Dynamics of Unemployment and Home Price Shocks on Mortgage Default Rates

Abstract

This paper uses a Structural Vector Autoregression (SVAR) model to study the dynamics of the impact of unemployment and home price index shocks on mortgage default rates from 1979 to 2000 and from 2001 to 2010. We first fit the model to the 1979 to 2000 sample and forecast the changes in the national and regional mortgage default rates from 2001 to 2010. The model did a good job in forecasting the actual changes in the mortgage default rates from 2001 to 2007; however, it failed during 2008 to 2010. The results for the 1979 to 2000 and 2001 to 2010 periods indicate that the dynamic response of the mortgage default rate to unemployment and home price index shocks changed at the national, regional and state levels after 2000. Unemployment and home price shocks seem to have become more important during the 2001 to 2010 period. The two shocks are responsible on average for about 60% of the movement in the regional mortgage default rates during this period. Except for the Pacific region, California and Florida, most of the variations in the mortgage default rates at the national, regional and state levels are explained by the unemployment shocks. The post 2000 results could be attributed to the increase in the number of mortgage loan borrowers who were more susceptible to unemployment and negative home price shocks.

Yaw Owusu-Ansah[1]

Economics Department, Columbia University

International Affairs Building, MC 3308

420 West 118th Street, New York NY 10027

yao2103@columbia.edu

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1. Introduction

The traditional model of mortgage default posits that borrowers default if and only if they have negative equity. A classic example is the option-based mortgage default model examined by Foster and Van Order (1984) in which default is a put option. Borrowers would exercise the put option when the value of the house plus any costs of exercising the option falls below the mortgage value. However, recent studies[2] have shown that many borrowers with negative equity do not necessarily default. These borrowers continue to honor their contractual obligation to the lenders even though their houses are worth less than the loans outstanding. These studies found that default is often associated with a negative income shock; i.e. being unemployed usually is a bigger factor than negative equity. Foote et al. (2009) found that a 1% increase in the unemployment rate raises the probability of default by 10-20%, while a 10% point fall in housing prices raises the probability of default by more than 50%. On the other hand, there have also been documented cases where borrowers have exercised the option to default when they have negative equity even though they could afford to pay their mortgages. Ashworth et al. (2010) concluded that negative equity shocks are far more important predictor of mortgage defaults than unemployment shocks. However, they also found that employment shocks can amplify the default rate if the borrower has already experienced a negative equity shock. As Mayer et al (2009) showed areas that experienced increased unemployment rates also experienced decline in house prices. As such, it is not easy to establish whether defaults in these areas are due to unemployment or house prices.

In this paper, we attempt to disentangle the interrelations between the home price index (which tracks housing prices) and unemployment shocks and mortgage default rates by studying the dynamics of these two shocks on mortgage default rates from 1979 to 2010. The 2001 to 2010 period represents a time when there have been significant changes in unemployment, house price indices and mortgage default rate at the same time. As such, this period presents a perfect period to empirically test which of these two shocks have had a bigger impact on mortgage default rates. We also want to know how the dynamics of the impacts of these two shocks in 2001 to 2010 have deviated from their historical dynamics (1979 to 2000). Not only have there been significant changes in these three variables during the 2001 to 2010 period, underwriting standards also deteriorated significantly during the period as the growing number of subprime

[2] Neil Bhutta et al. (2010)

loans originated during this period shows. Incentives in the mortgage market also shifted to the "originate-to-distribute" model, under which mortgage brokers originated loans and then sold them to institutions that securitized them. Because these brokers do not have to bear the cost of default, they may not be stringent in screening potential mortgage borrowers (Keys, Mukherjee, Seru, and Vig, 2008). About 700,000 subprime mortgage loans[3] were originated annually between 1998 and 2000 (Mayer and Pence, 2009); this increased to an average of 1.5 million between 2003 and 2006 annual. Lax underwriting standards were not the only factor in the increase in origination of subprime loans. A contributing factor was the house price appreciation after 2001 which made subprime origination easier as homeowners could easily resell their homes. Mayer and Pence (2009) documented that areas with high house price appreciation also experienced an increase in subprime mortgage origination.

Given the different composition of mortgage borrowers and the different types of mortgage loans originated during the two periods, a study of the impact of the unemployment and home price shocks on mortgage defaults over these two periods is necessary.

Mortgage default rates are influenced by the unemployment and home price shocks at the national, regional and state levels. However, describing the joint behavior of these three variables is not easy. This paper utilizes a Structural Vector Autoregression (SVAR) to decompose the national, regional and state mortgage default rates into unemployment and home price index shocks. The data consist of unemployment rates, home price indices and mortgage default rates at the national, regional[4], and state[5] levels covering a period from 1979 to 2010 at a quarterly frequency. The mortgage default rate is defined as the number of seriously delinquent mortgage loans as a percentage of all loans serviced in each quarter. The seriously delinquent loans are mortgage loans that are 90+ delinquent, i.e., they are loans for which the borrowers have not paid the mortgage in 90+ days.

We first fit the SVAR model to the 1979 to 2000 national and regional data and forecast the changes in the national and regional mortgage default rates for the 2001 to 2010 period. Not only are we interested in how well the model performs out-of-sample, we are more interested in its performance during the housing boom years of 2003 to 2006, and also during the recent Great

[3] Subprime loans are usually targeted to borrowers who have bad credit, little savings available for a downpayment and in some case no verifiable income or assets.
[4] See Appendix A for more details about the census regions.
[5] The states considered are Arizona, California, Florida, Michigan, Nevada and Pennsylvania.

Recession from 2008 to 2010. We examine the forecast errors from 2001 to 2010 and explore some of the factors that might have contributed to the model not fitting the data well during the Great Recession. We test for a structural break in the mortgage defaults rates during 2008 to 2010.

We then also estimate the model for the 2001 to 2010 sample and estimate the implied impulse response functions from the identification for both the 1979 to 2000 and 2001 to 2010 periods for the national, regional and state data. This allows us to examine whether there have been changes in the dynamics of the home price index and unemployment shocks on mortgage default for both periods. Finally, we measure the importance of the two shocks in explaining the changes in the mortgage default rate by performing variance decomposition for both sample periods.

The forecasted changes in the national and regional mortgage default rates from 2001 to 2010 using estimated results from fitting the SVAR model to the 1979 to 2000 sample were not far off from the actual changes in the mortgage default rates from 2001 to 2007. The model did well even during the housing boom years of 2003 to 2006. However, the model failed to forecast the changes in the mortgage default rates during the Great Recession. There has been a structural break in the national and regional mortgage default rates during the 2008 to 2010 period which could not have been anticipated by the model.

The empirical results also show that unemployment and home price index shocks on average had very little impact on mortgage default rate at the national, regional and state level during the 1979 to 2000 period. At the national level, an increase of one standard deviation in the unemployment and home price index led to an increase of 1.3% and a decrease of 1% in the mortgage default rate respectively during this period. At the regional level, the unemployment and the home price index shocks produced on average an increase of 1.2% and a decrease of 1.1% respectively during the period. In comparison to 2001 to 2010 period, a standard deviation increase in the national unemployment and the home price index shocks during this period led to an increase of 7.2% and a decrease of 4.9% respectively in the national mortgage default rate. At the regional level, there was an average increase of 12.9% for the unemployment shock and an average decrease of 7.3% for the home price index shock during this period. On average, the unemployment shocks seem to have had a bigger impact on the mortgage default rate than the home price index shocks.

Also during the 2001 to 2010 period, the unemployment shocks explained on average about 43% of the variation in the regional mortgage default rate, while the home price index shocks explained on average about 20% of the variation in the regional mortgage default rate. In effect, these two shocks were responsible on average for about 60% of the movement in the regional mortgage default rates during this period. The two shocks explained very little of the variation in the mortgage default rate during the 1979 to 2001 period.

The results indicate that the dynamic response of the mortgage default rate to unemployment and home price index shocks changed at the national, regional and state levels after 2000. Although there have been periods of higher national, regional and state unemployment during the 1979 to 2000 period, they seemed to not have impacted the mortgage default rates that much during this period. Except for the Pacific region, California and Florida, unemployment shocks have had a bigger impact on the national, regional and state mortgage default rates and can also explain more of the variation in the mortgage default rates than the home price index shocks during the 2001 to 2010 period. The post 2000 results could be attributed to the increase in the number of mortgage loan borrowers who were more susceptible to unemployment and negative home price shocks. These borrowers have little savings they could use to cushion them against unemployment and negative home price shocks. In their papers, Mayer et al (2009), Demyanyk and Van Hemert (2008) and Mian and Sufi (2009) also documented declining underwriting standards as a factor in mortgage default crises.

The paper proceeds as follows; Section 2 describes the SVAR model. Section 3 describes the data used. Section 4 provides the results for the forecast errors from 2001 to 2010 and the structural break tests. Section 5 provides the results for the impulse response functions and the variance decompositions for the 1979 to 2000 and 2001 to 2010 periods. Section 6 provides results for the impulse response functions and variance decompositions of the selected states. Section 7 concludes.

2. SVAR Model

The goal of the empirical analysis is to assess the impact of unemployment and home price index shocks on mortgage default rates. The SVAR system can be represented as:

$$(1) \qquad \begin{bmatrix} U_t \\ D_t \\ P_t \end{bmatrix} = A_1 \begin{bmatrix} U_{t-1} \\ D_{t-1} \\ P_{t-1} \end{bmatrix} + \cdots + A_p \begin{bmatrix} U_{t-p} \\ D_{t-p} \\ P_{t-p} \end{bmatrix} + \begin{bmatrix} \varepsilon_t^U \\ \varepsilon_t^D \\ \varepsilon_t^P \end{bmatrix}$$

where D_t denotes the first difference of mortgage default rate, U_t denotes the first difference of unemployment rate and P_t denotes the first difference of the home price index. Each A_i is a 3×3 matrix.

Let $\begin{bmatrix} U_t \\ D_t \\ P_t \end{bmatrix} = y_t$ and $\begin{bmatrix} \varepsilon_t^U \\ \varepsilon_t^D \\ \varepsilon_t^P \end{bmatrix} = \varepsilon_t$. Equation (1) can then be written as

$$(2) \qquad y_t = A_1 y_{t-1} + \cdots + A_p y_{t-p} + \varepsilon_t$$

The innovations $\varepsilon_t \sim N(O, \Sigma_\varepsilon)$ and $E\left[\varepsilon_t \varepsilon_s^{/}\right] = \mathbf{0_3}$ for all $s \neq t$. Multiplying equation (2) by matrix $\boldsymbol{B},$ equation (2) can then be represented as:

$$(3) \qquad \boldsymbol{B}\left[I_K - A_1 L^1 - A_2 L^2 \ldots - A_p L^p\right] y_t = \boldsymbol{B}\varepsilon_t = \boldsymbol{D} e_t$$

Where L is the lag operator, $\boldsymbol{B}, \boldsymbol{D}$ *and* $\boldsymbol{A_i}$ are 3×3 matrices of parameters, and e_t is a 3×1 vector of orthogonalized disturbances: i.e. $e_t \sim N(O, \mathrm{I}_3)$ and $E\left[e_t e_s^{/}\right] = \mathbf{0_3}$ for all $s \neq t$.

