ESSAYS ON THE TIME SERIES BEHAVIOR OF HOUSE PRICES IN THE U.S.

BY
ALBERT S. DAVIES

A DISSERTATION SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE

DOCTOR OF PHILOSOPHY – ECONOMICS

Jennings A. Jones College Of Business
Department Of Economics and Finance
Middle Tennessee State University

MURFREESBORO, TENNESSEE

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This dissertation is dedicated to my father, Emanuel, James, Bode, Davies, who went to be with the Lord January 17th, 1999. Dad was an inspiration to his children, as he encouraged us to pursue our dreams. It would have been a blessing sharing this moment with him.

I also dedicate this dissertation to my sister Victoria Yomi Davies, who passed away at the young age of 32 on June 1st, 1993. Yomi was my friend, my confidant and my big sister. She was the best big sister ever. I really miss her.

ACKNOWLEDGEMENTS

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I want to say a special thank you to my wife, Georgia and our children Jerry, Kevin, Mike, Denise, and Brianna for their continued support and encouragement. Thank you, Mike, Denise and Brianna for typing most of my work. Thank you to my Mom, Omotunde and my sister, Eyabo, for all your support through the years.

ABSTRACT

This dissertation is comprised of three essays regarding issues on house prices, with the focus of the analysis at the state and regional levels. The first say, "The Effects of Monetary Policy on Housing Using State Level Data," investigates how individual states respond to national policy actions. State level analysis can provide policy makers with additional information to use when making national forecasts. Results from impulse response functions indicate a wide range of possibilities from the states, in response to an exogenous monetary policy shock. The second paper, "The Effects of Adjustable Rate Mortgages on House Price Inflation," deals with house prices and the mortgage market. At the peak of the housing boom, adjustable rate mortgages represented more than two thirds of the subprime market and more than 20% of the overall mortgage market. The focus of this paper is therefore to study what determines adjustable rate mortgages and to address the possibility of a feedback effect between house prices and adjustable rate mortgages. The results are consistent with earlier finding on the importance of the spread between fixed rate and adjustable rate mortgages as the key determinant of the share of adjustable rate mortgages in the mortgage market. The assertion of the potential for a simultaneous relationship between house prices and adjustable rate mortgages is a plausible one. The third essay "Structural time series models of regional income and house prices," studies regional house prices, and regional income and the relationships between them. The use of unobserved components model gives us the tools to study unobserved factors affecting the relationship between house prices and income that is not often considered in traditional regressions. It also gives policy makers additional useful information to consider when making decisions. Results indicate no cointegrating relationships exist in regional income and regional house prices. Results also indicate that housing is an important determinant of fluctuations in regional income.

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1. INTRODUCTION

This dissertation is comprised of three papers dealing with issues regarding the housing market. The first paper deals with the issue of housing and monetary policy. Vector auto regressions are used for each state to determine the differential effects of an exogenous monetary policy shock on house prices and housing starts. The second paper examines the influence of adjustable rate mortgages on house price inflation and the possibility that a feedback relationship exists between housing and mortgage rates. The third paper uses unobserved components models to investigate regional house prices, regional income and the relationships between the two.

The first paper is entitled "The Effects of Monetary Policy on Housing Using State Level Data." An implicit assumption in the literature on the effects of monetary policy on economic activity is that it is the same across all 50 states. This paper uses structural vector autoregressive methods to examine whether the effects of monetary policy on housing market activity is the same across the 48 contiguous states. I use data for the period 1988:1-2010:4. Results from the impulse response functions indicate that there are differences in response to policy actions, with some of the responses being quite substantial. In addition, housing starts tend to be more sensitive to policy shocks compared to house prices. A closer look at four states with different housing market dynamics validates the general results. The results also indicate that monetary policy's influence on the fluctuations in housing market activity can be as high as 20%. The results are also robust to an alternative ordering of the variables in the model.

The second paper, "The Effects of Adjustable Rate Mortgages on House Price Inflation," examines two important issues regarding house prices and mortgage market activity. First given recent activity in the market regarding adjustable rate mortgages, we study the determinants of such mortgages. Our second objective is with regards to a potential simultaneity between house prices and adjustable rate mortgages. If house prices are expected to appreciate, then lenders are less concerned about defaults and may make available more funds to a large extent in the form of ARMs and to lower quality borrowers, for financing the purchase of a house. We investigate this potential feedback relationship using a dynamic panel model for the 48 contiguous states over the years 1986-2010. Fixed effects estimates on the determinants of the share of adjustable rate mortgages are consistent with earlier findings on the importance of the spread, between fixed rate and adjustable rate mortgages. We also find evidence of a possible feedback relationship between house prices and adjustable rate mortgages.

The main focus of the third paper is to analyze the dynamics of income and house prices and the relationships between them. Unobserved components (UC) models are used to identify common trends and common cycles for time series data on the four census regions of the US: Northeast, Midwest, South, and West. The UC models are multivariate decompositions of income and house prices into components of trend, cycle and irregular. Results indicate that trend and cycle movements in income and house prices at the regional level, although highly correlated, cannot be represented with variance disturbance matrices of less than full rank. Results also indicate strong regional relationships in the trends and cycles of income and house prices. However the relationship across the income series is stronger compared to the house price series.

2. THE EFFECTS OF MONETARY POLICY ON HOUSING USING STATE LEVEL DATA

This paper presents an empirical analysis of the impact of exogenous monetary policy actions on housing market activity using state level data. The expectation that states will respond differently to national policy actions is a plausible one, given the inherent heterogeneity in state economies. According to Hwang and Quigley (2006), housing is a local good and, therefore, fluctuations in housing market activity will reflect the economic conditions existing in the state at the time of the policy change. However, research on the extent to which there are differences in reaction to policy changes among the states is limited. In addition, interrelationships in housing activity among states and among regions have also not been explored.

The existing research is primarily concerned with the use of national level data series and, does not account for any relationships that may exist between states and regions. Nonetheless, Krzygusky and Triest (2010) believe that state level analysis could provide policy makers with additional information to use when making forecasts of the macro economy. They show that aggregating house price forecasts from state level forecasts is more effective at predicting house price fluctuations at the national level. They also argue that had policy makers considered such state level analysis, the housing bubble and the subsequent decline experienced recently could have been predicted.

The limited amount of research at the state level has either examined a group of cities (Case and Mayer, 1996; Ghent and Owyang, 2009), or a group of metropolitan statistical areas (MSA) across US states (Francis, Owyang, and Sekhposyan, 2009; Hwang and Quigley, 2006). A few studies have focused on states within a specific region (Kuethe and Pede 2009). There appears to be no comprehensive study that examines the effects of monetary policy shocks on housing market activity using data from all 48 contiguous states. The analysis in this paper adds to the literature by analyzing the effects of national monetary policy on housing activity in each of the 48 states. The analysis also looks at how monetary policy influences the interrelationships between states and regions.

I use structural vector autoregressions (SVAR's) to study how monetary policy affects house prices and housing starts in the 48 contiguous states. The SVAR's are estimated for the period 1988:1 to 2010:4. Results from the impulse response functions show that in general house prices and housing starts decline following a positive shock to the federal funds rate. The maximum decline occurs within 15 quarters after the shock in the case of house prices and 12 quarters in the case of housing starts. There is clear evidence of wide ranging differences in response among the states. For house prices, the negative responses in Florida and Indiana are the largest (1.59% decline) and smallest (0%) respectively. Housing starts tend to be more sensitive to a federal funds increase, with the maximum decline of 4.12% in Florida. The average response for all states is a decrease of 0.41% for house prices and 2.10% for housing starts. To gauge the significance of monetary shocks on housing activity, I run counter factual simulations. Results from the simulation exercise indicate that monetary policy has a major role to play in the fluctuations of house prices and housing starts in some states, but much less in other states. The results are robust to an alternative identification scheme and to an alternative instrument of monetary policy.

2.1 Literature Review

Some in the literature have focused their research on the effects of monetary policy on economic activity, both at the national and sub-national levels (Christiano, Eichenbaum, and Evans, 1998; Uhlig, 2005; Carlino and DeFina, 1998, 1999). The common finding is that monetary policy does play a role in the business cycles although, in most cases, the effects are small. At the regional level, the results indicate a differential effect of monetary policy with the Great Lakes and the Southwest, the most and least sensitive, respectively, to monetary policy changes. The literature on housing and monetary policy is predominantly at the national level. The typical study uses the SVAR approach with several variables representing housing activity. The main issue addressed is how exogenous monetary policy actions affect housing market activity. Jarocinski and Smets (2008) use Bayesian VAR's to study the effect of a federal funds rate shock on the Office of Federal Housing Oversight (OFHEO) house price index and on housing investment. They find that both housing investment and house prices decline, with housing investment being more sensitive to the shock. Vargas-Silva (2009) arrives at similar conclusions. His use of the sign restrictions methodology reveal that the negative impact of policy actions increases the longer the restrictions are in place. Lastrapes (2001) on the other hand, studies existing home sales and sales of new homes. He finds that a shock to monetary policy raises sales of both types of housing. Prices also rise, with the rise in the price of new homes more than the median price of existing homes.

Baffoe-Bonnie (1998) compares the national and regional responses in housing to a money supply shock. He finds that house prices fall while the number of houses sold rises at the national level. Regional responses vary, with the Northeast and the Southern regions mirroring the response at the national level. Fratanoni and Schuh (2003) conclude that timing and regional economic conditions are important determinants of the extent to which monetary policy changes affect housing at the regional level. Del Negro and Otrok (2007) use a combination of factor analysis and VAR's to investigate the importance of national, regional, and state level factors on the dynamics of housing activity. They find that housing is primarily driven by regional and state level factors, although national factors have gained some significance in the recent boom and bust cycle of the housing market.

Vansteenkiste (2007) investigate how house price shocks in California, New York, and Texas affect house prices in other states. The three states are chosen because of geography and because they represent housing market characteristics that are distinguishable from each other. Thirty one states are included in the study. The results indicate geographic proximity determines the magnitude of the interrelationships in housing between the states. The states that are closest to California, New York, and Texas see higher house price changes than states farther away.

2.2 Methodology

Structural vector autoregressions SVAR's are used to model housing market dynamics in the 48 contiguous states. SVAR's are useful for analyzing policy actions because they make use of the interactions among all the variables in the model and they allow us to isolate the response to specific shocks when the variables that are considered are all likely to be endogenous. For each of the 48 states, I examine a (10x1) vector of variables

$$F_{i,t} = \left(y_t, p_t, f_t, m_t, h_{i,t}, x_{i,t}, x_{r1,t}, x_{r2,t}, x_{r3,t}, x_{r4,t}\right)',$$

where i indicates the ith state, t, indicates time, and r indicates the census regions. The first three variables, per capita personal income *y*, the overall price level *p*, and the federal funds rate *f* are standard in monetary policy VAR models.[1] (example Peersman 2005, Christiano et al. 1996, Schorfheide and Del Negro 2003); *m* stands for mortgage interest rates; *h* stands for state level housing starts and the *x*'s are state and regional house prices.

The SVAR model is represented as

$$AF_{i,t} = B(L)F_{i,t-1} + u_{i,t}, \tag{1}$$

with $u_{i,t} \sim N(0, D)$,

where A is a (10×10) matrix of coefficients that represent the contemporaneous relationships among the variables; *B(L)* is a (10×10) matrix of coefficients representing the relationships among the variables after a time lag; and $u_{i,t} = \left[u_{1t}, u_{2t}, \ldots, u_{10t}\right]'$ are the state level structural shocks. The structural shocks are assumed to be exogenous, uncorrelated, and to have a diagonal covariance matrix D. The assumption that the covariance matrix is diagonal allows one to interpret specific shocks, such as monetary policy shocks, the main interest of this paper.

[1] I use state level per capita personal income in place of gross state product because data on state GDP is available only from 1997.

Bernanke and Mihov (1996) point out two ways in which a monetary policy shock can occur: through measurement error and through a change in the preferences of policy makers. Measurement error can occur in the sense that the data are incomplete or the data may need further revision. Policy makers may then have to revise earlier decisions to reflect actual economic conditions once the final data are known. In the SVAR setting, the difference between the revised policy action and the earlier action is regarded as a monetary policy shock. Preferences of committee members can change at random. Members can choose at any time to emphasize inflation targeting or output stabilization, the two main functions of the monetary authority. As a result the decision making process has a random component that can be interpreted as a shock (Gottschalk, 2001).

2.2.1 Identification

In standard or reduced form, the model is represented as:

$$F_{i,t} = C(L)F_{i,t-1} + \varepsilon_{i,t}, \tag{2}$$

where $C(L) = A^{-1}B(L)$ is a polynomial in lag form and $\varepsilon_{i,t} = A^{-1}u_{i,t}$ is a relationship between the structural errors and the reduced form errors.

The SVAR model is estimated equation by equation using ordinary least squares (OLS) to obtain reduced form estimates for *B(L), A* and $\varepsilon_{i,t} = A^{-1}u_{i,t}$. The reduced form estimates are not unique because they do not allow one to recover or identify all the structural parameters of the structural model. Enough restrictions are therefore needed for the model to be identified. Restrictions on the variance-covariance matrix of the structural residuals (u_t) and on the structural parameters (the *A* matrix) will provide enough identifying restrictions for the model to be just identified. Restrictions on the structural shocks are that 1) the variance-covariance matrix of the structural residuals is a diagonal matrix and 2) the structural shocks have unit variance.

The restrictions we impose on the A matrix follow a block recursive system as introduced by Sims (1980). The variables are partitioned into three blocks as follows:

$$F_{i,1t} = \{y_t, p_t\},$$

$$S_t = \{f_t\},$$

$$F_{i,2t} = \{m_t, h_{i,t}, x_{i,t}, x_{r1,t}, x_{r2,t}, x_{r3,t}, x_{r4,t}\}.$$

S_t represents the instrument of monetary policy. Variables in $F_{i,1t}$ are restricted in the sense that they are not affected by contemporaneous shocks from the policy instrument S_t. They react only with a lag because the variables in $F_{i,1t}$ are assumed to be determined in advance. However, shocks from variables in $F_{i,1t}$ have contemporaneous effects on S_t and on the variables in $F_{i,2t}$. Shocks from S_t affect variables in $F_{i,2t}$ contemporaneously, but shocks from $F_{i,2t}$ affects S_t and $F_{i,1t}$ with a lag. Ordering the variables as outlined is consistent with the assumption that monetary policy responds to overall economic conditions rather than to specific sectors of the economy (Christiano, Eichenbaum, and Evans, 1998).

2.2.2 Impulse Response Functions

The impact of shocks is best analyzed with impulse response functions. Using the errors obtained from the monetary policy instrument (federal funds rate), impulse responses can be calculated to describe the impact of exogenous monetary policy shocks on housing market activity. Given that enough restrictions have been placed on the structural parameters to identify the model, the impulse response functions can be calculated. Rewriting (2) in terms of a vector moving average process, and using the structural residuals, we get

$$F_{i,t} = D(L)u_{i,t} = D_0 u_t + D_1 u_{t-1} + \dots, \qquad (3)$$

where $D(L) - \left[I - C(L)\right]^{-1} A^{-1}$ are the structural parameters and $\frac{\partial F_{i,t}}{\partial u_{i,t-k}} = D_k$ is the impulse response functions.

2.3 Data

The analysis uses state, regional, and national variables in the model. The state level variables are per capita personal income *y*, house price index *x*, and housing starts *h*. The two housing variables are the variables of interest. Per capita personal income is included to control for the economic conditions in the state. Regional house price indices for the four census regions are included to account for the interrelationships that have been found to exist between states and regions. For example Fu (2006) finds that up to 45% of the variation in house prices in a Metropolitan Statistical Area (MSA) are due to regional factors. The GDP deflator *p*, the federal funds rate *f* and the 30-year conventional mortgage interest rate *m* are the national variables. These are included to control for the influences that national economic conditions may have on the individual states. The GDP deflator is the overall level of prices in the economy and the 30-year conventional mortgage rate represents the cost of financing a house purchase in the U.S. The federal funds rate is the monetary policy instrument. Overall there are 10 variables in the model.

Data on state level house price index are obtained from the Federal Housing Finance Agency (FHFA), previously known as the Office of Federal Housing Enterprise Oversight (OFHEO). House prices from mortgages purchased or securitized by government sponsored agencies Fannie Mae and Freddie Mac are used to compute the index. The index is a weighted repeat sales index. It measures the average price change from repeat sales of single family dwellings in the metropolitan areas of each of the 50 states and the District of Columbia. The data are available on a quarterly basis; they begin in the first quarter of 1975 and end in the fourth quarter of 2010. 1980 is the base year for computing the average. Calhoun (1996) provides an in-depth description of the construction of the OFHEO house price index.

Data on housing starts are obtained from the Census Bureau. The series measure the number of privately owned single family housing units started each month. The data are recorded monthly but are converted to a quarterly frequency for the analysis. Per capita personal income is obtained from the Bureau of Economic Analysis (BEA). The GDP deflator, the 30-year conventional mortgage interest rate, and the federal funds rate are obtained from the Federal Reserve Economic database. Table 1 provides further information on the data.

The model is estimated for the period 1988:1 to 2010:4. For each state I use the AIC recommended lag length of 2. The variables are in levels. Each one is transformed into logs, with the exception of the mortgage interest rate and the federal funds rate.

2.4 Results

2.4.1 House Prices

Figures 1 and 2 respectively, show the impulse responses of house prices and housing starts in each state to a one standard deviation increase in the federal funds rate. States are grouped by census regions. For comparison I also include a weighted average of state responses denoted US in each regional grouping. The responses of the macro variables in each state are relatively consistent with the prevailing wisdom in the monetary policy SVAR literature. That is, the federal funds rate and the mortgage interest rates rise immediately as a result of a contractionary monetary policy shock. Personal income and overall prices fall slightly following a delay.

With regards to the average response, house prices initially declines, then rises following a monetary policy shock as shown in Figure 1. This is followed by a sustained decline in house price for about 10 quarters. The maximum decline of 0.41% occurs on average 15 quarters after the initial shock. This pattern of response is somewhat in line with studies using national data. For example in Jarocinski and Smets (2008) and Iacoviello and Neri (2007), house prices fall a maximum of 0.75%. However the maximum decline occurs within 8 to 10 quarters after the shock.

There is clear evidence of variation in response among the states-and even among states in the same region. In many states, the responses follow a pattern similar to that of the average response. However for some states, specifically in the West and Midwest, the initial response consists of a rise in house prices lasting around 4 quarters. Over time, variation in response widens among states, both within and across regions, but house prices begins to recover after 16 quarters. In many states, prices are at levels higher than they were prior to the policy action within 4 quarters after reaching a low. In other states they remain at levels lower than they were prior to the policy shock for much longer although they continue to rise.

