ESSAYS ON MONETARY POLICY AND ASSET PRICE BUBBLES:

EVIDENCE FROM THE U.S. HOUSING BUBBLE

by

Christine L. Storrie

A dissertation submitted to the Faculty of the University of Delaware in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Economics

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ABSTRACT

The link between monetary policy and bubbles in asset prices is investigated in two separate empirical studies as well as an examination of theoretical models of asset-price bubbles. Common methods used to estimate bubbles are discussed including difficulties of empirically identifying bubbles in asset prices, and whether a response from central banks is appropriate. To empirically explore the relationship between monetary policy and asset-price bubbles, I examine the recent housing bubble in the United States to determine if the Fed's use of expansionary policy during this time contributed to the run-up in house prices. Methods employed include OLS and generalized method of moments (GMM) to estimate empirical Taylor-type policy reaction functions. Granger causality analysis, impulse response functions, and forecast error variance decomposition are applied to VAR models to determine the impact of the Fed's loose monetary policy on the U.S. housing market. Separate specifications for the Fed's traditional interest rate targeting policy as well as recent non-traditional policies including quantitative easing are tested to examine any impact of these monetary policies on house prices. The findings are consistent with the view that the Federal Reserve held interest rates artificially low during the years of the housing bubble, and both traditional and non-traditional policies of the Fed in recent years impacted house prices.

Chapter 1

BUBBLES IN ASSET PRICES

1.1 Introduction

Examples of bubbles in asset prices go as far back as Holland in 1636 when the first documented bubble occurred in the Dutch tulip market, known as Tulip mania. Since that time, dozens of other examples of asset bubbles can be traced throughout history. There is much debate in the literature on whether an asset price bubble can truly exist. Some economists, weary of violating the foundations of the rational expectations model, prefer to classify the periods of extreme run-up in prices and subsequent crash as manias. Manias can be defined as a run up in prices that trigger additional price increases. The upward movement in prices is based on the exaggerated beliefs about potential future earnings. The rise in price is followed by a collapse.

Whether or not these periods throughout history are or are not classifiable as bubbles is not the focus of this chapter. Instead, I focus on the theoretical model for pricing assets from both a classical rational expectations model as well as some of the theories from newer behavioral models. For the rest of this dissertation, I will refer to the periods of extreme price inflation of an asset followed by the subsequent collapse of prices as a bubble. Common empirical methods used to estimate bubbles are presented along with an examination of the difficulties of empirically identifying bubbles in asset prices. I provide a brief history of historical bubbles and conclude with a discussion on the role of central banks and whether a response on their part to asset-price bubbles is appropriate.

1.2 Rational or Irrational Investors? The Theory Behind a Bubble

A fundamental concept underlying the efficient market hypothesis (EMH) is the assumption that prices are always correct and reflect market fundamentals. In financial markets, stock prices are calculated as the discounted present value of all future cash flows. According to the efficient market hypothesis, the price of each stock adjusts to reflect all available information. No arbitrage opportunities are possible because the markets will adjust to any mispricing. If the price of an asset is high only due to investor expectations of future cash flows and not based on any fundamentals, this is because of the belief that the price of the asset will continue to be high in the future. Another major point of the EMH is that one cannot earn above average returns without taking on above average risk.

Any asset price bubbles are a result of self-fulfilling expectations of rising prices. Simply stated, rational bubbles represent a mispricing of the asset relative to pricing consistent in efficient markets (Malkiel, 2010). A rational bubble's equilibrium price is higher than the price justified by the value of the discounted dividend stream.

Shiller (2000) argues that according to the efficient market hypothesis, when prices appear to be too high or too low at times the apparent price distortion must be an illusion. Price changes are unpredictable since they occur only in response to new information. The fact that the information is genuinely new information makes it unpredictable. This approximately describes random walks through time. Efficient market theory has been commonly been used to justify what seems to be elevated market valuations. The efficient market hypothesis implies difficulty in predicting day-to-day price changes, therefore, one cannot predict *any* changes in price.

To derive the basic relationship between the price of an asset and its future flow of dividend stream we define the asset's growth rate. The growth rate of an asset can be expressed as

$$(1 + r_{t+1}) = \frac{P_{t+1} + d_{t+1}}{P_t} \tag{1.1}$$

where r is the rate of return, P_t Is the price of the asset at time *t,* and d_t is the dividend received on the asset. Assuming a constant rate of return on an infinitely-lived asset, then the expected future rate of return, $E_t(r_{t+1}) = r$ and Equation 1.1 becomes

$$P_t = \left(\frac{1}{1+r}\right) E_t(P_{t+1} + d_{t+1}) \tag{1.2}$$

Iterating forward *I* periods we can solve for the price of an asset for a finitely-lived asset such that,

$$P_t = \left(\frac{1}{1+r}\right) E_t[\textstyle\sum_{i=t+1}^{I} P_{t+i}]^I + \left(\frac{1}{1+r}\right) E_t[\textstyle\sum_{i=t+1}^{I} d_{t+i}]^I \tag{1.3}$$

Rational expectations assumes an infinitely-lived agent so in the limit,

$$P_t = \sum_{i=t+1}^{\infty} \left(\frac{1}{1+r}\right)^i E_t d_{t+i} + \lim_{i \to \infty} \left(\frac{1}{1+r}\right)^i P_{t+i} \quad (1.4)$$

Equation 1.4 is known as the dividend discount model. The transversality condition in infinite horizon models affirms that the expected future price converges to zero.

$$\lim_{i \to \infty} \sum_{i=1}^{\infty} \left(\frac{1}{1+r}\right)^i P_{t+i} = 0 \quad (1.5)$$

Using the dividend discount model, the price of an asset can be determined by the present value of discounted future dividends and can be expressed as

$$P_t = \sum_{i=t+1}^{\infty} \left(\frac{1}{1+r}\right)^i E_t d_{t+i} \quad (1.6)$$

Tests for rational bubbles in the model test for violations of the assumption of Equation 1.5 such that Equation 1.6 can be rewritten as

$$P_t = \sum_{i=t+1}^{\infty} \left(\frac{1}{1+r}\right)^i E_t d_{t+i} + B_t \quad (1.7)$$

where B_t represents any price beyond the fundamental value of the discounted value of future cash flows. B_t can be any stochastic process satisfying

$$B_t = \left(\frac{1}{1+r}\right) E_t(B_{t+1}) \quad (1.8)$$

Equation 1.7 rules out any arbitrage opportunities in the model. Scherbina & Schlusche (2014) describe the conditions in which a bubble can exist in context of the classical definition of a rational expectations model. The assumption is that all agents are perfectly rational and have the same information set at time *t.* A bubble can only exist if the rate of growth of the asset is equal to the discount rate and the asset is infinitely lived. Additionally, rational bubbles require an assumption of no upper limit to the size of the bubble. A rational bubble's equilibrium price is higher than the price justified by the value of the discounted dividend stream.

If the rate of growth of the asset was lower than the discount rate, the present value of the bubble is zero. If the asset's growth rate is higher than the discount rate, the present value of the asset is infinite. In both cases, the bubble cannot exist. A bubble can exist only if the rate of growth of the bubble is exactly equal to the asset's required rate of return. This condition implies that bubbles cannot exist when there is an upper bound to the price of the asset. If dividends grow slower than the rate of return on the bubble, the fundamental component of the asset price will converge but the bubble component will become infinite making the present value of the asset infinite. If the rate of return on the bubble is less than the rate of return on the dividends, the present value will be zero and the bubble cannot exist.

Gurkaynak (2008) presents an alternative method to obtain Equation 1.6 using a consumer's optimization problem. The present value model assumes the value of $B_t = 0$ in all periods. Other assumptions in addition to the constant rate of return include no asymmetrical information and the representative consumer is a risk-neutral agent.

A major implication of these models is that bubbles cannot exist in finitely-lived assets. Rational agents will anticipate the bursting of the bubble at the end of the asset's life at time T (Scherbina & Schlusche, 2014). No one would be willing to buy the asset at time T-1 since it has an inflated price. The agents will also recognize this for each preceding period prior to T-1. Backward induction would iterate back to the present value of the asset.

In some looser versions of rational expectations models, the assumption does not require all agents to be rational (Driscoll & Holden, 2014). If the possibility of arbitrage were to exist, some agents will profit by selling the asset if the price is above the fundamental price. The rational investors would choose to continue to hold the asset even if they believe the price is above the asset's fundamental value (Canterbery, 1999). Rational investors believe that naive investors will buy the asset at a higher price in the future allowing for them to profit from their investment. There is no way to predict the timing of the end of upward movement in the price of the asset, however. Therefore, there are no opportunities to exploit the mispricing.

A limitation of the EMH is that even given the knowledge of any mispricing, investors do not know how long the mispricing will last or when it will end. Additionally, unless one can prove this knowledge to a large audience, there is no way to profit from such knowledge. Proponents of the EMH argue that even if irrational or behavioral traders exist in the market, rational arbitrageurs will still force the asset price back to its fundamental value.

Whereas the efficient market hypothesis incorporates rational expectations into the model, irrational or behavioral models take another approach to explaining the behavior of buyers and sellers. One of the assumptions of the rational expectations model is that all agents have the same information set at time t. This information is reflected immediately in the price of the asset. But what if this assumption is relaxed and not all agents have the same information? Behavioral models describe heterogeneous agents and expectations (Driscoll & Holden, 2014). In these models, not all agents have the same information set. Some agents are more informed than others. The better informed agents choose to hold the asset even though the price is inflated above the fundamental price because they expect to eventually sell it to less informed agents.

Shiller (2003) describes speculative bubbles. These are bubbles in which investors are attracted irrationally to an investment due to the expectation of future price increases of the asset. As more and more people are attracted to the investment, the price increases creating a feedback loop. The bubble ends once the expectation that prices will continue to rise ends. Subsequently, demand falls and the bubble bursts.

Mishkin (2009a) describes two types of asset price bubbles. Bubbles driven by credit and bubbles formed by overly optimistic expectations. Credit-driven bubbles pose a higher risk to economic fundamentals since easy lending policies increase demand for lending and subsequently further increase the demand for the asset. This creates both a credit boom, which, in turn drives up the asset price generating the bubble in the asset price. When the bubble inevitably bursts, asset prices decline, lenders cut back on loans, and demand for the asset drops even further causing prices to plummet. This can cause a decline in household spending impacting the entire economy.

Bubbles, driven solely by "irrational exuberance" as described by Mishkin (2009a) and referring to Alan Greenspan's description of the overly optimistic markets during the tech-stock bubble, do not pose as great a threat to the economy. These bubbles are not associated with any credit boom, such as the technology stock bubble in the late 1990's. The burst of this bubble did not impact the economy as severely as the housing bubble and the recession following the technology stock bubble was fairly mild in comparison. As opposed to speculative bubbles as are the type often seen in the financial markets, Mishkin argues that credit-driven bubbles are in fact possible to identify and pose a greater threat to economic fundamentals than speculative bubbles.

1.3 Estimating Bubbles in Asset Prices

There is conflicting literature on the existence of bubbles. Often when a bubble is determined in one study, another study fits the data without using bubbles. Alternative explanations include studies of habit formation that make risk aversion a function of consumption, and allowing for the discount factor to vary with the business cycle (J. Y. Campbell & Cochrane, 1999). Models based on optimizing behavior have difficulty accounting for key real-world observations. Behavioral economic assumptions can be used in an attempt to make model predictions better fit the data (Driscoll & Holden, 2014). Behavioral models allow for irrational pricing and are associated with irrational bubbles (Gurkaynak, 2008).

The standard utility maximization problem and the present value of dividends model can be used to test for the presence of asset price bubbles. The present value of dividends model is used in equity pricing and tests the validity of a standard present value model. Assumptions of the present value model include no arbitrage conditions, a risk neutral consumer, a constant discount rate and an assumption of no asymmetrical information.

Econometric tests for the existence of bubbles using the standard present discounted value of the dividends model can show that data is inconsistent with the presence of a bubble. Econometric methods used for detecting bubbles include the variance bounds test, West's test of bubbles, integration/cointegration based tests as well as tests for collapsing bubbles. There are no tests however, that can eliminate other plausible explanations and conclude that the data is only consistent with the presence of a bubble.

Variance bounds tests for detecting bubbles in stock prices test whether stock prices are more volatile than traditional models imply. These econometric methods for testing the validity of the present value model were first proposed by Shiller (1981) and LeRoy and Porter (1981). This method derives a relationship between the variance of equity prices and the ex post realized discounted sum of present and future dividends. Shiller finds large variability in stock prices that cannot be justified by movements in nominal interest rates during the same sample period. He concludes that volatility in stock prices can be explained fundamentally by unobservables but cannot be evaluated statistically. A major criticism of this method is that the variance bound is only valid when dividends follow a stationary process (Engel, 2005; Kleidon, 1986; Marsh & Merton, 1986).

In contrast to the variance bounds tests that test for volatility in stock prices, West (1987) formally tests for the existence of speculative bubbles. West's test for speculative bubbles allows for a wider class of bubbles than in previous tests. This method can be applied even in the presence of non-stationarity. Two parameters are estimated separately. The first component regresses stock prices on a set of lagged dividends. The null hypothesis of the test is that the price of the stock is determined by the dividend discount model. If a bubble exists, the stock price is determined by two components, the price under the efficient market model and a bubble component. The second set of parameters is obtained indirectly using equations using an arbitrage equation for the discount rate as well as an ARIMA equation for the dividend process. Critics contend that it is an overly restrictive form of the present value model.

Campbell and Shiller (1987) test the validity of the present value model using a cointegrated vector-autoregressive VAR model. This method was first introduced by Engle and Granger (1987) and Phillips and Durlauf (1986). The cointegrated technique effectively addresses the issue of nonstationarity and incomplete data on the information set of the market participants, which are two of the problems found in the present value model. One of the major criticisms of the integration/cointegration-based tests for detecting bubbles is the difficulty in estimating cointegrating relationships and the econometric challenge of detecting non-stationarity (Gurkaynak, 2008).

Tests for collapsing bubbles addresses the issue of other tests' inability to detect the existence of bubbles that collapse periodically (Hall, Psaradakis, & Sola, 1999). Gurkaynak (2008) finds that all empirical tests for bubbles fail to distinguish between the existence of asset bubbles and misspecification of the fundamentals in the model. He therefore concludes that bubbles cannot be detected using econometric testing with any degree of certainty.

1.4 Historical Bubbles

Whether or not we can truly classify an asset price anomaly as a bubble, there are some famous examples of bubbles throughout history. I present a brief overview of some of these historical bubbles. This overview is not intended to encompass every historical bubble and be exhaustive. I merely summarize some of the more famous bubbles throughout history.

Discussion of historical bubbles typically begins with Holland's Tulip Mania. Tulip Mania is considered to be the first historical asset price bubble and occurred in the Netherlands during the 1600's. During this time, tulips were considered to be a rare and beautiful flower and were coveted among the wealthy. Tulip bulbs that produced unique patterns commanded higher prices than common bulbs (Garber, 1989). The price of certain tulip bulbs rose sharply as demand for bulbs affected by the mosaic virus increased. This virus produced "breaking" in the bulbs that resulted in uniquely patterned flowers but also reduced the bulb's rates of reproduction. The bulbs that were affected by the mosaic virus were considered rarer and commanded a higher market price.

Much of the tulip market was for the outgrowths of these rarer bulbs. The outgrowths needed to become an adequate size prior to delivery. This in essence, created a futures market for the bulbs. Written contacts were drawn outlining details for future payment and delivery. The increase in demand was caused not only by professional growers and flower enthusiasts but due to the sharp rise in prices, the tulip market attracted speculators.

Eventually, the price for tulip bulbs collapsed. Whether or not the bursting of the tulip mania bubble caused a subsequent severe economic distress in the Netherlands is difficult to conclude since data is difficult to obtain.

The run up in the prices of tulips in Holland is generally considered the first historical bubble. Not all economists agree, however, on the classification of Tulip Mania as a true asset bubble. In fact, Garber (1990) argues that the sharp rise and decline in the price of tulips is no different than other bulbs introduced into the market in following years. He finds only one month during which common bulb prices increased and rapidly crashed remains plausible as a potential bubble. He also finds no serious evidence of economic distress following tulip mania.

The next major historical bubble is known as The South Sea Bubble. The name South Sea refers The South Sea Company. This English firm aimed at managing the country's national debt and increasing faith in the credit-worthiness of the British government (Malkiel, 2010). The South Sea Company was granted monopoly rights for trading in the Spanish colonies of South America in exchange for purchasing £9.5 million of short-term government debt (Dale, 2004). The interest paid to the South Sea Company on the government debt was around 6% and provided earnings to shareholders.

A speculative craze began when investors learned that great profits could be earned from trade with South America after the war ended between Britain and Spain (Malkiel, 2010). In 1720, the stock price of the South Sea Company soared. The price of The South Sea Company's stock rose by of over 700 percent only to come crashing down by year end to only 50 percent above the stock price at the beginning of the year (Scherbina, 2013).

Much like the South Sea Bubble, the Mississippi Bubble was linked to expansive monetary policy and investor speculation (Kindleberger & Aliber, 2011). A Scottish financier by the name of John Law, founded a company called Compagnie d'Occident. It was later re-named Compagnie des Indes, but referred to as the Mississippi Company. Along with its other endeavors including the right to mint new coins in France and to collect all French indirect taxes, the Mississippi Company was granted a monopoly on trade in the Mississippi territory as well as China and the East Indies. Investors were lured by the prospect of gold and silver potentially in the Mississippi territory causing the share price for the Mississippi Company to rise sharply.

The Banque Royal, the Royal bank of France, increased the money supply by increasing its note issue to facilitate stock sales of the Mississippi Company. Shareholders began to convert shares into gold coins and share prices began to fall. Since the supply of gold coins was drying up, the company attempted to exchange shares for paper money (Garber, 1990). This caused inflation in France to explode to 23 percent by January 1720. In a series of stages, Law devalued shares of the

Mississippi Company and by September 1721, stock prices plummeted back down to their price prior to the bubble (Scherbina, 2013).

The first modern passenger British railway was introduced in 1830. Success of initial railway companies sparked a frenzy of applications for new railway companies in the early 1840's. Over one thousand new railway companies were created between 1844-1846. In 1850, the Bank of England raised interest rates. Investment began to flow to government bonds and away from the railways. Soon after, railway stock prices peaked and began to plummet.

Often, the assumption is that naïve investors fuel asset price bubbles. Campbell and Turner (2012) examine the British Railway Mania of 1845-1846 and find that these so called inexperienced investors did not contribute a disproportionate portion of the investments. They find that naïve investors fared no worse than those that could be considered more experienced investors.

The roaring twenties was a period of economic boom that ended with the crash of the stock market in October 1929. For the United States, this decade was marked by greater investor enthusiasm and vaster public attention in the stock market than previous eras (Shiller, 2000). During this time, economic growth was rapid and many technological advances were made available to the general population. This overall enthusiasm caused a run-up in the stock market.

The eventual decline in stock prices triggered an even bigger crash in the market. Investors, who bought stock on margin, were forced to sell their shares when they were either unwilling or simply unable to meet the call (Malkiel, 2010). Falling prices led to more and more margin calls creating a downward spiral. The stock market crash was followed by one of the most severe depressions in U.S. history.

The start of the Internet bubble began around 1995 and burst in March 2000. During this time, the stock market saw an increase in overall prices of over 200%. The market value of U.S. stocks grew from 60 percent of GDP in 1982 to 300 percent of GDP in 1999 (Kindleberger & Aliber, 2011). Although the United States saw the largest gains in stock prices, countries worldwide were also experiencing huge gains in their stock markets. The sharp rise in stock prices during this time is somewhat comparable to the stock market crash of 1929 if corrected for the latter's smaller scale. Since the bubble was not associated with credit increases, there was no effect on banks and the subsequent recession was fairly mild.

Much like the new trade opportunities of the South Sea Bubble, the Internet or dot-com bubble was brought on by new technology as well as new business opportunities sparked by the Internet. As with many other bubbles throughout history, one explanation for the rapid rise and crash of stock prices is speculation and enthusiasm for the new technology.

1.5 The U.S. Housing Bubble

The housing bubble that originated in the United States and eventually spread across the globe began in the second quarter of 1996. Although the price of homes did not rise sharply at first, according to the Case/Shiller House Price Index, house prices rose by over 132% from the first quarter of 1997 through the peak in the second quarter of 2006. The cause of the upward trend in house prices is still up for debate as many contributing factors could be partly to blame for the rapid increase in home values. Holt (2009) attributes the cause of the housing bubble to four factors: low mortgage interest rates, low short-term interest rates, relaxed standards for mortgage loans and irrational exuberance.

The decade of the 1990's saw increasing incomes in the United States that began in 1992. Savings rates in the U.S. were low but despite this, mortgage rates continued to fall. This was due in part to the influx of savings from other countries that had extremely high savings rates. The net savings inflow from foreign investors rose from 1.5% of GDP in 1995 to around 6% in 2006 (Bernanke & Gertler, 2009). These investors seeking low risk and high returns branched out from U.S. government securities to mortgage-backed securities.

Several government policies during this time encouraged the relaxation of traditional credit standards for mortgage acceptance rates. In addition to legislation, financial innovation during this time reinvented the mortgage industry. Once only granted to the most credit worthy borrower, mortgage loans were being redefined by a new class of borrower. Aided by technology, a new method of evaluating an individual's credit worthiness evolved. Individuals were assigned a numerical credit score known as a FICO score, first introduced in 1989. Government Sponsored Entities (GSE) like Fannie Mae and Freddie Mac first used FICO scores to determine credit worthiness in 1995. The FICO score was used to predict the likelihood of the borrower defaulting on a loan. This scoring enabled mortgage lenders to offer more than the traditional prime rate loans. The rise in popularity of the Internet during this time increased borrowers' options of available lenders helping to keep mortgage rates competitively low.

Two new classifications of mortgages were popularized during this time. A subprime mortgage was now available for borrowers with less than perfect credit scores, and Alt-A mortgages for those that had higher credit scores than those qualifying for sub-prime mortgages but still deemed as having a higher probability of defaulting on the loan than those receiving the prime rate. From 2003-2007 alone, the number of sub-prime mortgage originations rose by 292%.