It is usually better to transform $\boldsymbol{B}\varepsilon_t$ into mutually uncorrelated innovations before we can effectively analyze the effect of one time increase in the ith element of ε_t on the jth element of y_t. Let $\boldsymbol{D}$ be a matrix such that: $\boldsymbol{B}\Sigma_\epsilon \boldsymbol{B}^{/} = \boldsymbol{D}\boldsymbol{D}^{/}$. Then[6] $E\left\{\boldsymbol{D}^{-1}\boldsymbol{B}\varepsilon_t\left(\boldsymbol{D}^{-1}\boldsymbol{B}\varepsilon_t\right)^{/}\right\} = \mathrm{I}_3$ and $\{\boldsymbol{D}^{-1}\boldsymbol{B}\varepsilon_t = 0\}$. These transformations of the innovations allow us to analyze the dynamics of the system in terms of a change to an element of e_t.

[6] $E\{\boldsymbol{D}^{-1}\boldsymbol{B}\varepsilon_t(\boldsymbol{D}^{-1}\boldsymbol{B}\varepsilon_t)^{/}\} = \boldsymbol{D}^{-1}\boldsymbol{B}E\{\varepsilon_t\varepsilon_t{}^{/}\}\boldsymbol{B}^{/}\left(\boldsymbol{D}^{/}\right)^{-1} = \boldsymbol{D}^{-1}\boldsymbol{B}\Sigma_\epsilon\boldsymbol{B}^{/}\left(\boldsymbol{D}^{/}\right)^{-1} = \mathbf{I}_3$

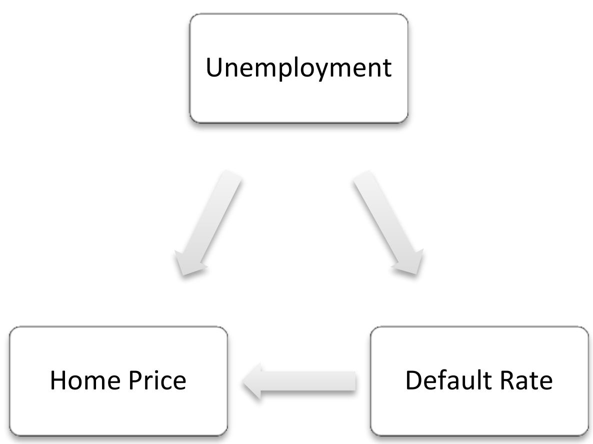
2.1 Short-Run Identification

In a short-run SVAR model, identification is obtained by placing restrictions on $\boldsymbol{B}$ and $\boldsymbol{D}$ matrices which are assumed to be nonsingular. At least 3 identifying restrictions are needed to be imposed to achieve unique identification. We impose restrictions on the SVAR system by applying equality constraints with the constraint matrices:

$$\boldsymbol{B} = \begin{bmatrix} 1 & 0 & 0 \\ a_{21} & 1 & 0 \\ a_{31} & a_{32} & 1 \end{bmatrix} \quad \text{and} \quad \boldsymbol{D} = \begin{bmatrix} b_{11} & 0 & 0 \\ 0 & b_{22} & 0 \\ 0 & 0 & b_{33} \end{bmatrix}$$

Because $y_t = (U_t, D_t, P_t)^/$, the identification scheme implies that changes in the unemployment rates are not contemporaneously affected by the changes in the home price indices and the mortgage default rates. It also implies that changes in the mortgage default rates are affected by the contemporaneous changes in the unemployment rates (if $a_{21} \neq 0$) but not the house price indices. Finally, it also implies that changes in the home price indices (if $a_{31} \neq 0$) are affected by contemporaneous changes in the unemployment rates and the mortgage default rates (if $a_{32} \neq 0$).

Contemporaneous Effects



We have enough restrictions that the innovations and the associated unique impulse responses are just-identified. We believe this identification strategy is reasonable: unemployed borrowers will experience difficulties paying their mortgages thereby leading to an increase in the default rate in the same quarter that they were unemployed, but borrowers who experience a negative equity do not make the decision to default in the same quarter. The second part was motivated by Deng, Quigley and Van Order (2000), which empirically tested some mortgage default theories and found that borrowers do not default as soon as home equity becomes negative; they prefer to wait since default is irreversible and house prices may increase.

3. Data

The nine census regions are: Pacific Census Division (P), Mountain Census Division (MT), West North Central (WNC), West South Central (WSC), East North Central (ENC), East South Central (ESC), New England (NE), Middle Atlantic (MA) and South Atlantic (SA)[7]. The states are Arizona, California, Florida, Michigan, Nevada, and Pennsylvania.

The mortgage default rate is defined as the total number of seriously delinquent mortgage loans as a percentage of all loans serviced in each quarter. The seriously delinquent loans are mortgage loans that are in 90+ delinquent, i.e., they are loans for which the borrowers have not paid the mortgage in 90+ days. The data is obtained from Mortgage Bankers Association National Delinquent Survey. The data consist of quarterly mortgage default rates from the second quarter of 1979 to the third quarter of 2010 for the national, 9 census regions and 6 states.

The house price indices data were obtained from The Federal Housing Agency House Price Indices (HPI)[8]. The indices are constructed from quarterly house price using data on conventional conforming mortgage transactions obtained from the Federal Home Loan Mortgage Corporation (Freddie Mac) and the Federal National Mortgage Association (Fannie Mae). The HPI measures broadly the movement of single-family house prices. It is a weighted, repeat-sales index, meaning that it measures average price changes in repeat sales or refinancing on the same properties. This information is obtained by reviewing repeat mortgage transactions on single-family properties whose mortgages have been purchased or securitized by Fannie Mae or Freddie Mac since January 1975.

The unemployment rates were obtained from the Bureau of Labor Statistics.

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[7] Appendix A provides more information about the census regions.

[8] There are other House Price Indices, (e.g. Case-Shiller Indices) which could have been used. The HPI is used here because it has a longer series than other indices.

4. Empirical Results

This section discusses the results of the forecast errors from 2001 to 2010 for the regional and national mortgage default rates using the SVAR estimates from 1979 to 2000.

4.1 Forecast Errors of Mortgage Default Rate: 2001 to 2010 Period

Given the SVAR system:

$$(4) \qquad \boldsymbol{B}\left[I_K - A_1L^1 - A_2L^2 \ldots - A_pL^p\right]y_t = \boldsymbol{D}e_t \qquad t = 1, \ldots, T$$

The optimal $l - step$ forecast (after T) of the system is given by:

$$(5)^9 \qquad \hat{y}_T(l) = \hat{v} + \hat{A}_1\hat{y}_T(l-1) + \cdots + \hat{A}_p\hat{y}_T(l-p) \qquad l = 1, 2, \ldots$$

The forecast error for the mortgage default rate is represented as:

$$(6) \qquad Forecast\ Error = y^D_{T+l} - \hat{y}^D_T(l)$$

Where y^D_{t+l} is the national and regional mortgage default rate observed at time $T + l$ and $\hat{y}^D_T(l)$ is the forecasted national and regional mortgage default rate at time $T + l$.

Figures[10] 1 to 4 represent the graphs of the forecast errors for the national and New England, East South Central and Mountain regions. The SVAR model was not far off in forecasting the changes in the national and regional mortgage default rates from 2001 to 2007. The big deviations in the forecast errors from 2006 to 2007 for the national and East South Central—which are also present in the forecast error graph for West South Central—are due to the effects of Hurricane Katrina. The model did a good job in forecasting the changes in the mortgage default rate even in the housing boom years from 2003 to 2006. However, the model failed during the Great Recession period (2008 to 2010). Section 4.2 explores some of the reasons behind this forecast failure.

[9] More information on the estimation of the forecast is provided in Appendix B.
[10] The forecast error graphs shown are similar in the regions not shown.

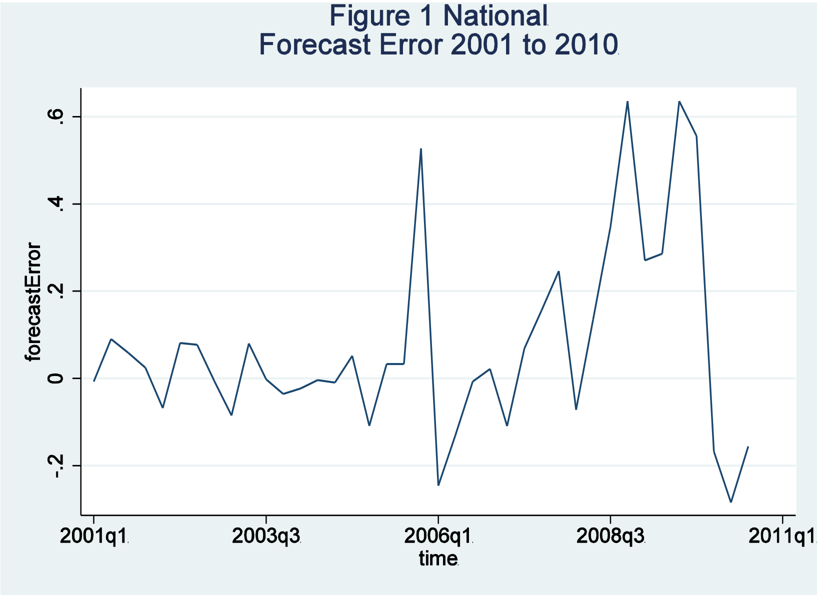
Figure 1 National
Forecast Error 2001 to 2010
forecastError
-.2
0
.2
.4
.6
2001q1
2003q3
2006q1
2008q3
2011q1
time