Among the states, the largest three responses to an exogenous monetary policy shock occur in Florida (1.59%), California (1.43%), and Arizona (1.05%). Eight other states New Jersey, New York, Nevada, Oregon, Rhode Island, Utah, Washington, and Wisconsin have higher responses than the average national response. The two least responsive states are West Virginia and Indiana, each responding less than 1% of the national average. Among all states the difference between the maximum response (Florida) and the minimum response (Indiana) is 1.58%.

Regional differences are also evident from the impulse responses. Regional responses are based on the average of constituent state responses. The average responses of the regions from most responsive to least responsive are the West (1.02%), Northeast (0.39%), South (0.29 %) and the Midwest (0.13%). These results contrast with Baffoe-Bonnie (1998), whose results indicate that the West and Northeast are the least sensitive to a monetary policy shock. However his data set runs from 1977:1 through 1991:4 and, therefore, may not reflect the current dynamics in the housing market.

2.4.2 Housing Starts

For the national average, housing starts rise on impact, but falls within 3 quarters following a monetary policy shock. The maximum fall in housing starts on average is 1.32% and it occurs 12 quarters after the initial shock. State responses show considerable variation and dispersion from the average response. This wide dispersion in response is maintained throughout the period of observation, especially in the South and in the West, where the variation is largest.

Florida is the most responsive state to a monetary policy shock, with housing starts falling 4.12% in 11 quarters after the shock. Housing starts in eight of the 11 states in the Western region fall by at least 1 percentage point. Housing starts in Texas and West Virginia are the least responsive to an exogenous policy shock. In fact they are already rising again at the time the national average response reaches its maximum decline. Housing starts in the Northeast and Midwest regions are the least responsive to a policy action.

Comparing the state responses of housing starts to house prices, it is clear that housing starts tend to be more sensitive to a federal funds rate increase. For example, in Florida, the maximum decline of 4.12% in housing starts is more than twice the maximum fall of 1.59% in house prices. Interest rate fluctuations therefore tend to influence housing starts more so than house prices. A plausible explanation could be that a rise in interest rates raises unavoidable user costs of construction, making it more expensive for builders to undertake new construction projects. Individuals also face higher costs to take out loans as interest rates rise. However, some of these costs can be mitigated through various programs available to individuals, such as adjustable rate mortgages, down payment assistance for first time home buyers, and federal and state tax credits for interest payments.

2.4.3 Variance Decompositions

The significance of a federal funds rate shock on housing activity can be determined by looking at the variance decompositions obtained from the forecast errors of the variables in the model. Variance decompositions show for each variable the proportion of its variance that is due to its own shocks and to shocks from the other variables in the model. In Figure 3, I show for each state the percentage of its variance in house prices and housing starts that is due to a federal funds rate shock at horizon 24. States are grouped by census regions.

As indicated in the bar graphs, the importance of monetary policy on housing market activity varies by state and by region. For house prices and housing starts, Florida is the state that is most influenced by monetary policy. Twenty one percent of the fluctuations in house prices in Florida are due to changes in the federal funds rate. It is 18% for housing starts. This supports earlier results from the impulse response analysis which showed that Florida is the most responsive to a federal funds rate increase. The results are also true for house prices in West Virginia and Indiana, the two states that are the least responsive of the 48 states with 2% and 2.2%, respectively, of their variance due to monetary policy. For housing starts, Arkansas in the South and Minnesota in the Midwest are the least influenced by monetary policy actions. On average the importance of monetary policy on house prices in the 48 states is less than 10%. Four states, Florida, California, Oregon, and Wisconsin have rates higher than 10%. These results support the notion that economic conditions at the state level play a role in the determination of the level of housing activity in each state.

2.4.4 A Closer Look at Four States

In general, the results reveal that there are state and regional differences in the response to a monetary policy shock. Also the effect is stronger for housing starts than for house prices. The analysis that follows looks at four states-New York, Michigan, Texas, and California. I chose these states because they each represent one of the four regions and because the housing market dynamics are different in each of these states. Vansteenkiste (2007) also discuss the different dynamics in California, Texas, and New York. California in region 4, for example, saw prices rise at least 10% on average during the bubble, and saw significant price declines during the eventual bust. Texas in region 3, on the other hand, did not participate in the bubble (Rick Timiraos, 2009), but maintained a 2% appreciation in house prices throughout the housing bubble. For Michigan in region 2, house prices fell slightly even during the housing bubble, and New York maintained higher prices during and after the housing bubble. Figure 4 shows the impulse responses for each of these states.

As shown in Figure 4a, following an increase in the federal funds rate, housing starts in New York initially rises by 1%, but begins to fall in the second quarter. Eventually housing starts fall 0.55% before beginning to rise again. House prices fall on impact and continue to fall for about 17 quarters before beginning to rise. Notice that the response of house prices in New York is typical of the response of the other states in region 1, of which New York is a part of, an indication that house prices in New York may influence house prices in the other states in the region.

In Figure 4b for Michigan, housing starts rise immediately and stay at levels higher than they are prior to the shock, for 6 quarters. Housing starts then fall, reaching a maximum decline of 1.8% 11 quarters after the shock. The maximum increase of 0.29% occurs 7 quarters after the shock. With the exception of a slight decline in house prices in region 2 initially, the pattern of response in region 2 is similar to the response in Michigan, although they differ slightly in terms of magnitude.

Figure 4c show the response for Texas. The immediate rise in housing starts continues for only 2 quarters and is followed by a sharp decline of more than 1% in the third quarter. The maximum decline of 1.24% occurs 8 quarters after the shock. House prices in Texas react very little to a monetary policy shock. The immediate fall of 0.13% is the largest decline in house prices. The response pattern in Texas is not typical of the response from the other states in region 3. Although the maximum decline is only 0.25%, house prices in region 3 remain lower for more than 4 years after the shock.

Housing starts in California as shown in Figure 4d rise immediately and remain positive for three quarters, then declines to a low of 1.99% in ten quarters. There are no movement in house prices for three quarters. House prices than fall gradually to a low of 1.43% in quarter 10 and then slowly rises. The response in California is typical of the response of the other states in region 4.

2.4.5 Variance Decompositions

In Figure 5, I show for each state at various time horizons the relative significance of the contribution of a monetary shock to housing starts and house prices.

In New York, monetary shocks explains very little of the variation in housing starts, accounting for less than 1% of the forecast error variance on impact and less than 3% at longer horizons. The influences of monetary shocks on house prices gradually rise to about 6% at longer horizons.

At longer time horizons the influence of monetary shocks on housing starts in Michigan is about 5%. For house prices, the influence rise to 4% at longer horizons. The importance of monetary shocks for house prices in Texas is about 6% on impact, and then decreases over time. At longer horizons, it increases again to about 7%. Monetary shocks account for a large portion of house price variation in California especially at longer horizons-13.9% at the 4 year horizon. For housing starts the influence of monetary shocks is about 5% at long horizons.

Given that housing activity is affected by other shocks such as own shocks, income and mortgage interest rates, these results on the influence of monetary policy appear reasonable.

2.4.6 Historical Decompositions

The SVAR methodology allows one to examine the quantitative significance of the structural shocks by looking at the historical decompositions of the model. In this procedure, contributions from all the innovations in the model are added to a base forecast to reconstruct the actual data. Excluding one or more of these innovations helps determine the relative contribution of the variable or variables in question. In Figure 6, the observed data for house prices and housing starts in New York, Michigan, Texas, and California is reconstructed by adding innovations from all the variables in the model to the base forecast. The solid line adds all innovations and the dotted line sets monetary innovations equal to zero.

Monetary shocks contribute very little to the determination of house prices in Texas. As shown in Figure 6, there is very little difference between the actual and counterfactual house price data. To verify this, recall from the impulse response functions that the maximum house price decline in Texas is 0.13% and that just 6% of house price variations are due to monetary shocks on impact and about 7% at long horizons. These results remain consistent even during the housing bubble (2001-2005). Shocks from the other variables explain a considerable portion of house price changes in Texas. The results for Michigan indicate that monetary shocks played a substantial role in determining house prices during the housing bubble. The counterfactual house price index in 2005 for example is about 85 points higher than the actual house price index. In New York and California the differences are even more substantial during the bubble. These results lend credence to the assertion by Taylor (2007) that in monetary easing facilitated the housing bubble.

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Monetary shocks contribute very little to the determination of house prices in Texas. As shown in Figure 6, there is very little difference between the actual and counterfactual house price data. To verify this, recall from the impulse response functions that the maximum house price decline in Texas is 0.13% and that just 6% of house price variations are due to monetary shocks on impact and about 7% at long horizons. These results remain consistent even during the housing bubble (2001-2005). Shocks from the other variables explain a considerable portion of house price changes in Texas. The results for Michigan indicate that monetary shocks played a substantial role in determining house prices during the housing bubble. The counterfactual house price index in 2005 for example is about 85 points higher than the actual house price index. In New York and California the differences are even more substantial during the bubble. These results lend credence to the assertion by Taylor (2007) that in monetary easing facilitated the housing bubble.

2.4.8 Robustness of Impulse Responses

According to McCarthy and Peach (2002), the housing finance system in the US has changed considerably from one that was heavily regulated to one that is now relatively unregulated. In light of these changes, the volatility in the housing market has been greatly reduced. Given these developments, they question whether the transmission of monetary policy might also have changed. They find that while the magnitude of the response remained the same, the timing of the response has changed. Response is delayed, similar to the reaction of the overall economy. This question the identification scheme used in this paper, which assumes that housing reacts contemporaneously to a monetary policy shock. As a robustness check, I reorder the variables to reflect the conclusions in McCarthy and Peach (2002). That is the housing variables are ordered so that the housing variables react with a lag following a monetary policy shock. I do so for California, Michigan, New York, and Texas. For space considerations, the results of this exercise are not shown but are available upon request. In all four cases, the results are identical to the results of the first ordering scheme.

2.5 Conclusion

Many previous studies on the influence of monetary policy have focused more attention on the use of national data for analysis. The view of this paper however, is that because states are fundamentally different, it makes sense to study the implications of policy on states individually. Using the SVAR methodology, this paper analyzed how monetary policy shocks affects housing starts and house prices at the state level. Monetary policy shocks are identified with the use of contemporaneous restrictions. The effects of these policy shocks are then analyzed using impulse response functions.

Results from the impulse response functions indicate that for house prices, Florida is the state most affected by an exogenous monetary policy shock, with house prices declining 1.59%; and Indiana is the least affected at 0.01%. In general, house prices fall following an increase in the federal funds rate. It takes on average 15 quarters for the maximum decline to occur. For housing starts Florida is again the most affected by an unanticipated monetary policy shock; housing starts, decline more than 4% within 12 quarters. Housing starts tend to be more sensitive to monetary policy shocks compared to house prices.

The evidence is mixed on how significant monetary policy is in impacting housing market activity. For some states like California and New York, monetary policy influences housing activity at a substantial rate, but in others, such as Texas, the influence is much less or not significant.

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Table 1. Definitions and Sources of Variables

Variables	Series Name	Source	Comments
y_i	State per capita personal income	BEA	
p_t	GDP Deflator	BEA	Quarterly, seasonally adjusted
f_t	Federal funds rate	FRED	Monthly, converted to quarterly frequency
m_t	Mortgage interest rate	FRED	Monthly, converted to quarterly frequency
h_i	State housing starts	FRED	Monthly, converted to quarterly frequency
x_i	State house price index	FHFA	Quarterly, 1980=base year
x_{r1}	House price index region 1	FHFA	Computed as a weighted average of the house price index of the states in region 1
x_{r2}	House price index region 2		Computed as a weighted average of the house price index of the states in region 2
x_{r3}	House price index region 3		Computed as a weighted average of the house price index of the states in region 3
x_{r4}	House price index region 4		Computed as a weighted average of the house price index of the states in region 4

Notes: BEA is the Bureau of Economic Analysis, FRED is the Federal Reserve Economic Database, FHFA is Federal Housing Finance Agency, * variables are in logs.

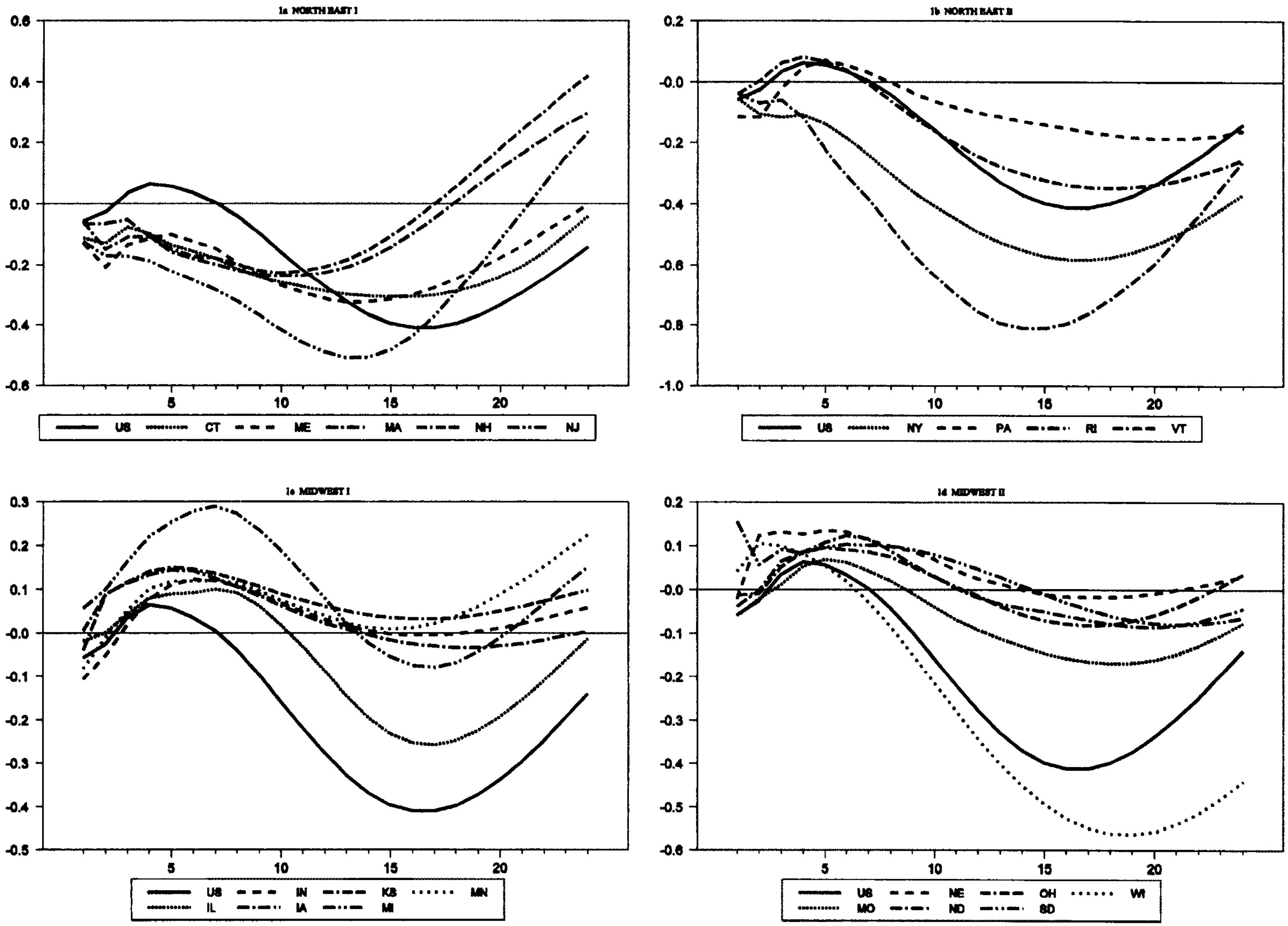


Figure 1: Impulse Response of House Prices to Federal Funds Rate Shock,Grouped by Census Region.

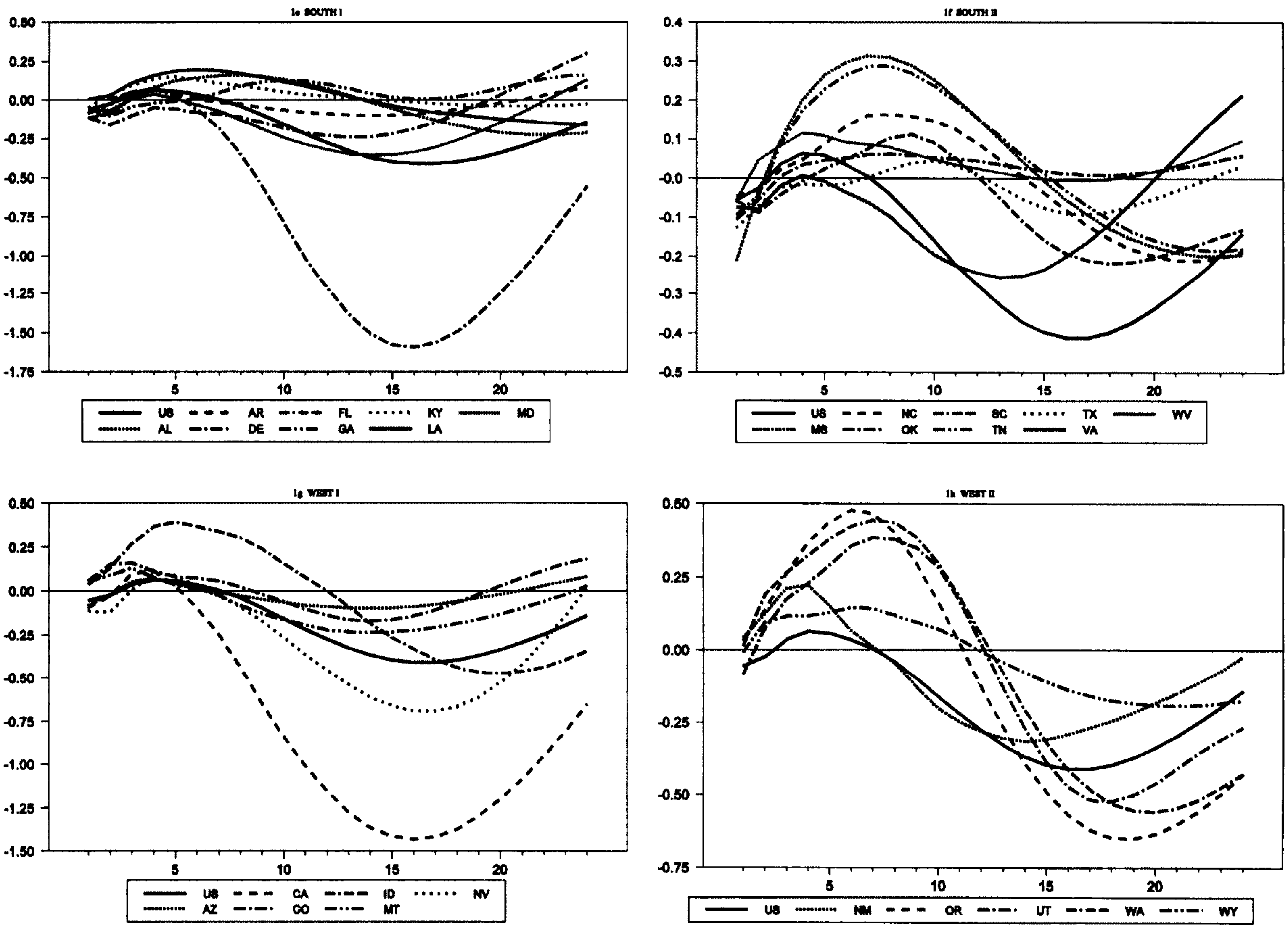


Figure 1: Continued.