The Federal Housing Enterprises Financial Safety and Soundness Act of 1992 created the Office of Federal Housing Enterprise Oversight (OFHEO) as an independent regulator within HUD. This Act amended Fannie Mae and Freddie Mac's charters and required them to meet "affirmative obligation to facilitate the financing of affordable housing for low-income and moderate-income families."[1] Then in 1995, HUD began to require Fannie Mae and Freddie Mac to meet certain mortgage purchase goals each year. The government service enterprises were mandated to purchase loans made to low to moderate income families, loans for mortgages on properties in underserved areas and mortgages made to families in very-low income brackets and low-income families in low-income areas. From 2002-2006 the combined purchases of Fannie Mae and Freddie Mac's mortgage-backed securities rose from $38 billion to $90 billion per year.

Other government policies enacted during this time include the Tax Payer Relief Act of 1997, which eliminated capital gains taxes on the sale of residential homes up to a two-hundred and fifty thousand dollars per individual providing that they occupied the home for at least two of the previous five years, and HUD's "National Homeownership Strategy" signed into law by Bill Clinton in 1996. This legislation further relaxed credit standards by eliminating the requirement that homebuyers make significant down payments as well as enabled the GSE's to reduce required loan documentation and to enter the 0% down payment mortgage market.

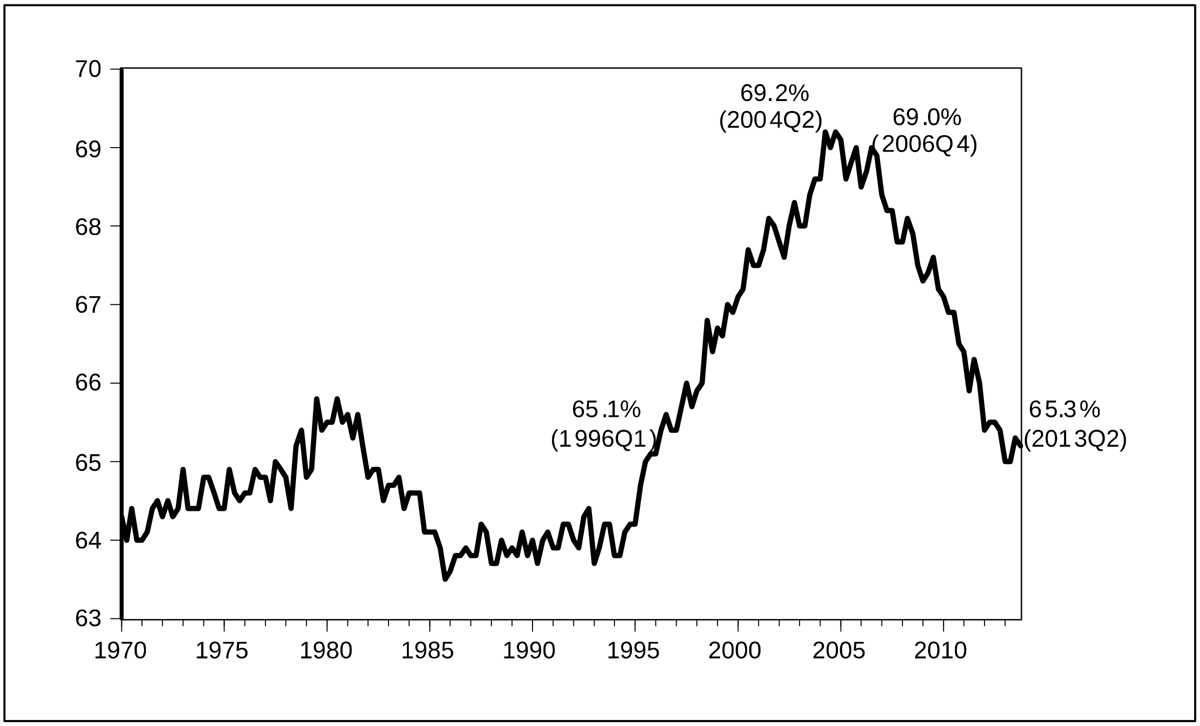
In an attempt to combat the recession in 2001 coupled with fears of a financial market collapse in the wake of 9/11, the Federal Reserve lowered interest rates eleven times from 6.5 percent to a low of 1.00 percent in June of 2003 (Greenspan, 2007).

Low short-term interest rates encouraged the use of adjustable rate mortgages (ARMs). These low rate mortgages allowed borrowers to invest in higher priced homes that they would not have been able to afford with a fixed rate mortgage. The assumption was if the rate were to increase beyond what the homeowner could reasonably afford, they could simply sell the home to pay off the loan or refinance with another ARM with a low "teaser" rate. From 2004-2006, it is estimated that over 90% of subprime loan originations were adjustable rate mortgages. Borrowers risk was limited due to small down payments and risk was transferred to the financial markets in the form of the bundled mortgage-backed securities (Gjerstad & Smith, 2009).

Another effect of the low short-term interest rates was that low short-term rates encourage leveraging (Holt, 2009). Investors could increase their returns by borrowing at low short term rates and investing in higher yield long-term investments like mortgage-backed securities. Leveraging also was a factor that increased the amount of financing available in the market and in turn helped fuel rising house prices.

As seen in Figure 1.1, the national rate of homeownership had increased from 65 on average to over 69 percent in the second quarter of 2004. As with all bubbles, house prices rose too far above their fundamental value and by the end of 2006 the housing bubble burst. The decline in house prices led many homeowners with loan amounts greater than the market value of the property to default on their loans due to inflated mortgage payments when their interest payments adjusted upward. Defaults on mortgages skyrocketed, eventually leading to over one million homes in foreclosure. Borrowers risk was limited due to small down payments. The risk was transferred to the financial markets in the form of the bundled mortgage-backed securities. In 2006, 93% of the foreclosures from loans made and bundled in subprime mortgage backed securities are attributed to adjustable rate mortgages.

The collapse of the housing market had a profound effect on the U.S. financial markets as well as banking systems across the globe. The financial crisis that followed was the worst since the Great Depression. Between 2007 and 2009 the U.S. saw a series of banking failures and fell into a prolonged recession lasting over 19 months and is now known as the Great Recession.



Source: Current Population Survey/Housing Vacancy Survey, Series H-111, U.S. Census Bureau.

Figure 1.1: National Homeownership Rates, 1970-2013Q2.

1.6 Should Central Banks Respond to Asset Price Bubbles?

A major obstacle in responding to asset price bubbles is the problem of identification. To identify an asset price bubble, one must accurately estimate unobservable fundamentals (Bernanke, 2002). Most economists agree on the implications of central banks responding to asset price bubbles. Monetary authorities should not to attempt to prick or slow the growth of asset bubbles. Any attempts to control asset price bubbles may cause more harm than good since monetary policy targets the entire economy not just asset markets.

Even a small response by monetary authorities can be problematic. A small change in short term interest rates will not dissuade investors since they are expecting exceptionally high returns on the asset. The small change will, however, weaken macroeconomic fundamentals. Bernanke (2002) maintains that a speculative bubble can only be slowed by a rate increase sharp enough to slow the whole economy.

Targeting an asset bubble with a policy instrument that is intended to target the entire economy will also have macroeconomic consequences. The effect of raising interest rates for example, may not be able to slow down the growth of the bubble since investors are expecting a higher than average return on their investment. Another possible consequence of raising interest rates is the rate hike could cause the bubble to burst more severely, causing a greater impact on the entire economy. Raising interest rates effects the whole economy by slowing down the economy causing job loss and price levels to fall below the desired level.

Bernanke notes that a stock market boom might signal higher spending indicating inflationary pressures. Policy actions are to contain inflation not address any stock market boom. If central bankers do in fact respond to asset price bubbles, the response should be in terms of how the central bank forecasts inflation (Bernanke & Gertler, 2009). Using an inflation-targeting approach, Bernanke and Gertler find "aggressive inflation targeting rule" substantially stabilizes not only inflation but also output in scenarios with a stock market boom-bust cycle. Assuming an aggressive response to inflation by a central bank, they find no additional benefit to responding to asset prices.

Monetary policy actions are intended to address changes in macroeconomic conditions. Only when an asset bubble affects inflation or GDP, should they intervene (Taylor, 2007). According to Shiller (2000):

> A small, but symbolic, increase in interest rates by monetary authorities at a time when markets are perceived by them to be overpriced may be a useful step, if the increase is accompanied by a public statement that it is intended to restrain speculation. But authorities should not generally try to burst a bubble through aggressive tightening of monetary policy.

Intervention on the part of the central bank is still not recommended, even if the bubble appears to be credit driven as opposed to a speculative bubble. Mishkin (2009b) does believe a policy response is appropriate, but it should be in the form of financial regulation and supervision on the part of policy makers or central bankers by ensuring credit standards are sufficiently high and not by altering monetary targets.

ENDNOTES FOR CHAPTER 1

[1] U.S. code title 12, ch 46, sec 4501. section 1302(7) of housing and community development act.

Chapter 2

THE HOUSING BUBBLE AND INTEREST RATES: FEDERAL RESERVE POLICY IMPLICATIONS

2.1 Introduction

Expansionary monetary policy is intended to encourage economic growth. It is used to increase aggregate demand. By setting interest rates low, a central bank can increase the amount of money and credit available in the economy. Credit then becomes easily attainable, encouraging borrowing. It has been argued that monetary policy was excessively loose during the housing bubble, particularly from 2001-2004, and is a contributing factor in the run-up of prices in the housing market. Bernanke and Greenspan (2007; 2010) among others have argued that the Fed's policy actions were not responsible for the housing bubble. Others contend the Fed's use of loose monetary policy was connected to the rise in housing prices during the real estate boom (Atesoglu, 2011; Poole, 2010; Taylor, 2012; White, 2009).

The rapid increase in house prices beginning in the second quarter of 1996 until the subsequent rapid decline at the end of 2006 has been classified by many as a housing bubble. The rise in the price of real estate can be classified as a bubble because the price increase is not linked to any fundamental economic values.

This study seeks to evaluate the performance of the Fed during housing bubble by estimating a monetary policy rule based on past behaviors of the Federal Reserve. I estimate empirical reaction functions following in the work of Clarida et al. (2000). This method of estimating policy reaction functions uses generalized method of moments (GMM) and has become a benchmark for the evaluating policy actions of a central bank. This empirical form of Taylor's (1993) original version of the Taylor rule allows for the coefficients to be determined empirically based on actual Fed behavior measured by the federal funds rate.

Much of the existing research evaluating the Fed's policy actions in the wake of the housing bubble, financial crisis and subsequent recession compare a Taylor rule target rate to the federal funds target rate. These studies evaluate the performance of the Fed by measuring deviations of the effective funds rate versus the prescribed target rate using a simple Taylor rule with equal-weighted coefficients for inflation and the output gap (Dokko et al., 2011; Judd & Rudebusch, 1998; Seyfried, 2010; Taylor, 2012).

This study is unique because I use a Taylor-type rule to estimate empirical reaction functions fashioned in the methods of Clarida et al. The empirical form of the Taylor rule allows the coefficients to be determined based on past behaviors of the Federal Reserve to various economic indicators rather than simply applying pre-defined fixed weights. Empirical reaction functions are typically used to determine if the Fed's actions were influenced by factors other than standard economic indicators measuring prices and economic growth. Another benefit of using the empirical Taylor-type rule is this model allows for the addition of variables into the model to account for the housing bubble and measures any effect that the housing bubble had on the federal funds rate.

To measure the impact of the housing bubble on interest rates, I include a dummy variable equaling one for each quarters during the housing bubble and zero otherwise and add it to the Fed's reaction function. I find evidence that the Fed deviated from the prescribed empirical Taylor rule during the housing bubble. The results presented show that the Fed held rates lower in the years during the housing bubble. As an alternative specification, the bubble period is split into two sub-periods where in the first period (1996-2000), rates were 50 basis points lower on average than other periods and 30 basis points in the second period (2001-2006). When examined on a year-by-year basis to account for each year during the housing bubble era, I find seven years during the bubble period to be negative and statistically significant. In these years, the size of the deviation is quite large. The year that had the largest deviation was 1999 where the deviation from the rule was almost 100 basis points lower.

As further evidence that the Fed deviated from the empirical Taylor Rule during the period of housing bubble, I present counterfactuals. I form a policy rule by estimating a baseline reaction function for the policy reaction to economic indicators for the period of 1987-1995 using an empirical Taylor-type reaction function. I then use the estimated rule to predict the reaction function for the period of the housing bubble, which started in the second quarter of 1996 and ended at the burst of the housing bubble by the end of 2006. I alter these weightings of the coefficients based on estimated results and use my estimates to predict the target Federal funds rate during the bubble period. Results of the counterfactual show that the effective funds rate was lower that what the forecasted Taylor Rule. The fed funds rate was 107 basis points lower that predicted in the first quarter of 2001 and stayed below the forecasted rate until 2005. These results provide more evidence to the argument that the Fed held rates too low during the housing bubble era creating an environment that fostered the rapid growth in house prices.

The remainder of this chapter is organized as follows. In Section 2.2, I present a model for a simple Taylor rule. I discuss the benefits, limitations and alternate specifications of the Taylor rule. Section 2.3 presents a survey of existing literature on monetary policy and the housing bubble. In Section 2.4, I compare historical trends of the federal funds rate and past monetary policy actions to a Taylor rule prescription rate. I present several models for estimating empirical reaction functions using a Taylor-type rule in Section 2.5 and describe the data in Section 2.6. In Section 2.7, results for Fed reaction functions are presented using OLS regressions as well as results for monetary reaction functions using generalized method of moments (GMM). I describe the econometric methods used in the specification of the models and provide a partial adjustment interpretation of the empirical results. Estimated monetary reaction functions are used in a dynamic forecast model to depict counterfactual simulations and compared to the actual path of the effective fed funds rate. Finally, Section 2.8 offers some concluding remarks.

2.2 Taylor Rule

One method to evaluate the actions of a central bank is to use the so-called Taylor rule. This method, first introduced by Taylor (1993), can be used for monetary policy analysis and also as a prescription for determining a future path for monetary policy. A prescription target interest rate is estimated based on an equation that weighs key economic measures of performance. Taylor shows that estimates of a monetary policy stance can be emulated by a simple rule based on two macroeconomic variables (Abrams & Iossifov, 2006).

When Taylor originally described his policy rule, the intension was for it to be used as a guide for setting monetary policy. According to Kahn (2012), the Taylor rule "has framed the conduct of policy as a systematic response to incoming information about economic conditions, as opposed to a period-by-period optimization problem."

Taylor advocates a less restrictive policy rule than previous policy rules. According to Taylor, policymakers should not automatically follow a restrictive policy rule using merely simple algebraic formulas. Policymakers require the use of judgment when making policy related decisions. Although the Federal Reserve does not officially follow the Taylor rule, it is often used as a gauge to determine if monetary policies are appropriate.

The Taylor rule has since become a widely used tool in monetary policy analysis. This policy rule calls for changes in the federal funds rate in response to changes in the price level or changes in real income. The federal funds rate is the overnight lending rate at which depository institutions lend balances to each other. The federal funds rate is the rate that is targeted by the FOMC in its monetary policy. According to the Taylor rule, the baseline nominal interest rate can be estimated as

$$R_t = r^* + \pi_t + a(\pi_t - \pi^*) + b(y_t) \quad (2.1)$$

where R_t is the target federal funds rate in period *t* and r^* is the equilibrium real rate. Equation 2.1 is a generalized version of the one originally presented by Taylor. For simplicity, many researchers estimate Equation 2.1 using a value of 2 percent as a long-term targeted inflation rate similar to that proposed by Taylor. The output gap, defined as the distance from the level of output that would prevail in the absence of nominal rigidities (Blanchard, Dell'Ariccia, & Mauro, 2010) and determined in the model by y_t, is the difference between the log values real GDP and potential real GDP in period *t*. π represents the actual current inflation rate, where $\pi_t - \pi^*$ captures the deviation from the inflation target objective set by policy makers. The coefficients *a* and *b* are weighting coefficients that can be manipulated to meet policy objectives. Although the variables and weights can easily be changed from those proposed in his original equation, Taylor uses the deviation from inflation target and the output gap as policy objectives assigning equal weighting to them.

A weakness in using the Taylor rule for forming policy decisions is the timeliness of the data. Gross domestic product (GDP) and potential real GDP are reported quarterly. A quarterly time period is too short to smooth out any jumps in the price level due to temporary shocks but it is too long to hold the federal funds rate fixed between adjustments (Taylor, 1993). These problems could be corrected by using a moving average of the price level. Other alternatives could include using averaging real output but would make the policy rule more complex than as originally formulated.

Alternatively, the employment gap can be used as a policy objective in determining the prescription target rate as opposed to using the output gap. The employment gap is estimated as the difference between the natural rate of unemployment and the actual unemployment rate. An advantage to using the unemployment rate gap over the output gap is that unemployment rates are available on a monthly basis providing more timely information. Hsing (2005) finds that the federal funds rate responds similarly to shocks in both the output gap and the unemployment rate gap and concludes that both can be considered in conducting monetary policy.

The prescription for the Taylor rule for quarterly data appears more volatile than the typical Taylor rule prescriptions that are often discussed. Depictions of Taylor's equation compared to the empirically estimated reaction functions commonly include a lagged dependent variable as a regressor for interest rate smoothing or policy inertia in the empirical model.

One of the limitations of the model is that the right-hand side variables are unobservable. The inflation and output gap are most frequently used to measure the key economic variables. The choice of how to estimate inflation, however, varies in the literature. Taylor estimates the price level using the GDP deflator. Alternative measures of inflation are the consumer price index (CPI), the price index derived from personal consumption expenditures (PCE), and personal consumption expenditures which excludes food and energy expenditures (PCEX), since these expenditures tend to be the most volatile to measure inflation. Beginning in 2000, the FOMC began measuring the inflation rate using changes in the core personal consumption expenditure index (PCEX) instead of the CPI inflation rate (Poole, 2007).

Another major drawback of the model is the sensitivity to the measurements of inflation and either the output gap or unemployment rate gap. Although the inflation variables tend to behave similarly over longer periods of time, their sensitivity to shocks in the short run can lead to differences in the prescribed interest rate.

One of the limitations of using the Taylor rule for policy decision-making is that much of the data used in determining the optimal prescription interest rate is not available in the current period. The FOMC makes policy decisions using all available information at time *t* to make decisions that will affect future periods. Kahn notes that an issue of using the Taylor rule as originally described in policy decisions is the model is not forward looking. Except for the output gap providing an indicator of future inflationary pressure, there is no way to capture future expectations. This could be improved however, by using forecasted values for inflation and the output gap.

2.3 Literature Review

Current research on U.S. monetary policy during the late 1990's through today generally agrees on the interpretations of Fed policy actions. A common conclusion in the literature is that monetary policy during the earlier years, particularly 2001-2005, was too easy (Seyfried, 2010; Taylor, 2009; White, 2009). It is not always agreed, however, as to the impact that this loose monetary policy had on the housing bubble.

Taylor (2007) compares housing starts with actual interest rates and presents a counterfactual simulation using the Taylor rule. This simulation focuses on the period from the fourth quarter of 2000 through the third quarter of 2006 when the Fed deviated from the Taylor rule prescribed rate. Housing starts follow the actual path of interest rates closely. The simulation path tracks housing starts closely until the point at which actual interest rates deviate from the rule. The counterfactual predicts a higher federal funds rate, which would have produced a smaller increase in housing starts. Taylor concludes that according to his model, a higher federal funds rate would have lessened much of the housing boom.

Taylor (2012) explains how the actions of the Fed during the period of 2000-2007 deviated from both the Taylor rule and the previous policy that had been followed during the period of the Great Moderation, which began in the early 1980's. He estimates an empirical relationship between interest rates and housing starts. Taylor argues that the extra easy monetary policy on the part of the Fed led to a house-price boom.

Taylor simulates the model to determine what would have happened if the Fed had followed the Taylor rule. Based on the counterfactual, he concludes that, had interest rates not been unusually low during this period, the housing boom and subsequent bust would not have been nearly as large. Poole (2007) does not use interest rate smoothing (previous period's interest rate) and extends the years from 1987-2006 but finds similar results as Taylor.

Seyfried (2010) links housing prices to past housing price movements, disposable income, the average thirty-year fixed mortgage rate, and an interest rate gap calculated as the difference between the federal funds rate and the Taylor rule prescription rate. The difference between the federal funds rate and the Taylor rule rate is positive and highly significant in explaining the behavior of housing prices. Neither the growth rates of the money supply (as measured by M2) nor the monetary base showed signs of loose monetary policy. The conclusion of this study is that if the Fed had followed the Taylor rule, housing prices would not have been as high.

Conversely, those attempting to provide alternative explanations for the housing bubble find that the link between housing prices and monetary policy is not strong enough to be a contributing factor in the global housing boom (2009). The severity of the financial crisis that began after the collapse of the housing market is often attributed to not only the extremely low interest rates of the Fed but also other factors such as loose credit policy and the role of government sponsored entities (GSE) like Fannie Mae and Freddie Mac.

Dokko et al. (2011) investigate monetary policy and the global housing bubble. Their work has a global focus, but they do use the Taylor rule to compare the performance of monetary policy in the United States using two estimates of the Taylor rule. The focus of their study is on loosening credit terms and any link to the rapid increase in housing prices. Their conclusion is that regulations, and not monetary policy, play the larger role in the global housing boom.

Groshenny (2013) evaluates Fed policy between 2002 and 2006 using deviations from the Taylor rule to determine the effect on price stability and unemployment using a New Keynesian model and presents a counterfactual analysis. The counterfactual model simulates what would have happened to employment and inflation if the Fed had strictly followed Taylor rule during the time period. Had the Fed followed the Taylor rule, there is an 80 percent probability that unemployment would have been above 8 percent. Conversely, the probability of an inflation rate below 1 percent would have been close to zero. Groshenny's results suggest that the loose monetary policy of the Fed in the early part of the decade was appropriate and consistent with the Fed's dual mandate to target both high levels of employment and price stability.

Bryant and Kohn (2013) discuss econometric issues with economic models cited in many of the current research on the housing bubble. The conclusions are based on the assumptions that the models are not only correct and but also current. When bubbles occur, the "normal" trends may no longer hold. These models must either be modified or updated to fit current circumstances.