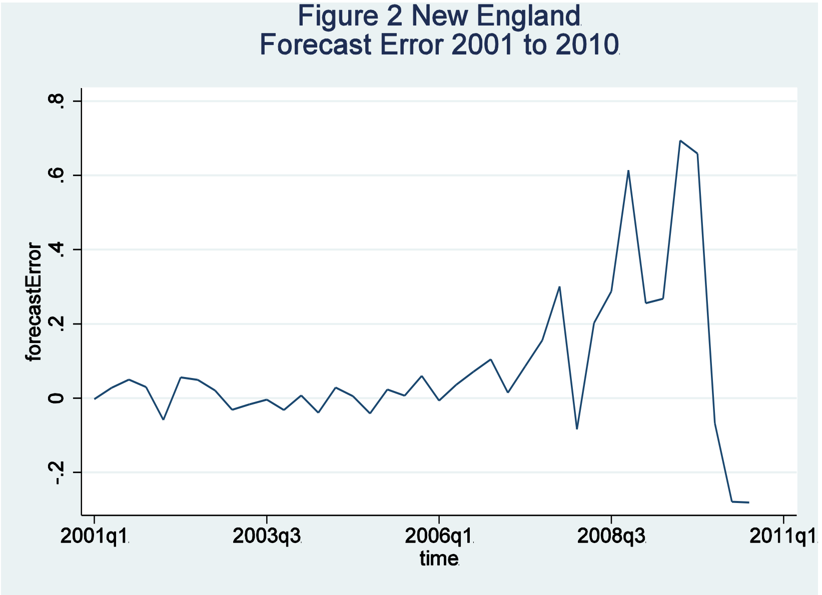
Figure 2 New England
Forecast Error 2001 to 2010
forecastError
-.2
0
.2
.4
.6
.8
2001q1
2003q3
2006q1
2008q3
2011q1
time

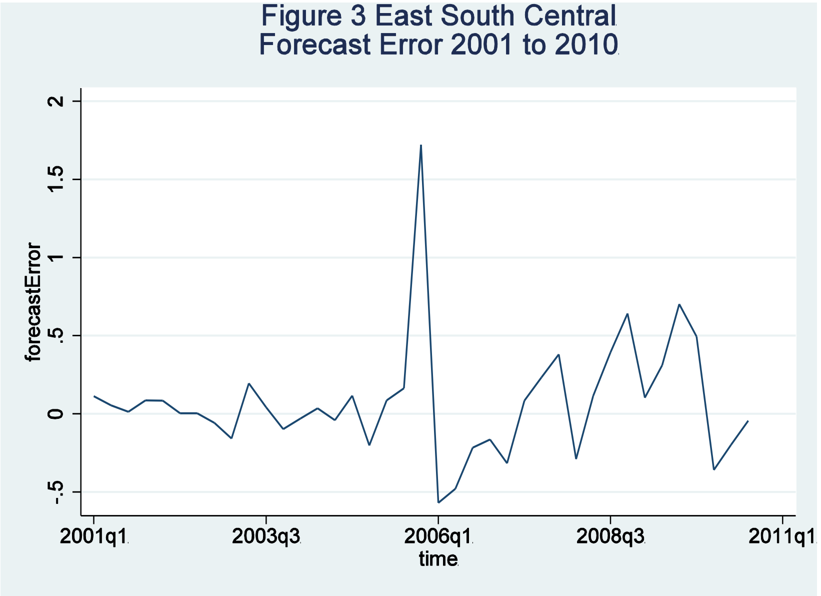
Figure 3 East South Central
Forecast Error 2001 to 2010
forecastError
-.5
0
.5
1
1.5
2
2001q1
2003q3
2006q1
2008q3
2011q1
time

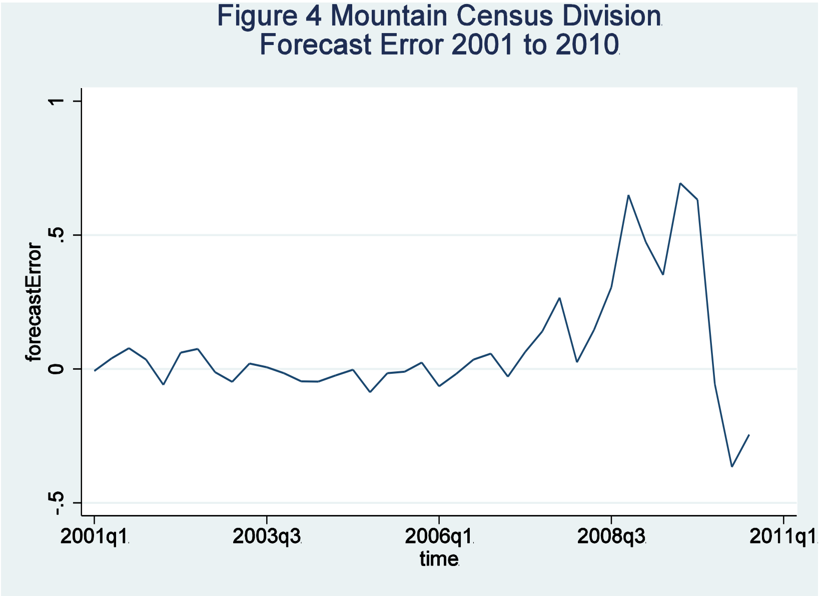
Figure 4 Mountain Census Division
Forecast Error 2001 to 2010
forecastError
-.5
0
.5
1
2001q1
2003q3
2006q1
2008q3
2011q1
time

4.2 Possible Reason for the Poor Fit during the Great Recession

(A) Joint Structural Break Test

A possible explanation for the poor performance of the model during the Great Recession is that there might have been a structural change in the trivariate system during this period which the model could not have anticipated.

This section outlines a procedure for testing for such a structural break. The test is based on Lutkepohl (1989).

Let the optimal $l - step$ forecast error of the SVAR system be represented as:

$$(7) \qquad e_T(l) := y_{T+l} - \hat{y}_T(l) = \sum_{i=0}^{l-1} \Theta_i e_{T+l-i} = [\Theta_{l-1} : \dots : \Theta_1 : I_3]\boldsymbol{e}_{T,l}$$

Where $\boldsymbol{e}_{T,l} := \left(\Theta_{T+1}^{/}, \dots, \Theta_{T+l}^{/}\right)^{/}$. The Θ_i is the coefficient of the canonical MA representation of y_t; Equation (13)[11]. Because $\boldsymbol{e}_{T,l} \sim N(O, I_l \otimes \Sigma_e)$, the forecast error is a linear transformation of a multivariate normal distribution and,

$$e_T(l) \sim N(0, \Sigma_y(l))$$

where:

$\Sigma_y(l) = \sum_{i=1}^{l-1} \widehat{\Theta}_i \hat{\Sigma}_e \widehat{\Theta}_i^{/} + \frac{1}{T}\Omega(l)$[12] is the forecast MSE matrix.

The optimal $1 \; to \; l - steps$ are also jointly normal:

$$(8) \qquad \boldsymbol{e}_T(l) \coloneqq \begin{bmatrix} e_{T,1} \\ \vdots \\ e_{T,l} \end{bmatrix} = \boldsymbol{\Theta}_l \boldsymbol{e}_{T,l} \sim N(0, \boldsymbol{\Sigma}_y(l)),$$

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[11] (13) $\quad y_t = \Theta_0 e_t + \Theta_1 e_{t-1} + \Theta_2 e_{t-2} + \cdots = \sum_{i=0}^{\infty} \Theta_i e_{t-i}$

[12] This term accounts for small sample and also for the fact that the forecasts are based on estimated process. Appendix B has more details

As was shown in Lutkepohl (2005)[13],

$$(9)\qquad \hat{\lambda}_l = \frac{T}{3l(T+3p+1)}\boldsymbol{e}_T(l)^{/}\left(\boldsymbol{\Sigma}_y(l)\right)^{-1}\boldsymbol{e}_T(l) \approx F(3l, T-3p-1)$$

Where 3 represents the numbers of endogenous variables in the SVAR. The test assumes that $y_{T+k},\ k = 1, \dots, l$ are generated by the same $SVAR(p)$ process that generated the $y_t\ for\ t \leq T$. $\hat{\lambda}_l$ test the null hypothesis that y_{T+k} is generated by the same Gaussian $SVAR(p)$ process that generated $y_1, \dots, y_T$.

The SVAR model is estimated from 1979 to 2007 period and the mortgage default rate is forecasted for the period 1st quarter of 2008 to 3rd quarter of 2010 (11 quarters). Table 1 presents the results of the test together with the p-values. The p-value is the probability that the test statistic assumes a value greater than the observed test value, if the null hypothesis is true. The results show that with the exception of East North Central region there does not seem to be a structural break in the underlying parameters for the other regions.

[13] Pages 187-188 and Appendix C

Table 1

This table reports the test statistic and the p-values for the joint structural break tests for the mortgage default rate, the unemployment rate and the home price index for the national and 9 regions. The estimation of the model (equation 3) is done using data from 1979 to 2008, and the forecast for the default rate, unemployment and home price index is from 2008 to 2010 (the Great Recession period).

National and Regions	Test Statistic $\hat{\lambda}_l$	p-values
National	0.390	0.99
East North Central	1.584	0.04
East South Central	0.624	0.94
Middle Atlantic	0.209	0.99
Mountain	0.532	0.98
New England	0.423	0.99
Pacific	0.274	0.99
South Atlantic	0.482	0.99
West North Central	0.323	0.99
West South Central	0.194	0.99

(B) Individual Structural Break Test

Lutkepohl (1989) showed that the power of a test based on joint variables may be lower than the power of a test based on the individual variables. Therefore we also run structural break tests for the national and regional mortgage default rates for the 2001 to 2010 period[14].

Suppose that the mortgage default rates follow an $ARMA(p,q)$ stochastic process represented as:

$$(10) \qquad \theta(L)X_t = \varphi(L)\gamma_t$$

Where L is the lag operator, $\theta(L) = 1 - \theta_1 L - \cdots - \theta_p L^p$ and $\varphi(L) = 1 - \theta_1 L - \cdots - \theta_q L^q$. γ_t is a Gaussian white noise with variance σ_γ^2.

The MA representation is

[14] We know from the analysis of the forecast errors that, if there is a structural break in the mortgage default rate it will occur post 2000.

$$(11) \qquad X_t = \beta(L)\gamma_t$$

Where $\beta(L) = \frac{\varphi(L)}{\theta(L)} = \sum_{i=1}^{\infty} \beta_i L^i$

A test statistic to test for a structural break is constructed as follows: Let the sum of squared residuals of the estimation of Equation (11) using data from 1979 to 2007 be represented as $\hat{\gamma}^{1979\ to\ 2007}$, and let the sum of squared residuals using data from 1979 to 2010 be represented as $\hat{\gamma}^{1979\ to\ 2010}$. Then a test for structural break in the mortgage default rate from 2008 to 2010 is:

$$(12) \qquad \tau = \frac{[\hat{\gamma}^{1979\ to\ 2010} - \hat{\gamma}^{1979\ to\ 2007}]/N_2}{[\hat{\gamma}^{1979\ to\ 2007}]/N_1 - k} \approx F(N_2, N_1 - k)$$

Where N_2 is the number of observations from 2008 to 2010, N_1 is the number of observations from 1979 to 2007 and $k = p + q$, the number of parameters to be estimated.