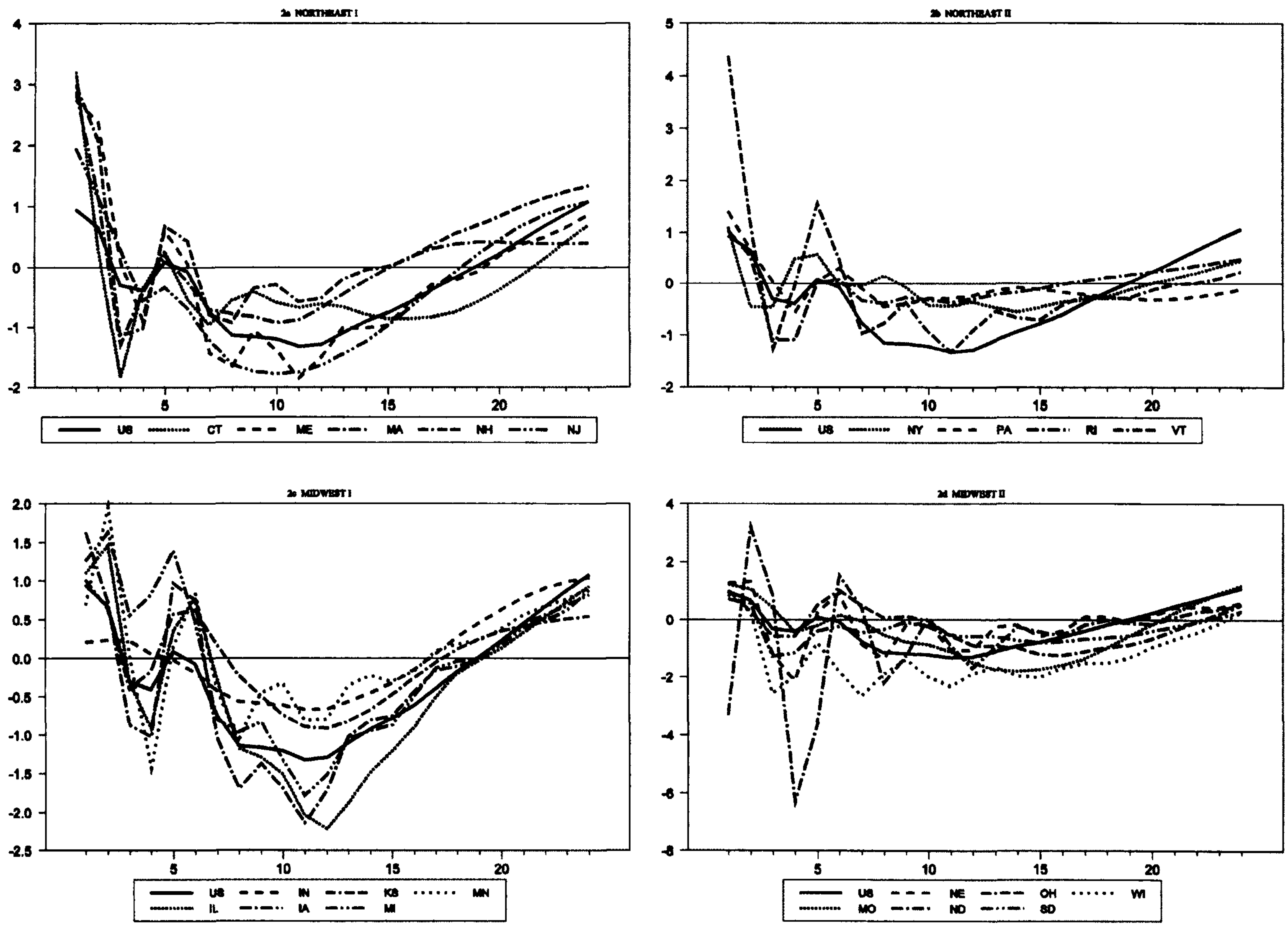
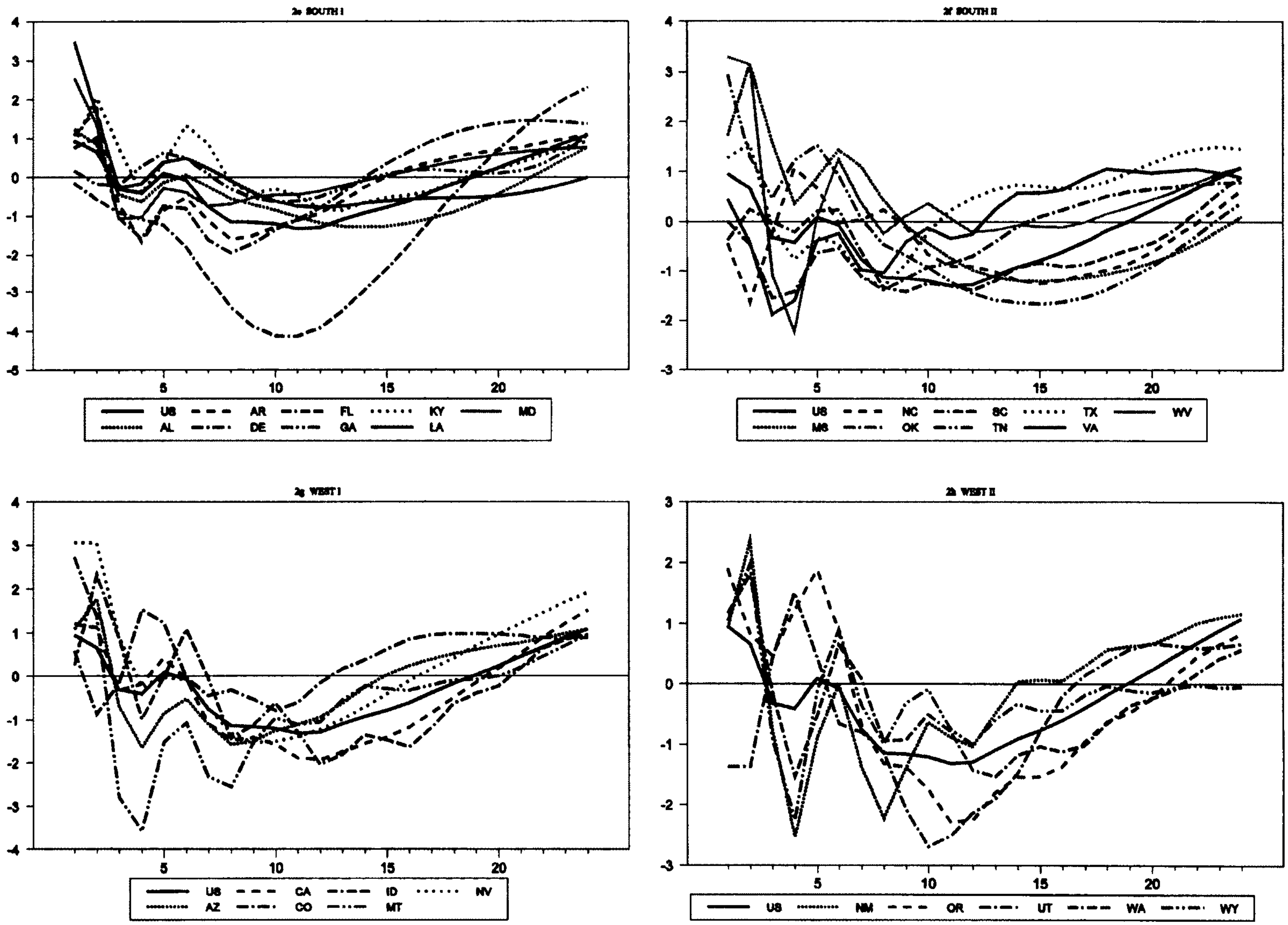


Figure 2: Impulse Response of Housing Starts to a Federal Funds Rate Shock,Grouped by Census Region.



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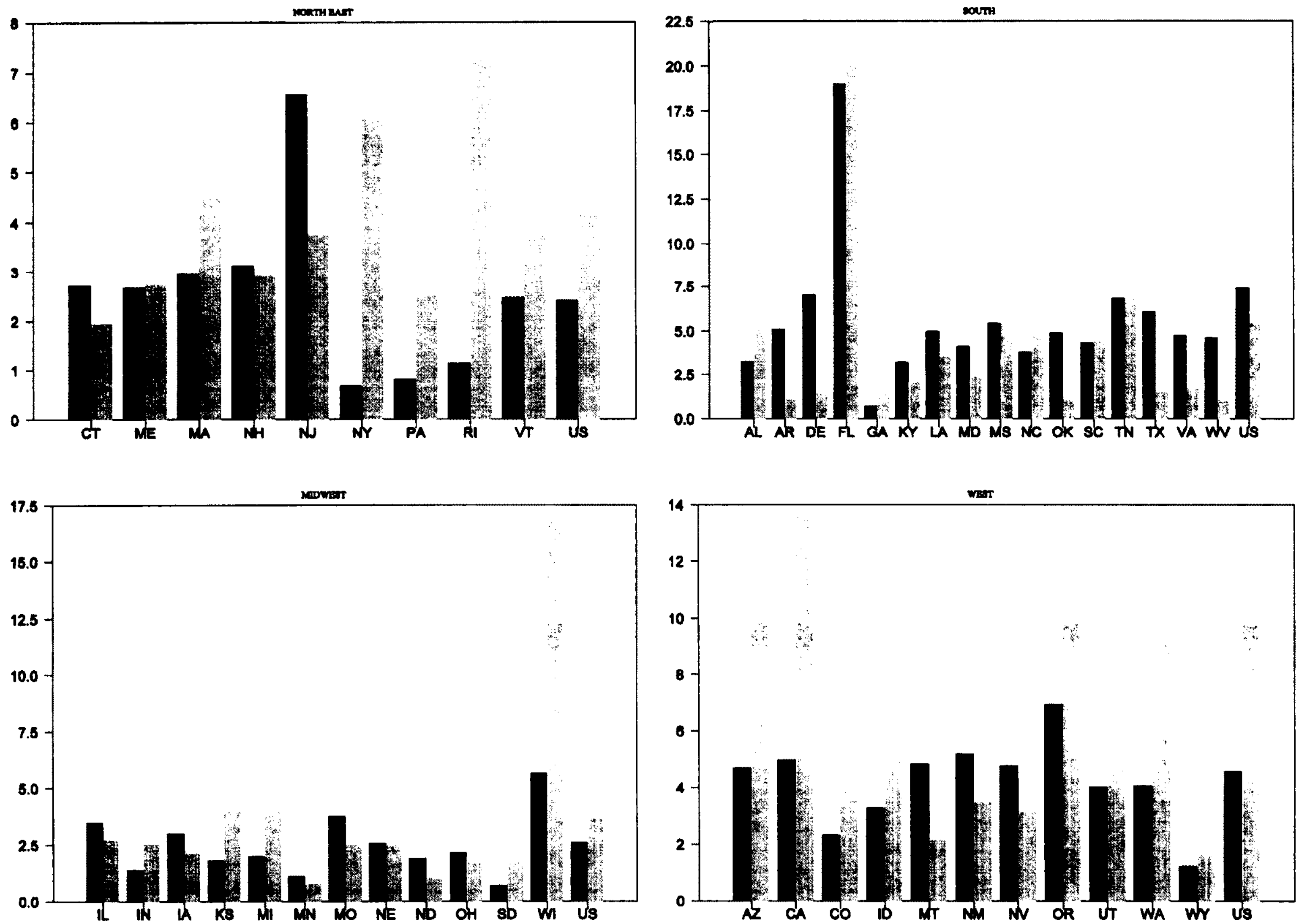

Figure 3. The bars represent the percent of variance due to the federal funds rate. The dark bars represent housing starts, the light bars, house price index