Atesoglu (2011) examines asset price bubbles and how the bursting of the bubbles can lead to recessions. Estimation includes asset price bubbles in equities and housing during the time period of August 1987 to September 2008. Atesoglu uses monthly data for the effective federal funds rate as the measure of the Fed's monetary policy reactions. He estimates the Fed's reaction function using unemployment and annual inflation rate measured by the Consumer Price Index (CPI). Preliminary results show that the Fed followed a stabilizing policy during the estimated time period. Additional estimates include dummy variables for both months during the time of housing as well as equity price bubbles.

To identify any asset price bubbles, Atesoglu estimates a simple model by fitting a linear trend curve. The linear trend curve is fitted to real house prices, which are corrected for changes in general prices by using the CPI. A subsequent linear trend curve is estimated for equity prices using the Dow Jones industrial average also converted to real terms by adjusting for price levels.

He identifies two housing bubbles during this time span. The first occurred from August 1987 through July 1991. The second housing bubble began in November 2003 and burst in November 2007. An equity bubble is also identified for the period of 1996 through 2003.

Atesoglu estimates monetary policy reaction functions and concludes that the Federal Reserve did follow a restrictive monetary policy during the time of the equity bubble but finds that the Fed was not successful at pricking the asset bubble. For the housing bubbles however, monetary policy did not respond. He also concludes that the bursting of the housing bubble in November 2007 was responsible for the financial crisis.

Dokko et al. (2009) find the relationship between the fed funds rate and housing activity is not strong enough to explain the rise in house prices. Demand in housing is determined by the level of interest rates as well as other factors and not by a deviation from the monetary policy rule. Therefore, it is possible to show a contribution on the part of the Fed in the housing bubble even if there was no deviation from any policy rule. The authors conclude that deviations in some measures of the policy rule that have been shown in previous studies are unlikely to have generated the level of appreciation in house prices. Developments in housing markets would only have been moderately different if the Fed followed a simple rule, such as one posed by Taylor. The authors suggest that it is possible that the Fed's accommodative policy stance may have interacted with shifts in housing finance. This is not captured in the relationships embedded in the macro-based approach to monetary policy. The study attempts to quantify the extent to which the easy policy stance could have contributed to the high level of housing activity. The results show the fed funds rate was lower than suggested by Taylor rule.

2.4 Historical trends of Federal Funds rate

Even though the US Federal Reserve does not officially follow the Taylor rule, it is often used as a tool for analysis of policy performance. The Taylor rule is useful for modeling target interest rates to compare to the target federal funds rate. Historically, the federal funds rate in the United States seems to behave similarly to what the Taylor Rule would have predicted, particularly during the Volker-Greenspan eras (Clarida et al., 2000). This period is often referred to as the Great Moderation.

The imputed Taylor rule prescription tracks the actual federal funds rate fairly closely, but depending on which inflation measure is incorporated into the model, the prescription rate's precision varies among past Fed Chair regimes. Arthur Burns' time as Fed chairman saw very low target federal funds rates compared to the prescription target for all four measures of inflation. This indicates that his policy was more expansionary than what was used in previous periods, other things being equal.

The prescription for the Taylor rule during the 1960's through the early 1970's follows closely with the actual federal funds rate. The period of the late 1970's resulted in the Taylor rule prescription being higher than the actual federal funds rate as the federal funds rate fell below previous trend.

Paul Volker worked to bring down high inflation rates in the late 1970's and early 1980's. His disinflationary policy helped to stabilize the economy. During that time, the Taylor rule predicts a lower rate than the target federal funds rate. During the early period of Alan Greenspan's tenure as chairman of the Federal Reserve, the Taylor rule accurately predicts the changes in the target federal funds rate using the CPI inflation rate.

The headline CPI and the PCE indices, tracked the target federal funds rate fairly closely through the 1990's but according to Kahn (2012), "the two measures diverged substantially between 2003-2005." Kahn argues that using the CPI as a measure in the Taylor rule lowers the prescription rate by around 2 percent "bringing the prescription rule much closer to the path of policy."

The CPI generally tracks the federal funds rate well, but is the most volatile of the four common measures of inflation.[1] The other measures of inflation, however, predict a lower target rate during the 1990's and all of the measures prescribe a higher target in the early 2000's. A common belief that during this time is that the Fed was concerned about avoiding deflation. Aggressively working to avoid the risk of deflation reduces the risk of reaching the zero bound on nominal interest rates and hitting the economy with a negative shock.

2.5 The Fed's Policy Reaction Function

Because the Taylor rule is a fairly simple model it has limitations. Kahn argues that weaknesses in the Taylor rule include a lack of a risk-management measure, challenges in judging potential output, and a limitation on measuring the entire state of the economy. Taylor's original model is a simple equation using equal weighting for the coefficients on the variables for inflation and output.

Conversely, a regression model can be used to empirically estimate the coefficients on the variables to estimate a policy reaction function for specific time periods. Judd and Rudebusch (1998) describe the Federal Reserve's reaction function as the modeling of the monetary policy response and relationship to economic developments. Estimates of the Fed's reaction function track how the Fed responds to changes in the economy. A benefit of using an empirical Taylor-type reaction function over a simple Taylor rule is that the empirical reaction function can incorporate forward-looking behavior on the part of the Fed (Clarida et al., 2000).

Modeling the Fed's reaction function is useful for several reasons. Not only can it be helpful in forecasting changes in short term interest rates, but it is also important for policy analysis. It can be effective for analysis of not only monetary policy but also can be used to evaluate fiscal policy actions.

Critics of Fed reaction functions argue about the instability of the reaction functions over time. Judd and Rudebusch (1998) conclude that the use of vector autoregressive models to estimate a reaction function may be misspecified. Rudebusch (2002) argues that the dynamic Taylor rule is also misspecified and finds interest rate changes are highly predictable. The question not answered by Rudebusch is what makes the interest rate changes highly predictable. It is not clear from his results if the high level of predictability is due to monetary policy inertia from the lagged interest rate variable or from predictability from inflation and output gaps from the Taylor equation (Soderlind, Soderstrom, & Vredin, 2003).

Using Rudebusch's model, Soderlind, Soderstrom, and Vredin (2003) show that one lagged interest rate variable does not show high predictability of interest rates. They find monetary policy inertia leads to movements in inflation and the output gaps. This translates into predicable movements in interest rates using a dynamic Taylor Rule. Soderlind, Soderstrom and Vredin conclude that a dynamic Taylor Rule is not a good tool for predicting interest rate changes, and thus, an ineffective tool for analyzing monetary policy.

The empirical methods of Clarida, Gali and Gertler (2000) are commonly used to estimate monetary policy reaction functions. These studies use the federal funds rate as an instrument for monetary policy and estimate a reaction function of the Federal Reserve using a Taylor-type rule as a measure of economic activity. This technique uses forward-looking behavior on the part of the Fed. Clarida, Gali and Gertler estimate a series of policy reaction functions using the generalized method of moments (GMM) and incorporate interest rate smoothing and exogenous shocks into their model.

Xiao (2013) attempts to determine if monetary policy rules should target housing prices in addition to inflation and the output gap. Xiao presents a dynamic stochastic general equilibrium model (DSGE) with imperfect competition and staggered price setting. The model incorporates adaptive learning and uses stability as a criterion to evaluate monetary policy and features credit constrained borrowers who finance purchases using their housing assets as collateral. Aggregate demand is affected only if consumers are credit-constrained with a change in policy. If the credit channel is a link between asset prices and the real economy, then monetary policy could use it to stabilize the economy. The results depend critically on the assumed information structure of the economy. For example, if actual data on housing is available but only forecasts of inflation and output, then responding to house prices is stabilizing. If current housing data is not observable and only forecasts are available, then responding to house prices is not stabilizing. If all data is available in real time, then responding to house prices is redundant.

Vera (2011) measures a monetary policy reaction function using alternative measures of the output gap. Vera considers an output gap based on the industrial production index and concludes that the behavior of the Federal Reserve is better captured using this proxy for the output gap than by using the unemployment rate. The reaction function is determined for the Greenspan era and shows that Fed reacted significantly to changes in inflation but the reaction to changes in output was not strong.

Due to the limitations of the simple Taylor rule, I estimate empirical reaction functions. These reaction functions build on the foundations of the Taylor rule similar to the methods of Clarida, Gali and Gertler. Specifically, I estimate the federal funds rate using quarterly inflation and output gap from 1970-2013Q2. The reaction function is estimated as

$$F_t = \alpha_0 + \alpha_{\pi} Inflation_t + \alpha_{y} Outgap_t \tag{2.2}$$

where F_t is the effective federal funds rate at time *t*. $Inflation_t$ is defined as the percentage change in the price index from the previous quarter. $Outgap_t$ represents the difference in the log values of potential and actual real GDP. It is expected that the coefficients of the inflation rate and the output gap to be positive. A positive value of the coefficient on inflation is expected due to the expectation that the Fed will increase interest rates in response to an increase in inflation rates. Similarly, we expect the Fed to tighten its monetary policy when real output is greater than potential GDP.

I extend the model by adding a dummy variable for the political monetary cycle ($Political_t$) to further explain the Fed's policy decisions. Abrams & Iossifov (2006) find election-cycle effects in federal funds rate behavior. They estimate a political monetary cycle to determine any connection between interest rates when the incumbent and the Fed chair are of the same party affiliation in months prior to an election. Abrams and Iossifov find evidence to support the existence of a political monetary cycle that corresponds to the presidential election cycle. They estimate reaction functions using various Taylor rules and find monetary policy actions are significantly more expansionary in the seven quarters prior to a U.S. presidential election when both the incumbent and fed chair have the same political party affiliation. The dummy variable for the election cycle effect $Political_t$ takes a value of one in the seven quarters prior to the election when the incumbent and fed chair are of the same political party and zero otherwise. The model then becomes:

$$F_t = \alpha_0 + \alpha_\pi inflation_t + \alpha_y outgap_t + \alpha_P Political_t \tag{2.3}$$

It is expected that the sign of the coefficient for the political dummy variable to be negative, similar to the findings in previous studies indicating downward pressures of interest rates preceding an election.

To determine if the Federal Reserve reacted to the housing bubble, I use dummy variables representing the various measures of the housing bubble ($Bubble_{i,t}$).

I focus on expanded versions of the following form:

$$F_t = \alpha_0 + \alpha_\pi Inflation_t + \alpha_y Outgap_t + \alpha_P Political_t + \alpha_{b_i} Bubble_{i,t} \qquad (2.4)$$

The significance of the bubble dummy variables will provide evidence to evaluate if the Fed did in fact keep interest rates artificially low creating an environment that led to the run up of house prices during the housing bubble.

2.6 Data

Various Taylor-type reaction functions are constructed and serve as metrics to determine if interest rates during the time preceding and during the rise of the housing boom were lower than those predicted by the model. I use macroeconomic data available from the St. Louis Federal Reserve Bank. Quarterly time-series data for the period of 1970 through the second quarter of 2013 is used to estimate the various empirical Taylor rules. I classify 1996 through 2006 as the housing bubble period as well as restricting the period of "the Great Moderation" from 1987 through 1995 when determining forecast models to present counterfactuals. Figure 2.1 provides rationale for determining the housing bubble period. As depicted from the graph, the run-up in house prices begins in 1996. The rapid rise in real house prices is not supported by a deviation of the average growth rate of real GDP during the same period. The spike in home values peaks in the last quarter of 2006 at which point house prices crash and the bubble bursts.

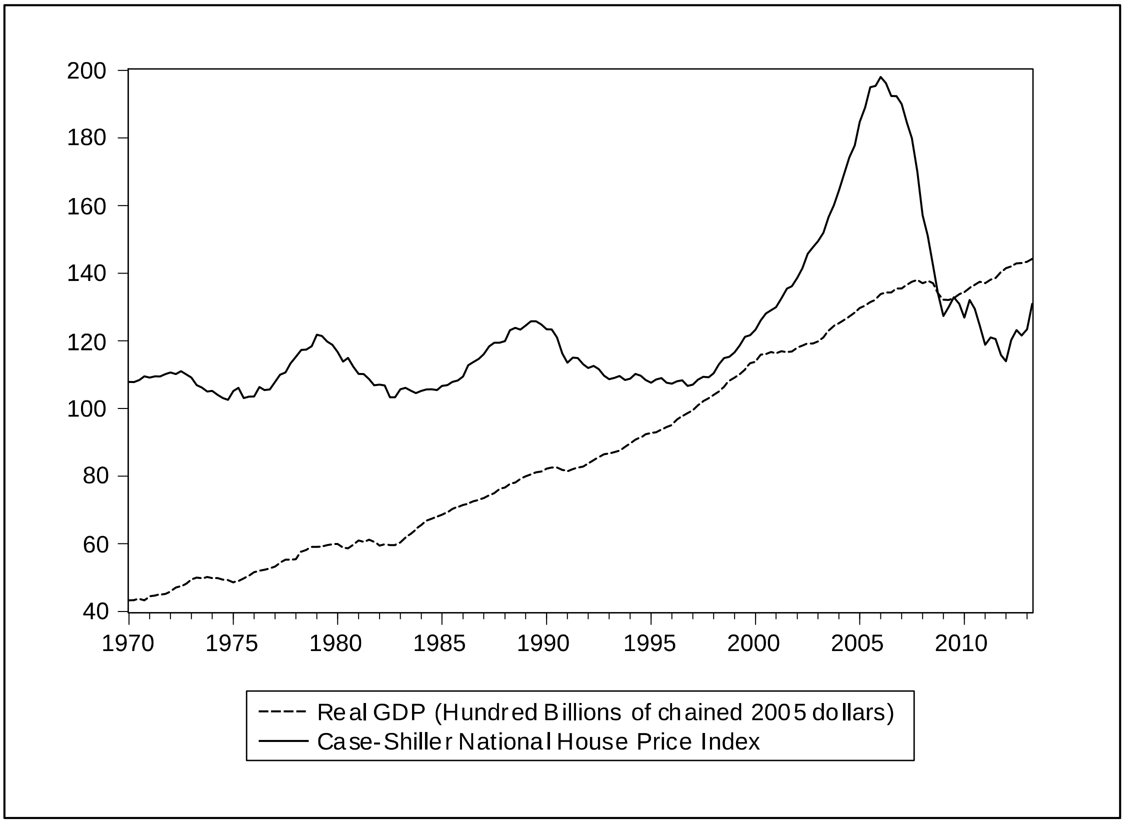


Figure 2.1: Real GDP and House Prices, 1970Q1-2013Q2.

Several measures of the price level can be used to estimate inflation. I include headline consumer price index (CPI), personal consumption expenditures (PCE), and core personal consumption expenditures (PCEX), which excludes excluding food and energy prices as well as the GDP deflator as there does not appear to be a consensus in the literature for the best measure of inflation rate. I also construct an inflation variable that incorporates the price index that the Fed preferred as its inflation proxy at that time. In 2000, the Fed switched their focus from the Consumer Price Index as its measure of the price level to the Personal Consumption Expenditure (PCE) index.

Therefore, I construct the variable *Inflation_var*$_t$ as the change in quarterly inflation rates using CPI from 1970-1999 and PCEX from 2000-2013Q2.

The output gap is measured as difference between the log values of potential and actual real GDP. I also include the unemployment gap to as an explanatory variable for alternative regressions to test the sensitivity of the variables in the model. The unemployment rate gap is approximated by measuring the difference between the actual unemployment rate and the natural rate non-accelerating rate of unemployment. Author calculations for quarterly estimates of the unemployment gap are determined by calculating quarterly averages of the reported monthly unemployment rates obtained from the St. Louis Federal Reserve.

2.7 Results

2.7.1 OLS Regressions

I estimate several baseline Taylor-type reaction functions using OLS and White's correction for heteroscedasticity. Although I present results using alternative measures of inflation for the reaction functions in the Appendix, I use percentage change in the quarterly consumer price index (CPI) as the inflation variable in regressions presented in the main results. Similar to previous work estimating monetary reaction functions (Abrams & Iossifov, 2006; Clarida, Galı, & Gertler, 1998; Clarida et al., 2000; Doménech, Ledo, & Taguas, 2002; Orphanides, 2001), I include a lagged variable for the previous quarter's federal funds rate (F_{t-1}) to allow for any

Fed interest rate smoothing behavior. The specifications for the reactions functions are imbedded in a partial adjustment specification.

Therefore, Equation 2.2 takes the form:

$$F_t = \rho(F_{t-1}) + (1-\rho)(\alpha_0 + \alpha_\pi Inflation_t + \alpha_2 outgap_t) \qquad (2.5)$$

Equation 2.3 in the partial adjustment model is rewritten as:

$$F_t = \rho(F_{t-1}) + (1-\rho)(\alpha_0 + \alpha_\pi Inflation_t + \alpha_2 Outgap_t + \alpha_P Political_t) \qquad (2.6)$$

and becomes the baseline equation. Similarly, Equation 2.4 becomes:

$$F_t = \rho(F_{t-1}) + (1-\rho)(\alpha_0 + \alpha_\pi Inflation_t + \alpha_2 Outgap_t + \alpha_{Pol} Political_t + \alpha_{\text{bubble}_i} Bubble\,)_{i,t} \qquad (2.7)$$

Initial results from the OLS regressions are presented in Table 2.1. The signs of the coefficients on the economic indicator variables are positive as expected in all models. . The size and significance of the coefficient on the lagged federal funds rate is consistent with the literature and the Fed's interest-rate smoothing behavior. The estimates for the baseline Equation 2.6 are presented column II. The negative coefficient on the political dummy variable for Equation 2.6 provides more evidence of the existence of the political business cycle indicating that interest rates tend to be lower in the run up of an election when the fed chair and incumbent are of the same political affiliation.

Table 2.1: OLS Regression Results for Monetary Reaction Functions, 1970-2013Q2.

	I	II	III	IV
Constant	-0.14	-0.05	0.08	0.10
	(0.11)	(0.11)	(0.14)	(0.14)
F_{t-1}	0.91***	0.90***	0.90***	0.89***
	(0.03)	(0.03)	(0.03)	(0.03)
Inflation	0.12***	0.14***	0.13***	0.13***
	(0.04)	(0.04)	(0.04)	(0.04)
Outgap	0.09***	0.09***	0.12***	0.11***
	(0.02)	(0.03)	(0.04)	(0.04)
Political		-0.33**	-0.36**	-0.35**
		(0.16)	(0.17)	(0.16)
Bubble			-0.38**	
(1996-2006)			(0.17)	
Bubble1				-0.27*
(1996-2000)				(0.19)
Bubble2				-0.46**
(2001-2006)				(0.18)
Adj. R Square	0.94	0.94	0.94	0.94
Durbin Watson	1.7	1.71	1.73	1.72

Taylor-type reaction functions estimated using OLS regressions. Quarterly data obtained from St. Louis Federal Reserve's (FRED) database and author calculations. *, **, *** denote statistical significance at 90%, 95% and 99% confidence levels respectively. Heteroscedasticity-consistent standard errors are presented in parentheses.

The coefficients for F_{t-1} represent the coefficient ρ in the partial adjustment specification. This result is similar to prior studies of Fed reaction functions. The economic indicator variables are fairly consistent between all models presented in Table 2.1. Durbin Watson statistics and adjusted R^2 values are reported.

If the Federal Reserve set target interest rates too low for too long during the housing bubble era, we would find evidence in the significance of the various housing bubble dummy variables. As seen in column III of Table 2.1, the coefficient for the bubble dummy is negative and statistically significant at the 95% confidence level. This suggests that during the years of the rapid growth of house prices, the Federal Reserve held rates approximately 38 basis points below what the empirical Taylor rule would have predicted.

To further test the hypothesis that the Federal Reserve's interest rate policy was too loose during the housing bubble, I split the housing bubble dummy into two sub-groups. I define *Bubble1* as the period from 1996 to 2000. *Bubble2* begins in 2001 and ends in 2006. *Bubble2* is statistically significant at the 95% confidence level. The results from column IV indicate that during the second bubble period, the Fed lowered rates, on average, almost 46 basis points lower than the prescribed rate.

I use the equations for the partial adjustment model and the empirical results obtained in Table 2.1 to solve for the coefficients for Equations 2.6, 2.7 and 2.8. These values represent the cumulative effects of the independent variables. If α_{π} is greater than 1, the target real rate adjusts to stabilize inflation and responds to accommodate inflationary pressure and if the coefficient is less than one, this signifies destabilizing behavior (Clarida et al., 1998). Likewise, if $\alpha_{y} > 0$, interest rates tend to be stabilizing and destabilizing when $\alpha_{y} \leq 0$. In both cases, the coefficients indicate stabilizing behavior of the Fed. Since α_{pol} and $\alpha_{bubble_{i,t}}$ are dummy variables dynamic fitted values using a distributive lag process to isolate their cumulative effects. α_{pol} is the cumulative effect of the political dummy variable after seven quarters in which the incumbent and Fed chair are of the same party affiliation. The cumulative effect of the entire bubble period is -3.76 percentage points. It is clear that rates were held lower the latter years of the housing bubble as depicted by the size of α_{bubble2} compared to α_{bubble1}.

Table 2.2: Cumulative Effects of Explanatory Variables.

	I	II	III	IV
ρ	0.91	0.9	0.9	0.89
α_{π}	1.22	1.36	1.28	1.31
α_{y}	0.88	0.87	1.15	1.11
α_{pol}		-1.72	-1.88	-1.77
α_{bubble}			-3.76	
α_{bubble1}				-2.21
α_{bubble2}				-4.01

To show that the reaction functions are robust to alternative specifications of the empirical Taylor rule, results are presented in Tables A.1 and A.2 of the Appendix. Table A.1 presents results of the baseline OLS reaction functions using various measures of inflation. The signs and relative sizes of the coefficients are statistically significant and similar for all measures of inflation. Column V incorporates the variable $Inflation\_var_t$ to measure inflation and represents the Fed's focus of the inflation variable at time *t*.