Table 2 presents the results of the structural break test together with the p-values. The results show that there has been a structural break in the national and regional mortgage default rates during 2008 to 2010. This break in the mortgage default rates accounts for the huge deviations in the forecast errors observed during the Great Recession (2008 to 2010). The SVAR model using just estimates from fitting the model to the 1979 to 2000 sample to forecast the mortgage default rates from 2001 to 2010 could not have anticipated this structural change. The graphs of the national and regional mortgage default rates (Appendix D) show that there was not much variation in the mortgage default rates until after 2007.

Table 2

This table reports the test statistic and the p-values for the individual structural break test for the mortgage default rate of the national and 9 regions. The estimation of the model (Equation 11)[15] is done using data from 1979 to 2010 and also data from 1979 to 2007.

National and Regions	Test Statistic (τ)	p-value
National	8.431	0.000
East North Central	11.439	0.000
East South Central	30.078	0.000
Middle Atlantic	27.557	0.000
Mountain	7.104	0.000
New England	18.327	0.000
Pacific	8.124	0.000
South Atlantic	17.479	0.000
West North Central	4.050	0.011
West South Central	18.344	0.000

5. Analysis of the Dynamics of the Unemployment and Home Price Index shocks on the Mortgage Default Rate (National and Regional): 1979 to 2000 vs. 2001 to 2010

In this section we evaluate the impact of the home price index and unemployment shocks on the mortgage default rates by examining the impulse response functions and the variance decomposition from 1979 to 2000 and also from 2001 to 2010. Not only are we interested in the dynamics of the two shocks on the mortgage default rates during both periods; we also want to assess the relative importance of the shocks in explaining the variation in the mortgage default rates.

5.1 Orthogonalized Impulse Response

An MA representation of equation (3) based on e_t is given by:

[15] The exact specification of the model for the national and the 9 regions are presented in Appendix C

$$(13) \qquad y_t = \Theta_0 e_t + \Theta_1 e_{t-1} + \Theta_2 e_{t-2} + \cdots = \sum_{i=0}^{\infty} \Theta_i e_{t-i}$$

Where $\Theta_j = \left[I_K - A_1 L^1 - A_2 L^2 \ldots - A_p L^p\right]^{-1} \boldsymbol{B}^{-1} \boldsymbol{D} \qquad (j = 0,1,2, \ldots)$. The elements of the Θ_j matrices represent the responses to e_t shocks.

5.2 Variance Decomposition

A variance decomposition is performed to measure the contribution of the home price and unemployment shocks to the changes in default rates. Using equation (13), the error optimal $h - step$ ahead forecast at time t, $\hat{y}_{t+h:t}$ is:

$$(14) \qquad y_{t+h} - \hat{y}_{t+h:t} = \sum_{l=0}^{h-1} \Theta_l e_{t+h-l}$$

Denoting the $mn - th$ element of Θ_l by $\theta_{mn,l}$, then the $h - step$ forecast error of the $m - th$ component of $y_{m(t+h)}$becomes:

$$(15) \qquad y_{m(t+h)} - \hat{y}_{m(t+h):t} = \sum_{n=1}^{3} \left(\theta_{mn,0} e_{t+h}^{n} + \cdots + \theta_{mn,h-1} e_{t+1}^{n}\right)$$

Thus the forecast error of the $m - th$ component consists of all the innovations: e_t^1, e_t^2 and e_t^3. Because the $e_t^{n\prime}s$ are uncorrelated and have unit variances, the mean square error of $\hat{y}_{m(t+h):t}$ can then be expressed as:

$$(16) \qquad MSE(\hat{y}_{m(t+h):t}) = \sum_{n=1}^{3} \left(\theta_{mn,0}^2 + \cdots + \theta_{mn,h-1}^2\right)$$

The contribution $\phi_{mn}(h)$ of the nth component to the MSE of the h-step ahead forecast of the mth component is

$$(17) \qquad \phi_{mn}(h) = \frac{\sum_{l=0}^{h-1} \Theta_{mn,l}^2}{MSE(\hat{y}_{mt+h:t})}$$

This is the proportion of the $h - step$ forecast error variance error of variable m accounted for by e_t^1, e_t^2 and e_t^3 innovations. We focus here on the proportion of the forecast error variance of the mortgage default rate accounted by the unemployment and home price index shocks.

5.3 Home Price Index and Unemployment Data: 2000 to 2010

The 2000 to 2010 period represents a time of significant changes in unemployment and house prices. Table 3 presents the percentage appreciation and depreciation of the house price index at the national and regional levels from 2000 to 2010.[16] The table shows some variations across the regions of the extent of house price appreciation and depreciation during this period. House prices in the Pacific region had the largest appreciation and also the largest depreciation during this period. There has not being significant house price depreciation in the West North Central, West South Central and East South Central regions. The East North Central region had the smallest house price appreciation but one of the largest house price depreciation. Housing prices in New England and Middle Atlantic experienced large appreciation, but not significant depreciation.

[16] This period was chosen because it has the highest home price index and also the period when the index depreciated (measuring from the peak value) the most. The window is wide enough to observe the scale of house price appreciation for the regions and the subsequent collapse in house prices for some of the regions.

Table 3

This table reports the maximum House Price Index appreciation and the minimum House Price Index depreciation from 1st quarter 2000 to 3rd Quarter 2010[17].

National and Regions	House Price Index Appreciation %	House Price Index Depreciation %
National	66	-13
East North Central	33	-11
East South Central	43	-4
Middle Atlantic	87	-9
Mountain	76	-28
New England	82	-12
Pacific	124	-38
South Atlantic	83	-18
West North Central	45	-5
West South Central	47	-2

Table 4 also reports the lowest and highest national and regional unemployment rates during 2001 to 2010. The table shows that there were significant increases in the unemployment rates both at the national and regional level during this period. East North Central and East South Central regions have their highest unemployment rates above the highest national unemployment rate. The two tables show that there were significant changes in house price indices and unemployment rates during this period. This presents a perfect sample to test the relative significance of home price index and unemployment shocks on the mortgage default rate.

[17] **National** [Peak (1st qtr. 2007)]: **ENC** [Peak (1st qtr. 2007): **ESC** [Peak (1st qtr. 2008)]: **MA** [Peak (1st qtr. 2007)]: **MT** [Peak (2rd qtr. 2007)]: **NE** [Peak (1st qtr. 2007): **P** [Peak (4th qtr. 2006)]: **SA** [Peak (1st qtr. 2007)]: **WNC** [Peak (2nd qtr. 2007)]: **WSC** [Peak (2nd qtr. 2008)]. For the national and all the regions the minimum house price index depreciation after the peak occurred during the 2nd qtr. 2010.

Table 4

This table reports the lowest and highest national and regional unemployment rates 2001 to 2010. The dates for the lowest and highest values are provided in the brackets.

National and Regions	Lowest Unemployment rate	Highest unemployment rate
National	**4.2** (1st qtr. 2001)	**9.9** (4th qtr. 2009)
East North Central	**4.3** (1st qtr. 2001)	**11.1** (4th qtr. 2009)
East South Central	**4.6** (1st qtr. 2001)	**10.7** (4th qtr. 2009)
Middle Atlantic	**4.1** (1st qtr. 2001)	**9.1** (4th qtr. 2009)
Mountain	**3.2** (1st qtr. 2007)	**9.2** (1st qtr. 2010)
New England	**3.3** (1st qtr. 2001)	**8.6** (4th qtr. 2009)
Pacific	**4.6** (1st qtr. 2007)	**9.7** (4th qtr. 2009)
South Atlantic	**4.0** (2nd qtr. 2006)	**9.6** (4th qtr. 2009)
West North Central	**3.3** (1st qtr. 2001)	**6.5** (2nd qtr. 2009)
West South Central	**4.1** (1st qtr. 2008)	**7.7** (1st qtr. 2010)

5.4 Impulse Response Functions

This section presents the results of the impulse response functions for the mortgage default for the 1979 to 2000 and 2001 to 2010 samples.

Figures 5 to 8 represent the dynamics of the impulse response functions of the mortgage default rates for the national, East South Central, West North Central and Middle Atlantic regions[18] respectively to an increase of one standard deviation in the home price index and the unemployment rate. In response to the unemployment shocks, the national and regional mortgage default rates increase and they take about 15 quarters after the shocks to get back to their pre shock level. The home price shocks are unchanged in the period of impact because of our identification scheme, which implied that it takes more than a quarter for the home price index shocks to have an impact on the mortgage default rates. In response to the home price index shocks the national and regional mortgage default rates decrease and they also take about 15 quarters to get back to its pre shock level. The national and regional mortgage default dynamics after the shocks seem to be similar; however, there are regional variations in the peaks and troughs of the impulse response functions.

[18] The dynamics of the other regions are similar to those reported here.

Table 5 reports the peak and trough of the national and regional mortgage default rates after the unemployment and home price index shocks. From 1979 to 2000 the national unemployment and home price index shocks led to a maximum increase of 1.3% and a decrease of 1% in the national mortgage default rates respectively. For the regions the unemployment and home price index shocks led to an average increase of 1.2% and a decrease of 1.1% in the regional mortgage default rate respectively. Compared to the 2001 to 2010 period, the national unemployment and the home price index shocks led to maximum increase of 7.2% and a decrease of 4.9% in the national mortgage default rate respectively. For the regions, the unemployment and the home price index shocks led to an average increase of 12.7% and a decrease of 7.3% respectively. Although there have been a lot of changes in the unemployment rate at both the national and regional levels during the 1979 to 2000 period, these changes did not seem to have impacted the national and regional mortgage default rates that much. The results for the home price index during this period are not surprising because the indices did not change much during the period.

For the 2001 to 2010 period, the unemployment results for the East South Central (which had one of the highest unemployment rates at 11.1%) and West South Central (influenced by Louisiana in particular) were mainly driven by the effects of hurricane Katrina. These two regions were among the regions with the smallest house price index appreciation and depreciation (Table 3); however the house price shocks seem to have generated a big impact on the mortgage default rates.

Overall the response to the unemployment shocks is larger than the response to the home price index shocks.

Table 5

This table reports the peak and trough of the impulse response functions of the national and regional mortgage default rates due to a one standard deviation increase in the national and regional unemployment rate and the national and regional home price indices.

