fourth quarter 2010.

Figure 9a: Predictions based on AR model

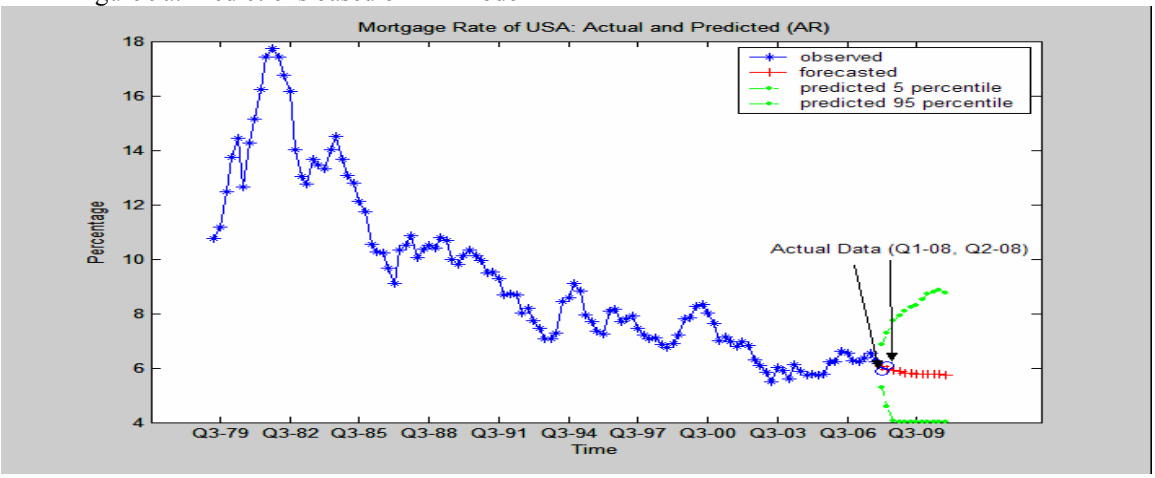


Figure 9b: Predictions based on VAR model with OFHEO's House Price Returns

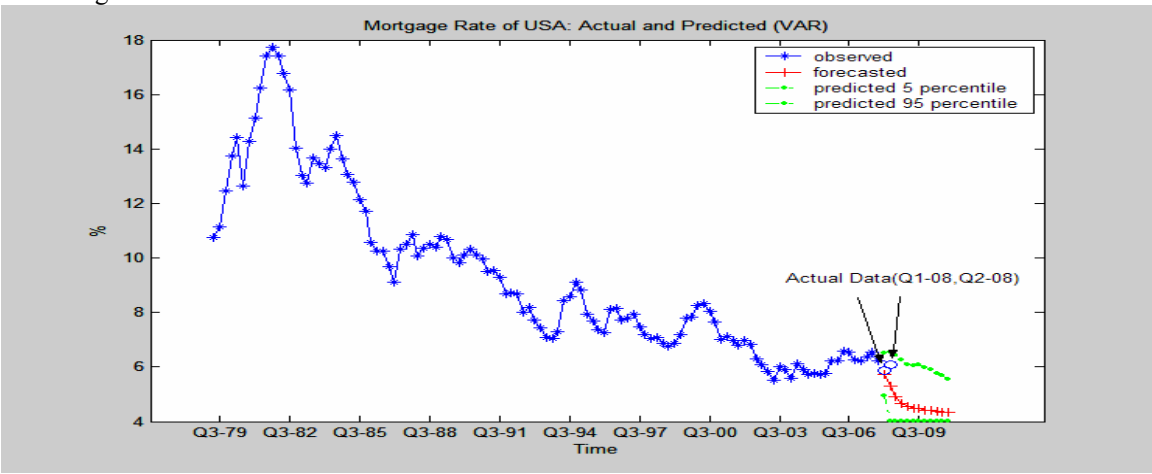


Figure 9c: Predictions based on VAR model with Case-Shiller's House Price Returns