Table A.2 reports estimates of the Baseline reaction function using current unemployment gap in time *t.* It is expected that the sign of the coefficient on the unemployment gap will be negative, as we would expect the Fed to raise target interest rates if they expect the gap between actual unemployment and potential unemployment to decrease. As expected, the unemployment gap coefficient is negative and significant in all models and the results of the bubble dummy variables are consistent in sign and significance with the models measuring the Fed's response to the output gap. The results also show that the reaction to a one percent increase in the unemployment gap is larger than a one percent increase in the output gap suggesting that changes in unemployment signify a greater response from the Fed than changes in output.

2.7.2 Generalized Method of Moments (GMM) Estimates

Following the methods adopted by Clarida et al., (2000) I estimate policy reaction functions using Generalized Method of Moments. Researchers studying reaction functions have used GMM to estimate a baseline monetary policy rule. Common results show positive coefficients for both measures of the economic conditions for the Taylor-type rule for the baseline GMM estimates (Abrams & Iossifov, 2006; Clarida et al., 2000; Consolo & Favero, 2009; Vera, 2011).

The right-hand side variables of the reaction function contain expected inflation and expected output. Therefore, Equations 2.6 and 2.7 are re-estimated using Generalized Method of Moments. Since these variables are based on expectations, they are not directly observable. A second reason for using GMM estimation is the potential for simultaneity bias. The Federal Funds rate responds to expected output and expected inflation but these variables can also be affected by the Fed Funds rate (Vera, 2011).

Generalized Method of Moments (GMM) estimation is typically used to correct for endogeneity in the explanatory variables. Hansen (2007) studied large sample properties of GMM estimators. These large sample properties are a class of econometric estimators that are defined in terms of orthogonal conditions. Hansen (2007) recasts the requirements for instrument exogeneity. Instruments are exogenous if they satisfy a conditional mean restriction. He specifies a GMM estimator and suggests sufficient conditions that determine convergence to the parameter vector being estimated. Hansen also contends that the two criteria for a valid instrument are exogeneity and instrument relevance. Therefore, the conditions for the instrumental variables are that they are correlated with the fed funds rate, but uncorrelated with the error term.

Weak instruments can lead to misleading results. These weak instruments correspond with weak identification of some or all of the unknown parameters (Stock, Wright, & Yogo, 2002). If the instruments are weak, implying weak identification, GMM estimation can be sensitive to changes in the sample or the addition of instruments. In the case of the policy reaction function, weak instruments could be future inflation and the output gap. Consolo and Favero (2009) find the future output gap and future inflation as weak instruments could explain the "illusion" of high monetary policy persistence found in much of the literature.

I select instruments consistent with other GMM specifications of monetary reaction functions found in the literature. In addition to the variables used in the OLS specification, the GMM model adds an additional lag of the fed funds rate and two lags of the output gap and inflation variables. The addition of the additional lags allows for both short term and long term responses of the interest rate to changes in economic conditions. Four lags of the dependent and explanatory variables are used as instruments. The GMM representation of the full model with the dummy variables for the various bubble specifications is presented in the following form:

$$F_t = \rho_1(F_{t-1}) + \rho_2(F_{t-2}) + (1 - \rho_1 + \rho_2)(\alpha_0 + \alpha_{\pi_t} Inflation_t + \alpha_{\pi_{t-1}} Inflation_{t-1} + \alpha_{\pi_{t-2}} Inflation_{t-2} + \alpha_{y_t} Outgap_t + \alpha_{y_{t-1}} Outgap_{t-1} + \alpha_{y_{t-2}} Outgap_{t-2} + \alpha_{Pol} Political_t + \alpha_{bubble_i} Bubble_{i,t}) \quad (2.8)$$

Proper identification requires that the GMM moment conditions be uniquely satisfied (Stock & Wright, 2000). Overidentification can occur if there are more exclusion restrictions than necessary. The Hansen J-statistic is presented for each model in Table 2.3. The value of the J-statistic is not significant in any of the models. Therefore, the null hypothesis that the model is over identified cannot be rejected.

Modifications of the measure of the housing bubble are tested in the augmented model. The findings presented in Column I of Table 2.3 are consistent with the OLS findings and provide further support the conclusion that the Fed lowered rates

Table 2.3: GMM Regression Results for Policy Reaction Functions 1970-2013.

Federal Funds Rate	I	II
α_0	-0.37*	-0.38*
	(0.19)	*(0.20)*
ρ_1	0.85***	0.85***
	(0.07)	*(0.07)*
ρ_2	0.06	0.06
	(0.07)	*(0.07)*
α_{π_t}	0.15*	0.15
	(0.09)	*(0.09)*
$\alpha_{\pi_{t-1}}$	-0.07	-0.07
	(0.06)	*(0.06)*
$\alpha_{\pi_{t-2}}$	-0.13**	-0.13***
	(0.05)	*(0.05)*
α_{y_t}	1.11***	1.12***
	(0.27)	*(0.28)*
$\alpha_{y_{t-1}}$	-0.83**	-0.84***
	(0.32)	*(0.32)*
$\alpha_{y_{t-2}}$	-0.12	-0.12
	(0.13)	*(0.13)*
α_{Pol}	-0.48***	-0.50***
	(0.15)	*(0.15)*
α_{Bubble}	-0.39***	
	(0.13)	
$\alpha_{Bubble1}$ (1996-2000)		-0.51**
		(0.21)
$\alpha_{Bubble2}$ (2001-2006)		-0.30**
		(0.12)
Hansen J Statistic	3.64	3.65

*, **, *** denote statistical significance at 90%, 95% and 99% confidence levels respectively. Heteroscedasticity-consistent standard errors are presented in parentheses.

on average 38 basis points during the years leading up to the bursting of the housing bubble.

Column II of Table 2.3 presents results for the model when the bubble dummy is split into two sub-periods. In this model, both of the bubble dummies are statistically significant at the 95% confidence level. The first bubble period which represents the time from 1996 through 2000, show average rates 50 basis points lower than other periods and the second period measured by *Bubble2,* saw rates 30 basis points lower than other years.

In addition to the results from the overall housing bubble dummy (*Bubble)* as well as the 2-period model (*Bubble1, Bubble2*) presented in Table 2.3, I include separate dummy variables for each of the years during the housing bubble. Separate year dummies help determine which years during the housing bubble period had the lowest rates. The results of the reaction function for Equation 2.8 with year dummies are presented in Table 2.4. Seven of the twelve years of the housing bubble era are significant at the 95% confidence level.

The years with the largest deviation from average rates interest rates are seen in the earlier years of the bubble period. The results presented in Table 2.3 suggest that rates are statistically lower than average in 1996-1999. A weakness of this model is that the year bubble dummies do not distinguish between the housing bubble and the technology bubble that occurred during that period. Testing the link between the low policy rates and house prices will be the focus of the next chapter and will measure the impact of the low interest rates on housing and the housing market.

Table 2.4: GMM Reaction Functions with Housing Bubble Year Dummy Variables for 1996-2007.

Baseline Reaction Function Variables

	Constant	F_{t-1}	F_{t-2}	$Inflation_t$	$Inflation_{t-1}$
Coefficient	-0.32	0.84***	0.08	0.14	-0.07
Std. Error	*(0.23)*	*(0.07)*	*(0.07)*	*(0.09)*	*(0.06)*
	$Inflation_{t-2}$	$Outgap_t$	$Outgap_{t-1}$	$Outgap_{t-2}$	Political
Coefficient	0.12**	1.13***	-0.85**	-0.11	-0.54***
Std. Error	*(0.05)*	*(0. 31)*	*(0.35)*	*(0.13)*	*(0.19)*

Year

	1996	*1997*	*1998*	*1999*	*2000*	*2001*
Coefficient	-0.62***	-0.42**	-0.79**	-0.96***	-0.39	-0.57***
Std. Error	*(0.16)*	*(0.21)*	*(0.31)*	*(0.31)*	*(0.24)*	*(0.20)*
	2002	*2003*	*2004*	*2005*	*2006*	*2007*
Coefficient	-0.14	-0.27	-0.36**	-0.50**	-0.29	-0.16
Std. Error	*(0.26)*	*(0.18)*	*(0.15)*	*(0.21)*	*(0.30)*	*(0.23)*

2.7.3 Counterfactuals

I present a counterfactual for actual interest rates to determine if the effective federal funds rate was lower than rates predicted by a dynamic forecast model. The sample period is 1987-1995. 1987 marks the start of the period known as the Great Moderation. This time period is referred to as the Great Moderation because of its stable prices, low macroeconomic volatility and improved monetary policy.

I use Equation 2.6 as the baseline for the sample period. The estimates for the sample period are then used in a dynamic forecasting model to predict the fed funds rate from 1996 through 2013Q2. This method uses the entire sample period and forecasts based on the past Federal Reserve behaviors during the previous years in the sample period.

Figure 2.2 shows forecasted path for the counterfactual graphed with the historical effective federal funds rate. 95% confidence interval bands are included for the counterfactual. The actual fed funds rate was outside the 95% confidence band in many of the periods. In particular, the actual rate was lower and outside the confidence interval for most of 2001-2004 and again in 2006-2007.

Next, I use Equation 2.7 as the model for the counterfactual. Results of the counterfactual simulation are shown in Figure 2.3. Even when accounting for the housing bubble, the fed funds rate was still significantly lower than the counterfactual. This result may be indicative of the Fed responding to deflationary pressures not captured in the model.

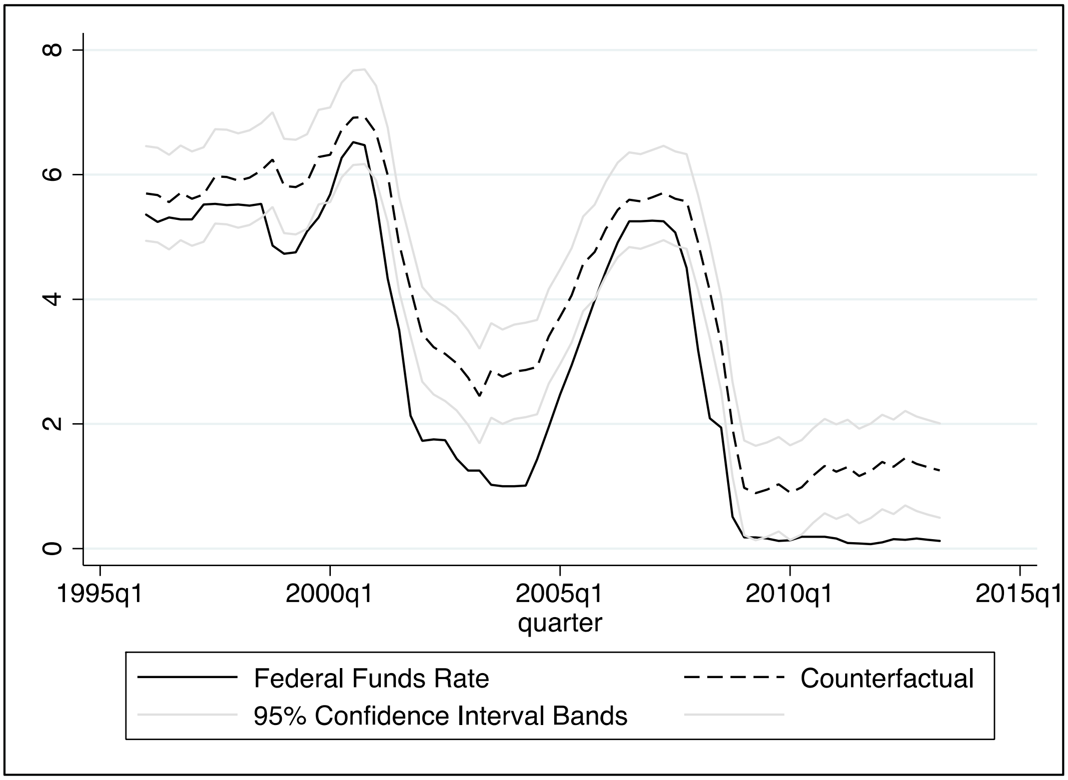


Figure 2.2: Dynamic Forecast of the Empirical Reaction Function

Figure A.7 of the Appendix depicts the counterfactual estimated using the unemployment gap as opposed to the output gap. The unemployment gap counterfactual suggests a much higher forecasted fed funds rate than counterfactuals estimated with the output gap. This result is not surprising given the results presented in Table A.3 for the reaction functions estimated using the unemployment gap. The response to changes in the unemployment gap is larger than in the output gap in alternate specifications of the models.

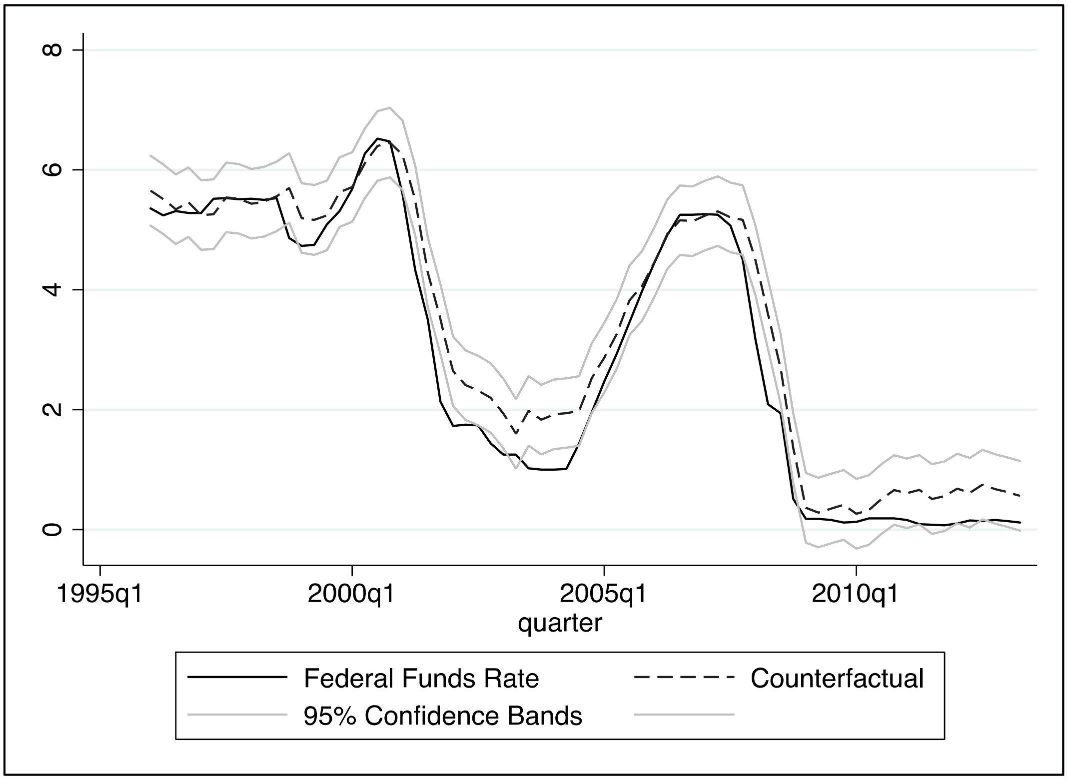


Figure 2.3: Dynamic Forecast of the Empirical Reaction Function with a Bubble Dummy

An interesting result obtained in the counterfactual exercise is the sensitivity of the inflation variable in the forecasted interest rate. All counterfactuals estimated using alternate measures of inflation find the Fed Funds rate were lower than predicted. Graphs of counterfactuals estimated using alternate measures of inflation are presented in Appendix A. The CPI and *Inflation_var* counterfactuals suggest a greater deviation from the actual path of the effective fed funds rate than the other measures of inflation. The counterfactual for the CPI calls for higher rates than alternative measures of inflation. The results suggest that the switch of the Fed's focus from CPI to core PCEX in 2000 could have resulted in policy decisions that lowered interest rates more than prescribed by economic indicators and could be a possible focus for a future study.

2.8 Conclusion

The Federal Reserve has claimed that their policy actions were not linked to the run-up in house prices during the recent housing bubble in the United States. The results of this study provide further evidence that interest rates were held artificially low during the housing bubble years. Various forms of dummy variables of the housing bubble were constructed and their effects on the effective Fed Funds rate were tested using empirical Taylor-type reaction functions. The findings are consistent in both OLS and GMM estimations. These findings are reinforced by the robustness checks testing alternative measures of inflation and output.

A counterfactual exercise was conducted which explored a forecasted federal funds rate using the estimated reaction function of the Fed during the Great Moderation. The estimated forecast rate was significantly higher in seven years out of the approximately ten-year span of the housing bubble. These results provide empirical evidence to support the conclusions from previous work that used the original form of the Taylor rule finding monetary policy contributed to the housing price bubble through its implementation of low federal funds rates.

ENDNOTES FOR CHAPTER 2

[1] The measures of inflation as reported by the St. Louis Federal Reserve (FRED) are the Consumer Price Index (headline CPI), personal consumption price index, which excludes food and energy (CPILFESL), Personal consumption expenditures excluding food and energy (PCEX), GDP Deflator.

Chapter 3

THE U.S. HOUSING BUBBLE: DID THE FED PLAY A ROLE?

3.1 Introduction

The price of real estate in the United States had been relatively stable through the mid-nineteen-nineties. In the spring of 1996, however, real house prices began to rise. On average, house price inflation rose by over eleven percent per year from 1997 through the peak of the housing bubble in January of 2006. In 2005 alone, home values escalated by a staggering eighteen percent from the prior year.

There is much finger pointing when it comes to causes of the housing bubble in the United States. Overall, it appears that many factors may have contributed to creating the perfect storm that seems to have occurred in the housing market beginning in March 1996 and lasting through December 2006. Common culprits blamed either solely or, in part, for their contributions to the rapid growth of prices in the housing market during this time are: excessively loose monetary policy, increases in capital inflows from foreign investors, fiscal policies aimed at increased home ownership, large scale purchases and securitizations of mortgages from government sponsored entities like Fannie Mae and Freddie Mac, low mortgage interest rates, and lastly, high mortgage acceptance rates for non-optimal credit risks, otherwise known as subprime mortgages.

Building upon previous empirical studies examining the effects of monetary policy on house prices during the housing bubble, I estimate a structural VAR with monetary and housing variables to examine any effects of these variables on house prices. Although the focus of this dissertation is on monetary policy actions that may have contributed to the changes in housing prices during the housing bubble, I incorporate additional variables in the model to capture effects of other potential contributing factors cited in the literature.

The housing market plays a vital role in the economy through the monetary transmission mechanism. Mishkin (2009a) provides an excellent explanation of the monetary transmission mechanism in which he discusses how monetary policy affects the housing market either directly or indirectly through at least six channels and demonstrates how the user cost of capital is a determinant of residential housing demand by using a standard neoclassical model. When monetary policy decreases short-term interest rates, long-term interest rates tend to fall because of their link with expectations of future short-term rates. This causes a decrease in user cost of capital and increases housing demand. This increase in housing demand results in an increase in housing starts, which, in turn, increases the economy's aggregate demand. Mishkin contends that policy makers need to understand the role of the housing market in the economy in order to achieve maximum employment and price stability.

Financial innovation and growth in the secondary mortgage markets has caused the housing market to have an even greater role in the economy than in the past (Miles, 2009). Consequently, a shock in the housing market can impact the entire macroeconomy. There are four channels through which a downturn in the housing market affects the macroeconomy (Hatzius, 2008). For example, a downturn in home values directly lowers output through decreased residential investment. Spending on goods and services can be reduced due to an increase in unemployed workers linked to the housing market through construction and real estate. The housing downturn can cause a wealth effect in consumption from changes in home values. Lastly, the decreased home values can cause losses in mortgage credit due to a reduction in lender's capital thus decreasing capital available to borrowers.

The Federal Reserve has been criticized for its use of extremely low interest rates during the early part of this century. It is commonly agreed upon in the literature that from 2001-2004, the federal funds rate was well below what would have been predicted during the time of the Great Moderation. Bernanke (2010), Greenspan (2004) and Brunnermeier (2008), among others argue that the low rates were necessary in the wake of 9/11 and to combat the recession after the bursting of the Internet bubble. Proponents of the Fed's policy actions during this time argue that the low rates played little or no role in the housing bubble. Conversely, some economists such as Taylor (2009), McDonald and Stokes (2013b), and White (2009) contend that it was in fact the low interest rates that fueled the run-up in house prices and helped sustain the above average growth in the housing markets during this time.

This study takes a different approach in identifying determinants of house price movements during the bubble. Existing studies using VAR methodology use a single variable to measure the stance of monetary policy in an attempt to reveal the relationship between house prices and the federal funds rate. I use VAR methodology to test effects of the Fed's policies on housing using two measures of monetary policy. Two policy variables are necessary in order to capture the effects of both the conventional and the unconventional policies enacted by the Fed in recent years.

Prior to the recession of 2008-2009, the Fed adjusted the target federal funds rate up or down in order to achieve desired macroecomic results. In December 2008, the federal funds rate effectively reached its zero lower bound on nominal interest rates and has remained at a near zero-rate since then. Traditional policy tools became essentially ineffective. A prescription for a simple Taylor rule would recommend a negative nominal interest rate but the rate cannot fall below zero percent however, as market interest rates are bound by a zero rate due to the ability of individuals to hold non-interest bearing cash (Joyce, Miles, Scott, & Vayanos, 2012).

Since 2008, the Federal Reserve has introduced new policy measures that had previously never been used. Most notably of these, was the introduction of large-scale asset purchases, referred to as quantitative easing (QE) due to the shift in the focus of monetary policy to quantity targets. In December 2008, the Federal Reserve initiated the first round of quantitative easing, now known as QE1. QE1 lasted sixteen months and ended in March 2010. QE2 was announced in October 2010 and lasted seven months. The final round, introduced in September 2011 and extended in the summer of 2012, is referred to as Operation Twist. QE1 differs from the other QE's because of the composition of the purchases. QE1 was comprised of purchases of direct obligations of housing-related government-sponsored enterprises (GSEs) and mortgage-backed securities (MBS). The first round of quantitative easing was intended to increase the availability of credit and improve the overall housing market. QE2 expanded the Fed's holdings in longer-term Treasury securities and was intended to support the economic recovery. Operation twist was named aptly because of the goal to essentially twist the yield curve by buying and selling long-term and short-term government bonds. Since monetary policy actions can no longer be captured completely by the federal funds rate after quantitative easing began, an additional variable to capture monetary policy actions is necessary.