National and Regions	1979 to 2000		2001 to 2010	
	Unemployment %	Price Index %	Unemployment %	Price Index %
National	**1.3**	**-1.0**	**7.2**	**-4.9**
East North Central	**1.9**	**-1.5**	**11.4**	**-6.0**
East South Central	**1.4**	**-1.7**	**18.0**	**-12.5**
Middle Atlantic	**1.1**	**-0.2**	**6.9**	**-5.1**
Mountain	**1.0**	**-1.2**	**10.4**	**-5.9**
New England	**1.2**	**-1.1**	**8.4**	**-5.6**
Pacific	**0.6**	**-1.6**	**5.9**	**-5.7**
South Atlantic	**0.7**	**-1.0**	**9.1**	**-7.8**
West North Central	**1.4**	**-0.5**	**5.4**	**-3.7**
West South Central	**1.4**	**-1.5**	**39.0**	**-8.7**

Impulse Response Functions 1979 to 2000 vs. 2001 to 2010: National and Regional

Figure 5 National

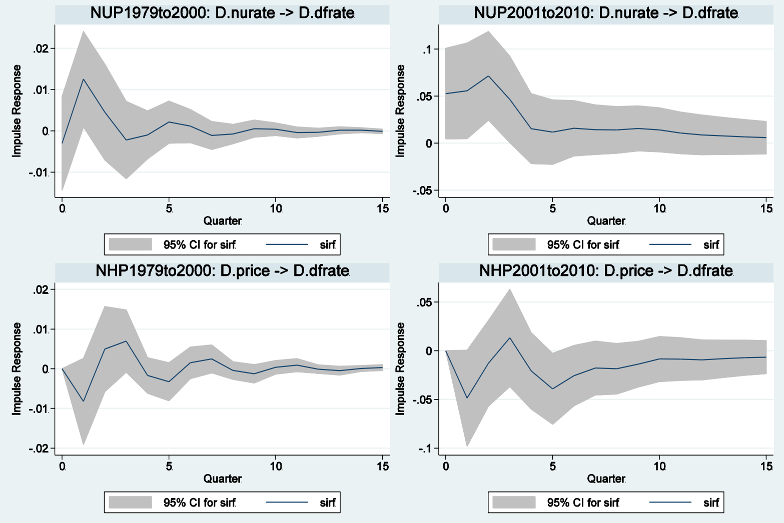


Figure 6 East South Central

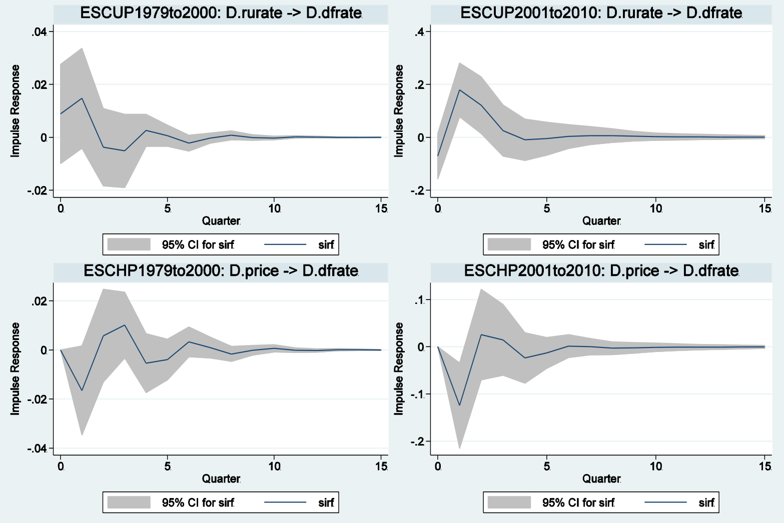


Figure 7 West North Central

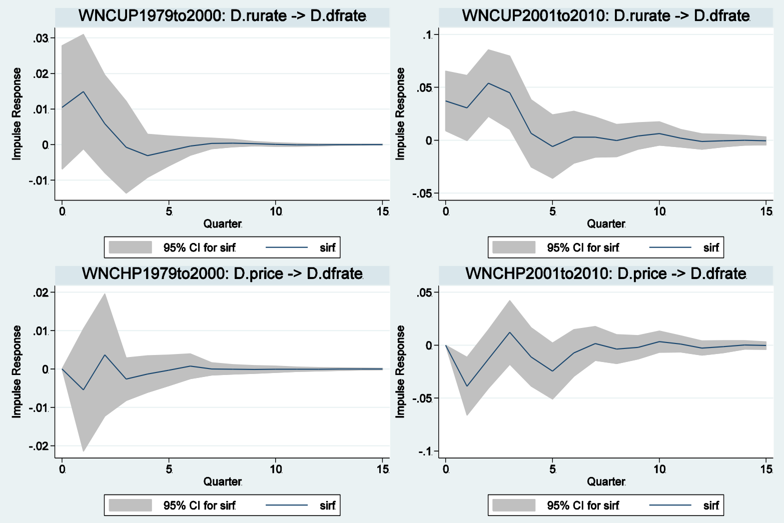
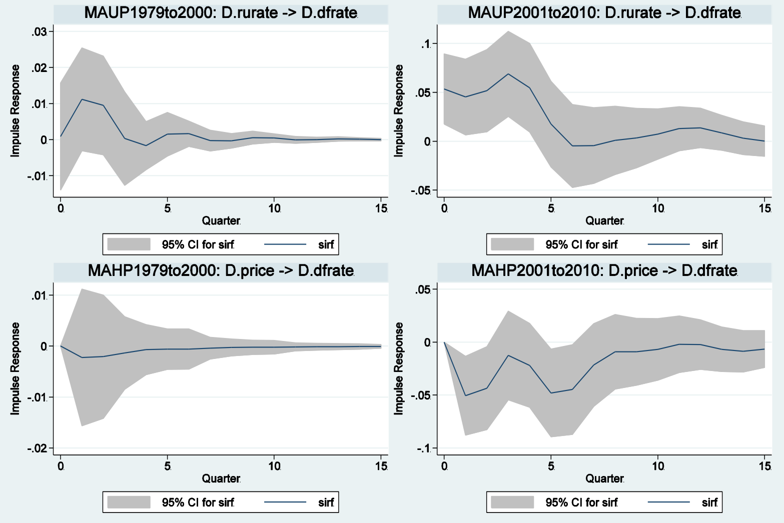


Figure 8 Middle Atlantic



5.5 Variance Decomposition

To gauge the relative contributions of the unemployment and the home price index shocks to the variance of the mortgage default rates during both the 1979 to 2000 and the 2001 to 2010 periods; the variance decompositions are constructed for the SVAR system using Equation (17) at $h = 4\ (year)$ and $h =\ 8(two\ years)$[19]. Table 6 presents the results of the variance decomposition. Again in this case also, the unemployment and home price index shocks do not explain much of the variation in the forecast errors of the mortgage default rates at both the national and regional levels for the 1979 to 2000 period. Although there are some regional variations in the impact of the unemployment and home price index shocks during the 2001 to 2010 period, on average, employments shocks explain a larger percentage in the movement of the mortgage default rates than the home price index shocks. The unemployment shocks explain about 44% of the movement in the mortgage default rates at $h = 4\ (year)$ and 43% $h = 8(two\ years)$. While the home price index shocks explains about 13% at $h = 4\ (year)$ and 20% $h = 8(two\ years)$. In effect, the two shocks are responsible on average for about 60% of the movement in the regional mortgage default rates.

The empirical results show that unemployment shocks have been a bigger contributor to national and regional mortgage default rates than the home price index shocks.

[19] As h increases, the decomposition of the variance of the forecasting error coincides with the decomposition of the unconditional variance.

Table 6

This table reports the variance decompositions, equation (17), of the national and regional mortgage default rates for 1979 to 2000 and 2001 to 2010 samples for $h = 4$ $(a\ year)$ and $h = 8$ $(two\ years)$. The decompositions are expressed in percentages.

National and Regions	1979 to 2000				2001 to 2010			
	Unemployment		Price Index		Unemployment		Price Index	
	$h = 4$	$h = 8$	$h = 4$	$h = 8$	$h = 4$	$h = 8$	$h = 4$	$h = 8$
National	**4.7**	**4.2**	**3.5**	**3.6**	**32**	**31**	**7**	**12**
East North Central	**5.0**	**5.1**	**2.3**	**2.7**	**56**	**51**	**11**	**14**
East South Central	**3.3**	**3.4**	**4.0**	**4.5**	**37**	**37**	**11**	**12**
Middle Atlantic	**3.4**	**3.3**	**0.2**	**0.2**	**38**	**38**	**14**	**24**
Mountain	**3.3**	**3.7**	**5.1**	**5.3**	**61**	**57**	**14**	**22**
New England	**2.3**	**2.6**	**1.9**	**2.2**	**36**	**39**	**15**	**21**
Pacific	**1.3**	**2.1**	**3.4**	**5.0**	**23**	**22**	**26**	**41**
South Atlantic	**2.1**	**2.1**	**2.0**	**2.1**	**43**	**38**	**20**	**30**
West North Central	**5.0**	**5.1**	**0.7**	**0.7**	**42**	**39**	**11**	**14**
West South Central	**2.6**	**2.5**	**3.6**	**3.6**	**63**	**63**	**4**	**4**

6. Dynamics of Some Selected States

The dynamics of the home price index and unemployment shocks on the mortgage default rates were examined for Arizona, California, Florida, Michigan, Nevada, and Pennsylvania. These states have had mortgage default rates higher than the national average. Some of the states (Michigan, Nevada and Pennsylvania) have also had unemployment rates higher than the national average. Arizona, California, Florida, Michigan and Nevada have also experienced some of the biggest drop in housing prices during the 2001 to 2010 period.

6.1 Home Price Index and Unemployment Data: 2000 to 2010

From Table 7 Florida had the largest appreciation in the house price index from 2000 to 2010 and also one of the largest house price index depreciations during the period. Michigan had one of the lowest appreciations in the house price index, but also one of the largest house price index depreciation during the period. Nevada had the largest depreciation in the home price index. Michigan had the smallest home price appreciation but a large home price index depreciation. There does not seem to be have been much depreciation in housing prices in Pennsylvania. Mayer and Pence (2009), document that areas with high house price appreciation experienced an increase in subprime mortgage origination. Mayer et al (2009) also showed that in California, Florida, Arizona and Nevada over half of subprime borrowers had negative equity in their home and over a third of borrowers in Michigan had negative equity by mid-2008

Table 7

This table reports the maximum House Price Index appreciation and the minimum House Price Index depreciation from 1st quarter 2000 to 3rd Quarter 2010.

States	House Price Index Appreciation %	House Price Index Depreciation %
Arizona	132	-36
California	353	-30
Florida	387	-36
Michigan	27	-23
Nevada	169	-45
Pennsylvania	72	-6

Table 8 also reports the lowest and highest state unemployment rates during this period. The results show that there have been significant increases in the unemployment rates for these states during this period. With the exception of Pennsylvania, all the states have their highest unemployment rates above the highest national unemployment rate and also larger house price index depreciation than the national. Again, these states present a perfect sample to test the relative significance of home price index and unemployment shocks on the mortgage default rate.

Table 8

This table reports the lowest and highest state unemployment rates 2001 to 2010. The dates for the lowest and highest values are provided in the brackets.