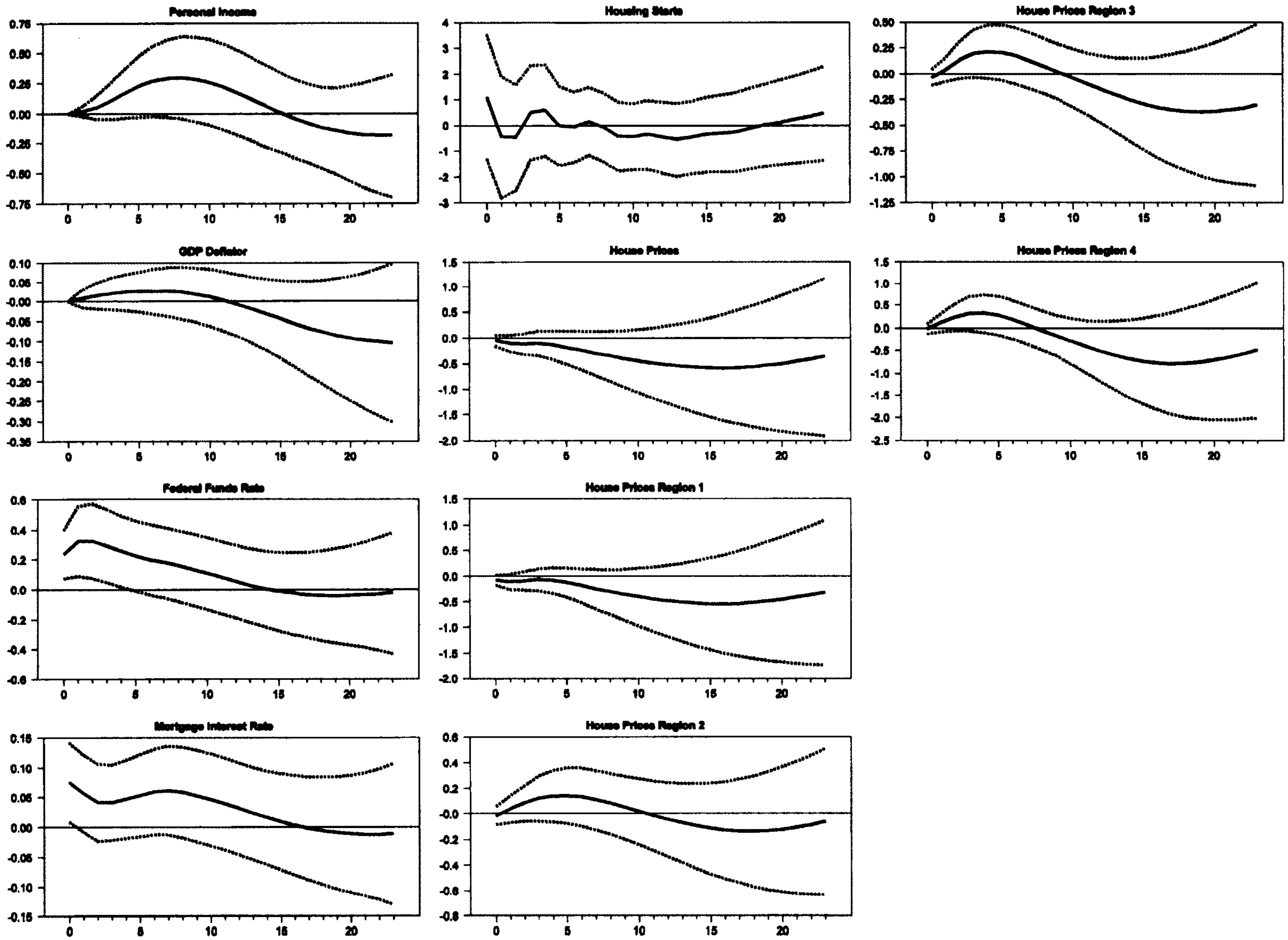

Figure 4a: Impulse Response of New York to a Federal Funds Rate Shock

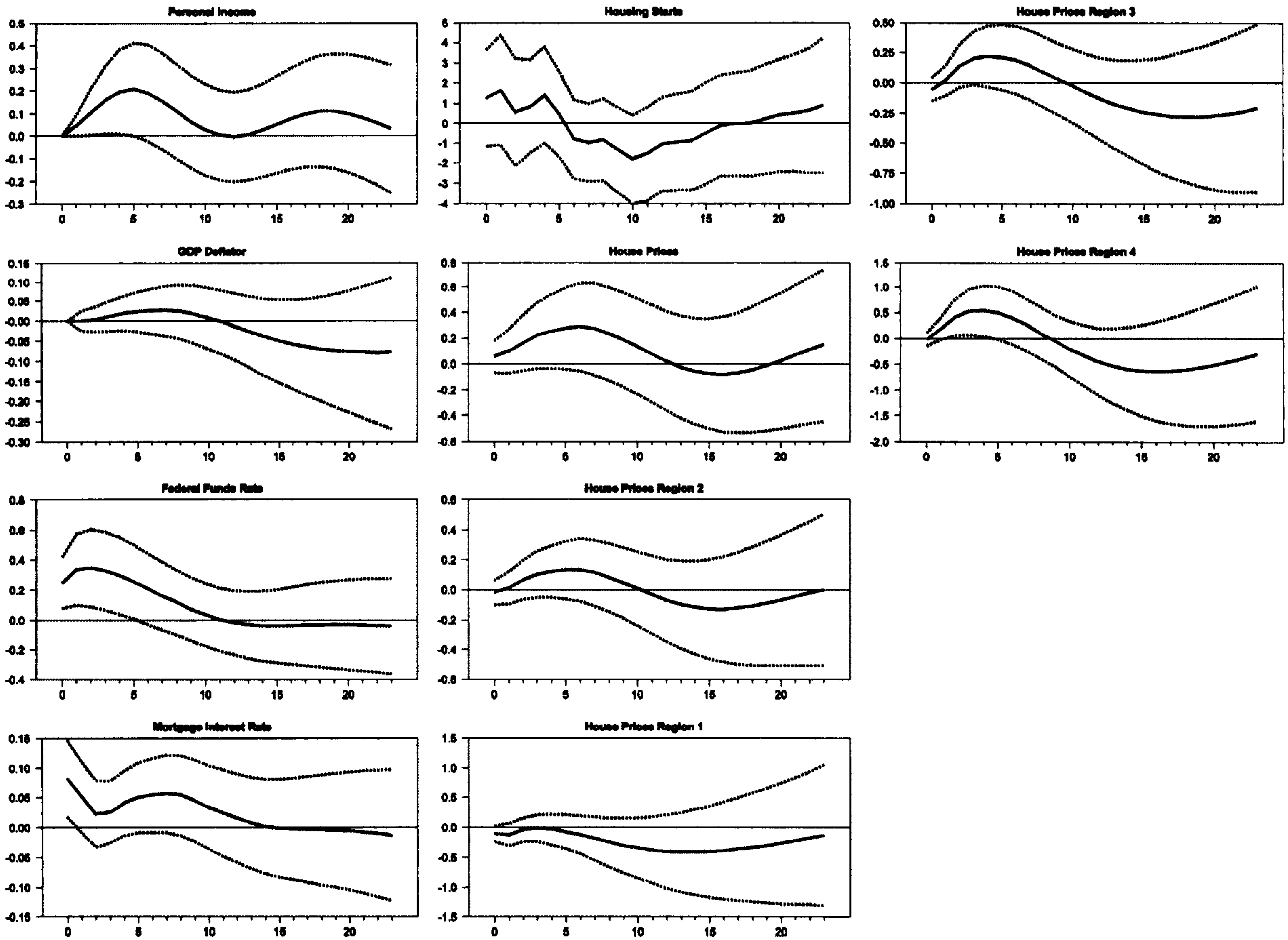

Figure 4b: Impulse Response of Michigan to a Federal Funds Rate Shock

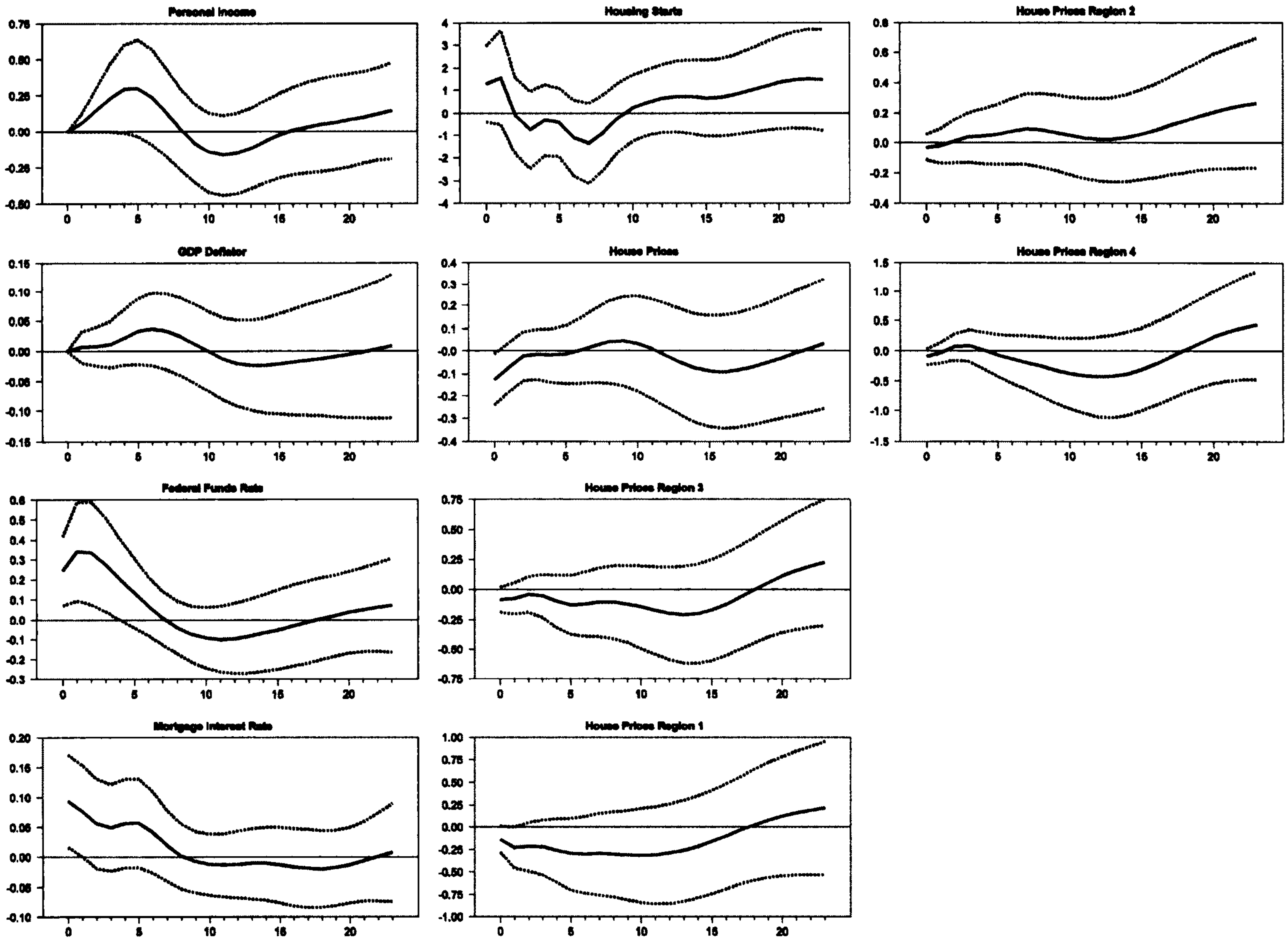

Figure 4c: Impulse Response of Texas to a Federal Funds Rate Shock

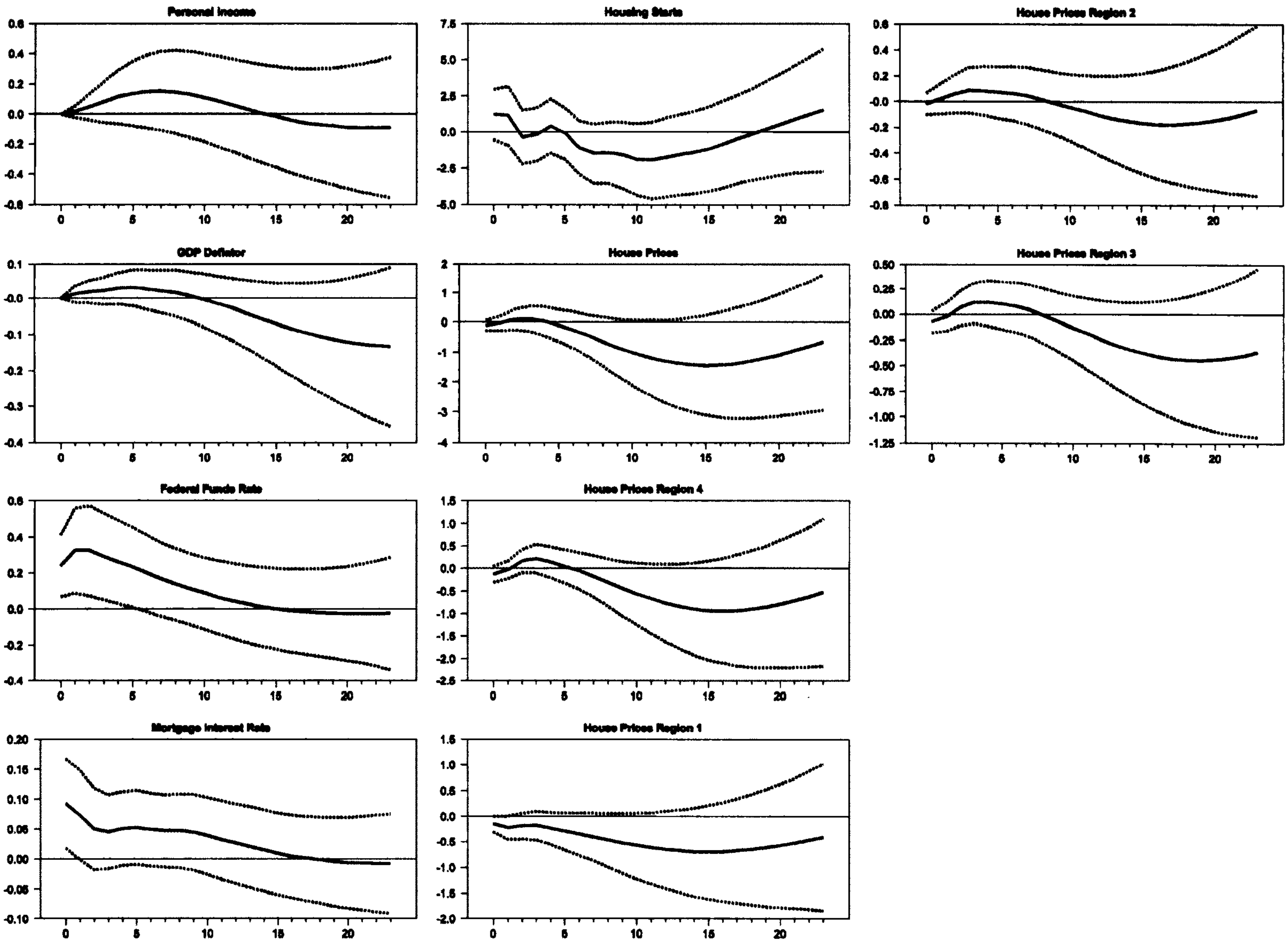

Figure 4d: Impulse Response of California to a Federal Funds Rate Shock

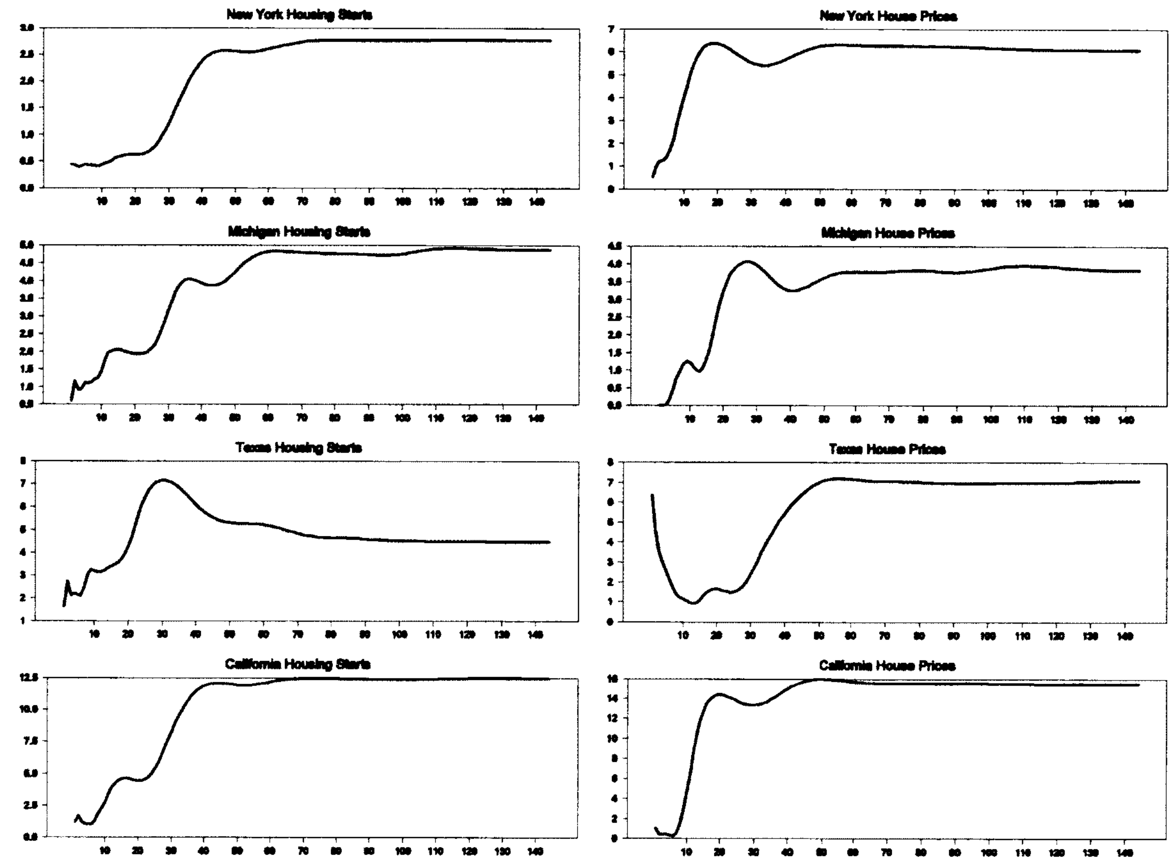

Figure 5: Contribution of Federal Funds Rate Shocks to the variance in Housing Starts and House Prices.

3. THE EFFECTS OF ADJUSTABLE RATE MORTGAGES ON HOUSE PRICE INFLATION

3.1 Introduction

The typical mortgage borrower in the United States makes a choice between two types of mortgages – a fixed rate mortgage or an adjustable rate mortgage. A fixed rate mortgage offers the borrower an interest rate and payments that are fixed for the life of the loan. The typical fixed rate mortgage is offered for 30 years, but fixed rate mortgages are also available for 15 and 20 year terms. By offering fixed rate mortgages, lenders assume certain risks. For example, if inflation rises, lenders receive less in real, inflation adjusted interest payments, since they cannot adjust interest rates to account for the rise in inflation. Borrowers can also prepay their mortgages early, depriving lenders of future interest payments. Therefore lenders are faced with the task of balancing their short term obligations with longer term receipts from mortgages. To help manage some of these risks, lenders were allowed to offer adjustable rate mortgages beginning in the early 1980's.

Interest on adjustable rate mortgages (ARMs) adjusts after an initial period in which they are fixed. Interest rates can remain fixed from 1 month to 5 years. Interest rates are then adjusted based upon an index. The most common indices used are the one-year constant maturity treasury (CMT), the cost of funds index (COFI) and the London Interbank offered rate (LIBOR). During the initial period, payments are generally lower for ARMs than for fixed rate mortgage payments, for the same loan amount. But payments may adjust upwards, depending on the index, after the initial period.

As a share of the conventional mortgage market, ARMs reached their all-time average high of 78% just a few years after they were introduced into the mortgage market. Prior to the subprime crisis, ARMs were on a downward trend as a share of the market, but began to rise again from 26% in 2001 to more than 50% of the subprime market at the height of the housing boom in 2006.

The significance of ARMs as a share of the mortgage market is evident from the fact that more than two thirds of subprime lending, which is often cited as a cause of the recent housing crisis, was comprised of various forms of ARMs. The subprime crisis negatively affected banks and other lending institutions such as investment banks, as mortgage default rates increased. Numerous banks and bank-like institutions ultimately failed, because they could not cope with the losses suffered from the rise in foreclosures. As a consequence, the subprime crisis evolved into a general and severe economic downturn. Against the background of the recent economic crisis and its origin in the housing sector, this paper examines the determinants of what factors drive ARMs. The idea is to get a better understanding of the potential effects of ARMs on the overall economy.

The existing literature on ARMs is predominantly concerned with the choice between fixed rate and ARMs (Berkovec, Kogut and Nothaft (BKN) (2001), Stanton and Wallace (1999) and Smith (1987). Recently however, the literature has been extended to look at the influence of the subprime crisis on house prices (Brueckner, Calem, and Nakamura (BCN) 2011, Mian and Sufi 2008). In light of the recent developments in the housing market, we focus our analysis on the potential feedback relationship between house prices and ARM share.

We explore the possibility that a feedback relationship exists between house price appreciation and the share of ARMs. In particular, we suggest that the share of ARMs of the mortgage market may not only cause house prices to rise, but may also be the result of higher house prices or other causes, such as high interest rates. The intuition behind our idea is as follows. If house price are expected to appreciate, then lenders are less concerned about defaults and may make available more funds to a large extent in the form of ARMs and to lower quality lenders, for financing the purchase of a house.[2] At the same time, borrowers have a strong economic incentive to buy because they fear being priced out of the market in the future. Both behavioral patterns, those of lenders and those of buyers, cause the demand for housing to increase. Given the time lag in housing supply, or the physical limits of adding new housing in desirable locations, prices rise. As long as investors expect to be reimbursed for the rising risk of a downturn in prices with ever higher expected returns,[3] it is rational for them to ride the price bubble. Blanchard (1979) has termed this a rational bubble.[4] We argue that changes in the share of ARMs can be both a result and a cause of the bubble in the housing market.

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[2] During the mid 1990's, the proportion of all mortgage originations that were subprime was only about 8%. At the height of the bubble, subprime mortgage origination was as high as 30% in such markets as California, Arizona, and Florida. The typical subprime loan is an adjustable rate mortgage.

[3] Blanchard and Watson (1982) show that we also need a non-zero chance of the bubble deflating slowly over time. That means a sudden collapse of the bubble must not be a deterministic outcome.

[4] Blanchard and Watson (1982) give the theoretical framework for why bubbles can exist within a rational expectations framework. See Gürkaynak (2008) for a recent overview of empirical tests for the existence of rational bubbles.

Competition among lenders stimulated the growth in financial innovations to include other subprime mortgage instruments such as pay-option ARMs, negative amortization ARMs, and interest-only ARMs.[5] These arrangements have essentially the same objective: to reduce monthly mortgage payments at least temporarily and stimulate the demand for housing. These new instruments made it easier for borrowers to obtain financing and led to an increase in home ownership rates from 61 percent in 1995 to 69 percent by 2006. Home ownership in minority households grew substantially during this time period.[6]

Our key contribution is to demonstrate that there is a potential feedback relationship between house price appreciation and the percentage of total mortgages with adjustable rates. This potential simultaneity problem is addressed using two stage least squares (TSLS) methods. Given that there are two major choices of mortgages available to borrowers to finance a house purchase, understanding what determines one's choice between the alternatives is also of interest in its own right. We, therefore present results on the determinants of the share of ARMs using various methods of analysis.

All the empirical models make uses of a panel data set constructed from data on the 48 contiguous states. The Federal Housing Finance Agency's (FHFA) monthly interest rate survey (MIRS) is our main source of mortgage data. The FHFA also provide data on the house price index. Our results confirm our claim of a possible feedback relationship between house price appreciation and adjustable rate mortgages.

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[5] Interest only ARMS allow borrowers, for a period of time, to make interest payments only, leaving the principal the same. Pay option and negative amortization ARMS allow the borrower to make interest payments that are less than the interest due on a monthly basis.