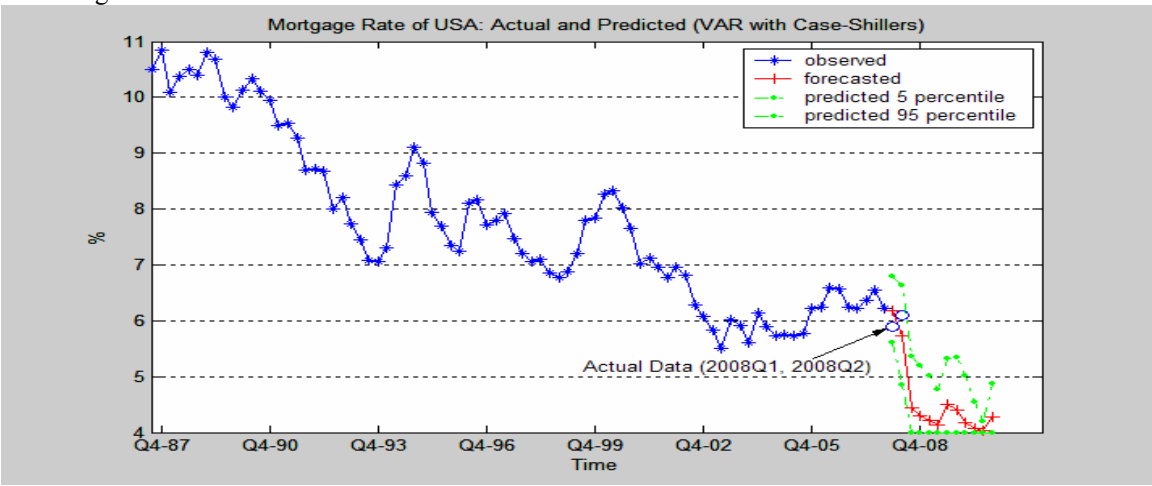


Figure 10: Predictions via VAR with OFHEO's House Price Returns

The models use the data through second quarter 2008 and there are 3-year predictions through second quarter 2011.