National and Regions	Lowest Unemployment rate	Highest unemployment rate
Arizona	**3.6** (2nd qtr. 2007)	**10.4** (4th qtr. 2009)
California	**4.8** (3rd qtr. 2006)	**12.5** (3rd qtr. 2010)
Florida	**3.3** (2nd qtr. 2006)	**11.7** (3rd qtr. 2010)
Michigan	**4.7** (1st qtr. 2001)	**14.1** (3rd qtr. 2009)
Nevada	**4.2** (4th qtr. 2006)	**14.9** (3rd qtr. 2010)
Pennsylvania	**4.2** (1st qtr. 2007)	**8..8** (1st qtr. 2010)

6.2 Impulse Response Functions

This section presents the results of the impulse response functions for the mortgage default for the 1979 to 2000 and 2001 to 2010 samples.

Figures 9 to 14 represents the dynamics of the impulse response functions of the mortgage default rates for the states to an increase of one standard deviation in the home price index and the unemployment rate. The dynamics of the states' mortgage default rates after the unemployment and home price shocks are similar to the dynamics of the national and regional mortgage default rates after the shocks. That is, in response to the unemployment shocks the states mortgage default rates increase and they take about 15 quarters after the shocks to get back to its pre shock level. The home price shocks are also unchanged in the period of impact due to the implication of our identification scheme. In response to the home price index shocks the states mortgage default rates decrease and for some of the states it takes about 20 quarters to get back to their pre shock level during the 2001 to 2010 period. However, for these selected states the peak and trough of the impulse response functions are higher and lower for the unemployment and home price index shocks respectively.

Table 5 reports the peak and trough of the state's mortgage default rates after the unemployment and home price index shocks. For the selected states also, there does not seem to have been much of an impact on the mortgage default rates during the 1979 to 2000 period for both the unemployment and home price shocks.

For the 2001 to 2010 period, the home price index shocks produced a larger impact on the mortgage default rates of California and Florida than the unemployment shocks. For the other

4 states the impact of the unemployment shocks was larger. For Nevada—which had the largest home price depreciation and the highest unemployment rate during this period—the unemployment shocks seem to have had a bigger impact on its mortgage default rates.

Table 9

This table reports the peak and trough of the impulse response functions of the state mortgage default rates due to a one standard deviation increase in the state unemployment rate and the state home price indices.

National and Regions	1979 to 2000		2001 to 2010	
	Unemployment %	**Price Index %**	**Unemployment %**	**Price Index %**
Arizona	**1.1**	**-1.2**	**19.9**	**-12.0**
California	**1.8**	**-0.7**	**8.0**	**-10.4**
Florida	**2.3**	**-0.8**	**11.6**	**-14.8**
Michigan	**1.5**	**-0.6**	**15.1**	**-7.7**
Nevada	**2.4**	**-0.6**	**19.8**	**-11.4**
Pennsylvania	**0.6**	**-1.4**	**7.1**	**-3.7**

Impulse Response Functions 1979 to 2000 vs. 2001 to 2010: States

Figure 9 Arizona

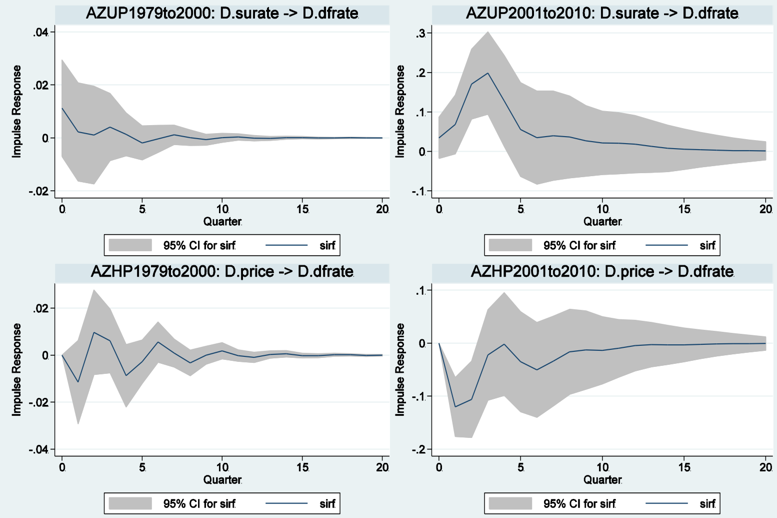


Figure 10 California

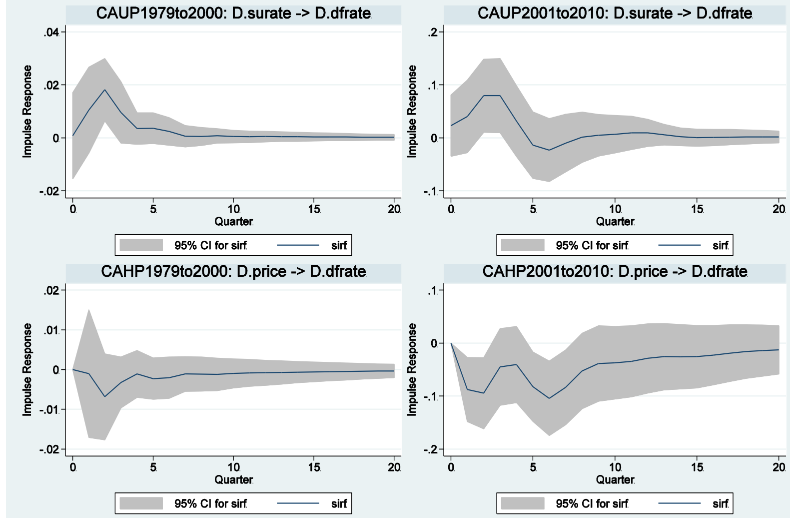


Figure 11 Florida

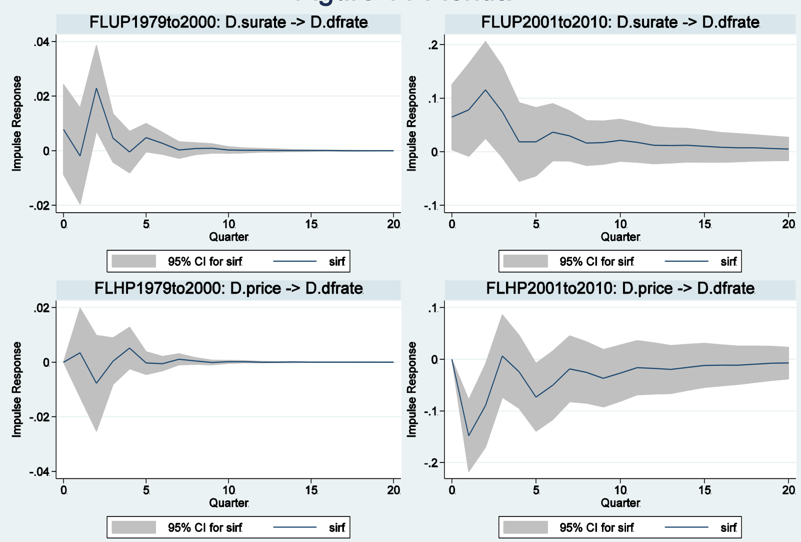
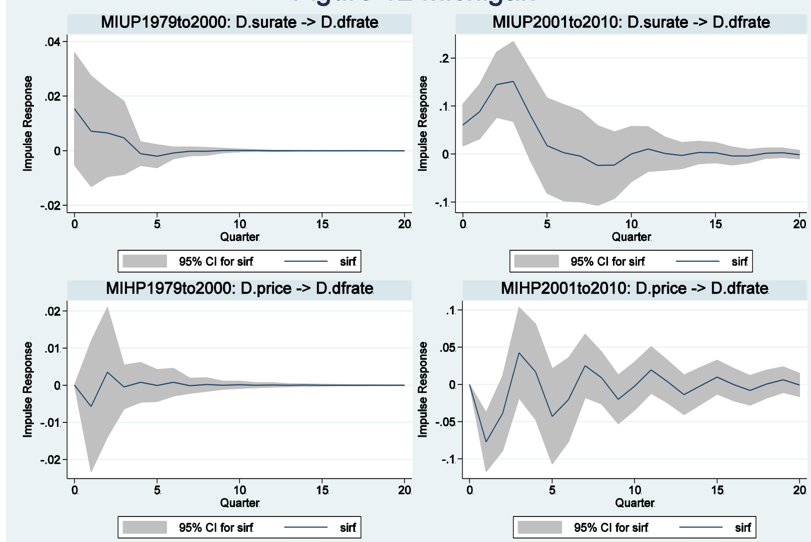
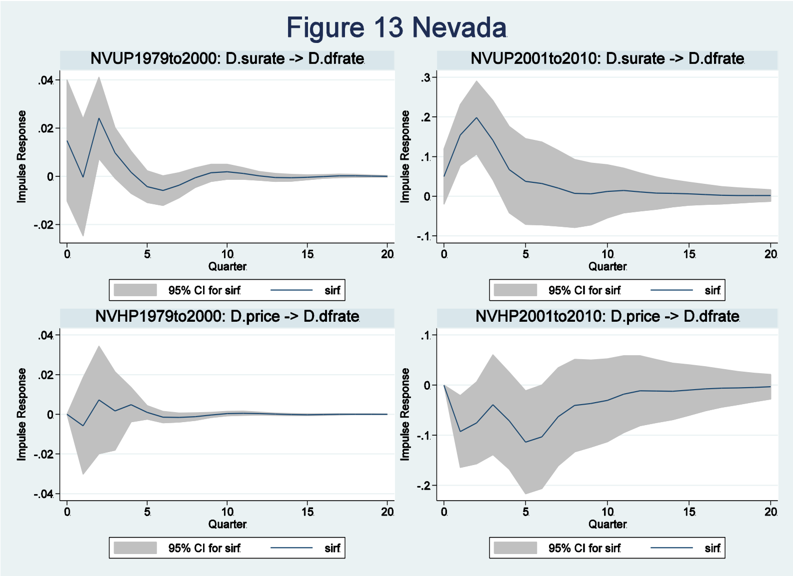
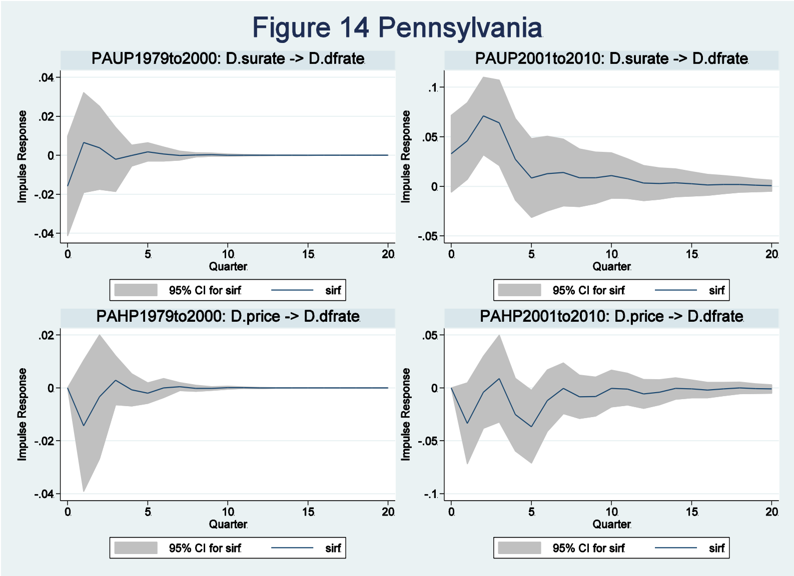


Figure 12 Michigan



Impulse Response Functions 1979 to 2000 vs. 2001 to 2010: States





6.3 Variance Decomposition

The variance decomposition is performed for both the 1979 to 2000 and the 2001 to 2010 periods at $h = 4\ (a\ year)$ and $h = 8 (two\ years)$. Table 10 presents the results. At the state level also the unemployment and home price index shocks do not explain much of the variation in the forecast errors of the mortgage default rate for the 1979 to 2000 period. During the 2001 to 2010 period, the unemployment shocks explained more of the variation in the mortgage defaults rates than the home price index shocks at both the one and two year horizon. As Tables 7 and 8 shows, there have been significant changes in both the unemployment rates and the home price indices, but the changes in the unemployment rate on average explained more of the variation in the state mortgage default rates than the changes in the home price indices.