[6] Chambers, Garriga, and Schlagenhauf (CGS) (2008) provide evidence that ARMs aided the increase in home ownership rates since the 1990's

3.2 Literature Review

The literature on the factors that determine borrower's choice of ARMs as opposed to fixed rate mortgages is extensive. However, much of it was established soon after ARMs became available in the mortgage market. Examples include Berkovec, Kogut, and Nothaft (2001) on the determinants of the share of ARMs in FHA and conventional loans, and Nothaft and Wang (1992) on the determinants of the share of ARMs at the regional and national level; Phillips and Vanderhoff (1992) and Brueckner and Follain (1989) investigate ARMs and its effect on the demand for housing. The issue regarding the choice between fixed rate mortgages and ARMs is examined in Goldberg and Henson (1992), Smith (1987), and Dhillon, Shilling and Sirmans (DSS) (1987); Stanton and Wallace (1999) investigate interest rate risks associated with ARMs.

Recently, Bucks and Pence (2006) and Coulibaly and Li (2007) have made use of a new data set from the Federal Reserve Board – the Survey of Consumer Finances (SCF) to analyze mortgage choice. Koijen, Van Hemert and Nieuwerburg (KVN) (2008) and Campbell and Cocco presents theoretical models of ARM choice. The fundamental conclusion of current and past analysis is that the spread between fixed rate and adjustable rate mortgages is the key determinant of ARMs as a mortgage choice. This remains true in spite of the recent subprime crisis.

Studies on the potential feedback relationship between the share of ARMs in the mortgage market and house prices is limited. BCN (2011) examines whether there is a possible link between subprime lending and house price appreciation. Having shown in a theoretical model how a feedback relationship can exist between house prices and subprime lending their empirical results also suggest a potential simultaneity effect between subprime lending and house price inflation.[7] They suggest the use of instrumental variables methods to verify their findings.

There is little disagreement in the literature as to the role of the subprime market in the recent rise and fall in house prices. However, at no time has the subprime market exceeded 30% of the overall mortgage market. On the other hand, ARMs can be found also in the much larger market for prime mortgages. How ARMs in this larger market interact with house prices appears to have not been addressed. It is the primary purpose of the current paper.

Del'Arricia et al. (2009) identify the decline in lending standards leading up to the housing price crash as the primary cause of the rapid growth of the subprime market. What they label as reduced lending standards is a decrease in the denial rates of mortgage applications and an increase in the loan to income ratio. With denial rates as the dependent variable, and using fixed effects estimation techniques, they find that denial rates fall as house prices appreciate in value. This is true for both prime and subprime lenders. In addition, denial rates are significantly lower in areas with the highest appreciation in prices. Other regression results indicate that entry of new large lenders in an area forces existing lenders to lower their standards in order to compete.

According to Goetzman, Peng, and Yen (GPY) (2009), forecasts of house price appreciation prior to 2006 were typically bullish, not only for the near term but for far into the future and with little or no possible concern for a decrease in home values. These

[7] Bruekner, Calem and Nakamura (2011) include lags of house price appreciation as an explanatory variable.

rosy forecasts they believe, led to the increase in the demand and supply of mortgages. Their empirical model suggests that at the MSA level, higher house price appreciation is associated with a higher volume of mortgage applications. They also show that for the same MSAs, subprime lenders behave differently from prime lenders in their loan approval process. Prime lenders tend to approve borrowers with lower loan to income ratios whereas subprime lenders approve borrowers with high loan to income ratios. At the loan level, the probability of a subprime loan being approved increases as the appreciation in house prices goes up. They conclude that both lenders and borrowers considered past house price appreciation as a key factor in the purchase and underwriting of mortgages.

Coleman et al. (2009) however find no evidence that subprime lending was a leading cause of the rise and subsequent fall in housing prices experienced recently. They argue that economic fundamentals provided adequate explanation of house price fluctuations up to early 2004. After that, economic fundamentals became practically insignificant in explaining housing prices. They also argue that the rise in financial innovation along with the higher house price appreciation was a result of the changing regulatory environment after early 2004. While more than 50 percent of all conventional mortgages were issued and purchased by Fannie Mae and Freddie Mac prior to early 2004, new legislation made it no longer possible for them to do so. This vacuum was filled by private issuers of these products and these private issuers typically had lower standards.

The study by BCN (2011) examines a feedback relationship between credit risk scores for consumers in all 50 states and expected house price appreciation. Our study appears to be the first attempt at analyzing a potential feedback between ARMs and house price appreciation.

3.3 Methodology

To capture the relationship between the share of ARMs in the prime mortgage market (*arm*) and house price appreciation we estimate the model:

$$hpi_{it} = \beta_0 + \beta_1 hpi_{it-1} + \beta_2 arm_{it} + \beta_3 x_{it} + \mu_i + \lambda_t + \upsilon_{it}, \quad (4)$$

where subscript i stand for the ith state and the subscript t represents the tth year. *hpi* represents the dependent variable house price appreciation, which is constructed as the first difference in logs of house prices.

Case and Shiller (2003) consider a bubble to be a condition in which expectations of future rises in house prices cause current house prices to be elevated. Given that expectations are formed on the basis of past observations, we include a lag of the dependent variables as a proxy for expected house price appreciation. A lagged dependent variable can also reduce the effects of autocorrelation that may be caused by omitted variables.

Our key variable of interest is the percentage of mortgages with adjustable rates (*arm*). The variables contained in x include a number of control variables. All are measured at an annual frequency. More specifically, they include at the state level the unemployment rate (*ur*), the growth rate of non-farm employment (*empl*), and the growth rate of population (*popn*). We also include two variables more specific to the housing market: the interest rate on 30-year mortgages (*mortg*) and the loan to value ratio (*ltv*). We note that β_2 and β_3 are short run impact parameters that represent the change in house prices as a result of a change in *arm* and the explanatory variables in x. The error term is comprised of state specific fixed effects μ_i, year specific fixed effects λ_t, and a disturbance term $v_{it} \sim \text{IID}(0,\sigma^2_v)$. The year specific effects are estimated as time dummies.

Year specific fixed effects account for the numerous policy regulations enacted over the years that directly impact the housing market in all states and in the same way. Some of the more recent policy interventions include (i) the Housing and Economic Recovery Act of 2008 (HERA), (ii) the American Dream Down payment Initiative (ADDI) of 2003, and (iii) the Community Reinvestment Act (CRA), first enacted in 1977.

The HERA law was enacted to 'stem the tide' in the subprime mortgage crisis and to restore confidence in the mortgage market. It guarantees payment to lenders of subprime mortgages. To be eligible, lenders must be willing to convert from subprime mortgages to 30-year fixed rate mortgages, and also to write down current loan balances to 90% of their appraised value. The legislation also includes a temporary tax credit to first-time home buyers. First-time home buyers can take advantage of a $7,500 refundable tax credit for purchasing a principal residence. Other provisions of the law include an increase in loan limit for Federal Housing Authority (FHA) loans. The law requires the FHA to finance loans to 110% of the median home price in the given area. The previous loan limit was 95%. The law also included a minimum 3.5% down payment for FHA loans.

The ADDI law was enacted in December 2003 to aide home buyers and increase home ownership rates. The idea behind the law was to alleviate the two biggest impediments to home ownership for low income first time home buyers. ADDI provided first time home buyers with up to $10,000 or 6% of the purchase price for down payment, closing costs or for the rehabilitation of a property to be purchased. Individuals in all 50 states living in localities with population of at least 150,000 were eligible to receive assistance. Funding for ADDI ended in 2008.

The CRA originally passed in 1977, but has undergone regulatory and legislative changes over the years, the latest revision being in 2008. One of the reasons for passing this law was to end a practice known as redlining, a discriminatory practice where banks refuse to provide loans to individuals in certain low income neighborhoods. The law encouraged banks to lend to members of the communities in which they have branches. Banks not meeting minimum requirements under the law may be subject to denial for new branching or merger and acquisition requests. These rules apply without exception to all states in the same manner.

Unobserved heterogeneity across states is accounted for by state-specific fixed effects. State specific fixed effects account for, among others, inter-state differences in the treatment of real estate transactions. For example in some states such as Florida and New Jersey, foreclosures are handled through a judicial process, but in other states such as Michigan and New Hampshire, foreclosures are handled by state statutes.

Our specification of equation (1) presents two econometric problems. First, given our assumption of a feedback relationship between *arm* and *hpi*, the variable *arm* is necessarily endogenous and therefore correlated with the error term. Second, because of the lagged dependent variable, serial correlation may be an issue. That is since the dependent variable is a function of μ_i, lags of the dependent variable are also functions of μ_i. Therefore the lagged dependent variable is correlated with the error term.

To remove these problems, of endogeneity we employ a two stage least squares model approach. In particular, our first stage model makes the share of ARMs in each state (*arm*) a function of (i) expected housing price appreciation, (ii) the control variables contained in equation (1), and (iii) additional exogenous covariates that have been found in the previous literature to drive ARMs. Expected house price appreciation serves as a valid instrument given that it is pre-determined and hence uncorrelated with the error term (BCN 2011). As in previous studies, for example Goetzman, Peng and Yen (GPY) (2009), we use past house price appreciation to proxy expectations. The additional exogenous covariates that have been found in previous studies to drive ARMs include the difference between the 30-year fixed and the 1-year adjustable rate mortgage (*spread_mortg*) and the difference between the 10-year and the 1-year treasury constant maturity rate (*spread_treas*).[8] Increases in the variable *spread_mortg* are expected to increase *arm* because it suggests that as *spread_mortg* widens, *arm* becomes more attractive. Borrowers may therefore opt for arm-type mortgages. *spread_treas* serves as an indication of short term expectations for interest rates. An increase in *spread_treas* is therefore expected to reduce *arm* (Berkovec, Kogut and Nothaft 2001).

The second issue we face in estimating equation (1) is how to deal with the lagged dependent variable in our panel data setting. As is well known, the fixed-effects estimator is biased, but in contrast to the least squares estimator, it is consistent. However, the number of time series observations we have per state may not be enough to rely on consistency. We therefore, also estimate a dynamic panel model as proposed by Arellano and Bond (1991), which uses additional instruments in the form of differenced lagged

[8] See for example BKN 2001, Vickery, and Aragon (2010)

levels of the variables in the model. Adding lags of the endogenous variables makes them pre-determined and uncorrelated with the error term in equation (1).

3.4 Data

Data are obtained from several sources. The key variables in this study are the percentage of mortgages with adjustable rates (*arm*), interest on fixed rate mortgages (*mortg*), interest on adjustable rate mortgages (*armrate*), employment (*empl*), population (*popn*), *spread*, and *treasury*. The data on *arm* is from the Monthly Interest Rate Survey (MIRS), while the data on fixed rate and adjustable mortgages are obtained from the primary mortgage market survey (PMMS). The PMMS is conducted by Freddie Mac. The house price index is from the FHFA. Data on economic conditions are obtained from various federal agencies: state level employment and unemployment is from the Bureau of Labor Statistics (BLS). Table 1 summarizes the definitions and sources of data used in this study.

MIRS provide mortgage information differentiated by property type, loan type, and type of lender. Information is for new or previously occupied single family homes. Fixed rate and adjustable rate mortgages are included in the survey. Five days prior to the end of the month, a sample of lenders are asked to provide information on mortgages they have issued to borrowers. FHA insured and VA loans are excluded from the survey. Therefore these are conventional conforming mortgages which normally require a higher down payment of at least 20 percent, and a strong credit history for the borrower. The MIRS data provides the most comprehensive information on conventional mortgages.

The FHFA updates MIRS monthly. Historical data are presented in tables. Our model uses data from table 15 titled "Terms on Conventional Single Family Mortgage by State." Data can be obtained from FHFA website.[9] From this table we also extract information on the loan to value ratio (*ltv*), and the percent of adjustable rate loans (*arm*). The data are yearly and starts in 1978. Our model uses yearly data from 1986-2010.

The PMMS data, obtained from Freddie Mac, are based on a weekly survey of financial institutions in the United States, that are offering mortgage products to borrowers. The survey compiles data on 30-year and 15-year fixed mortgage rates. Information on points and origination fees are also collected as part of the survey. Data on interest for adjustable rate mortgages are based on a 1-year treasury index. The PMMS data are limited to conventional rate mortgages with an *ltv* of 80%.

Data on state level house price indices are obtained from the Federal Housing Finance Agency (FHFA), previously known as the Office of Federal Housing Enterprise Oversight (OFHEO). House prices from mortgages purchased or securitized by government sponsored agencies Fannie Mae and Freddie Mac are used to compute the index. The index is a weighted repeat sales index. It measures the average price change from repeat sales of single family dwellings in the metropolitan areas of each of the 50 states and the District of Columbia. The data are available on a quarterly basis; they begin in the first quarter of 1975 and end in the fourth quarter of 2010. 1980 is the base year for computing the average. Calhoun (1996) provides an in-depth description of the construction of the OFHEO house price index. Table 2 presents summary statistics for the data used in the analysis.

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[9] http://www.fhfa.gov/default.aspx?page=252

Data on the percent of ARMs are missing for all states in 2008. Multiple imputation methods are used to fill in the missing data. Multiple imputations uses existing data to find the imputed value by regressing the variable with the missing data on other variables in the data set. An error component drawn at random from the residuals is added to the predicted values. This process is repeated several times to reduce the chance of underestimating the error terms. Details of the procedure are beyond the scope of this paper. However, technical details on the procedure are found in Allison (2002) and Schafer (1999). Penn (2008) also provides an in-depth analysis of multiple imputations with economic applications.

3.5 Results

3.5.1 Results from a fixed effects model

Table 3 presents results from a fixed effects model that explains the determinants of the share of ARMs in the primary mortgage market. Results are reported for several models with *arm* as the dependent variable, and with alternative combinations of the explanatory variables.

The lag of house price appreciation, which we interpret to represent expected house price appreciation stimulates lending by raising the percentage of loans offered to borrowers seeking adjustable rate mortgages. This observation is consistent and statistically significant throughout the various models estimated. These results support the findings of earlier studies (BCN, 2011, GPY, 2008) and our earlier suggestion that anticipated higher future prices stimulates lending activity.

With respect to the other covariates, most of them are statistically significant at least at the 5% level and with the expected signs. Population and the unemployment rate however are notable exceptions. One would expect a rise in population to increase the share of ARMs, since there are more borrowers when the population increases. However, the results indicate otherwise. A rise in unemployment is also seen to have a positive rather than the expected negative influence on *arm* share in some of the models. Consistent throughout are the signs on the interest rate measures. A rise in the 30-year fixed rate mortgage raises the percentage of adjustable rate mortgages. This makes sense because adjustable rate mortgages typically carry lower interest rates at least initially, compared to the 30-year interest rate. This suggests that some borrowers will choose adjustable rate mortgages over the 30-year fixed rate mortgage. This is also verified by the sign of the coefficient of *spread_mortg,* which measures the difference between the fixed rate and the adjustable interest rates. As the *spread_mortg* increases, more borrowers will choose adjustable rate mortgages. It is also plausible to suggest that anticipation of future rate increases, as indicated by *spread_treas* reduces the percentage of adjustable rate mortgages.

Moench, Vickery and Aragon (2010) documents that the share of ARMs has fallen to less than 10% of the overall mortgage market in the last several years. They argue that while most people blame the subprime crisis for this decline, the primary cause of the decline was and still is the term structure of interest rates. Current interest rates are at unusually low rates and are expected to remain low in the foreseeable future. Borrowers therefore choose the more conventional 30-year fixed rate mortgage. The importance of the term structure of interest rate is indicated in our model by the variable *spread_treas*.

3.5.2 Results from Two Stage Least Squares

Estimates from both OLS and TSLS of house price inflation are presented in Table 4. State specific fixed effects are used. Since our model is dynamic in nature, OLS and fixed effects estimates do not account for the simultaneity presented as a result of the lagged dependent variable. TSLS is used to address our concern of a simultaneous relationship between the share of ARMs in the mortgage market and house price inflation. In estimating the TSLS model, we use the fitted values of *arm* from Model 5 of Table 3 at the second stage to estimate Equation 1.[10] Our choice of the first stage model is based on its R-square value and the fact that it contains variables most pertinent to the determinants of ARMs.

All the coefficients of the lagged dependent variable are statistically significant, with estimated coefficients of at least 0.61. This suggests a significant level of persistence for house prices appreciation. The marginal effect for employment is significant in all of the models estimated and range from 0.4 to 0.65. Estimates for *mortg* and *ltv* are also significant and with the expected signs.

Estimates from the TSLS results suggest that *arm* has a positive and statistically significant relationship with house price appreciation. This relationship is consistent across all of the alternative specifications of TSLS. Holding everything else constant, a 1% increase in the level of *arm*, raises house price appreciation by a factor of 10%. Long run marginal effects are obtained by multiplying the short run effects by $1/(1-\hat{\beta}_1)$, where $\hat{\beta}_1$ is the coefficient estimate for expected house price inflation. The long run

[10] Standard errors and R-square values are adjusted properly to account for the fact that the fitted values of *arm* are used in a two stage OLS estimate with fixed effects.

marginal effect for *arm* in Model 6 is 0.31, suggesting a significant long run influence of *arm* on house price inflation. We note that *arm* is not statistically significant in the least squares estimates, which suggests an endogeneity bias in those estimates.

3.5.3 Results from a Dynamic Model

Table 5 presents parameter estimates from the Arellano-Bond (1991) estimator which removes the potential bias in the estimates presented in Table 4 that have their origin with the lagged dependent variable.[11] In Models 1 and 2 we use the Arellano-Bond one-step estimator, and in Models 3 and 4 we use the two-step Arellano-Bond estimator.[12] To eliminate the simultaneity bias as in Table 4, we use the predicted *arm* values from the estimates of Model 5 in Table 3.

In all the regressions reported in Table 5, the parameters are of the correct signs and are mostly statistically significant at least at the 5% level. The estimates from Models 1 and 2 are inconsistent because they do not satisfy the autocorrelation tests. According to Arellano and Bond (1991), estimates are consistent only if there is evidence of first order but not of second order autocorrelation in the residuals. In Models 1 and 2 the null of no first order autocorrelation is rejected; but the null of no second order autocorrelation is also rejected, which indicates inconsistency. Model 3 satisfies the autocorrelation tests, but does not satisfy the Sargan test of over-identifying restrictions. The null hypothesis of the Sargan test is that the instruments are valid. The test results of Models 1, 2 and 3 reject the null hypothesis of valid instruments. The test results of Model 6 satisfy all of the specification requirements and hence provide us with consistent estimates.

[11] We note in this context that the two-stage fixed effects estimates of Table 4 are consistent.

[12] The one-step estimator assumes homoscedastic errors, while the two-step estimator constructs heteroscedasticity-consistent errors using the residuals from the one-step estimator.

The parameter estimates of Model 6 suggest a long run marginal effect of 0.739 for employment and a long run marginal effect with respect to population of 0.92. With respect to *arm* the long run marginal effect is 0.026, which suggests that a 1% percent increase in *arm* raises house price appreciation by 2.6%. This is more plausible compared to the increase in house appreciation implied by the TSLS results of Table 4.