Bagliano and Fevero (1998) evaluate VARs designed to estimate the monetary policy transmission mechanism and conclude that only models containing one policy variable do not show signs of parameter instability or evidence of misspecification. Building upon this result, I specify separate models to determine effects of both the Fed's interest rate policy, as well as its large-scale asset purchases during the recent rounds of quantitative easing. Measuring the effects of both federal funds rate targeting policy as well as QE policy will determine not only the relationship between these variables and house prices during the years in which house prices were rising, but will also capture the period after collapse of the housing market.

I estimate two forms of a structural VAR using the empirical methods employed by Bernanke and Blinder (1992). The first version (Model 1) includes the federal funds rate as the policy variable. I then re-estimate the model with an alternate measure of monetary policy. Open market operations can be measured through changes to the Fed's balance sheet. Federal Reserve bank credit captures conventional open market operations as well as recent purchases beyond traditional Treasury securities during the various rounds of quantitative easing as well as other nontraditional monetary policies initiated by the Fed after the bursting of the bubble in the housing market and the subsequent financial crisis. A benefit of splitting the model is that it allows for analysis of each component of recent monetary policy separately. The federal funds rate captures monetary policy actions through the bubble period and Reserve bank credit captures the Fed's post-bubble policy when the fed funds rate reached its zero lower bound.

VAR framework allows consideration of two questions on monetary policy stance; whether monetary policy was too loose during the housing bubble and if so, was it a major contributing factor to the strength of the housing markets. Use of a VAR model also allows for the ability to test some of the hypotheses of other possible contributing factors to the housing bubble.

The evidence provided in this study support the findings in the empirical study by Fitwi, Hein and Mercer (2015). Fitwi, Hein and Mercer develop a reduced-form pricing equation for U.S. house prices. They add a measure of monetary policy and an international capital inflow variable to determine if either or both of the variables explain the recent cyclical behavior in the housing market and find evidence supporting both explanations.

The global savings glut (GSG) refers to the significant increase in the global supply of saving. Bernanke (2005; 2011; 2007) ascribes the reduction of long-term interest rates to the increase in capital inflows into the United States from Asia and the Middle East countries dubbed GSG countries.

The results presented in this study also lend support to Bernanke's GSG hypothesis. Shocks to the long-term interest rate show an immediate positive response to net capital inflows. The response to house prices to a shock in net capital inflows is significantly positive only after eighteen months suggesting the lag in the time for prices in the housing market to react to the surge in inflows from foreign investment.

Neither the 30-year conventional nor the 1-year adjustable mortgage rates are shown to affect price movements in the housing market. The long-term mortgage interest rate is highly sensitive to changes in short-term rates of the Fed funds rate and the 1-year ARM. Much of the variation in the 30-year fixed mortgage rate is due to both short-term rates.

3.2 Literature Review

McDonald and Stokes (2013c; 2015) group the literature on the housing bubble into four categories. The first of these categories is the financial sector. This area of literature focuses on contributions on the part of the financial sector through unsound lending practices, high degrees of financial leverage and short-term borrowing and the issuance of complex mortgage-backed securities. Another major category in the literature is those that support the views of Bernanke's (2007) global savings glut hypothesis. The argument is that the flood of foreign capital that resulted in a trade deficit pushed up asset prices in the housing market. Then there are those like Shiller

(2007) who claim that the housing bubble is a classic asset price bubble that had its own momentum until its inevitable crash. The final category attributes blame to Fiscal and Monetary policies. The government gets its share of the blame through deregulation and lax use of existing regulations as well as the Federal government's aggressive policy to increase the rate of homeownership.

Excessively loose monetary policy on the part of the Fed, particularly from 2001-2004, is the focus of much of the current literature on the housing bubble including this dissertation. Critics of the Fed's loose policy contend that low interest rates were at least, in part, a contributing factor in the housing bubble.

Taylor (2007) models monetary policy during the housing bubble using a simple Taylor rule and provides a counterfactual. Taylor's analysis suggests that a higher federal funds rate would have avoided much of the boom and the subsequent bust would not have been as sharp. He also notes that long-term rates did not increase as much when the federal funds rate rose as would have been expected from past experience.

Payne (2006) examines the long-run relationship between the federal funds rate and long-term interest rates. Understanding the relationship between the short-term interest rates and mortgage rates, in particular, changes in the federal funds rate and the response of mortgage rates is vital to understanding and assessing the impact of monetary policy actions on the housing market. Payne utilizes the Johansen (1995) cointegration/vector error correction model and finds there is no feedback between fixed rate mortgages and the federal funds rate in the short run. In the long run however, fixed rate mortgage rates adjust asymmetrically to changes in the federal funds rate. The results indicate unidirectional causality from the federal funds rate to the fixed mortgage rate.

Questioning whether monetary policy reacts to house price fluctuations, Finocchiaro and Von Heideken (2013) investigate the Federal Reserve's, the bank of England's, and the Bank of Japan's responses to changes in house prices using a dynamic stochastic general equilibrium model (DSGE) for each country, using Bayesian methods. They conclude that a response to house price inflation is optimal but caution drawing normative conclusions for policy decisions.

Bryant and Kohn (2010) test the relationships between the consumer price index, housing inventory, vacancy rates, personal income, population, 30-year conventional mortgage rates, and median asking rents using median asking price as their dependent variable. Consistent with the results presented in this chapter, Bryant and Kohn find mortgage rates were not significant in the model.

In a subsequent study, Bryant and Kohn (2013) test for interest rate effects on the housing boom. Instead of merely using the traditional 30-year conventional rate to test the interest rate effect on housing, they employ several measures of interest rates including the one-year adjustable rate as well as the federal funds rate. Although they find that interest rates did indeed have an effect, both long term and short term interest rates were not the cause of the bubble. They conclude that interest rates in general played no role in the housing bubble nor did the easy monetary policy of the Federal Reserve.

Rigobon and Sack (2004) present an empirical analysis of central banks' reaction functions using the generalized method of moments (GMM). Rigobon and Sack find adding stock prices to Taylor-type reaction functions introduces endogeneity into the model. Finocchiaro and Von Heideken (2013) find similar results when adding house prices into the Taylor rule using a single equation partial equilibrium model and show that both GMM estimates of a policy reaction function and FIML-VAR methods both produce biased estimates. A medium-scale general equilibrium model is estimated and compared to different Taylor rules using Bayesian methods. This model properly identifies the parameters of the monetary policy function. The results are robust to different specifications of the policy rule and show price movements in the housing market play a separate role in the Fed's policy reaction function.

To evaluate the 2003-2008 period, Dokko et al. (2009), estimate a VAR for 1977-2002 and present a conditional forecast approach. The VAR model is specified using seven macroeconomic variables with two lags of each variable. If realized paths differ significantly from the conditional forecast, it would suggest that the path of the variable under consideration deviated from historical links with the other variables entering into the VAR. The realized path of the federal funds rate does not deviate from the forecast band and implies that the path of the federal funds rate has been consistent with the policy strategy that had been seen over the previous twenty years. The results of the conditional forecasts for the housing market however show that the realized path is outside the confidence bands on observed macro variables including the federal funds rate.

In a series of papers, McDonald and Stokes estimate various forms of a VAR to study the effects of monetary policy on house prices. In the first of the series, McDonald and Stokes (2013b) employ VAR modeling methods and Granger causality tests to study the relationship between the fed funds rate and the S&P/Case-Shiller aggregate 10-city monthly house price index. They find that the federal funds rate significantly Granger-causes house prices from 2000 through August of 2010. They conclude that the interest rate policy of the Federal Reserve during 2001-2004 is at least one of the contributing causes of the housing bubble. Further, McDonald and Stokes find that the sharp increase in the fed funds rate during 2004-2006 was the cause of the rapid consequent decline in housing prices.

McDonald and Stokes (2013d) next estimate a modified vector autoregressive (VAR) model of federal funds rate and house prices, foreclosure rate, mortgage interest rates and the unemployment rate for the period of January 2000 to August 2010 and present impulse response functions. They find the federal funds rate was the cause of the house price movements and the low federal funds rate during 2000-2004 was the cause of the rapid surge in house prices through 2006. An important result of this study was that the effect of shocks in the federal funds rate continued to have a significant effect on house prices when control variables are added to the model.

McDonald and Stokes (2013a) extend their model to investigate how house prices and foreclosure rates interact over time. Results from a VAR model with a 30-

year interest rate included show a positive shock in foreclosure rate spurs a decline in the housing market, further increasing the foreclosure rate. Increases in the federal funds rate trigger more foreclosures and larger declines in house prices. The housing market generates a negative externality from increasing foreclosure rates further pushing down house prices which in turn increases the rates of foreclosures in the area.

Questioning the conclusions made by Taylor (2007) and McDonald and Stokes (2013b), Miles (2014) attempts to determine if Fed policy was truly the main cause or even a major contributing factor of the housing bubble. Miles points out that previous empirical papers blame the Federal Reserve for the run-up and subsequent collapse in the housing market fail to include long-term interest rates. Miles estimates how well the federal funds rate can predict long-term rates. He also attempts to determine how well the federal funds rate and the 30-year mortgage rate can be used to predict housing variables and how the relationship between interest rates and housing variables has evolved over time. The filtering technique developed by Hodrick and Prescott (1997) and refined by Christiano and Fitzerald (2003) is used to decompose the variables into a stochastic trend and cyclical component. This method corrects for any non-stationary components common in the time series macroeconomic variables. Miles splits the sample periods, using the methodology of Friedman and Kuttner (1992) to follow how the relationship of interest rates and housing evolves over time. Results from regression analysis and structural change tests indicate that the mortgage rate is not a proxy for monetary policy demonstrating the declining influence of a central bank over long-term interest rates. Long-term rates have an independent and predictive power for housing variables that at times was greater than the federal funds rate.

In reaction to criticisms made by Miles, McDonald and Stokes (2013c) attempt to justify their methods and prior results by building upon their two previous VAR models (2013a; 2013d). A VAR methodology is again used, this time adding 16 lags of all right hand and left hand side regressors. They find shocks to the federal funds rate move house prices in a negative direction. Shocks to the federal funds rate also move mortgage rates. Shocks to mortgage rates only move house prices in a negative direction when a CF filtered data transformation similar to Miles is employed. A key finding of this study is the importance of longer lags in the VAR to capture the delay in interest rate changes and actual price movements. When mortgage rates change, there is a lag response for those with existing mortgages to refinance at the new lower rates. Their results suggest a longer VAR may be needed in order to pick up the effect.

In a follow up paper, McDonald and Stokes (2015) add variables to control for fiscal policy and a measure for net capital inflows. They also address the question of whether a short-term adjustable mortgage rate should be considered. The key finding of this work is that both the federal funds rate and the adjustable rate mortgage have impacts on house prices as measured by the Case-Shiller 10-city composite index. This result implies that variable mortgage rates and not the 30-year fixed rate may be the appropriate variable to use when analyzing causes of the housing bubble.

Results from the monetary reaction functions presented in Chapter 2 enforce the conclusions of previous work that find the Fed held rates too low during the years of the house price bubble. What is not consistent in the literature, however, is agreement on whether the low interest rates during this time specifically impacted housing variables. Rigobon and Sack (2004) and Finocchiaro and Von Heideken (2013) show that incorporating house prices into a monetary reaction function introduces endogeneity into the model and produces biased estimates. Therefore, a VAR methodology is necessary to explicitly link the low fed funds rates to house prices during the housing bubble.

I specify a VAR model including not only housing and monetary policy variables, but also incorporating variables to test some of the hypotheses propounded in previous studies and thought to be important determinants of house prices. Bernanke (2007) demonstrates how the inflows from foreign investment strongly impacted house prices during this time. Consequently, I include net capital inflows in the VAR as an endogenous variable. Miles (2014) contends long-term mortgage rates have a predictive power on house prices. McDonald and Stokes (2015) demonstrate the impact of short-term ARM rates on house prices and the importance of including a longer lag length to capture slow adjustment to changes in key variables in the model. Building upon many of these specifications, I include both the 30-year fixed mortgage rate as well as the 1-year ARM to attempt to address the inconsistencies in the conclusions from Miles and McDonald and Stokes as well as Bryant and Kohn (2013) and Payne (2006) as to the impact of mortgages rates on house prices during the housing bubble.

I improve upon existing models by using a time period that is long enough to encompass the entire housing bubble but short enough to ensure stability in the results. The house price index variable and optimal lag length are chosen using econometric selection criteria. No other study to my knowledge includes specifications to capture all of the recent non-traditional policies used by the Fed nor has the delinquency rate been considered as a potential contributor to movements in house prices.

3.3 Data

I use monthly data beginning in 1991, as this was the first year all key variables in the model are available. I extend the period through 2012, several years after the burst of the housing bubble. This will not only capture any contributions to the increase in housing price inflation but also contributions to the collapse in the housing market as well as a possible current run-up in house prices as seen by the upswing of house prices since 2011.

The choice of variable used as house price index is an important decision. There is not a general consensus in the literature as to which index best captures movements in house prices in the United States. Fitwi, Hein and Mercer (2015) discuss the difficulties in selecting an appropriate measure of U.S. housing prices. Figure 3.1 presents a graphical comparison of the most commonly used U.S. house price indices.

The S&P Case-Shiller home price series are available in various formats. Both seasonally and non-seasonally adjusted index values are available as a 10-city or a 20-city composite as well as a national average. The 10-city composite index is an aggregation of monthly changes in home prices for ten major metropolitan statistical areas (MSAs). The Case-Shiller national house price index measures the average value for single-family homes in the nine U.S. Census divisions and is also provided monthly. All Case-Shiller house price indices are indexed with a base period of 2000M01 and are measured by repeat sales of single-family homes.

Del Negro and Otrok (2007) have argued that the housing bubble was a regionalized and not a national phenomenon. By visual inspection of the various house price indices presented in Figure 3.1, it is apparent that the Case-Shiller 10-city composite index (CSXR) was more sensitive to the upswing and downturn in home values during the bubble period than the national average indices. The CSXR series measures repeat home sales in the ten metropolitan MSA's. The areas may have experienced more or a sharp run-up and subsequent crash than the other areas of the country. The national average indices may reflect the issue of spatial heterogeneity in house prices across the United States during the housing bubble (Glaeser & Nathanson, 2014).

Both the Freddie Mac and the U.S. Federal Housing and Finance Agency house price indices are based on mortgages that have been purchased or securitized by Fannie Mae or Freddie Mac. The Freddie Mac house price index is a weighted average of the fifty states and Washington D.C. The Freddie Mac index is based on a database of loans purchased either by Fannie Mae or Freddie Mac. Values are indexed with a base period of 2000M12. Data used in this study is from the series updated as of March 2015. The U.S. Federal Housing and Finance Agency (USHFA) house price index is a measure of the movement of single-family house prices in the United States and measures repeat mortgage transactions on single-family properties.

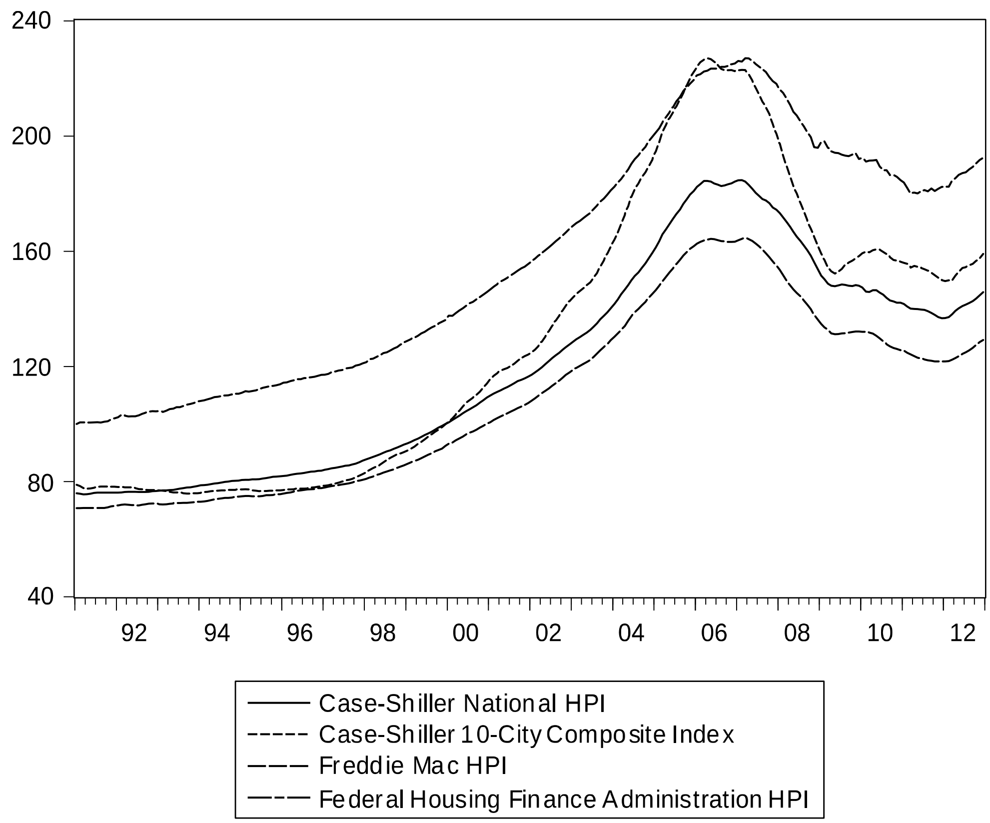


Figure 3.1: Seasonally Adjusted U.S. House Price Indices, 1991-2012.

The effective federal funds rate (FFR) is reported as a monthly average of daily figures. The federal funds rate has long been used as the measure of monetary policy actions. Bernanke and Blinder (1992) present an empirical model for studying the channels of the monetary transmission mechanism and find empirical evidence in favor of using the federal funds rate and confirm the federal funds rate is informative about future movements in macroeconomic variables. Historically, the federal funds rate records supply shocks in Reserve bank credit, making it the best predictor variable of monetary policy actions.

Bernanke and Mihov (1995) test several approaches for policy targeting. Although they advocate a fed funds-rate targeting approach of Bernanke and Blinder, they find a borrowed-reserve approach which measures shocks to the negative values of borrowed reserves yields similar results as the funds-rate approach. Christiano and Eichenbuam (1991) assume nonborrowed reserves only respond to policy shocks but Bernanke and Mihov find their approach does not perform well in econometric tests except for the period of 1979-1982 when the Fed officially followed a nonborrowed reserves targeting procedure. Another approach, proposed by Strongin (1995), measures monetary policy actions by the proportion of nonborrowed reserves growth rate that is orthogonal to the total reserve growth rate. Strongin's approach assumes that monetary policy only responds to demand shocks. Bernanke and Mihov note a weakness of this model is the possibility of a supply shock therefore, eliminating this approach as a possible method for measuring recent QE policy. The empirical studies of Bernanke and Blinder, Christiano and Eichenbuam and Strongin focus on the measurement of monetary policy innovations, but the results are useful in specification of proper policy variables in the assessment of shocks to the housing market.

There are several options to attempt to capture the effects of quantitative easing. One possibility is to use dummy variables for the QE periods. This method follows the "narrative approach" used by Romer and Romer (1989) in which they created dummy variables for periods of explicit contractionary monetary policy actions intended to combat inflation. Romer and Romer estimate a VAR and use current and lagged values of dummy variables for the six postwar episodes of deliberate contractionary monetary policy to examine the behavior of unemployment and industrial production in the post-World War II period. One of the benefits to this approach as noted by Bernanke and Mihov is that it is not necessary to model the details of the Fed's operating procedures in order to implement the procedure. A drawback to this method is that the use of dummy variables does not measure the magnitude of the large-scale asset purchases. Another potential pitfall is that dummy variables for the QE's would only be able to show significance during these periods but would not necessarily indicate that it was in fact due to the quantitative easing instead of some other factor not captured in the model.

Another possibility to measure the Fed's QE policy is to directly measure the purchases by the Fed in the QE periods. Christiano and Eichenbuam (1991) suggest the use of nonborrowed reserves as a measure of monetary policy. Nonborrowed reserves, according to Bernanke and Mihov (1995) may be the Fed's most closely controlled instrument. Essentially, by purchasing assets, the central bank is expanding its balance sheet. Reserve bank credit (RBC) not only captures the LSAPs of the Fed during quantitative easing but also captures Fed policy of Term Auction Facility. (TAF). TAF is a temporary program instituted by the Federal Reserve to increase liquidity in the credit markets in response to the problems associated with the subprime mortgage crisis. TAF was instituted in December 2007. TAF funds were auctioned to banks. The Fed initially engaged in defensive open market sales to keep the monetary base stable. Thus, discount lending increased and open market security holdings decreased by equal amounts. TAF lending was sizable, so using only open market security holdings would inaccurately reflect Fed policy at this time.

Reserve Bank Credit (RBC) is comprised of purchases of government securities, loans to the banking system, float and other miscellaneous activities. Federal Reserve holdings of securities make up of the bulk of RBC. Monthly data for RBC, available from the St. Louis Federal Reserve, captures not only the purchase of the large scale assets purchased (LSAP) through the various QE's and the sizable TAF lending, but RBC also historically measures the holdings of Treasury securities. Using RBC as a policy variable will determine any impact and magnitude of monetary policy actions through the various rounds of quantitative easing on other variables in the model.