Policies that aim to decrease the default rates across the states should take into account the relative impact of the two shocks in explaining the variation in the mortgage default rate. If home price should dominate, then government programs that reduce the overall principal might be beneficial for that state. By contrast, if unemployment shocks dominate, reduction in payments (or subsidization mortgage payments) might be the better policy for the state.

Table 10

This table reports the variance decompositions, equation (17), of the states' mortgage default rates for 1979 to 2000 and 2001 to 2010 samples for $h = 4\ (a\ year)$ and $h = 8\ (two\ years)$. The decompositions are expressed in percentages.

States	1979 to 2000				2001 to 2010			
	Unemployment		Price		Unemployment		Price	
	$h = 4$	$h = 8$	$h = 4$	$h = 8$	$h = 4$	$h = 8$	$h = 4$	$h = 8$
Arizona	**1.5**	**1.5**	**2.7**	**3.6**	**53**	**57**	**19**	**18**
California	**7.0**	**7.3**	**0.8**	**0.9**	**17**	**14**	**21**	**38**
Florida	**7.6**	**7.9**	**0.9**	**1.2**	**27**	**26**	**28**	**32**
Michigan	**3.1**	**3.2**	**0.4**	**0.4**	**62**	**60**	**10**	**12**
Nevada	**4.8**	**5.1**	**0.5**	**0.6**	**54**	**43**	**10**	**22**
Pennsylvania	**1.8**	**1.8**	**1.3**	**1.3**	**40**	**37**	**4**	**9**

7. Conclusion

The increase in mortgage default rates over the last several years has created a renewed interest in the factors drive mortgage defaults. There has been an increase in the number of subprime loans originated after 2003, due to lax mortgage underwriting standards. This has increase the number of borrowers who are more susceptible to unemployment and negative home price shocks. These borrowers have little savings they could use to cushion them against unemployment and negative home price shocks. Studies have drawn conflicting conclusions as to which of these two factors have accounted for the most of the variation in the mortgage default rates. There is an important policy implications for how best to help home owners under water depending on which factor dominates. As Elul et al (2010) stated if negative equity dominates, then government programs that reduce the overall principal might be beneficial. By contrast, if unemployment shocks should dominate, reduction in payments (or subsidization mortgage payments) might be the better policy.

The paper uses an SVAR model to disentangle the interrelations between the home price index (which tracks housing prices) and unemployment shocks and mortgage default rates by studying the dynamics of these two shocks on mortgage default rates from 1979 to 2010 at the national, regional and state levels. The results show that, with the exception of the Pacific region, California and Florida, unemployment shocks explain more of the variation in the mortgage default rates than home price indices shock at the national, regional and state levels, especially, during the 2001 to 2010 period. These two shocks together are responsible on average for about 60% of the movement in the regional mortgage default rates.

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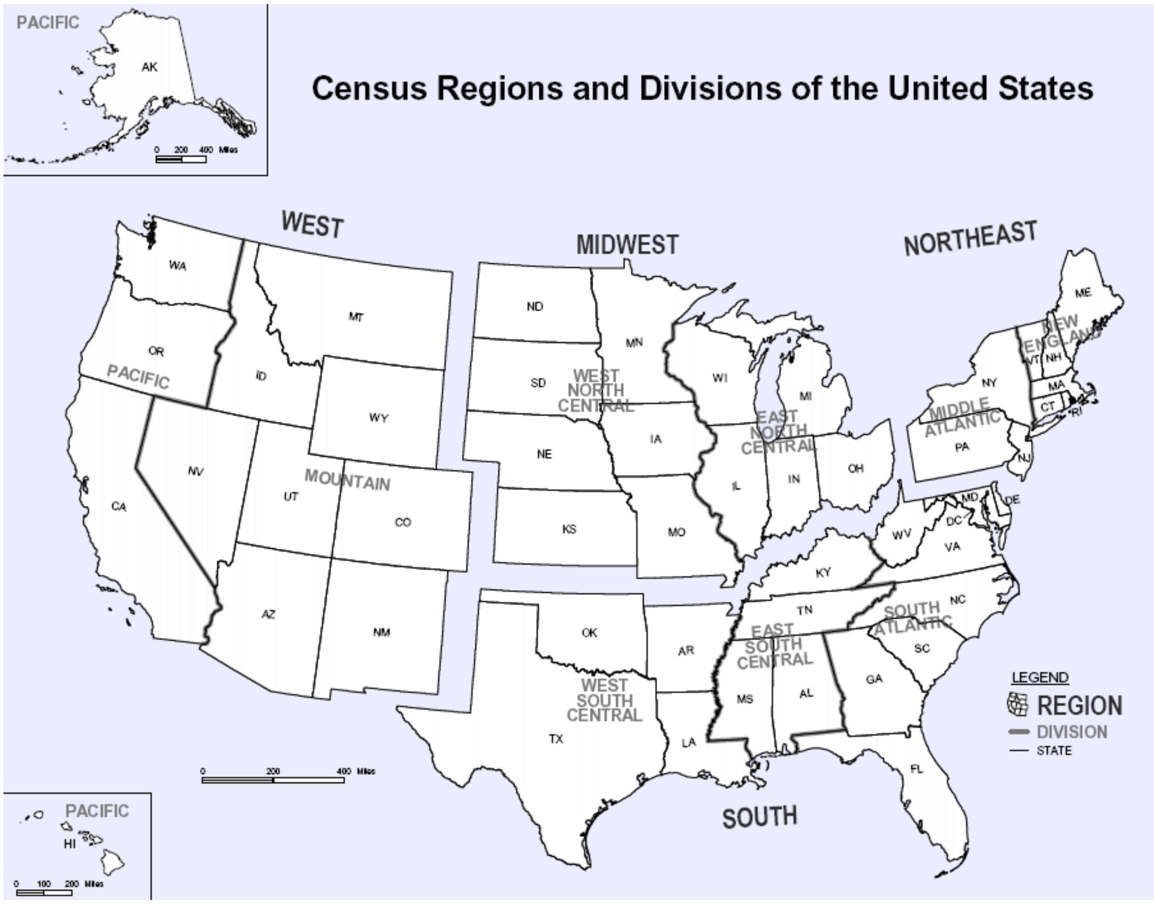
Appendix A (Regions: US Census Bureau)



East North Central: Michigan, Wisconsin, Illinois, Indiana, Ohio

East South Central: Kentucky, Tennessee, Mississippi, Alabama

Middle Atlantic: New York, New Jersey, Pennsylvania

Mountain Census Division: Montana, Idaho, Wyoming, Nevada, Utah, Colorado, Arizona, New Mexico

New England: Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut

Pacific Census Division: Hawaii, Alaska, Washington, Oregon, California

South Atlantic: Delaware, Maryland, District of Columbia, Virginia, West Virginia, North Carolina, South Carolina, Georgia, Florida

West North Central: North Dakota, South Dakota, Minnesota, Nebraska, Iowa, Kansas, Missouri

West South Central: Oklahoma, Arkansas, Texas, Louisiana

Appendix B

Forecasting with Estimated Process

From Lutkepohl (2005), if we denote the parameter estimators of the SVAR system, Equation (3), as $\widehat{A_1}$... $\widehat{A_p}$ and $\hat{\beta}$

The asymptotic estimator of the covariance matrix of the prediction error is given by:

$$(B.1) \qquad \Sigma_{\hat{y}}(l) = \Sigma_y(l) + \frac{1}{T}\Omega(l)$$

Where

$$(B.2) \qquad \Sigma_y(l) = E\{[y_{t-l} - y_t(l)][y_{t-l} - y_t(l)]^{/}\} = \textstyle\sum_{i=1}^{l-1} \widehat{\Theta}_i \hat{\Sigma}_e \widehat{\Theta}_i^{/}$$

And Θ_i is the $i - th$ coefficient of the canonical MA representation of y_t, Equation (13).

$$(\mathrm{B}.3) \qquad \Omega(l) = \frac{1}{T}\sum_{t=0}^{T}\left\{\sum_{i=0}^{l-1} Z_t^{/}\left(\widehat{B^{/}}\right)^{l-1-i} \otimes \widehat{\Theta}_i\right\}\hat{\Sigma}_\beta\left\{\sum_{i=0}^{l-1} Z_t^{/}\left(\widehat{B^{/}}\right)^{l-1-i} \otimes \widehat{\Theta}_i\right\}^{/}$$

$$\hat{B} = \begin{bmatrix} 1 & 0 & 0 & \cdots & 0 & 0 \\ \hat{v} & \hat{A}_1 & \hat{A}_2 & \cdots & \hat{A}_{p-1} & \hat{A}_p \\ 0 & I_K & 0 & \dots & 0 & 0 \\ 0 & 0 & I_K & \cdots & 0 & 0 \\ \vdots & \vdots & \vdots & \ddots & \vdots & \vdots \\ 0 & 0 & 0 & \cdots & I_K & 0 \end{bmatrix}$$

$$Z_t = \left(1, y_t^{/}, \dots, y_{t-p-1}^{/}\right)^{/}$$

$$\widehat{\Theta}_0 = I_K$$

$$\Theta_i = \sum_{j=1}^{i} \Phi_{i-j}\hat{A}_j \qquad\qquad 1 = 1,2, \dots$$

$$\hat{A}_j = 0 \qquad for\ j > p$$

$\hat{\Sigma}_e$ is the estimate of the covariance matrix of the innovations and $\hat{\Sigma}_\beta$ is the covariance matrix of the asymptotic distribution of $\sqrt{T}(\hat{\beta} - \beta)$.