As we mentioned earlier our Equation 1 is similar to BCN's (2011) model. However the dependent variable in their case is credit risk scores. Just as we do here, they use a panel data set comprised of information on the 48 contiguous states. Our results are similar to theirs in that we find strong evidence of persistence in house price appreciation. Additionally, our model reveals that fluctuations in the share of adjustable rate mortgages can influence house price appreciation.

3.6 Conclusion

This paper considers two important issues regarding house prices and mortgage market activity. First, we study the determinants of the share of adjustable rate mortgages over time. Second, we look at the possibility of a simultaneous relationship between appreciation in house prices and the share of adjustable rate mortgages. For our analysis, we construct a panel data set at the state level with yearly frequency. Fixed effects estimates are used to study the determinants of *arm*, whilst a dynamic panel model is used to investigate the potential simultaneity between ARMs and house price appreciation.

Studying the determinants of ARMs is important given the recent crisis in the mortgage market which showed that two thirds of the subprime market was made up of

ARMs. We use several modeling techniques to analyze this issue. Our fixed effects model uses state specific and year specific effects to account for differences in state characteristics and changes in the regulatory environment over time. Our results confirm earlier results of the importance of the spread between the 30-year fixed and the 1-year adjustable rate mortgages. The difference between the 10-year and the 1-year treasury constant maturity rate is also an important determinant of ARMs. These results remain consistent even during the housing boom and bust cycle that we experienced. In addition, expectations of higher house prices have a positive and statistically significant effect on the share of ARMs.

Our second objective addresses the possibility that a simultaneous relationship exists between adjustable rate mortgages and house price appreciation. When house prices are projected to increase in the future, both lenders and borrowers increase the supply of funds and demand for housing, respectively, in a feedback type loop. A dynamic panel model which uses lags of the explanatory variables in the model as instruments provides the most consistent results. It shows that house prices are affected positively by the share of mortgages with adjustable rates.

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Table 1. Definitions and Sources of Data Used in the Analysis

Variables	Definition	Source
hpi	Quarterly house price index	Federal Housing and Finance Agency (FHFA)
empl	State level non-farm employment	Bureau of Labor Statistics (BLS)
arm	Percent of conventional mortgages with adjustable rates	Monthly Interest Rate Survey (MIRS)
popn	Yearly estimates of population by state	US census Bureau
mortg	30-year fixed mortgage interest rate	Federal Reserve Economic Database (FRED)
armrate	1-year interest rate on adjustable mortgages	Primary Mortgage Market Survey (PMMS)
r-mortg	Average 30-year fixed mortgage interest based on Freddie mac regions	Freddie mac
spread_mortg	Difference between 30-year fixed and 1-year adjustable rate mortgages.	
Spread_treas	Difference between 10-year treasury constant maturity rate and the 1-year treasury constant maturity rate	
ltv	Loan to value ratio	Monthly Interest Rate Survey (MIRS)
ur	Unemployment rate by state	Bureau of Labor Statistics (BLS)

Notes: Data from FRED is provided by the Federal Reserve Bank of St. Louis.

Table 2. Summary Statistics for the Data Used in the Analysis

Variables	Mean	Standard Deviation	Minimum	Maximum	Number of Observations
hpi	234.64	105.93	81.16	713.94	1200
empl	2502.60	2564.00	183.10	15174.00	1200
arm	20.87	14.82	0.00	78.00	1200
popn	5650.90	6047.50	453.59	37254.00	1200
mortg	7.59	1.68	4.69	10.34	1200
armrate	5.89	1.45	3.76	8.80	1200
r-mortg	7.59	1.68	4.65	10.43	1200
spread	1.71	0.69	0.08	3.33	1200
treasury	1.38	1.02	-0.14	3.12	1200
ltv	77.11	3.78	63.40	96.70	1200
ur	5.50	1.82	2.20	14.90	1200

Notes: The data is yearly and covers the period 1986-2010.

Table 3. Results from a Fixed Effects Model with *Arm* as the Dependent Variable

Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Constant	0.404***	0.218	0.259	-0.573***	0.718***	-0.442**
	(0.124)	(0.177)	(0.180)	(0.175)	(0.175)	(0.178)
dln hpi (-1)	0.619***	0.700***	0.694***	0.441***	0.407***	0.451***
	(0.085)	(0.101)	(0.102)	(0.111)	(0.112)	(0.111)
dln empl	1.414***	1.566***	1.544***	0.975***	-0.304	0.950***
	(0.240)	(0.245)	(0.246)	(0.257)	(0.265)	(0.269)
dln popn	-0.917*	-0.932*	-0.910*	-0.713	0.674	-0.713
	(0.555)	(0.552)	(0.551)	(0.541)	(0.464)	(0.552)
mortg	0.015**	0.022***		0.195***		
	(0.007)	(0.008)		(0.011)		
armrate				-0.118***		-0.106***
				(0.007)		(0.007)
r-mortg			0.019**			0.175***
			(0.008)			(0.011)
spread_mortg					0.152***	
					(0.011)	
spread_treas					-0.049***	
					(0.006)	
ltv	0.032	0.052	0.056	-0.036	-0.092	-0.024
	(0.209)	(0.208)	(0.209)	(0.192)	(0.199)	(0.194)
ur		0.007	0.006	-0.006	-0.012**	-0.006
		(0.005)	(0.005)	(0.006)	(0.006)	(0.006)
Adj. R^2	0.467	0.468	0.467	0.539	0.538	0.528

Note: Standard errors are in parenthesis. -dln stands for log-difference. The stars ***, **, and * indicate significance at the 1-, 5-, and 10% level respectively.

Table 4. Results from Two Stage Least Squares Model with *hpi* as the Dependent Variable

Variables	(1) OLS	(2) TSLS	(3) OLS	(4) TSLS	(5) OLS	(6) TSLS
Constant	0.084***	0.061***	0.089***	0.078***	0.088***	0.080***
	(0.018)	(0.019)	(0.019)	(0.023)	0.018)	(0.021)
dln hpi (-	0.722***	0.668***	0.716***	0.609***	0.715***	0.637***
1)	(0.015)	(0.016)	(0.016)	(0.022)	(0.015)	(0.019)
dln empl	0.650***	0.523***	0.641***	0.411***	0.639***	0.470***
	(0.054)	(0.060)	(0.057)	(0.078)	(0.057)	(0.072)
arm	-0.007	0.103***	-0.006	0.153***	-0.006	0.111***
	(0.007)	(0.016)	(0.007)	(0.026)	(0.007)	(0.018)
dln popn	-0.095	-0.029	-0.095	0.002	-0.095	-0.024
	(0.097)	(0.110)	(0.096)	(0.120)	(0.095)	(0.110)
mortg	-0.002***	-0.005***	-0.002***	-0.007***		
	(0.000)	(0.001)	(0.000)	(0.001)		
r-mortg					-0.001***	-0.005***
					(0.000)	(0.001)
ltv	-0.090***	-0.045**	-0.093***	-0.045**	-0.090***	-0.058**
	(0.023)	(0.023)	(0.023)	(0.027)	(0.022)	(0.025)
ur			-0.0003	-0.002***	-0.0004	-0.002***
			(0.000)	(0.001)	(0.0004)	(0.001)
Adj. R^2	0.690	0.622	0.689	0.548	0.689	0.692

Note: Standard errors are in parenthesis. The dependent variable is dln *hpi*, where dln stands for log difference. The stars ***, **, and * indicate significance at the 1-, 5-, and 10% level respectively.

Table 5. Results from a Dynamic Panel Model with dln *hpi* as the Dependent Variable

Variables	Model 1	Model 2	Model 3	Model 4
constant	-0.001***	-0.001***	-0.002***	-0.001***
	(0.000)	(0.000)	(0.000)	(0.000)
dln hpi (-1)	0.619***	0.730***	0.606***	0.716***
	(0.023)	(0.026)	(0.022)	(0.023)
dln hpi (-2)		-0.184***		-0.180***
		(0.026)		(0.032)
dln empl	0.516***	0.392***	0.460***	0.343***
	(0.055)	(0.057)	(0.043)	(0.057)
arm	0.010	0.014*	0.009**	0.012**
	(0.008)	(0.008)	(0.003)	(0.005)
dln popn	0.458***	0.443***	0.446***	0.425***
	(0.118)	(0.1160	(0.060)	(0.062)
mortg	-0.005***	-0.004***	-0.005***	-0.004***
	(0.001)	(0.001)	(0.001)	(0.031)
ltv	-0.158***	-0.193***	-0.143***	-0.192***
	(0.030)	(0.030)	(0.040)	(0.031)
ur	-0.0004***	-0.002**	-0.001*	-0.003***
	(0.0010	(0.001)	(0.001)	(0.0010
Arellano-Bond test of no AR(1)	-13.207 (0.000)	-17.178 (0.000)	-2.615 (0.009)	-3.456 (0.001)
Arellano-Bond test of no AR(2)	-2.660 (0.008)	-1.722 (0.085)	-2.400 (0.016)	-1.008 (0.313)
Sargan test of over-identifying restrictions	1084.480 (0.000)	1072.590 (0.000)	46.201 (0.998)	46.507 (0.998)

Notes: Standard errors are in parenthesis. The variables dln *hpi* is the dependent variable, where dln stands for log difference. The stars ***, **, and * indicate significance at the 1-, 5-, and 10% significance level. Models 1 and 2 uses the one-step estimator and models 2 and 3 uses the two-step estimator.

4. Structural Time Series Models of Regional Income and House Prices

4.1 Introduction

The goal of this paper is to examine the time series properties of regional income and regional house prices and their relationship with each other. This is an important issue given the recent crisis in the housing market and in the economy, which shows evidence of a significant influence of housing on economic activity. Fluctuations in house prices can influence GDP by affecting wealth and household's ability to borrow. On the other hand economic activity, dictated largely by disposable income and employment can influence house prices. The sensitivity of income to house price fluctuations makes housing increasingly important in policy debates. For example, Cecchetti et al. (2000) and Borio and Lowe (2002) suggests ways in which monetary policy should respond when house prices deviate too far from fundamentals, so as to prevent a slowdown in economic activity. Therefore understanding the relationship between income and housing is essential for policy formulations. Analysis of the relationship between income and housing at the regional level is limited, although it has been shown that house prices respond more so to regional economic shocks, as opposed to national shocks. (Kim and Bhattacharya, 2009) Regional Analysis also allows us to make comparisons across regions.

The housing market plays a key role in the determination of economic activity in the United States. Developments in the housing market have been shown to be a precursor of the direction of economic activity. For example the persistent drop in house price as indicated by the Case-Shiller index beginning in August 2006 was seen as an indication of the recession we just experienced. Mishkin (2007) showed that up to 1% of growth in real GDP was lost as a result of the fall in residential investment beginning in 2006. During this same time period, single family housing starts fell from their peak of 1.84 million in 2006 to about 1.15 million in mid-2007.

The recent fluctuations in housing prices have renewed interest in the dynamics of the housing market. The recent boom and bust cycle in the housing market affected some states more so than others. In the West, for example, Arizona, California and Nevada experienced new highs and new lows in housing prices, with annual growth in some states upwards of 10% and record declines during the bust. Similar experiences were observed in select states throughout the rest of the country: Florida in the South, and Maryland and Rhode Island in the Northeast. States in the Midwest did not appear to experience above average growth in house prices. While these house price statistics point out observable differences, there may be interactions among the states and regions that are unobservable. These unobservable characteristics might become apparent if one analyzes the trend and cycle frequencies inherent in the actual data series. The goal of this paper is to analyze these unobserved components at the regional level and to determine whether common trends or cycles frequencies exist among the census regions.

This paper analyzes the dynamics of housing and its relationship to income in the 4 census regions of the United States. We analyze data on median home sale prices and income using multivariate unobserved components model as proposed in Harvey (1989). An unobserved components model analyzes a time series by decomposing it into its trend, cyclical and irregular components. We model the components of house prices and income simultaneously to determine if there is co-movement in the two series and to identify possible relationships between the two. Multivariate models are also analyzed to determine if common trends or cycles exist between two or more regions. The data are quarterly and cover the period 1963:1-2011:4. Our results indicate that for income a very strong positive relationship exists between the four regions. In terms of housing cycles, the Midwest and the South are strongly related. Our results also indicate that regional income cycles and regional house prices have a short to medium term relationship in that fluctuations between the two are correlated in five to eight years cycles. In all four regions, the housing market provides an important contribution to the growth rate of income.

4.2 Literature Review

The literature on housing and the business cycle is extensive. However much of it is at the national level with the focus on OECD countries (Goodhart and Hofman, 2008; Tsatsaronis and Zhu, 2004; Borio and McGuire, 2004) and the Euro area (Alvarez, Bulligan, Cabrero, Ferrara and Stahl, 2010; Ferrara and Koopman, 2010) Studies involving specific countries include Alvarez and Cabrero (2010) for Spain, Ferrara and Vigna (2009) for France and Leamer (2007) for the US.

A strand of the literature looks at the importance of housing in determining economic activity. Leamer (2007) for example studies the relationship between housing market cycles and business cycles by relating the components of gross domestic product (GDP) to National Bureau of Economic Research (NBER) recession dates. He finds that more than any of the other components of GDP, declines in residential investment is almost always a precursor to declines in economic activity. He documents that eight of the ten NBER recessions were preceded by downward trends in residential investment. He also calls the business cycle a consumer cycle, because the top four components in GDP to signal a recession are consumer driven, with the main driver being residential investment.

Dufrenot and Malik's (2009) paper is on housing dynamics and its ability to predict turning points in the business cycle in three countries – the UK, Spain and the US. They find that, overall, the tendency of housing fluctuations to predict turning points in the business cycle is good; however, it is more accurate during periods of expansion. That is an increase in housing activity can predict a business cycle expansion. While declines in housing activity can also precede a recession in the business cycle, housing activity during a recession provides no useful information on the business cycle. Put differently, a housing crash can cause a recession, but there is no convincing evidence that housing activity can help bring the economy out of a recession.

In the wake of the recent recession which most analysts believe was driven by a decline in housing activity, Ferrara and Koopman (2010) study common trends and cycle's in house prices and how they relate to the business cycle. They do so for 4 Euro zone countries – France, Germany, Italy and Spain. They use multivariate structural time series methods, in which house prices and GDP are modeled as functions of their components – trend, cycle, and irregular. If common trends and cycles exist in the components of two or more countries, then the variances of the component disturbances are driven by similar dynamics. The variance-covariance matrix of the component would therefore be less than full rank. They find that the business cycles in France, Italy and

Spain are closely related. Housing dynamics in France and Spain are also closely related. Germany, however, possesses housing and business cycle frequencies that are different from those of the other countries.

Alvarez et al. (2010) find strong correlations between GDP cycles but not between housing cycles in the same four Euro countries. Analyses using housing indicators other than house prices (permits, housing starts and residential investment) indicate strong correlations for data on France (Ferrara and Vigna, 2009) and Spain (Alvarez and Cabrero 2010)

Regional studies include Cavalho and Harvey's (2005) study on the convergence of per capita income in the eight census divsions. They find evidence of convergence in what they call the six poorest Bureau of Economic Analysis (BEA) regions - Great Lakes, Plains, Southeast, Southwest, rocky mountain and the far West. The two richest divisions (New England, Mideast States) appear to be diverging from the other regions. Coggin and Clark (2009) also find evidence of convergence in the Federal Housing Finance Agency's (FHFA) house price index for the nine census divisions in the U.S.

Similar to our study is the study by Fadiga and Wang (2009). They are concerned with common housing dynamics in the four census regions of the United States. They use a multivariate unobserved component analysis to determine the existence of common movements in median home sales prices in the four regions. They find that housing dynamics in the four regions is determined by two common trends and three common cycles. They also find that explanatory variables most influential in the determination of regional house prices are the unemployment rate, the federal funds rate and the rate of inflation.

One important distinction between this study and similar studies is that our data extends to the last quarter of 2011 and covers the period after the housing boom. For example Fadiga and Wang's (2009) sample end in 2006:2, the period just after the peak of the housing boom, while Clark and Coggin's (2009) analysis ends at the peak of the housing boom in 2005:2. Our analysis could therefore serve as a robustness check on prior analysis

4.3 Methodology

Our analysis employs an unobserved components model (UCM) which is based on the use of components such as the trend and cycle of the data series. Our model is multivariate, and uses the correlations of the errors in the components to determine the relationship between the series

In a UCM, a given time series is decomposed into stochastic or non-stochastic components that represent certain features of the series as functions of time. A common decomposition of a time series includes a trend, cyclical and an irregular component. The trend component features the general upward or downward movement of the data and the cyclical component recurring cycles. The irregular component is a white noise process. A UCM can be specified as follows:

$$y_t = \mu_t + \psi_t + \sum_i \sum_j \alpha_{ij} x_{i,t-j} + \varepsilon_t, \quad \varepsilon_t \sim \text{NID}(0, \sigma_\varepsilon^2), \quad t = 1, \ldots, T, \tag{5}$$

where y_t is the dependent variable, and $x_{i,t-j}$ represents current and lagged values of explanatory variables. The trend component is μ_t, the cyclical component is ψ_t, and ε_t represents the irregular component.

The trend component is represented in this study as a local linear trend model specified as follows:

$$\begin{aligned} \mu_t &= \mu_{t-1} + \beta_{t-1} + \eta_t, \qquad \eta_t \sim \text{NID}(0, \sigma_\eta^2), \\ \beta_t &= \beta_{t-1} + \xi_t \qquad\qquad\quad \xi_t \sim \text{NID}(0, \sigma_\xi^2), \end{aligned} \tag{6}$$

where the stochastic trend is assumed to comprise a level component μ_t and a slope or drift term β_t. The disturbances of the level and slope components are assumed to be independent of each other and of the error term ε_t.

Note that if one or more of the variances (σ_η^2 and σ_ξ^2) is set equal to zero, then we could have a stochastic trend with drift ($\sigma_\xi^2 = 0$), a smoothed trend ($\sigma_\eta^2 = 0$) or the common deterministic linear trend ($\sigma_\eta^2 = \sigma_\xi^2 = 0$). If in addition β_t is zero, the model collapses to a least squares model with constant term.

The cyclical component is specified as follows

$$\begin{bmatrix} \psi_t \\ \psi_t^* \end{bmatrix} = \rho \begin{bmatrix} \cos\lambda_c & \sin\lambda_c \\ -\sin\lambda_c & \cos\lambda_c \end{bmatrix} \begin{bmatrix} \psi_{t-1} \\ \psi_{t-1}^* \end{bmatrix} + \begin{bmatrix} \kappa_t \\ \kappa_t^* \end{bmatrix}, \qquad t = 1, \ldots, T, \tag{7}$$

Where λ_c is the cycle frequency and ρ is a damping factor; κ_t and κ_t^* are disturbance terms which are uncorrelated with the other disturbances, have zero means and a common variance σ_κ^2. Analysis of cyclical component requires estimating the variance, the cycle frequency and the damping factor.