Changes in interest rates can lead to reactions on the parts of investors and savers through the monetary transmission mechanism. If rates are low, demand for borrowing increases. Various forms of adjustable rate mortgages (ARMs) became increasingly cheap relative to 30-year fixed rates. By 2006, about one quarter of all

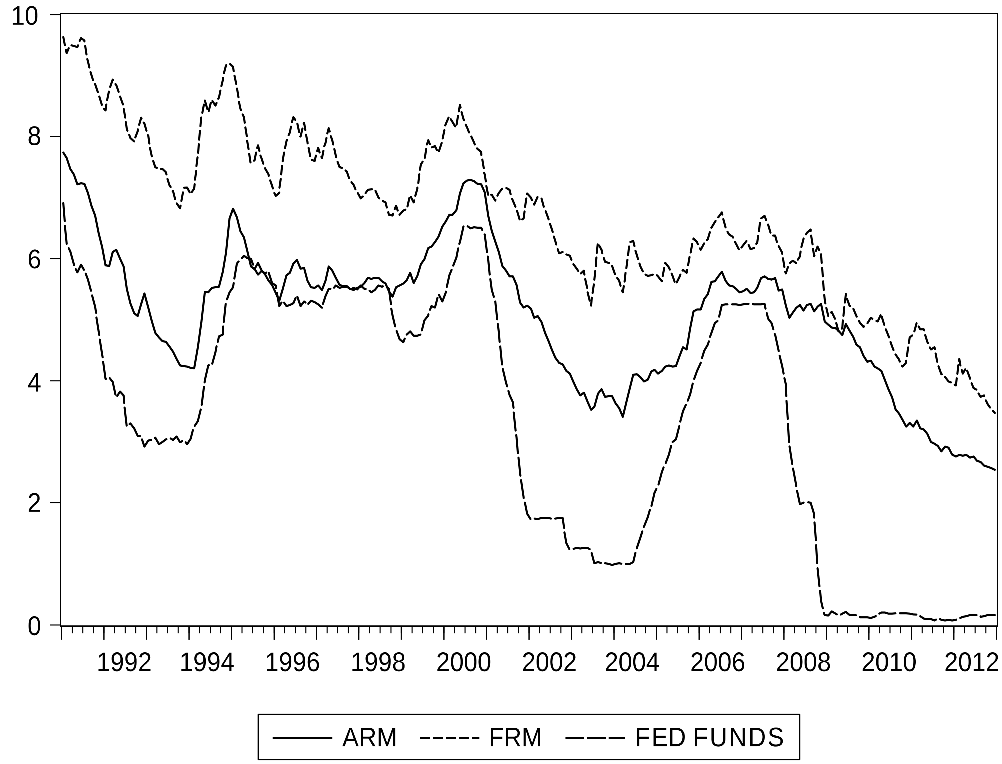


Figure 3.2: Federal Funds Rate and Mortgage Interest Rates, 1991-2012. Source Freddie Mac and St. Louis Federal Reserve.

mortgages were ARMs and three-fourths of the ARMs were considered subprime. Average 30-year fixed mortgage rates (FRM), as well as the 1-year adjustable rate mortgage (ARM) average were obtained from the St. Louis Federal Reserve.

Upon examination of Figure 3.2 it is apparent that the federal funds rate and the 30-year mortgage rate have some degree of comovement. The correlation between the two interest rates is 0.801 for the entire sample period. As expected, the 1-year ARM and the federal funds rate have a higher degree of comovement and have a correlation of 0.869. The higher rate of correlation implies short-term adjustable rates are more responsive to changes in monetary policy than the long-term fixed mortgage rate. The correlation between the federal funds rate and the fixed mortgage rate fell to 0.671 during the housing bubble period, while the correlation between the federal funds rate and the ARM remained strong during that period with a correlation of 0.847.

In July 2011, approximately one-third of all home sales were the result of foreclosures. Data on average foreclosure rates did not become available until 2000. The delinquency rate can be an early indicator of foreclosures, however. The delinquency rate on single-family residential mortgages is an average delinquency rate for all domestic commercial banks and measures the percentage of loans that are 30 days or more past due. The rate captures all types of mortgages and does not distinguish between prime and subprime mortgages. Figure B.1 of Appendix B displays historical rates for both the delinquency rate and the foreclosure rate. The mortgage delinquency rate is available for the entire sample period and tracks the foreclosure rate fairly closely until 2010 when the foreclosure rate begins to decline while the delinquency rate remains fairly stable.

As part of a federal stimulus packages indented help in the economy recovery after the crash of the housing market, almost $50 million was allocated to a mortgage rescue plan in 2009. This legislation was intended to help homeowners who were delinquent on their mortgage payments to stay in their homes by allowing them to make loan modifications to their existing mortgage. Homeowners who were current on their mortgage but unable to refinance due to home values dipping below their existing loan amount could qualify for the government-refinancing program. Refinancing and loan modifications helped reduce the foreclosure rate while the foreclosure rate has remained fairly high.[1]

According to Bernanke's "global savings glut hypothesis" (2005; 2011; 2007), capital inflows from foreign investors helped hold down long-term interest rates, including mortgage rates particularly during 2003-2007 (Bernanke et al., 2011). Quarterly data for the balance on current accounts, available from the St. Louis Federal Reserve and measured in billions of dollars is interpolated into monthly values. A negative value of the balance on current accounts is used to construct the measure of net capital inflows (Inflows). This transformation is necessary in order to properly measure the effects of a positive shock of inflows from foreign investors in the impulse response functions.

The St. Louis Federal Reserve is the source for the mortgage interest rates, Reserve bank credit, capital inflows, the mortgage delinquency rate and the effective federal funds rate. The Case-Shiller 10-City Composite Index is available from the S&P Case-Shiller Indices website. Values for mean, median, maximum, minimum, and standard deviation are reported in Table 3.1.

Figures B.2-B.7 in the Appendix present graphs for key variables in the VAR model. HPI, Fed Funds Rate, RBC, ARM, FRM, and Delinquency Rate are depicted in both levels and log values. Inflows are displayed in levels only as it can take on negative values. The sample period is from 1991-2012 and consists of 264 observations before adjustments for first differencing. The federal funds rate shows great variation during the entire sample period ranging from a high of almost seven percent to low of near zero percent. The huge spike in RBC starting in 2008 signifies the acquisition of assets by the Fed reaching a high of over 2.5 trillion dollars by the end of QE2 in June 2011. The delinquency rate also displays excessive volatility in the sample period with a low of 1.39% in the forth quarter of 2004 to a high of 11.27% in 2010.

Table 3.2 presents descriptive statistics for three sub-periods of the sample. By splitting the sample into sub-periods, it is easy to see how behaviors of the variables vary before, during and after the bubble. Panel A provides statistics for the period prior to the housing bubble. Prior to 1996, house prices had been fairly stable. The average delinquency rate on mortgages was under three percent with the highest rate of 3.36%, which occurred in 1991. The spread between the 1-year adjustable ARM and the 30-year fixed mortgage rate was almost 250 basis points.

Table 3.1: Descriptive Statistics 1991-2012.

	N	Mean	Median	Max.	Min.	Std. Dev.
HPI	264	130.21	124.43	226.91	75.81	49.41
Fed Funds	264	3.33	3.75	6.91	0.07	2.15
RBC	264	791.50	523.03	2650.40	241.11	680.69
ARM	264	5.08	5.29	7.74	2.54	1.17
FRM	264	6.67	6.78	9.64	3.35	1.43
Inflows	264	202.15	172.74	726.91	-166.67	170.20
Delinquency	264	3.81	2.29	11.27	1.39	3.12

Table 3.2: Descriptive Statistics for sub-periods.

Panel A Pre-Bubble: 1991- 1996m2

	N	Mean	Median	Max.	Min.	Std. Dev.
HPI	62	77.10	76.97	78.87	75.81	0.73
Fed Funds	62	4.48	4.35	6.91	2.92	1.23
RBC	62	317.02	318.97	381.09	241.11	45.51
ARM	62	5.73	5.69	7.74	4.20	0.95
FRM	62	8.22	8.32	9.64	6.83	0.81
Inflows	62	65.36	58.60	121.39	7.59	33.89
Delinquency	62	2.70	2.70	3.36	2.10	0.46

Panel B Bubble Era: 1996m3-2006

	N	Mean	Median	Max.	Min.	Std. Dev.
HPI	130	133.97	120.53	226.91	77.17	49.70
Fed Funds	130	3.93	4.78	6.54	0.98	1.83
RBC	130	563.62	534.23	776.17	379.89	124.96
ARM	130	5.27	5.53	7.29	3.41	0.99
FRM	130	6.84	6.88	8.52	5.23	0.84
Inflows	130	231.22	230.28	545.65	24.23	110.08
Delinquency	130	1.98	2.01	2.42	1.39	0.29

Panel C Post-Bubble: 2007-2012

	N	Mean	Median	Max.	Min.	Std. Dev.
HPI	72	169.16	157.71	222.95	149.59	22.98
Fed Funds	72	1.25	0.18	5.26	0.07	1.87
RBC	72	1611.54	1846.34	2650.40	479.01	844.13
ARM	72	4.16	4.32	5.71	2.54	1.09
FRM	72	5.04	4.95	6.70	3.35	0.96
Inflows	72	244.68	255.06	726.91	-166.67	234.13
Delinquency	72	8.04	9.95	11.27	2.03	3.24

Panel B of Table 3.2 describes the years during the housing bubble. House price inflation increased by over 70 percent from years prior to the bubble and hit an all time high of 226-index value at the peak of the bubble in March 2006. Although the Federal Funds rate hovered under 2% for over two years after 9/11 and even dipped down below 1% in December 2003, the average rate during the bubble period was just under 4% with a high of 6.54% in July 2000. During the almost ten year span of the bubble, the spread between the 1-year ARM and the 30-year fixed rate had shrunk to only 157 basis points and average delinquency rate on mortgages fell to under 2%. Inflows from foreign investment during the housing bubble are almost six times greater than average inflows in the pre-bubble period.

Panel C describes the period after the peak of house prices in March 2006. The mortgage delinquency rate was relatively low until after the bursting of the housing bubble in 2007. After which time, the delinquency rate rose from less than 2% to over 8% of mortgages on average with a high of 11.27% in the first quarter of 2010.

The Federal Reserve has expanded its balance sheet by an astronomical 195% during the various QE rounds based on mean values of RBC in the bubble period. Mortgage interest rates remained low after the bursting of the bubble. In fact, the spread between the rates was only 88 basis points on average from 1997 through 2012 and the 30-year fixed rate dropped as low as 3.3% by the end of 2012.

3.4 VAR Methodology

A vector autoregression (VAR) model has been proven to be successful in describing the dynamic behavior of economic of time-series variables. The appeal of VARs is that they are quite flexible and can be used for policy analysis and structural inference. VARs have become a benchmark for analyzing the relationships of macroeconomic variables. One of the benefits of using VAR methodology is it allows for analysis without the need for a complete specification of a structural model of the economy (Bagliano & Favero, 1998).

Bernanke and Blinder (1992) specify a structural economic model by estimating a VAR consisting of monthly data for the federal funds rate, unemployment rate, and the inflation rate as measured by the consumer price index. Each of the variables is regressed on six lags of itself and the other explanatory variables. Previous studies find structural models are sensitive to the choice of specification and identifying assumptions (Bernanke, 1986). By using a structured vector autoregressive (VAR) model Bernanke and Blinder present an empirical flow of the monetary policy mechanism by examining the responses of banks' balance sheet variables and target variables to federal funds rate shocks.

Whereas Bernanke and Blinder find that prior to 1979 changes in the federal funds rate relate to changes in inflation and unemployment, Balke and Emory (1994) extend the period after 1982, when the Fed began specifically targeting the federal funds rate to determine if the relationships found by Bernanke and Blinder hold up over time. Their results confirm that monetary policy reacts counter-cyclically to changes in the business cycle.

Separate models are necessary in order to correct for serial correlation persistent in a model comprising of both monetary policy variables. Both the federal funds rate and the open market operations of the Fed through buying and selling of assets are ways to measure monetary policy. Therefore, it is not unexpected that including both variables in the model would produce some degree of correlation among the variables. Therefore, I specify two separate models using alternate measures of monetary policy.

Model 1 contains the federal funds rate to measure the effects of monetary policy on house prices. In addition to the federal funds rate, mortgage interest rate variables are included. McDonald and Stokes (2015) show the importance of including both short-term and long-term mortgage interest rates when identifying a structural VAR studying the determinants of house price movements. To test Bernanke's GSG hypothesis, I include a variable to measure net capital inflows. I also include mortgage delinquency rates to assess the effect of delinquency rates on home values. The ordering in the VAR is Fed Funds rate, net capital inflows, 1-year ARM, 30 FRM, delinquency rate and house prices ordered last to capture the effect of all other endogenous variables to the left of house prices in the model.

I then re-estimate the model using the RBC to capture the effects of the increasing the size of the Fed's balance sheet, particularly through quantitative easing. The RBC variable serves as the monetary policy measure in Model 2. The VAR (6) includes all of the other variables and ordering as in Model 1.

As a robustness check, I estimate a third model. The full model (Model 3) includes both policy variables in the VAR ordering the fed funds rate first, followed by RBC and then the other variables in the system. Caution when using this model for inference is suggested as this model does present higher levels of serial correlation in the lag values.

Rudebusch (1998) questions the results of a VAR in studying monetary policy transmission when monetary policy variables are treated as endogenous variables in the model. To properly gauge the effects of monetary policy actions, the monetary policy variables need to be exogenous in the model. Without a complete structural model of the economy it is the response of variables to exogenous policy actions that must be examined in order to gauge the effects of monetary policy. Bagliano and Favero (1998) however, find no statistical difference between VAR models that treat the policy variables as either exogenous or endogenous. Wright (2012) uses daily data and estimates a VAR to study the effects of the QE policy announcements on the financial markets. Similarly, the dummy variables for the QE periods are included as exogenous variables in the model as well as a model with an exogenous housing bubble dummy variable.

3.5 Empirical Results

Prior to any analysis of monetary policy, I preform several specification tests. This is an important step in ensuring the VAR system is well specified to ensure the validity of the results. A summary of some the results of various specification tests are presented in Appendix Tables B.1, B.2, B.3 and B.4.

I use an econometric approach for selecting the house price index (HPI) to best measure housing inflation in the United States. All HPI series are found to be non-stationary in levels. Seasonally adjusted HPI's performed better than non-seasonally adjusted models in econometric tests. I vary the estimation periods in the model to test for stability of the variables over time.

Bagliano and Favero (1998) show longer sample periods show parameter instability and shorter sample periods for evaluating monetary policy shocks in the economy provide more stable results. Some of the existing work on interest rates and housing bubbles use relatively short sample periods in their models consistent with the findings of Bagliano and Favero.[2] These shorter sample periods may also be due to the availability of important variables thought to play key roles in house price movements.[3] In order to capture the effects of some of these variables, the sample period is restricted to a time in which prices of homes had already started to increase dramatically or their sample period ends prior to the bursting of the bubble. I extend the sample period prior to the start of the bubble in order to properly assess any impact of monetary policy on the price of homes during the housing bubble.

Only the results obtained from the VARs containing the seasonally adjusted Case-Shiller 10-city series (CSXR) remained stable over time and provided consistent results. CSXR was also the only index that did not present serial correlation in the lag values. Table B.6 of the Appendix highlights the results of the LM test for serial correlation for the models using the various house price series. Although my main results are presented using CSXR, as robustness checks, I present results for other HPI's in the Appendix.

I consider a VAR with macroeconomic and housing variables. I estimate a VAR (6) in first differences for all variables for models 1 and 2. I use log values of all variables except net capital inflows since net inflows can have both positive and negative values. Eighteen lags are determined as the optimal lag length by AIC information criteria. This lag length is long enough to correct for serial correlation present models with shorter lag lengths. Models with a longer lag length are non-stationary and eliminated from consideration as they could lead to spurious results. Table B.1-B.3 of the Appendix presents results of the lag order information criteria for the various models.

A recursive procedure similar to that first used by Sims (1980) imposes a contemporaneous ordering of shocks. This method is consistent with the approach used by Del Negro and Otrok (2007) and Christiano, Eichenbuam and Evans (2005). A recursive ordering implies that contemporaneous values of the variables ordered to the left have an effect on the variables ordered on the right but the effect works only in one direction so contemporaneous values of variables ordered after a variable will not have an effect on variables ordered first.

Therefore, to properly measure any response in house prices to shocks from the other endogenous variables in the model, I order HPI last. This ordering is similar to the ordering of McDonald and Stokes (2013c; 2015; 2013d) and Iacoviello (2005).

Variables that serve as the monetary policy measure are ordered first, followed by net capital inflows (Inflows), 1-year adjustable mortgage rate (ARM), 30-year fixed mortgage rate (FRM), and delinquency rate (Delinquency). As a robustness check, alternative orderings are also considered to test the sensitivity of the ordering and the results are consistent with the ordering presented.

I present two sets of empirical results. The results from Model 1 provide evidence that the federal funds rate was a contributing factor to the movement in house prices. The results presented for Model 2 provide evidence that the large-scale asset purchases (LSAP) on the part of the Fed has an effect on housing variables.

I present another set of results (Model 3) in the Appendix. These results presented for Model 3 represent a VAR that incorporates both monetary policy variables in the system of equations. Model 3 is estimated in first differences and is a VAR (6) with eighteen lags of all variables. The ordering for Model 3 is similar to the previous models. The Federal Funds rate is ordered first, followed by RBC, and all other variables follow the same ordering as Models 1 and 2.

VAR variables are expressed as past values of itself and past values of other variables in the system (Balke & Emery, 1994). A VAR model is difficult to interpret due to the complex interactions and feedback between the variables. Instead, structural analysis of a VAR includes Granger causality, impulse response functions and forecast error variance decompositions of the variables in the model.

Granger (1969) first demonstrated that causality and feedback between variables is testable and can be explicitly defined. Granger causality analysis has since become a hallmark in structural analysis of VAR models.

Table 3.3 presents the results of the Granger Causality tests for both models. The results from the Granger causality tests confirm the views of Carletti and Allen (2010), and Fitwi, Hein and Mercer (2015) who find the two main causes of the housing bubble are the low interest rate environment and increased debt holdings from international investors, particularly those in Asian countries. The p-values for the Wald tests indicate rejection of the null hypothesis of no-causality for the federal funds rate in Model 1. In Model 2, when RBC is used as the policy variable, the conclusion is the same. Net capital inflows are shown to Granger cause house prices in both models at all conventional confidence levels.

I test the stability of the VAR by estimating alternative specifications. Results of Granger causality tests on alternative specifications of the VAR are reported in Table B.5 of the Appendix. Column I of Table B.5 presents the results when current and lagged values of the dummy variables for the QE periods are added as exogenous variables to the model. The results are consistent with the results of the baseline specifications reported in Table 3. 3.

Column II of Table B.5 shows the results when a dummy variable equaling one for the months during the housing bubble and zero otherwise is added as an exogenous variable to the VAR. When the exogenous housing bubble dummy is included, the hypothesis of non-causality of monetary policy can only be weakly rejected.

Finally, Column III reports the results for the Granger causality tests when the sample period is restricted to 1996-2012. Any shorter time span and the model becomes non-stationary. This specification omits the stable period of house prices and interest rates prior to the housing bubble but still encompasses the aftermath of the bust of house prices and the LSAPs of the Fed during the QEs. These results are consistent with the previous tests but add an additional rejection of non-causality for the delinquency rate in Model 1. The results of the Granger causality tests are robust to all specifications of the models however alternative specifications provide weaker rejection of the null hypothesis of non-causality.

When both variables are included in the VAR for Model 3 the null hypothesis of non-causality of house prices on the part of monetary policy cannot be rejected. Results for the Granger causality tests for Model 3 are presented in Table B. When the exogenous housing bubble dummy is included, the delinquency rate is shown to significantly Granger cause house prices and at the 95% confidence level. Rejection of the null hypothesis of non-causality of the Fed Funds rate on house prices is rejected for the restricted sample period. Results for this test are found in Column III of Table B.5 in the Appendix.

Table 3.3: Granger Causality Tests, 1991-2012.

Model 1

	Chi-sq.	df	Prob.
FED FUNDS RATE	34.10	18	0.012
INFLOWS	31.57	18	0.025
ARM	18.04	18	0.453
FRM	13.25	18	0.777
DELINQUENCY	19.49	18	0.362
All	153.00	90	0.000

Model 2

	Chi-sq.	df	Prob.
RBC	36.70	18	0.006
INFLOWS	29.91	18	0.038
ARM	18.22	18	0.441
FRM	18.64	18	0.414
DELINQUENCY	21.75	18	0.243
All	157.42	90	0.000

Granger causality tests were also performed using alternative measure of house prices. Tables B.7, B.8 and B.9 report results for the Case-Shiller National HPI, the US HPI and the Freddie Mac HPI respectively. Unfortunately, the results using the various HPI's are not consistent. Although all HPI's show that the Fed Funds Rate Granger-causes house prices in Model 1, and RBC Granger cause house prices in Model 2 for all HPI's, that is where the consistency ends. The Case-Shiller National

HPI results show Granger causality for both variables measuring monetary policy as well as Inflows and the delinquency rate in Model 3. The results for Model 1 are consistent with the results for the CSXR. Model 2 however, finds both the short-term and long-term interest rates are significant. The USFHFA HPI results display significance for the monetary policy variables, as well as net capital inflows and the delinquency rate, where the Freddie Mac HPI does not show any causality on the part of inflows from foreign investment. As opposed to the CSXR series, the results from alternative specifications of the models using the other three HPI series do not remain consistent, further strengthening the argument for CSXR as the best measure of HPI in the models. This result also could be indicative of the measurement methods of the various indexes.

The use of Granger causality tests has been criticized in economic analysis. A variable that is revealed to Granger cause another variable in the VAR does not necessarily imply true causality. The results merely suggest that the variable has predictive power in forecasting ability. Therefore, we now turn to other methods of structural analysis to further strengthen any conclusions from the results of the Granger causality tests.

Impulse responses trace out the responses to present and future values of the variables in the system to a one unit increase to the errors of one of the variables in the VAR model while holding all other errors constant. The one unit increase can be interpreted as an innovation or shock to the variable. We then can examine the dynamic response to the other variables in the VAR to the shocks.