For a simulation with R repetitions, this algorithm is used[20]:

1. Fit the model and save the estimated coefficients. Only data up to T is used for the estimation.

2. Use the estimated coefficients to calculate the residuals.

3. Repeat steps 3a–3c R times.

3a. Draw a simple random sample with replacement of size T +h from the residuals. When the tth observation is drawn, all K residuals are selected, preserving any contemporaneous correlation among the residuals.

3b. Use the sampled residuals, p initial values of the endogenous variables, any exogenous variables, and the estimated coefficients to construct a new sample dataset.

3c. Save the simulated endogenous variables for the h forecast periods in the bootstrapped dataset.

[20] StataCorp, 2011, Time Series Reference Manual p. 151

Appendix C
Individual structural test

Table C.1

This table reports the optimal lag for estimating equation (16) for the full sample (1979 to 2010) and the 1979 to 2007 sample. Akaike's information criterion (AIC) was used in selecting the optimal lags

National and Regions	ARMA	Degrees of Freedom
National	(6,2)	F(11,107)
East North Central	(4,2)	F(11,109)
East South Central	(6,2)	F(11,107)
Middle Atlantic	(3,2)	F(11,110)
Mountain	(4,2)	F(11,109)
New England	(3,1)	F(11,111)
Pacific	(5,2)	F(11,108)
South Atlantic	(2,2)	F(11,111)
West North Central	(5,2)	F(11,108)
West South Central	(3,2)	F(11,110)

Appendix D
Graphs of National and Regional Mortgage Default Rate

Figure D.1 National: Default Rate

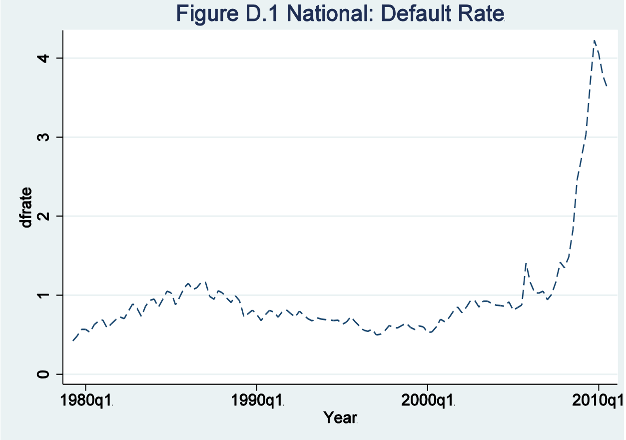


Figure D.2 East North Central: Default Rate

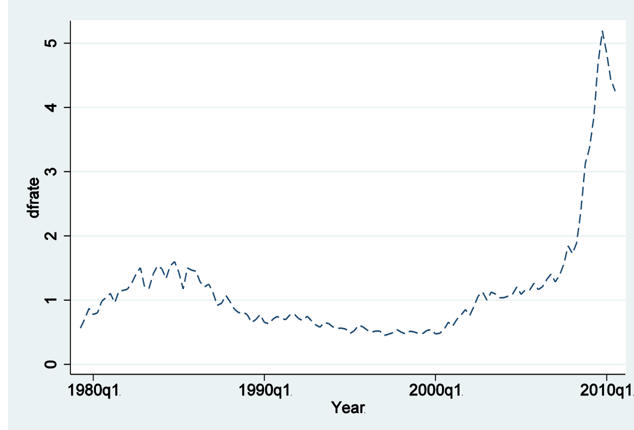


Figure D.3 Middle Atlantic: Default Rate

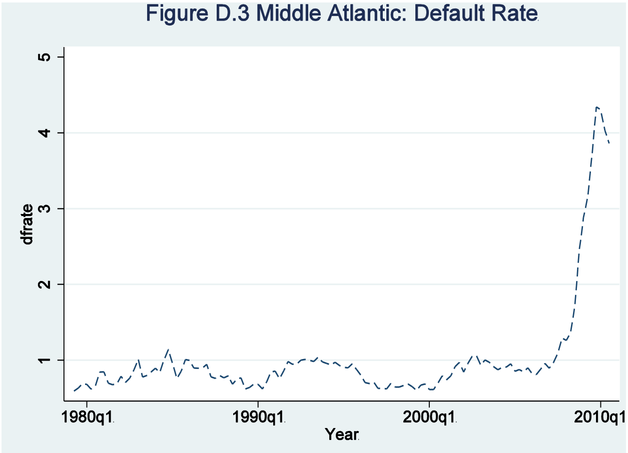


Figure D.4 East South Central: Default Rate

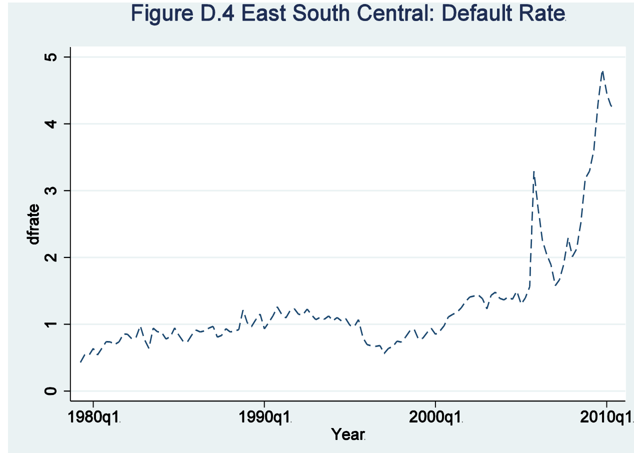


Figure D.5 Mountain: Default Rate

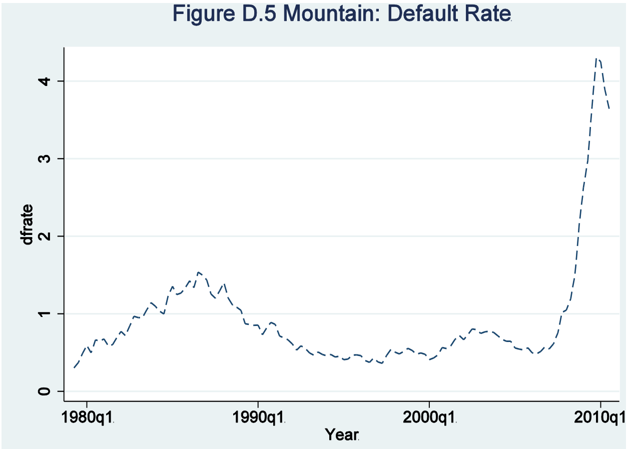


Figure D.6 New England: Default Rate

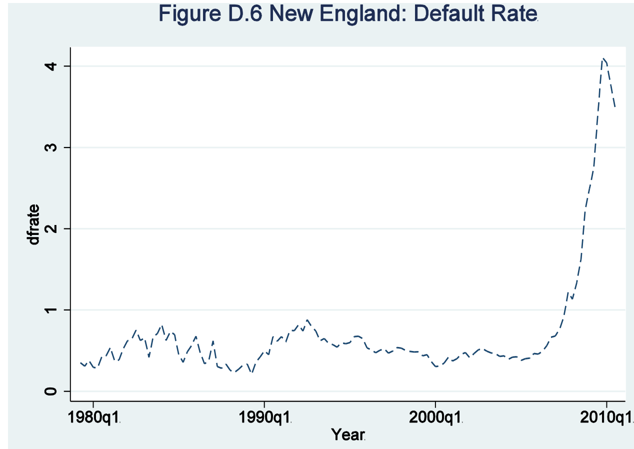


Figure D.7 Pacific: Default Rate

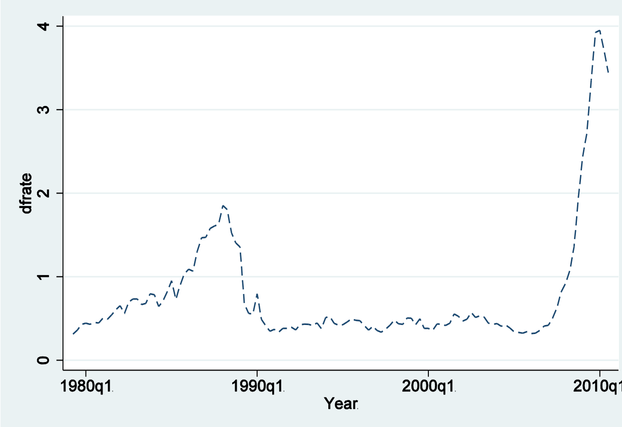


Figure D.8 South Atlantic: Default Rate

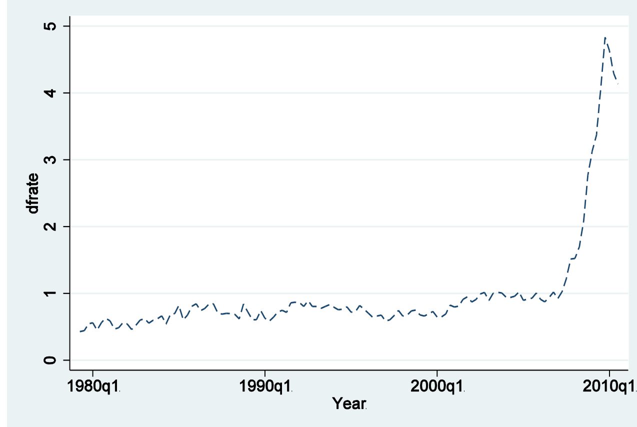


Figure D.9 West North Central: Default Rate

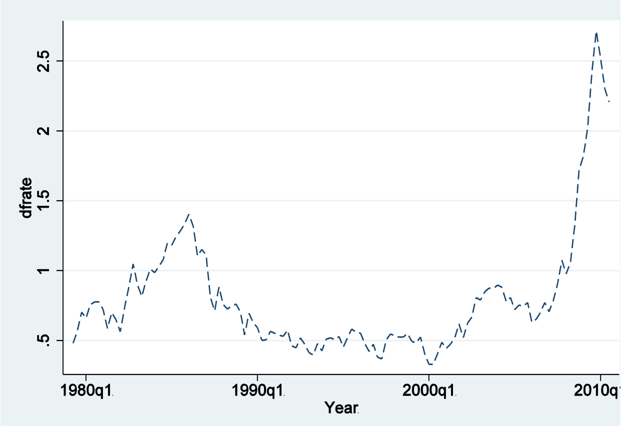


Figure D.10 West South Central: Default Rate