Figure 10a: Predictions of OFHEO's house price returns

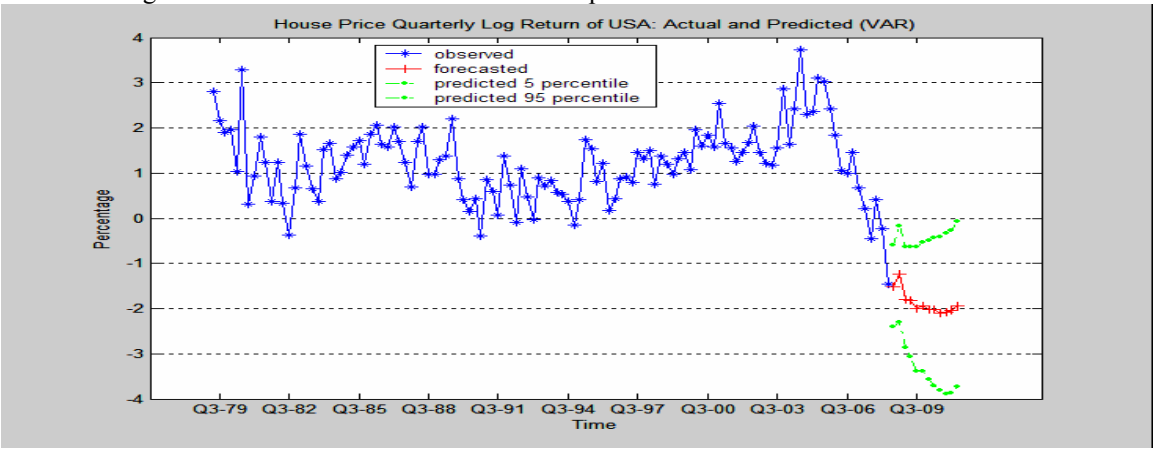


Figure 10b: Predictions of Default Rate

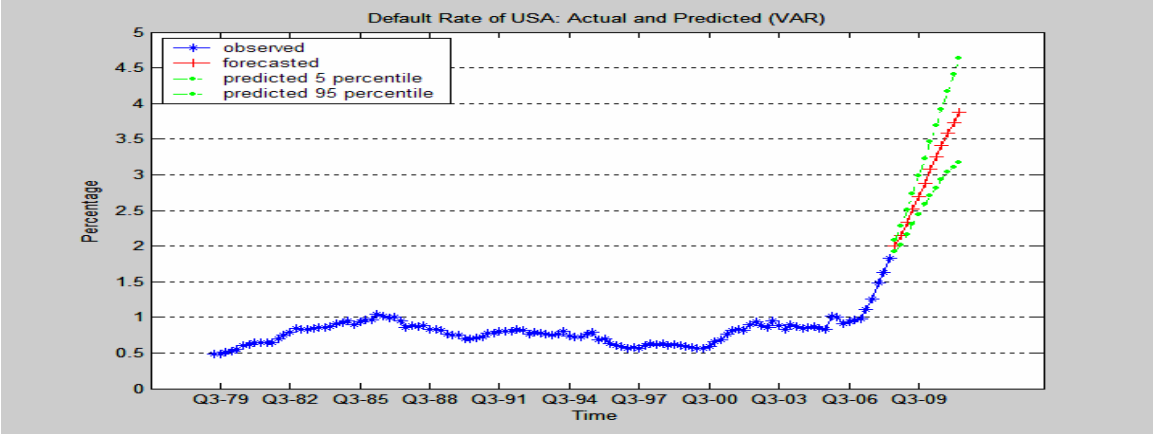


Figure 10c: Predictions of Mortgage Rate

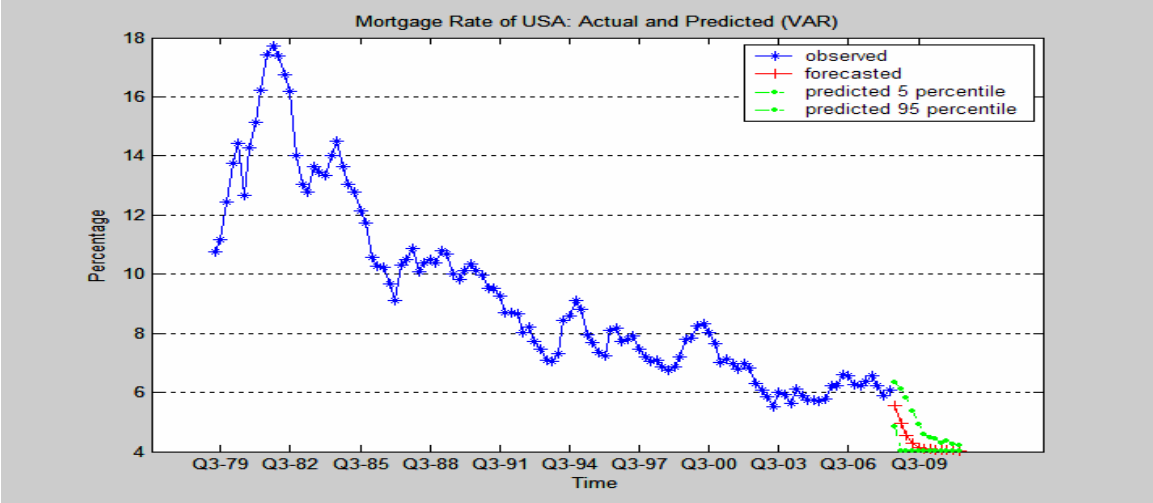


Figure 11: Predictions via VAR with Case-Shiller's House Price Returns

The model use data through second quarter 2008 and there are 3-year predictions through second quarter 2011.