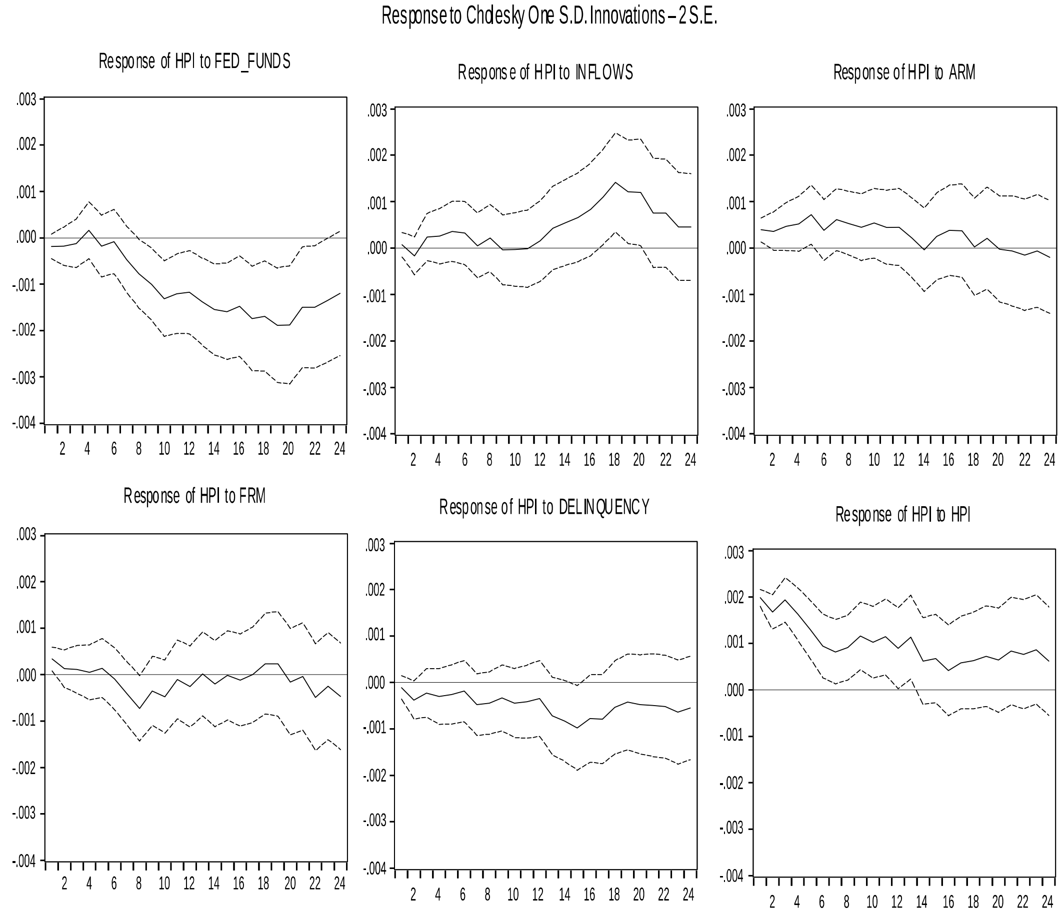


Figure 3.3: Impulse Response of House Prices for Model 1

Graphs of the impulse response functions for house prices for Model 1 are shown in Figure 3.3 and found in Figure 3.4 for Model 2. Asymptotic response standard error bands are added. Results for impulse responses for all variables in the VAR system for both models are presented in the Figures B.9 and B.10 of the Appendix. Consistent with the results from the Granger causality tests, monetary policy shocks have an impact on the housing market. A positive shock in the Federal funds rate would have a negative impact on house prices. A positive shock to RBC has a positive impact on house prices.

Both models show a slow response in house prices to innovations in the other variables in the system. House prices do not initially respond to monetary policy

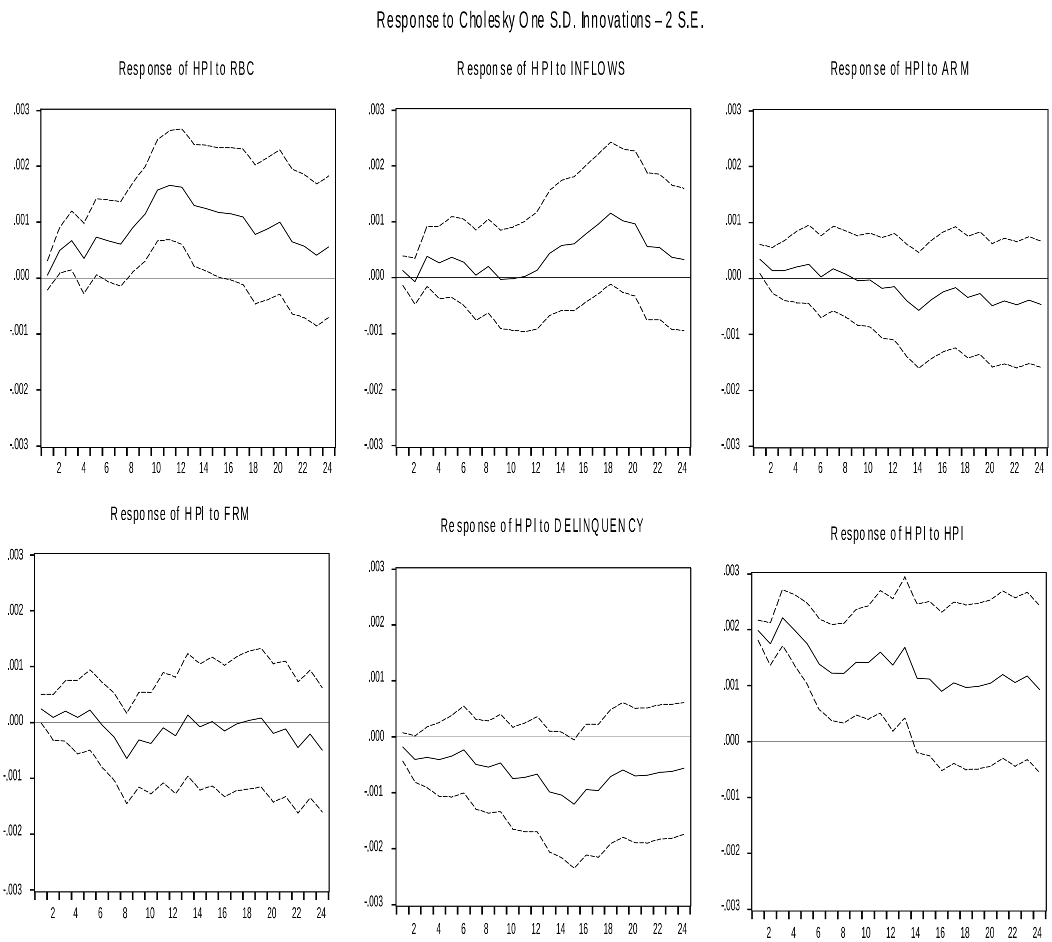


Figure 3.4: Impulse Response of House Prices for Model 2

innovations in the interest rate. A statistically negative response is seen at about nine months. The effect of the interest rate shock persists for almost two years. The shock to RBC has a quicker response in house prices than the fed funds rate, but the shock dies out sooner than an interest rate shock seen in Model 1.

Recall, Inflows is measured as the negative value of the balance on current accounts. Therefore, a positive shock to Inflows represents a spike in the level of foreign investment. Both models represent positive movement in house prices after a positive innovation in capital inflows indicating that a surge in foreign inflows drives up house prices. The effect is stronger and statistically significant Model 1, however.

When the responses of the impulses are accumulated, only the monetary policy shocks move house prices. Impulse Responses with accumulated error responses for Model 1 and Model 2 are found in Table A.13 and Table A.14 respectively. The results are similar in both models. A positive shock in Inflows decreases the delinquency rate and a positive shock in the delinquency rate also decreases inflows from foreign investment. Both the long-term and short-term mortgage interest rates increase with a shock to inflows. Interestingly, both models show a positive response to a positive shock to house prices for inflows. House prices have consistently responded to a shock in house prices. This result is typically expected with a shock to one's own variable. The combined result of the positive response of both house prices and inflows to a positive shock to house prices could lend evidence to support the house price momentum theorists like Shiller, claiming the bubble in the housing markets took on a momentum of its own until its inevitable burst by the end of 2006.

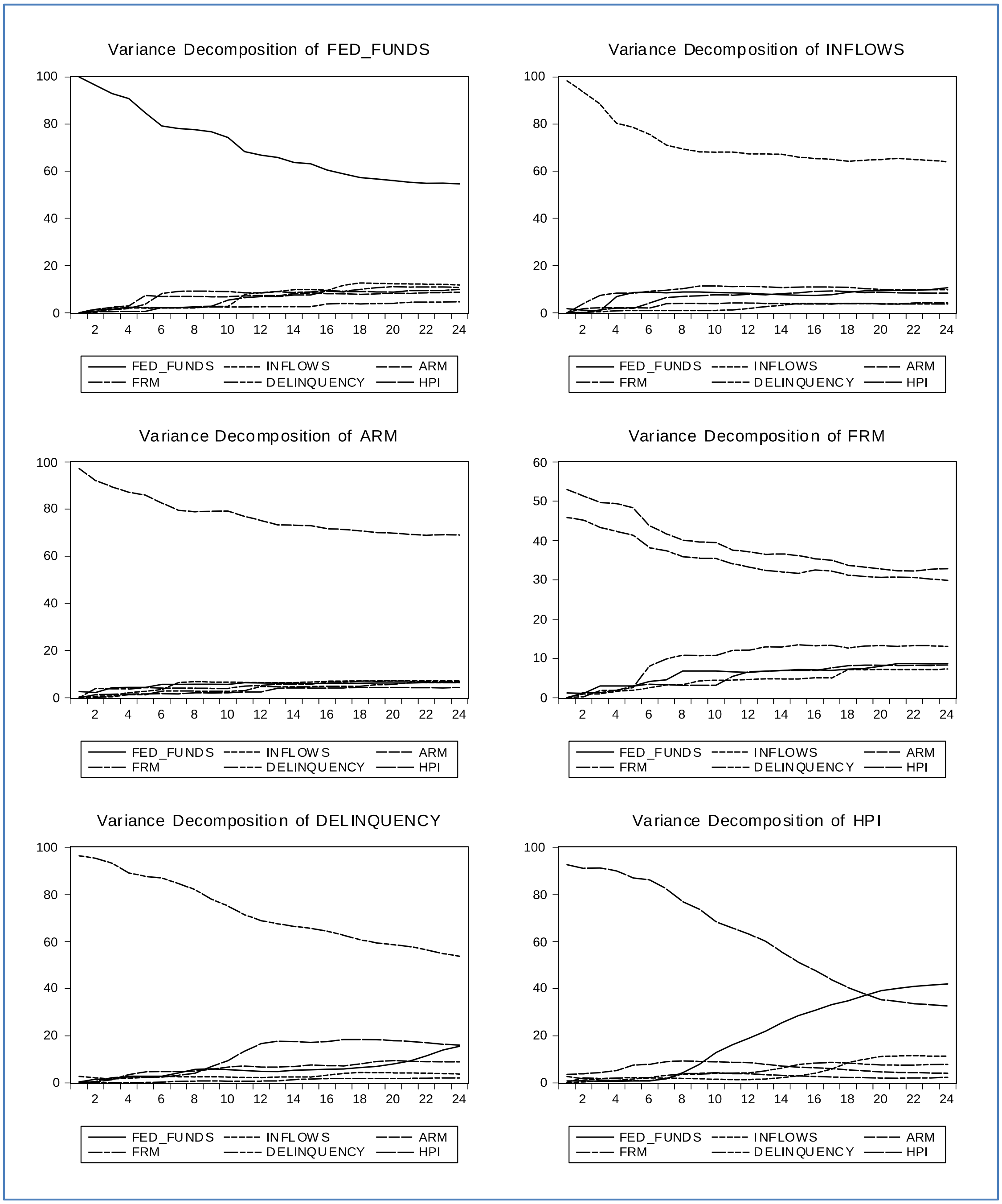


Figure 3.5: Variance Decomposition Graphs for Model 1

Forecast error decompositions measure the contribution of each type of shock to the forecast error variance. The variance decompositions are estimated for twenty-four months. Tables B.10, B.11 and B.12 present the results of the variance decomposition of HPI for models 1, 2 and 3 respectively. The forecast error variances for house prices tell similar stories for all models. The forecast error variance decomposition of house prices in Model 1 is presented graphically in Figure 3.5. Figure 3.6 depicts the graphical representation of the variance decompositions for HPI for Model 2.

Almost all of the forecast variance for the first nine periods can be explained by the HPI itself. As the forecasted period continues, monetary policy variables begin to account for a greater percentage of the variation in the forecasted values of house prices. As shown in Model 1, the Federal Funds rate begins to explain a larger amount of the variation in house prices. In fact, after 19 months, the federal funds rate explains a greater amount of the variation in house prices than house prices itself. Although RBC does account for approximately one-quarter of the variation in house prices, overall, the interest rate has greater predictive power in forecasting house prices than RBC. Figure B.14 presents the results for Model 3 confirming the conclusions drawn in the previous two models. The variance decomposition for the 30-year fixed mortgage rate (FRM) shows an interesting result. In both models, the ARM rate accounts for an equal, or as in the case of Model 1, larger portion of variation in the long-term rate than the variable itself. This result persists through all of the periods.

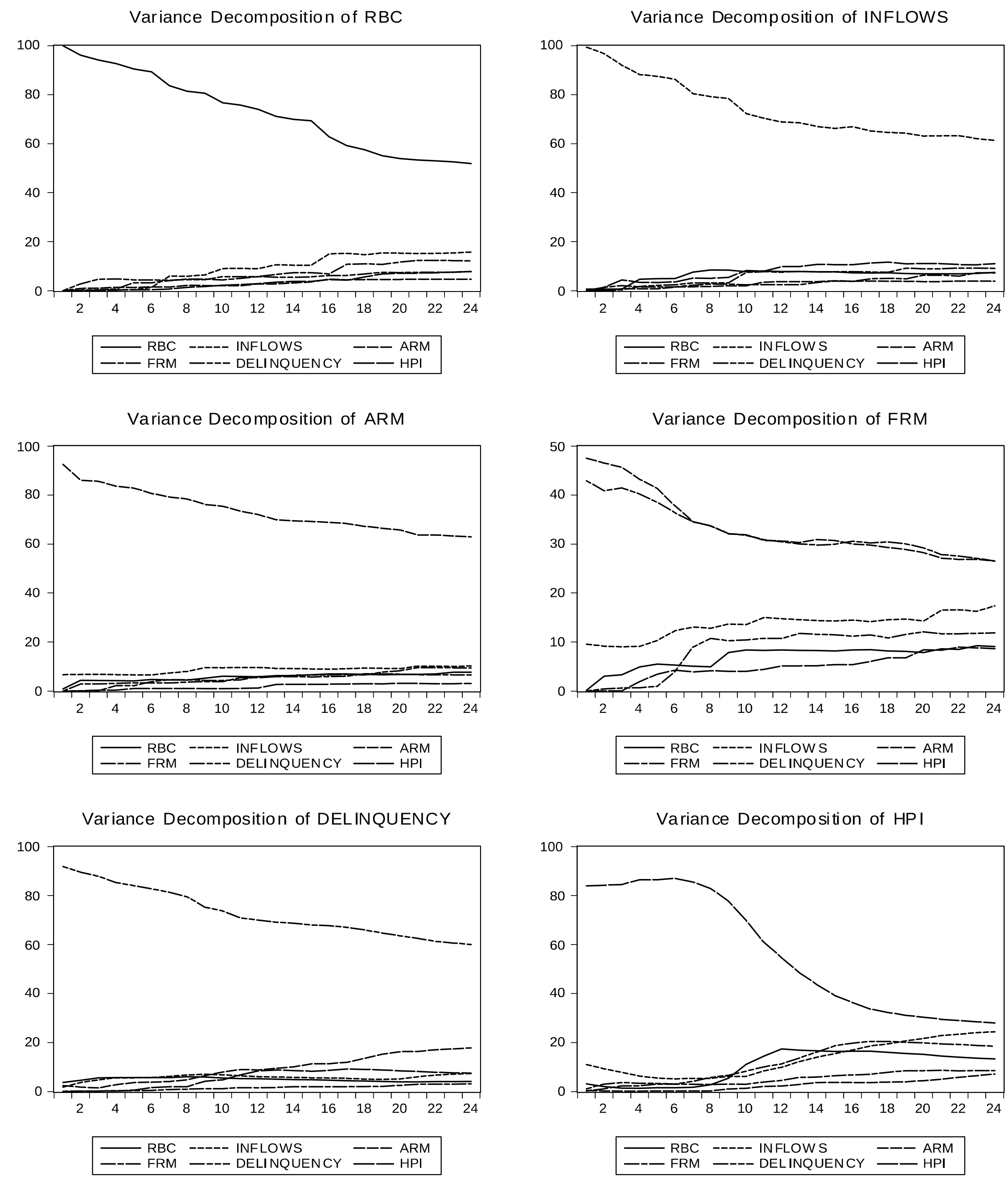


Figure 3.6: Variance Decomposition Graphs for Model 2

The delinquency rate in Model 1 plays a large part in describing the variation in the FRM. All of the variables appear to account for variation in the 30-year fixed rate in Model 2, particularly the ARM rate and the delinquency rate. The same results are not seen in the variance decomposition of the ARM rate, however. Almost all of the variation in the forecast errors for the ARM rate can be explained by its own errors.

This result is also true for net capital inflows and the Fed funds rate. Some of the variation in RBC can be attributed to the net capital inflows but as the results of the impulse response functions show, effects of net capital inflows have a slow response rate. The variation in the RBC due to inflows becomes larger only after year one. As expected, some of the variation in the delinquency rate can be explained by house prices. These effects are only seen after about a year as well.

The results from Model 3 found in Figure B.14 are consistent with the previous models and confirm the results from the separate models. The overall results provide evidence that responses in house prices are slow and longer lags are necessary to capture the delayed responses of the variables in the system.

3.6 Conclusion

This study attempts to determine the reaction of housing prices to various measures of monetary policy actions. Eighteen lags of all endogenous variables are determined to be necessary to correct for serial correlation within the model. Separate VAR specifications for interest rate policy and quantitative easing are necessary due to serial correlation that persisted even after differencing the variables and increased lag orders are added.

Results show that house prices respond to both shocks in the federal funds rate as well as shocks to increases in the Fed's balance sheet. These results by no means imply that monetary policy was the sole contributor to the extreme swings in house prices that we saw during the upsurge and subsequent burst of the bubble in the housing market. Monetary policy, particularly traditional interest rate targeting policy through its targeting of the Federal Funds rate has an effect on house prices through the monetary transmission mechanism. The results of this study suggest that the relationship is strong but does not show an immediate effect. The inclusion of higher lag orders in the VAR is necessary to capture the delayed response of important variables affecting the housing market.

Another result obtained was that inflows are found to Granger cause house prices. Inflows also account for some of the variation in house prices as well as the long-term interest rate and lend support in favor of the GSG hypothesis.

I test the robustness of the models by specifying alternate methods of the VAR's. The results for the restricted sample period (1996-2012) show a stronger effect of the Federal Funds rate on house prices than the full sample. Dummy variables for QEs and the housing bubble do not significantly alter the results.

The results are not robust to specification of house prices however. Although monetary policy variables continued to be a determinant of housing prices in alternate specifications using the other house price indices, there was no other contributing factor to house prices that was consistently present in all models. A possible explanation for the lack of consensus in the results could be the measurement methods of the various indexes. The delinquency rate is shown to Granger cause house prices in both indexes that are measured from mortgages purchased or securitized by one of the government-sponsored entities (GSE). Due to their composition, these indexes therefore may be more sensitive to delinquencies and foreclosures, especially those attributed to sub-prime mortgages that may have been purchased or securitized by Fannie Mae or Freddie Mac. These indices also may not properly capture any effect of an influx in foreign capital in the housing market. Net capital inflows are shown to be a contributing factor to house prices in both Case-Shiller series used in this study. Both Case-Shiller series are measured by repeat sales of single-family homes so the effect of net capital inflows might be better captured in one of the Case-Shiller series. The source for the discrepancy in the results obtained by the various HPI's is perhaps a topic for future investigation.

ENDNOTES FOR CHAPTER 3

[1] As a robustness check, the model is restricted to 1998m1-2012m12 and the foreclosure rate was substituted for the delinquency rate. The lag length determined by AIC was reduced 7 to adjust for the shorter sample period. Results of the VAR(6) using delinquency on the shorter sample period were similar to the VAR(6) using the foreclosure rate.

[2] McDonald and Stokes focus on 2000m1-2010m8, Del Negro and Otrok's sample period is 1986Q1-2005Q4

[3] For example, data on foreclosure rates in the United States is only available beginning in 1998. The dataset for the Case-Shiller 20-City Composite Index starts in 2000.

REFERENCES

Abrams, B. A., & Iossifov, P. (2006). Does the fed contribute to a political business cycle? *Public Choice, 129*(3-4), 249-262.

Allen, F., & Carletti, E. (2010). An overview of the crisis: Causes, consequences, and solutions. *International Review of Finance, 10*(1), 1-26.

Atesoglu, H. S. (2011). Asset price bubbles, monetary policy and financial crisis. *International Journal of Public Policy, 7*(1-3), 195-202.

Bagliano, F. C., & Favero, C. A. (1998). Measuring monetary policy with VAR models: An evaluation. *European Economic Review, 42*(6), 1069-1112.

Balke, N. S., & Emery, K. M. (1994). The federal funds rate as an indicator of monetary policy: Evidence from the 1980s. *Federal Reserve Bank of Dallas Economic Review, 1*

Bernanke, B. S. (2005). The global saving glut and the US current account deficit. *Board of Governors of the Federal Reserve System (US),* (No. 77)

Bernanke, B. S. (2002). Asset-price "bubbles" and monetary policy. *Remarks by Governor Ben S. Bernanke before the New York Chapter of the National Association for Business Economics,* New York, NY.

Bernanke, B. S. (2007). Global imbalances: Recent developments and prospects. *Bundesbank Lecture Speech, (September),* Bernanke, B. S. (2010). Monetary policy and the housing bubble. *Annual Meeting of the American Economic Association,* Atlanta, Georgia.

Bernanke, B. S., Bertaut, C. C., DeMarco, L., & Kamin, S. B. (2011). International capital flows and the return to safe assets in the united states, 2003-2007. *FRB International Finance Discussion Paper,* (1014)

Bernanke, B. S., & Blinder, A. S. (1992). The federal funds rate and the channels of monetary transmission. *The American Economic Review, 84*(4), 901-921.