The period of the cycle is $2\pi / \lambda_c$ where $0 < \lambda_c < \pi$; and the cycle variance is $\sigma_\kappa^2 = (1-\rho)\sigma_\psi^2$. If λ is close to 0 or π, the outcome is an AR(1) process. A value of ρ close to 1 implies a stationary or deterministic cycle.

The univariate UC model can be extended to include more than one time series variable. For a multivariate UCM, often referred to as the seemingly unrelated time series equation (SUTSE) model, the parameters of all the time series are estimated simultaneously, and y_t is now a $N \times 1$ vector of time series. The scalar components of the univariate model are now vector components. Thus a multivariate UCM is specified as:

$$y_t = \mu_t + \psi_t + \sum_i \sum_j \alpha_{ij} x_{i,t-j} + \varepsilon_t, \quad \varepsilon_t \sim \text{NID}(0, \Sigma_\varepsilon), \quad t = 1,\ldots,T, \tag{8}$$

where the stochastic trend μ_t and the cycle component ψ_t are $N \times 1$ vectors; and x_t represents a vector of explanatory variables. The irregular component ε_t has a multivariate normal distribution with zero mean and variance matrix Σ_ε.

The specifications of the trend and cycle components are the same as for the univariate case, except that the scalar process is now a vector process. The errors are also vectors with a multivariate normal distribution, with mean zero and variances $\Sigma_\eta, \Sigma_\xi, \Sigma_\kappa, \quad t = 1,\ldots,T$. In the cycle specification, the cycle frequency and damping factor remain scalar components.

All models are estimated using structural time series analyzer, Modellar and Predictor (STAMP) software. STAMP uses maximum likelihood techniques to estimate the parameters of the unobserved components. The maximum likelihood estimates are based on state space methods and the Kalman filter.

4.4 Data

The two key variables used in this study are median sales price of houses sold and total personal income for the four census regions of the United States: Northeast, Midwest, South and West. Table 1 presents the regional distribution of the states as defined by the Census Bureau.

Median sales price data for each of the four regions are obtained from the Census Bureau, and are expressed in terms of dollar values. The census Bureau uses data obtained from the survey of construction (SOC). The SOC interviews home builders on housing projects at various stages in the construction process. A detailed description of the methodology is presented in Thompson and Sigman (2001) Data on regional GDP are unavailable. As a proxy we use total personal income, which is only available at the state level. Each state's contribution to regional income is calculated as a weighted average of the state's population. Estimated population is obtained from the census Bureau. All variables are quarterly and are from 1963:1-2011:4. Figures 1 shows graphs of regional house prices and regional income.

Summary statistics are provided for regional house prices and regional income in Table 2. The data reveals that median house prices are highest in the Northeast ($145,320.41) and lowest in the South ($95,245.92) Maximum house price values are recorded in the Northeast, followed by the West. As indicted by the standard deviations, house prices are more volatile in the Northeast and least volatile in the South. Case and Shiller (2003) observed similar characteristics for the Case-Shiller house price index.

Income is most volatile in the West. The Midwest has the lowest income and the least volatility.

4.5 Results

In a preliminary step, we study the observed characteristics of income and house prices, in each of the four regions. We present in Figures 2 and 3, for income and house prices respectively, correlograms to identify persistence in the data; spectral density graphs provide information about possible cycle frequencies; and a histogram gives us an indication of the distributional properties of the data.

The correlograms for housing indicate no similarities in terms of dynamics among the regional house series over time. There is also little evidence of persistence in all the series especially for the southern region, which shows virtually no indication of auto correlation in the data. The dynamics of the autocorrelation function for the regional income series however, are similar and exhibit evidence of significant persistence over time. The high level of serial correlation is especially noticeable for the Midwest, the south and the west. The spectra for income display no obvious sign of a cycle. The spectra for house prices show some evidence of a cycle, particularly for the Midwest.

Our preliminary results indicate the existence of only a few common characteristics among the regions. Structural time series analysis is useful in this instance because it will provide us with evidence on the interactions of the unobserved components, which may not be apparent from our preliminary analysis.

Our UC model decomposes regional income and house prices into a trend, cycle and irregular components. We assume a short cycle frequency of five years for both income and house prices. We use a short cycle because on average the business cycle in the US lasts 5 years (Watson, 1992; Cunningham and Kolet, 2007). Clark and Coggin (2009) estimate a housing cycle in the U.S. to be between 1.37-2.25 years.

4.5.1 Univariate Models of Income and House Prices

To asses further whether a trend –cycle decomposition is appropriate for the data, we estimate and analyze univariate trend-cycle models for each region, for both income and house prices. A smooth trend model is estimated for the income series. A smooth trend allows one to clearly distinguish the trend and cycle frequencies in the data. We follow Fadiga and Wang (2009) and estimate a local level with drift model for the housing series. That is we assume a stochastic level and a deterministic slope for the trend component.

Results of the components variances and other statistics are reported in Table 3. For comparison, the variances of the components are expressed as percentages of the variance of the irregular component. If the variance of the irregular component is zero, then the component with the largest variance is used to make the comparisons.

Estimates for income in each of the four regions indicate short to medium cycle frequencies of 4 years in the West, 5 years in the Northeast, 6 years in the South, and 8 years in the Midwest. These cycle frequencies also persist for long periods into the future as indicated by the damping factor which is at least 0.9 in the 4 regions. The highest cycle variance is recorded in the Midwest at 14.4 followed by the Northeast, the West and the South. Variability in the trend component is less than that in the irregular component with the exception of the South. Cyclical volatility tends to dominate trend variability in regional income.

Regional housing prices are characterized by long cycle dynamics with cycle lengths of more than 13 years. The South is the only exception with a cycle length of 6.4 years. Regional housing price cycles appear to be deterministic in the South and in the Midwest, given the low estimated cycle variance and damping factor of 1 in these regions. The trend component dominates and is persistent. We note that our analysis of the components of house price series is consistent with most analysts' view of the housing market which is characterized by long periods of rising house prices.

Overall, our results indicate that trend-cycle decomposition can provide us with useful information on the dynamics of regional income and house prices. The analysis provides plausible trend and cycle frequencies in both regional series. Diagnostics results are also satisfactory.

4.5.2 Analysis by Regions

In Figure 4 the cycle components for income and house prices in each region are plotted together. The cycle components are from the univariate models discussed in the previous section. The graphs clearly show some periods of co-movement between income and house prices. We examine this co-movement and study the relationship between housing and income in a multivariate UC model. A multivariate UC model with two variables is specified as follows

$$y_t = \mu_t + \psi_t + \varepsilon_t. \tag{9}$$

For each region y_t is a 2×1 vector of income and house prices. The estimated unobserved components $(\mu_t, \psi_t, \varepsilon_t)$ are 2×1 vectors as well with stochastic error terms that are correlated with each other. The model is estimated with similar cycles. That is the damping factor, and frequency in both the income and house price series are the same. Income is estimated with a smooth trend (fixed level and stochastic slope), and house prices is estimated with a local linear trend with drift (stochastic level and fixed slope). The results are presented in Table 4.

For the cycle components, the results indicate perfect or near perfect correlation between housing and income in three of the four regions, although a correlation of 0.68 in the South is also significant. The high level of cyclical correlation is a clear indication of the importance of housing in the dynamics of the business cycle. It also supports Leamer's (2007) assertion that "housing is the business cycle." The Midwest is the only region with a business cycle that is typical of the business cycle in the US. The cycle frequency in the South, at 6.65 years is slightly higher than the typical US business cycle. The cycles in the Northeast and West are over three years longer than the US business cycle. This underscores the importance of disaggregated analysis at the regional or state level.

Given the high correlation in the cycle disturbances, in all regions, we also estimate a model with common cycles. However, the results are similar to those of the unrestricted model reported in Table 4. This is confirmed by a likelihood ratio test, which indicates that the models are statistically identical.[13]

4.5.3 Multivariate models of income and house prices

In this section we analyze whether common trends and cycles exist in the data for regional income and regional house prices. Recognizing such relationships may give

[13] Carvalho, Harvey, and Trimbur (2007) estimate the critical value at 2.71 for a chi-square distribution. The likelihood ratio statistic in all for regions was less than 0.1.

policy makers insights into the influence that surrounding regions or areas may have on the local economy. For example the question of whether regional migration influences economic activity and house prices can be better understood by looking at the relationship between the regions

Income in the 4 regions is estimated jointly in a multivariate UC model framework. A similar model is also estimated for house prices. The multivariate models are specified as in equation 4 where y_t is a 4×1 vector of regional income or house prices. The model for house prices is specified as is Fadiga and Wang (2009) – a local level with drift. Regional income is specified using a smooth trend. Both models assume a cycle frequency of 5 years.

Preliminary analysis indicates that the estimated models are adequate representation of the data. The presence of serial correlation (Ljung-Box Q-Statistic) in the residuals is rejected for most regions. Tests of normality based on the Bowman-Shenton normality test rejects the null that the income data are from a normal distribution, for some of the regions (Northeast and West) but does not reject the null for most of the house price series (West, Midwest, South)

Table 5 presents the correlation matrix for the estimated coefficients of regional income and house prices. The components of regional income are highly correlated. For example, the correlation coefficient between any two regions is at least 0.93 (between Northeast & Midwest) for the slope component of the trend. Regional income cycles are also highly correlated, although not as strong as the slope component. The income cycle for the South is strongly correlated with the cycle for the Northeast, West and Midwest. Correlation is at least 0.68 for cycles between the South and the other regions.

For house prices, the highest correlation is between house price trends in the Midwest and the South (0.94). Housing trends in the South are also strongly correlated with housing trends in the Northeast. The Northeast and the Midwest also have strong connections (0.69).

Overall, the results show evidence of common dynamics in income and house prices across the 4 regions. However, the evidence is much stronger for income compared to house prices. This is supported by recent activity in the economy. For example each of the 4 regions was adversely affected by the economic downturn. Between 2007 and 2011, average unemployment was 7% across the regions. The rise and subsequent fall in house prices however was uneven across the regions. Above average rises in house prices were observed in many states in the West (Arizona, California, and Nevada) and the Northeast (Massachusetts, New Jersey, and Rhode Island), but not so in the other regions. The fall in house prices also affected states in the west more so than in the other regions.

Figures 5 and 6 are graphs of the cyclical and trend components of regional income and housing prices. The cyclical components of the income series in Figure 5 clearly show the down turn in economic activity across regions beginning in 2008. Other recessionary periods (1982, 2001) are also evident in the graphs. The cyclical components of house prices in Figure 6 clearly identify the rise and fall in housing prices beginning around 2001. The graph clearly shows the substantial increase in housing prices in the West and Northeast compared to the other regions. The housing boom of the late 1980's to early 1990's is also evident in the graphs.

The high level of correlations suggests that the error variances of the components may be less than full rank. We can, therefore, re-estimate the model with restrictions to reflect a reduced rank in the error variances of the components. A likelihood ratio test can then be used to determine whether the restrictions are valid.

For income, our model suggests a rank of 3 for the error variance of the slope components. That is the high correlation among the components and the low eigenvalues for the slope component of the South indicate that this restriction is justified. The eigenvalues for the cycle components of income do not suggest estimating the cycle variances with reduced rank. The log likelihood statistic for the unrestricted model is 3919.72 and that for the reduced rank model is 3366.44, which is a very large difference relative to the chi-squared distribution. This suggests that the unrestricted model is preferred and that regional incomes are not cointegrated. The eigenvalues for the components of regional house prices do not suggest the need for a reduced rank model

4.6 Conclusion

In this paper we study the time series properties of regional income and house prices using structural time series techniques. Multivariate UC models are analyzed to identify common trends and cycles in income and housing data in the 4 census regions.

Evidence from a bivariate analysis of income and house prices reveal that income and house price dynamics are strongly related in each of the 4 census regions. The correlation coefficient between income and house prices in the components is almost 1. In all 4 regions the role of housing on the determinants of income is very significant.

Our UC model of regional income and regional house prices showed the existence of common characteristics in the components of income and housing. In particular, house prices can be modeled with three common trends and two common cycles. We find strong co-movements in income and house prices among the 4 regions. However, co-movements are much stronger for income compared to house prices. As evidence of this outcome, income receipts in all 4 regions were down during the recent recession. However, the severity of the housing crisis was uneven across regions.

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Table 1. A listing of the States by Census Region

Northeast	West	Midwest	South
Connecticut	Alaska	Illinois	Alabama
Maine	Arizona	Indiana	Arkansas
Massachusetts	California	Iowa	District of Columbia
New Hampshire	Colorado	Kansas	Delaware
New Jersey	Hawaii	Michigan	Florida
New York	Idaho	Minnesota	Georgia
Pennsylvania	Montana	Nebraska	Kentucky
Rhode Island	Nevada	North Dakota	Louisiana
Vermont	New Mexico	Ohio	Maryland
	Oregon	South Dakota	Mississippi
	Utah	Wisconsin	North Carolina
	Washington		Oklahoma
	Wyoming		South Carolina
			Tennessee
			Texas
			Virginia
			West Virginia

Table 2. Summary Statistics for House Prices and Income

Regions	Mean	Std. Deviation	Minimum	Maximum	Observations
		House Prices			
Northeast	145,320.41	108,928.12	19,600.00	385,200.00	196
West	128,386.73	95,717.89	18,000.00	356,500.00	196
Midwest	103,353.06	64,954.70	17,500.00	224,200.00	196
South	95,245.92	62,619.92	15,800.00	222,900.00	196
		Income			
Northeast	243,803.73	177,913.02	31,954.76	609,166.42	196
West	381,508.98	303,996.61	33,341.07	991,359.05	196
Midwest	142,612.38	100,811.64	17,894.06	335,487.22	196
South	168,769.17	151,632.04	9,659.14	507,906.53	196

Note: Data are quarterly and cover the quarters from 1963:1 to 2011:4. Income is in millions of dollars.

Table 3: Unrestricted Univariate Estimates for Income and House Prices.

	Northeast	West	Midwest	South
Variances for Income:				
slope	0.082	0.723	0.262	0.046
cycle	6.737	2.271	14.440	1.000
Irregular	1.000	1.000	1.000	0.000
damping factor	0.933	0.892	0.891	0.929
length of cycle	8.384	3.902	5.035	6.443
Normality	0.0001*	0.0002*	0.0001*	0.0009*
Q-statistic	0.4559	0.0694	0.3285	0.1701
R-square	0.1746	0.3687	0.2773	0.4035
Variances for House Prices:				
level	0.358	1.807	0.631	1.977
cycle	0.015	0.446	0.000	0.000
irregular	1.000	1.000	1.000	1.000
damping factor	0.992	0.996	1.000	1.000
period cycle	15.376	13.781	12.782	6.482
Normality	0.0001*	0.0484*	0.1241	0.1614
Q-statistic	0.0176*	0.3960	0.0027*	0.0595
R-square	0.9947	0.9955	0.9911	0.9984

Notes: variables are in logs; models are estimated for the period 1963:1-2011(4); income models are estimated with a smooth trend (fixed level, stochastic slope); house prices are estimated with a local level with drift (stochastic level, fixed slope); reported variances are relative to the irregular variance; the period of the cycle is in years; normality is the Bowman-Shenton Normality test; Q-statistic is the Box-Ljung Q-statistics; p-values of the normality and Q-statistic are reported; * indicates rejection of the null at 5% level.

Table 4; Estimates from a Bivariate model of Income and Housing by Region

	North east		West		Midwest		South	
Variance Terms	Income	House Prices	Income	House Prices	Income	House Prices	Income	House Prices
level	0.000	0.428	0.000	1.000	0.000	0.761	0.000	1.000
slope	0.012	0.000	0.031	0.000	0.016	0.000	0.041	0.000
cycle	1.000	0.000	1.000	0.000	1.000	0.000	1.000	0.335
Irregular	0.147	1.000	0.027	0.163	0.052	1.000	0.003	0.086
Damping factor	0.934		0.953		0.891		0.938	
Period-cycle	8.445		8.227		5.216		6.649	
Cycle correlations	1.000		1.000		0.999		0.679	
Normality	0.0001	0.001	0.0001	0.137	0.0001	0.153	0.0000	0.017
Q-statistic	0.5176	0.017	0.0513	0.000	0.4206	0.000	0.1261	0.062
R-square	0.9998	0.997	0.9999	0.993	0.9999	0.999	0.9999	0.995

Notes: income is estimated with a smooth trend; house prices is estimated with a local level with drift correlations are the correlation coefficient between income and housing for each region; the period of the cycle is in years; normality is the Bowman-Shenton Normality test; Q-statistic is the Box-Ljung Q-statistics; p-values of the normality and Q-statistic are reported; * indicates rejection of the null at 5% level; reported variances are relative to the irregular variance.

Table 5: Variances and Correlations for trend and cycle components

	Northeast	West	Midwest	South
Income: slope				
Northeast	2.897	0.996	0.926	0.957
West		5.739	0.948	0.978
Midwest			2.306	0.980
South				6.488
Income-cycles				
Northeast	4.582	0.861	0.676	0.801
West		4.644	0.751	0.798
Midwest			5.422	0.840
South				5.029
Eigenvalues (%)	97.92	1.760	0.320	0.001
House Prices: level				
Northeast	250.2	-0.119	0.689	0.686
West		199.90	0.531	0.476
Midwest			447.5	0.938
South				385.0
House Prices: cycles				
Northeast	0.277	0.855	0.455	0.677
West		0.526	0.803	0.831
Midwest			0.155	0.495
South				0.017
Eigenvalues (%)	57.98	25.74	9.300	6.970

Notes: Variances are in the main diagonal. Variances are multiplied by 10^6

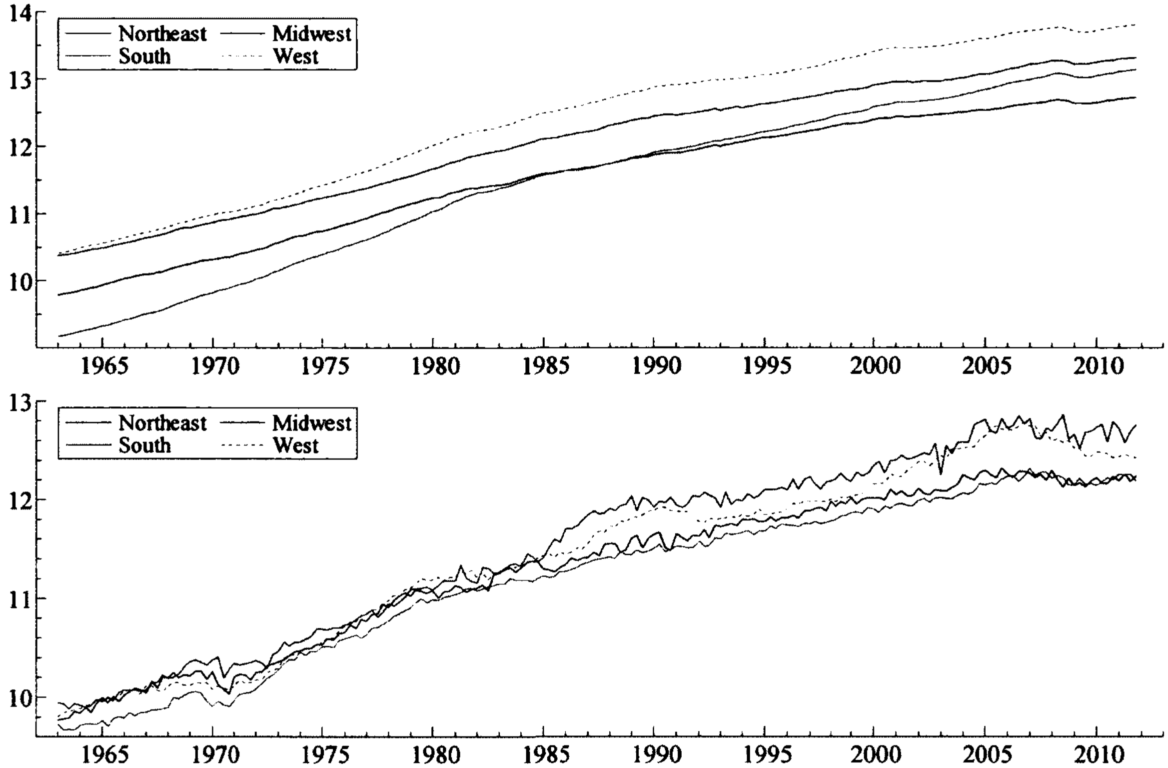

Figure 1: Regional Income (top graph) and Regional House prices (bottom graph).