Figure 11a: Predictions of Case-Shiller's house price returns

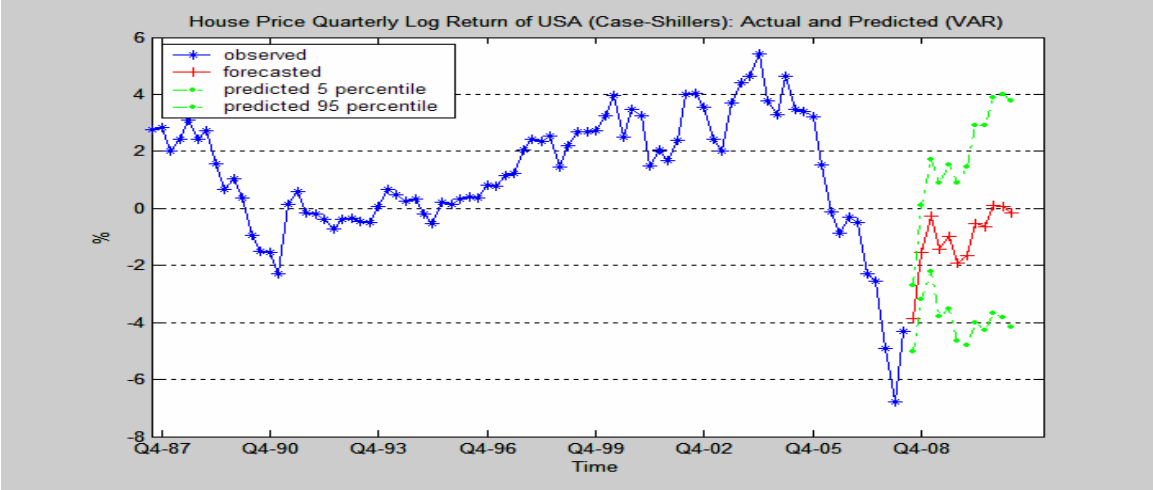


Figure 11b: Predictions of Default Rate

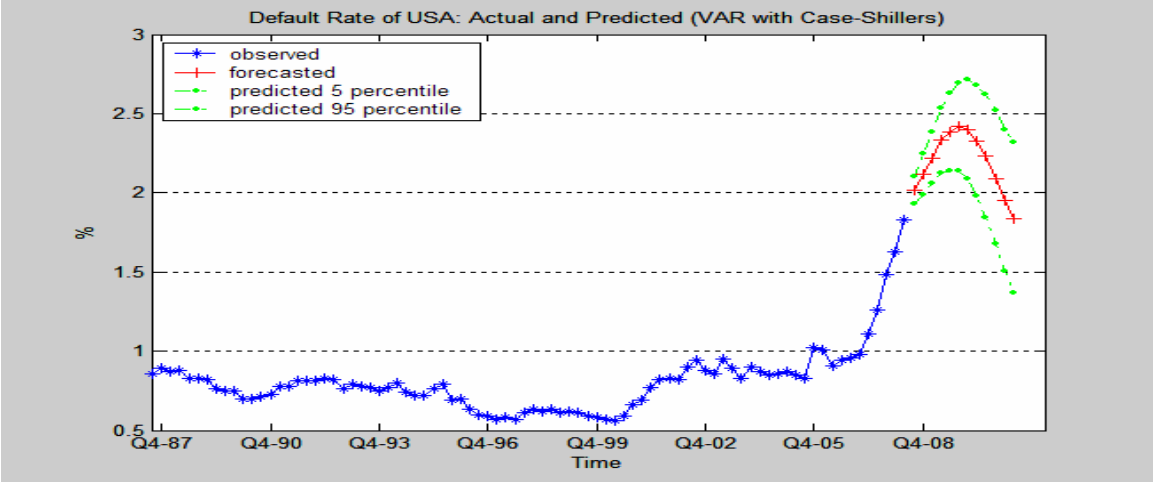


Figure 11c: Predictions of Mortgage Rate