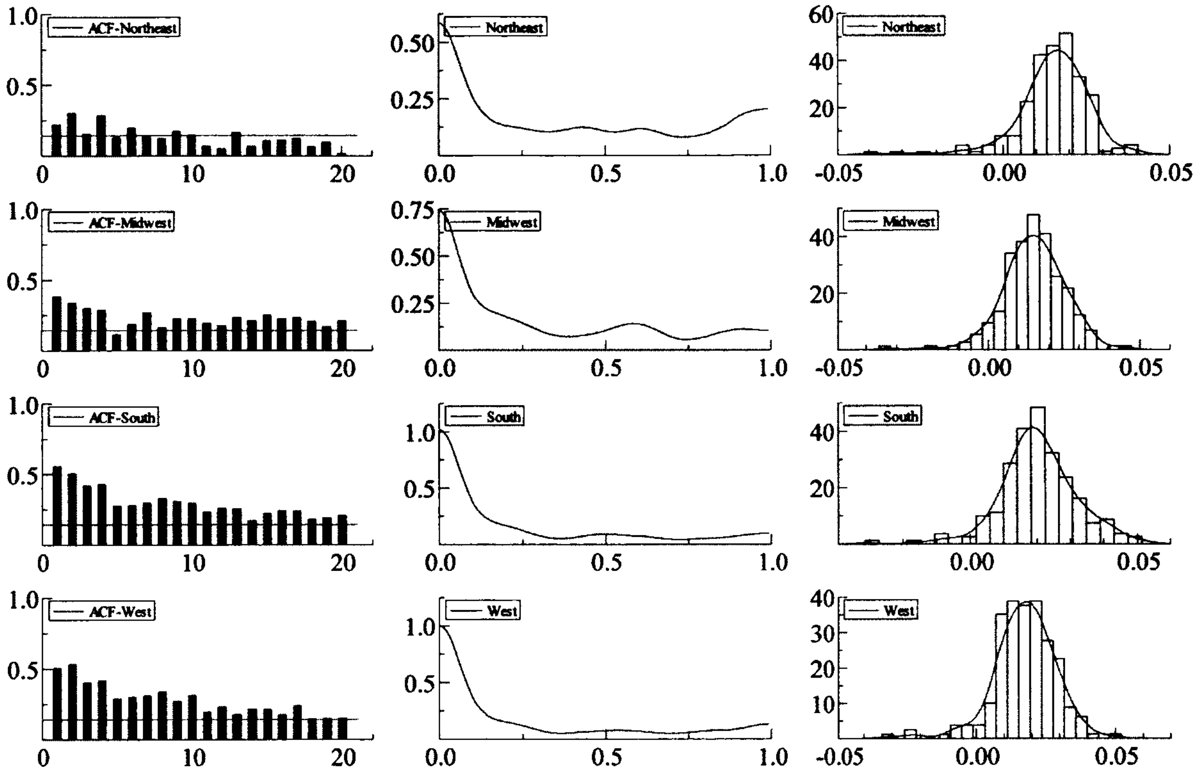

Figure 2: Correlogram, spectral density, and histogram of income for the census regions-Northeast, West, Midwest, and South. For each region the data are for the period 1963:1-2011:4.

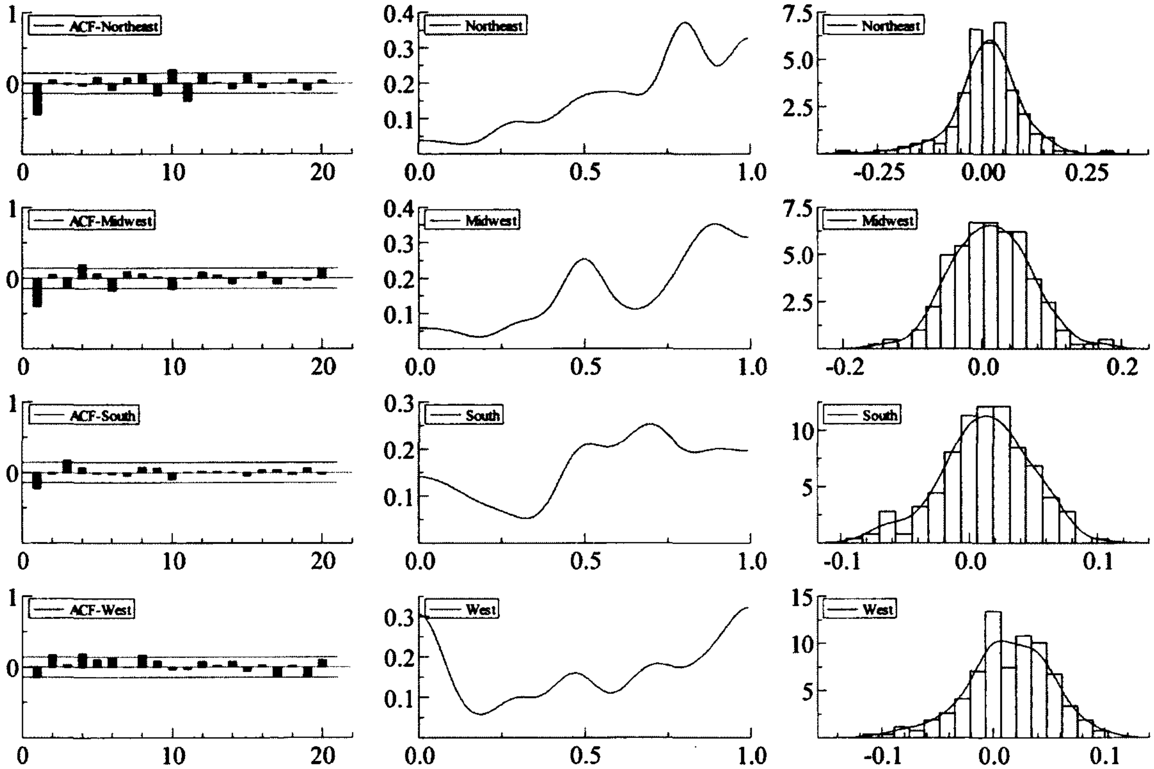

Figure 3: Correlogram, spectral density, and histogram of house prices for the census regions-Northeast, West, Midwest, and South. For each region the data are for the period 1963:1-2011:4.

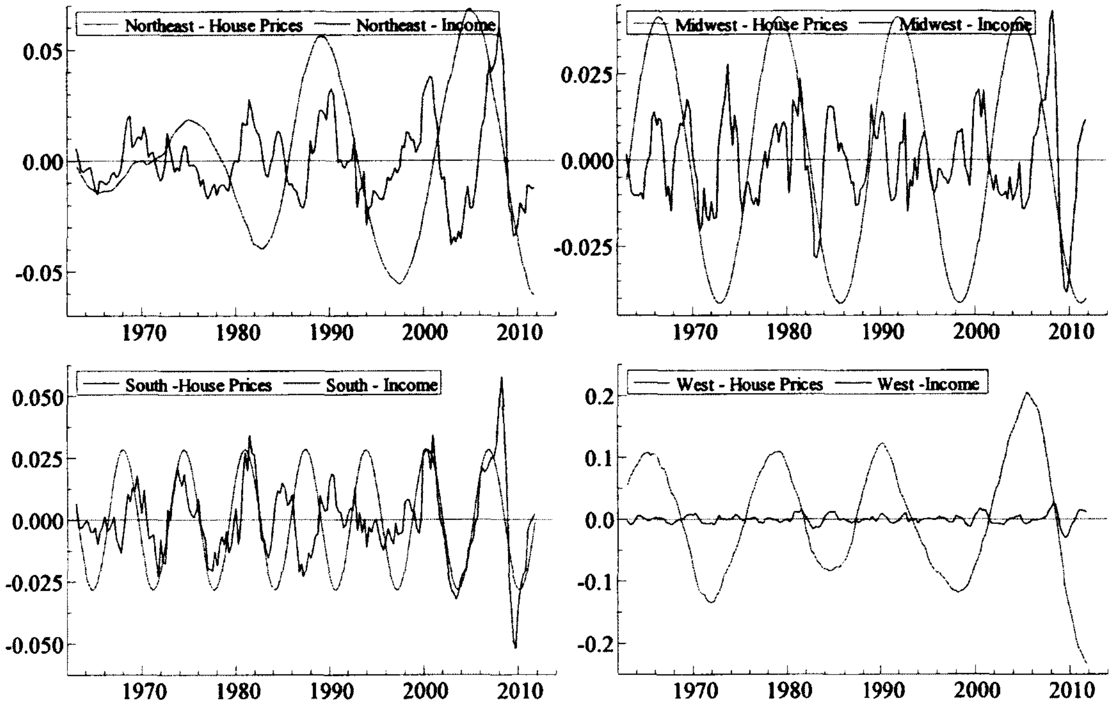

Figure 4. Income and house price cycles for each region from the univariate models.

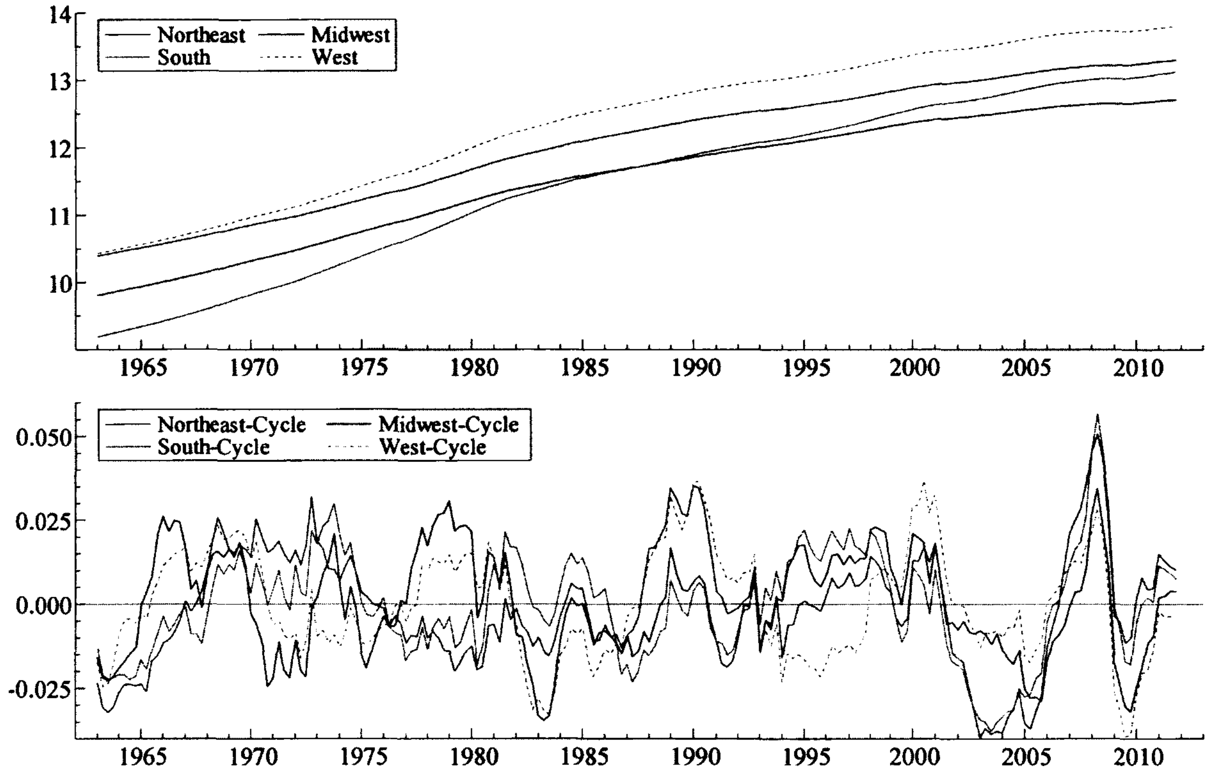

Figure 5: Four variable trend and cycle decomposition of Income for the Northeast, West, Midwest, and the South.

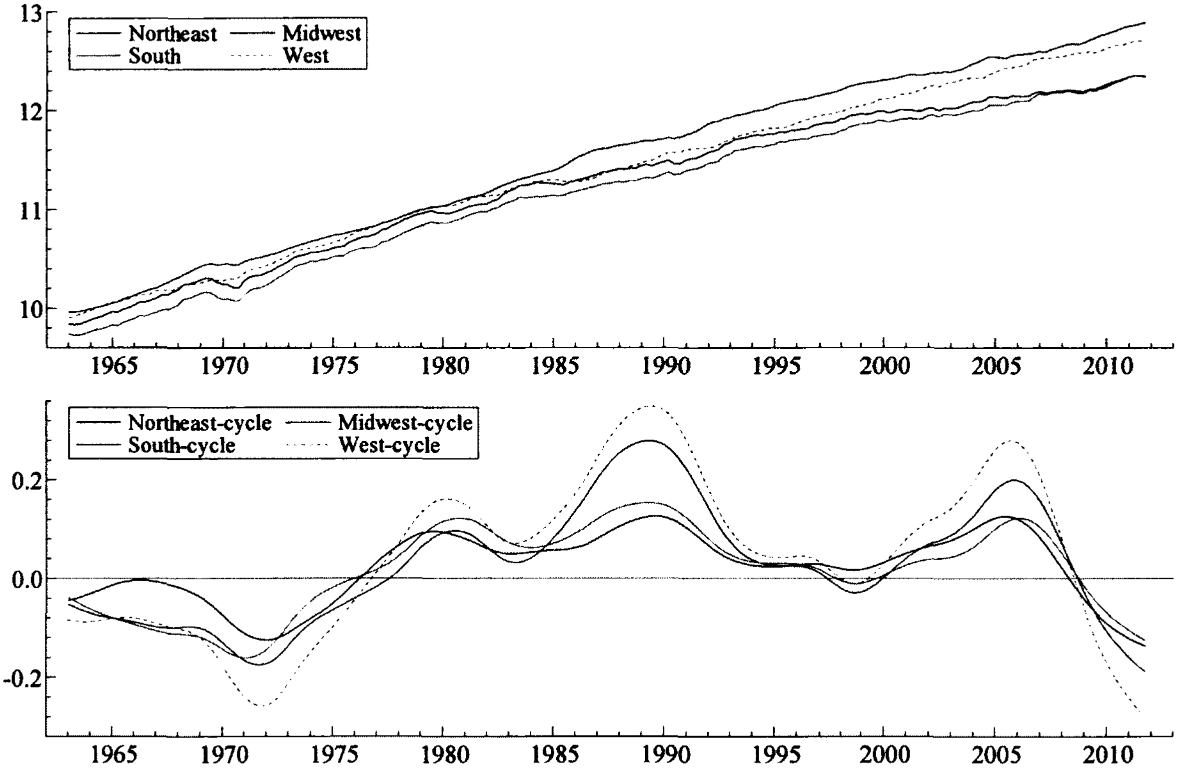

Figure 6: Four variable trend and cycle components of house prices for the Northeast, West, Midwest, and the South.

5. OVERALL CONCLUSION

The first essay of this dissertation, "The Effects of Monetary Policy on Housing Using State Level Data," studies the influence of exogenous monetary policy shock on house prices and housing starts at the individual state level. Many previous studies on the influence of monetary policy have focused more attention on the use of national data for analysis. However the view of this paper is that because states are fundamentally different, it makes sense to study the implications of policy on states individually. Impulse response functions from individual states reveals that housing starts are more sensitive to a monetary shock compared to house prices. The impact of monetary policy on house prices range from a fall in house prices as low as 0.01% in Indiana to a high of 1.59% in Florida. Housing starts in Florida is also the most affected by a monetary policy shock with a 4% decline.

The second essay, "The Effects of Adjustable Rate Mortgages on House Price Inflation," examines two issues with respect to the housing market. First the paper studies the determinants of the share of adjustable rate mortgages. This issue is important given the recent activity in the housing market, which finds adjustable rate mortgages, more than two thirds of all subprime mortgages, was a leading cause of the housing crisis. We find that even before the crisis, the main determinant on the choice of adjustable rate mortgages is the spread between fixed rate and adjustable rate mortgages. The bigger the spread, the more likely borrowers will choose ARM. The second issue addresses the possibility that a simultaneous relationship exists between adjustable rate mortgages and house price appreciation. If prices are expected to rise into the foreseeable future, lenders are motivated to lend. Borrowers are also eager to borrow for the purchase of a home. Lenders and borrowers can bolster each other's position in a feedback type loop, hence raise house prices. Using a dynamic panel model of the 48 contiguous states, we find that this feedback like behavior is indeed possible.

The third essay, "Estimating the Relationship between Income and House Prices Using Structural Time Series Methods," uses multivariate unobserved components models to analyze and identify common trends and cycles in income and house prices using data on the four census regions of the U.S.: Northeast, Midwest, South and West. The idea is that the unobserved factors, not often considered in traditional regressions, can provide added information to policy makers that they can use in making decisions regarding the economy. Results indicate a strong correlation between income and housing in all four regions. The results from a bivariate model of income and house prices reveal that housing contributes considerably to the determinants of income.

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