Bernanke, B. S., & Mihov, I. (1995). Measuring monetary policy. *National Bureau of Economic Research,* (No. w5145)

Bernanke, B. S., & Gertler, M. (2009). Should central banks respond to movements in asset prices? In A. Chrystal, & P. Mizen (Eds.), (pp. 3-7) Elgar Reference Collection. International Library of Critical Writings in Economics, vol. 235.

Blanchard, O., Dell'Ariccia, G., & Mauro, P. (2010). Rethinking macroeconomic policy. *Journal of Money, Credit and Banking, 42*(s1), 199-215.

Brunnermeier, M. K. (2008). Deciphering the liquidity and credit crunch 2007-08. *National Bureau of Economic Research,* (No. w14612)

Bryant, S. K., & Kohn, J. W. (2010). An econometric interpretation of the recent US housing boom. *Research in Business and Economics Journal,* (March)

Bryant, S. K., & Kohn, J. W. (2013). A housing bubble debate resolved. *Journal of Applied Finance and Banking, 3*(4), 55-72.

Campbell, G., & Turner, J. D. (2012). Dispelling the myth of the naive investor during the British Railway mania, 1845—1846. *The Business History Review, 86*(1), 3-41.

Campbell, J. Y., & Cochrane, J. H. (1999). By force of habit: A consumption-based explanation of aggregate stock market behavior. *Journal of Political Economy, 107*(2), 205-251.

Campbell, J. Y., & Shiller, R. J. (1987). Cointegration and tests of present value models. *Journal of Political Economy, 95*(5), 1062-1088.

Canterbery, E. R. (1999). Irrational exuberance and rational speculative bubbles. *The International Trade Journal, 13*(1), 1-33.

Christiano, L. J., & Eichenbaum, M. (1991). Identification and the liquidity effect of a monetary policy shock. *National Bureau of Economic Research,* (No. w3920)

Christiano, L. J., Eichenbaum, M., & Evans, C. L. (2005). Nominal rigidities and the dynamic effects of a shock to monetary policy. *Journal of Political Economy, 113*(1), 1-45.

Christiano, L. J., & Fitzgerald, T. J. (2003). The band pass filter. *International Economic Review, 44*(2), 435-465.

Clarida, R., Galı, J., & Gertler, M. (1998). Monetary policy rules in practice: Some international evidence. *European Economic Review, 42*(6), 1033-1067.

Clarida, R., Gali, J., & Gertler, M. (2000). Monetary policy rules and macroeconomic stability: Evidence and some theory. *Quarterly Journal of Economics, 115*(1), 147-180.

Consolo, A., & Favero, C. A. (2009). Monetary policy inertia: More a fiction than a fact? *Journal of Monetary Economics, 56*(6), 900-906.

Dale, R. (2004). *The first crash: Lessons from the south sea bubble*. Princeton, NJ: Princeton University Press.

Del Negro, M., & Otrok, C. (2007). 99 luftballons: Monetary policy and the house price boom across US states. *Journal of Monetary Economics, 54*(7), 1962-1985.

Dokko, J., Doyle, B., Kiley, M. T., Kim, J., Sherlund, S., Sim, J., & Van den Heuvel, S. (2009). Monetary policy and the housing bubble. *Finance and Economics Discussion Series,* (49)

Dokko, J., Doyle, B. M., Kiley, M. T., Kim, J., Sherlund, S., Sim, J., & Van, D. H. (2011). Monetary policy and the global housing bubble. *Economic Policy, 26*(66), 233-283.

Doménech, R., Ledo, M., & Taguas, D. (2002). Some new results on interest rate rules in EMU and in the US. *Journal of Economics and Business, 54*(4), 431-446.

Driscoll, J. C., & Holden, S. (2014). Behavioral economics and macroeconomic models. *Journal of Macroeconomics, 41*, 133-147.

Engel, C. (2005). Some new variance bounds for asset prices. *Journal of Money, Credit, and Banking, 37*(5), 949-955.

Engle, R. F., & Granger, C. W. J. (1987). Co-integration and error correction: Representation, estimation, and testing. *Econometrica, 55*(2), 251-276.

Finocchiaro, D., & von Heideken, V. Q. (2013). Do central banks react to house prices? *Journal of Money, Credit, and Banking, 45*(8), 1659-1683.

Fitwi, A. M., Hein, S. E., & Mercer, J. M. (2015). The U.S. housing price bubble: Bernanke verses Taylor. *Journal of Economics and Business, 80*(July-August), 62-80.

Friedman, B. M., & Kuttner, K. N. (1992). Money, income, prices, and interest rates. *The American Economic Review, 82*(3), 472-492.

Garber, P. M. (1990). Famous first bubbles. *The Journal of Economic Perspective, 4*(2), 35-54.

Garber, P. M. (1989). Tulipmania. *Journal of Political Economy, 97*(3), 535-560.

Gjerstad, S., & Smith, V. L. (2009). Monetary policy, credit extension, and housing bubbles: 2008 and 1929. *Critical Review, 21*(2-3), 269-300.

Glaeser, E. L., & Nathanson, C. G. (2014). Housing bubbles. *National Bureau of Economic Research, No. w20426*

Granger, C. W. (1969). Investigating causal relations by econometric models and cross-spectral methods. *Econometrica: Journal of the Econometric Society, 37*(3), 424-438.

Greenspan, A. (2004). Risk and uncertainty in monetary policy. *American Economic Review, 92*(4), 33-40.

Greenspan, A. (2007). *The age of turbulence: Adventures in a new world*. New York, NY: The Penguin Press.

Greenspan, A. (2010). The crisis. *Brookings Papers on Economic Activity,* , 201-246.

Groshenny, N. (2013). Monetary policy, inflation and unemployment: In defense of the Federal Reserve. *Macroeconomic Dynamics, 17*(6), 1311-1329.

Gurkaynak, R. S. (2008). Econometric tests of asset price bubbles: Taking stock. *Journal of Economic Surveys, 22*(1), 166-186.

Hall, S. G., Psaradakis, Z., & Sola, M. (1999). Detecting periodically collapsing bubbles: A Markov-switching unit root test. *Journal of Applied Econometrics, 14*(2), 143-154.

Hansen, L. P. (2007). Large sample properties of generalized method of moments estimators. In A. W. Lo (Ed.), (pp. 309-334) Elgar Reference Collection. International Library of Financial Econometrics, vol. 5. Cheltenham, U.K. and Northampton, Mass.: Elgar.

Hatzius, J. (2008). Beyond leveraged losses: The balance sheet effects of the home price downturn. *Brookings Papers on Economic Activity, 2008*(2), 195-227.

Hodrick, R. J., & Prescott, E. C. (1997). Postwar US business cycles: An empirical investigation. *Journal of Money, Credit, and Banking, 29*(1), 1-16.

Holt, J. (2009). A summary of the primary causes of the housing bubble and the resulting credit crisis: A non-technical paper. *The Journal of Business Inquiry, 8*(1), 120-129.

Hsing, Y. (2005). Did U.S. monetary policy respond to exchange rates, long-term interest rates, and the unemployment rate gap? *International Trade Journal, 19*(1), 67.

Iacoviello, M. (2005). House prices, borrowing constraints, and monetary policy in the business cycle. *American Economic Review, 95*(3), 739-764.

Johansen, S. (1995). Likelihood-based inference in cointegrated vector autoregressive models. *OUP Catalogue,*

Joyce, M., Miles, D., Scott, A., & Vayanos, D. (2012). Quantitative easing and unconventional monetary policy–an introduction. *The Economic Journal, 122*(564), F271-F288.

Judd, J. P., & Rudebusch, G. D. (1998). Taylor's rule and the fed: 1970-1997. *Federal Reserve Bank of San Francisco Economic Review,* (3), 3-16.

Kahn, G. A. (2012). *The Taylor rule and the practice of central banking*. Stanford University: Hoover Institution.

Kindleberger, C. P., & Aliber, R. Z. (2011). *Manias, panics, and crashes A history of financial crises* (6th ed.). New York, NY: Palgrave Macmillan.

Kleidon, A. W. (1986). Variance bounds tests and stock price valuation models. *Journal of Political Economy, 94*(5), 953-1001.

LeRoy, S. F., & Porter, R. D. (1981). The present-value relation: Tests based on implied variance bounds. *Econometrica, 49*(3), 555-574.

Malkiel, B. (2010). Bubbles in asset prices. *Princeton University, Department of Economics, Center for Economic Policy Studies, Working Paper Series*(1204)

Marsh, T. A., & Merton, R. C. (1986). Dividend variability and variance bounds tests for the rationality of stock market prices. *The American Economic Review, 76*(3), 483-498.

McDonald, J. F., & Stokes, H. H. (2013a). Dynamics of housing price: Foreclosure rate interactions. *ISRN Economics, 2013*

McDonald, J. F., & Stokes, H. H. (2013b). Monetary policy and the housing bubble. *The Journal of Real Estate Finance and Economics, 46*(3), 437-451.

McDonald, J. F., & Stokes, H. H. (2013c). Monetary policy, mortgage rates and the housing bubble. *Economics & Finance Research, 1*(1), 82-91.

McDonald, J. F., & Stokes, H. H. (2015). Monetary policy, fiscal policy, and the housing bubble. *Modern Economy, 6*(2), 165.

McDonald, J. F., & Stokes, H. H. (2013d). The housing price bubble, the monetary policy and the foreclosure crisis in the US. *Applied Economics Letters, 20*(10-12), 1104-1108.

Miles, W. (2009). Housing investment and the US economy: How have the relationships changed? *Journal of Real Estate Research, 31*(3), 329-349.

Miles, W. (2014). The housing bubble: How much blame does the fed really deserve? *Journal of Real Estate Research, 36*(1), 41-58.

Mishkin, F. S. (2009a). Central banking and the conduct of monetary policy. In D. Battista (Ed.), *The economics of money, banking, & financial markets* (9th ed., pp. 415-419) Addison-Wesley.

Mishkin, F. S. (2009b). Is monetary policy effective during financial crises? *The American Economic Review, 99*(2), 573-577.

Orphanides, A. (2001). Monetary policy rules based on real-time data. *American Economic Review, 91*(4), 964-985.

Payne, J. E. (2006). More on the monetary transmission mechanism: Mortgage rates and the federal funds rate. *Journal of Post Keynesian Economics, 29*(2), 247-257.

Phillips, P. C. B., & Durlauf, S. N. (1986). Multiple time series regression with integrated processes. *The Review of Economic Studies, 53*(4, Econometrics Special Issue), 473-495.

Poole, W. (2007). Understanding the fed. *Federal Reserve Bank of St. Louis Review, 89*(1), 3.

Poole, W. (2010). Causes and consequences of the financial crisis of 2007-2009. *Harvard Journal of Law & Public Policy, 33*(2), 421-441.

Rigobon, R., & Sack, B. (2004). The impact of monetary policy on asset prices. *Journal of Monetary Economics, 51*(8), 1553-1575.

Romer, C. D., & Romer, D. H. (1989). Does monetary policy matter? A new test in the spirit of Friedman and Schwartz. *NBER macroeconomics annual 1989, volume 4* (pp. 121-184) MIT Press.

Rudebusch, G. D. (1998). Do measures of monetary policy in a VAR make sense? *International Economic Review, 39*(4, Symposium on Forecasting and Empirical Methods in Macroeconomics and Finance), 907-931.

Rudebusch, G. D. (2002). Term structure evidence on interest rate smoothing and monetary policy inertia. *Journal of Monetary Economics, 49*(6), 1161-1187.

Scherbina, A. (2013). Asset price bubbles: A selective survey. *International Monetary Fund Working Paper, 13*(45), 2-36.

Scherbina, A., & Schlusche, B. (2014). Asset price bubbles: A survey. *Quantitative Finance, 14*(4), 589-604.

Seyfried, W. (2010). Should the fed have followed the rule? *Journal of Applied Business and Economics, 10*(6), 11-21.

Shiller, R. J. (2007). Understanding Recent Trends in House Prices and Home Ownership*, National Bureau of Economic Research,* No. w13553.

Shiller, R. J. (1981). Do stock prices move too much to be justified by subsequent changes in dividends? *American Economic Review, 71*(3), 421-436.

Shiller, R. J. (2000). *Irrational exuberance*. Princeton, New Jersey: Princeton University Press.

Shiller, R. J. (2003). From efficient markets theory to behavioral finance. *Journal of Economic Perspectives, 17*(1), 83-104.

Sims, C. A. (1980). Macroeconomics and reality. *Econometrica: Journal of the Econometric Society, 48*(1), 1-48.

Soderlind, P., Soderstrom, U., & Vredin, A. (2003). *Taylor rules and the predictability of interest rates.* Unpublished manuscript.

Stock, J. H., & Wright, J. H. (2000). GMM with weak identification. *Econometrica, 68*(5), 1055-1096.

Stock, J. H., Wright, J. H., & Yogo, M. (2002). A survey of weak instruments and weak identification in generalized method of moments. *Journal of Business and Economic Statistics, 20*(4), 518-529.

Strongin, S. (1995). The identification of monetary policy disturbances explaining the liquidity puzzle. *Journal of Monetary Economics, 35*(3), 463-497.

Taylor, J. B. (2009). *Getting off track: How government actions and interventions caused, prolonged, and worsened the financial crisis* Hoover Press.

Taylor, J. B. (1993). Discretion versus policy rules in practice. *Carnegie-Rochester Conference Series on Public Policy, v. 39*(December), pp. 195-214.

Taylor, J. B. (2007). Housing and monetary policy. *NBER Working Paper Series,* (13682)

Taylor, J. B. (2012). The great deviation. In E. F. Koenig, R. Leeson & G. A. Kahn (Eds.), *The Taylor rule and the transformation of monetary policy* (pp. 163-172). Stanford, California: Hoover Institution Press.

Vera, D. (2011). How robust is the fed reaction function to changes in the output-gap specification? *Applied Economics, 43*(9), 1059-1065.

West, K. D. (1987). A specification test for speculative bubbles. *Quarterly Journal of Economics, 102*(3), 553-580.

White, L. H. (2009). Federal reserve policy and the housing bubble. *CATO Journal, 29*(1), 115-125.

Wright, J. H. (2012). What does monetary policy do to long□term interest rates at the zero lower bound? *The Economic Journal, 122*(564), F447-F466.

Xiao, W. (2013). Learning about monetary policy rules when the housing market matters. *Journal of Economic Dynamics and Control, 37*(3), 500-515.

Appendix A

APPENDIX FOR CHAPTER 2

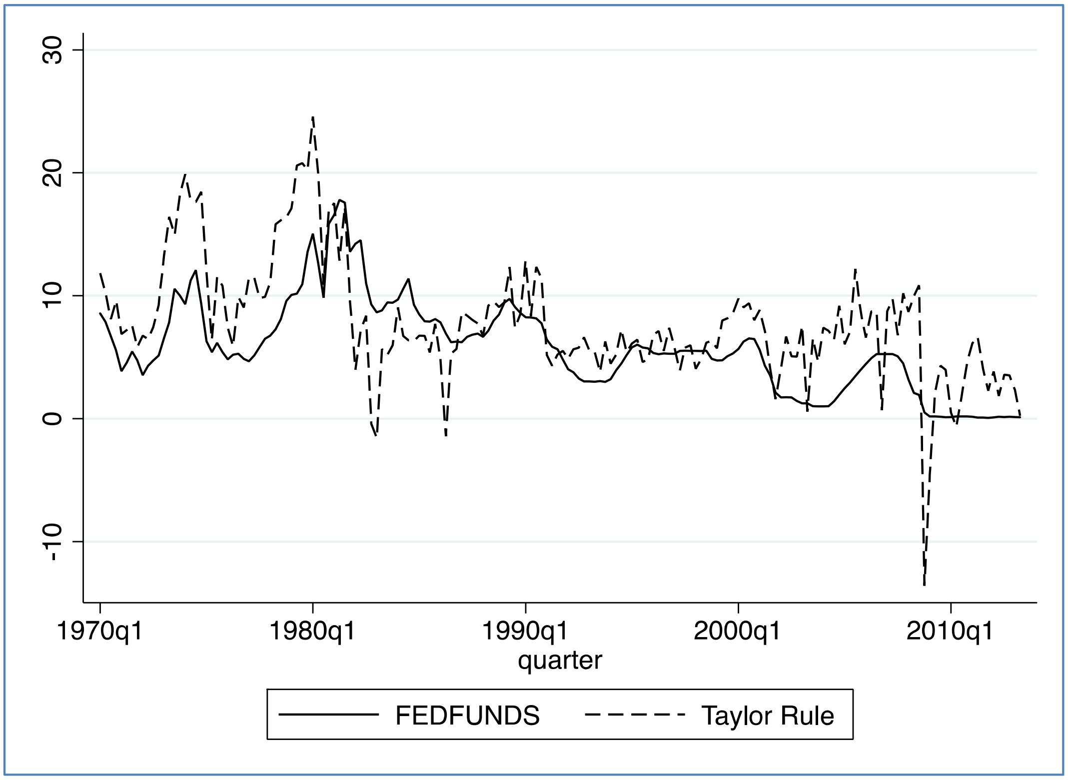


Figure A.1: Estimated Taylor Rule and the Effective Federal Funds Rate, 1970Q1-2013Q2.

Table A.1: Estimates of the Fed's Reaction Function Using Alternative Measures of Inflation.

Federal Funds Rate	I	II	III	IV	V
Constant	0.05	0.09	-0.19	*-0.11*	*-0.04*
	(0.11)	*(0.11)*	*(0.13)*	*(0.15)*	*(0.11)*
F_{t-1}	0.90***	0.90***	0.87***	0.91***	*0.88****
	(0.03)	*(0.03)*	*(0.04)*	*(0.03)*	*(0.03)*
CPI	0.14***				
	(0.04)				
PCE		0.17***			
		(0.05)			
PCEX			0.24***		
			(0.08)		
GDPDEF				*0.16***	
				(0.07)	
Inflation_var					*0.16****
					(0.05)
Outgap	0.09***	0.10***	0.14***	*0.11****	*0.10****
	(0.03)	*(0.03)*	*(0.04)*	*(0.03)*	*(0.03)*
Political	-0.33**	-0.35**	-0.35**	*-0.29***	*-0.31***
	(0.16)	*(0.16)*	*(0.17)*	*(0.18)*	*(0.15)*
Adj. R-Squared	0.94	0.94	0.94	0.94	*0.94*
Durbin Watson	1.71	1.73	1.64	1.68	1.73

Table A.2: Estimates of the Fed's Reaction Function Using the Unemployment Gap

Federal Funds Rate	I	II	III	IV
α_0	0.16	0.27	0.44*	0.44*
	(0.19)	*(0.19)*	*(0.25)*	*(0.25)*
ρ	0.90***	0.89***	0.88***	0.88***
	(0.03)	*(0.03)*	*(0.03)*	*(0.04)*
α_π	0.12***	0.13***	0.13***	0.13***
	(0.04)	*(0.14)*	*(0.04)*	*(0.04)*
α_u	-0.13**	-0.14***	-0.17***	-0.17*
	(0.06)	*(0.05)*	*(0.07)*	*(0.07)*
α_p		-0.37**	-0.41**	-0.39**
		(0.16)	*(0.16)*	*(0.16)*
α_b			-0.26*	
			(0.14)	
α_{b1}				-0.13
				(0.14)
α_{b2}				-0.37**
				(0.16)
Adj. R Square	0.94	0.94	0.94	0.94

Note: the partial adjustment now becomes:
$F_t = \rho(F_{t-1}) + (1-\rho)(\alpha_0 + \alpha_\pi \pi_t + \alpha_u U_t)$, where U is the unemployment gap.

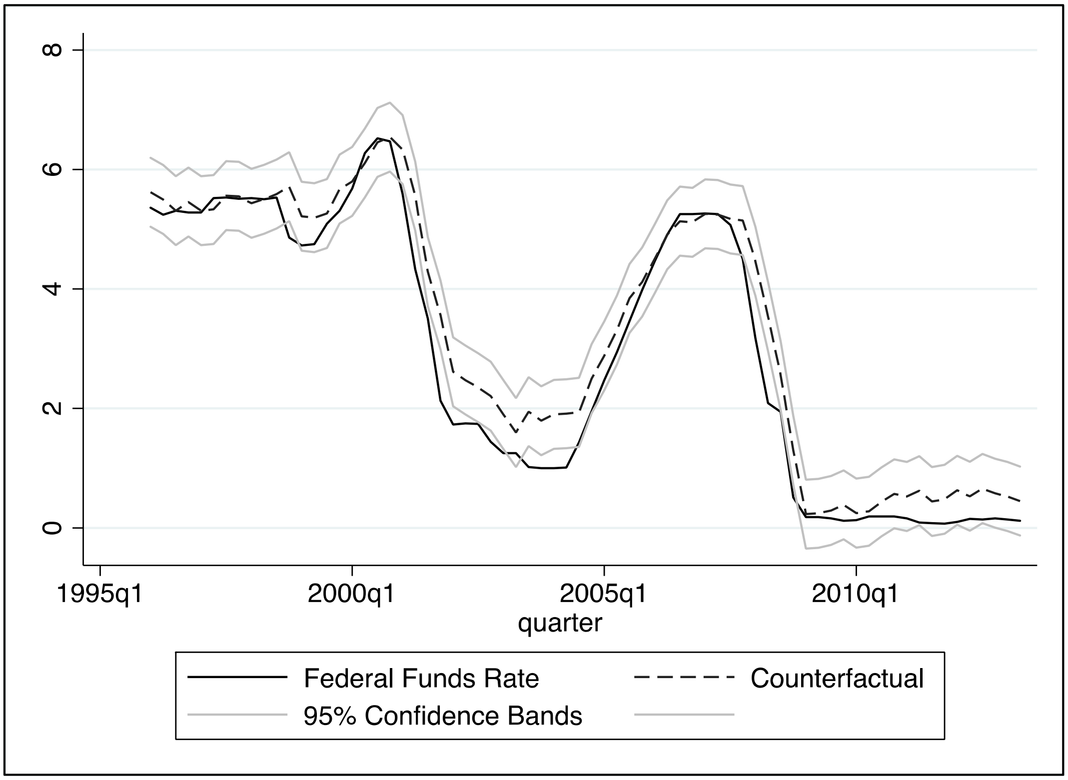


Figure A.2 Counterfactual using PCE inflation, 1996Q2-2013Q2.

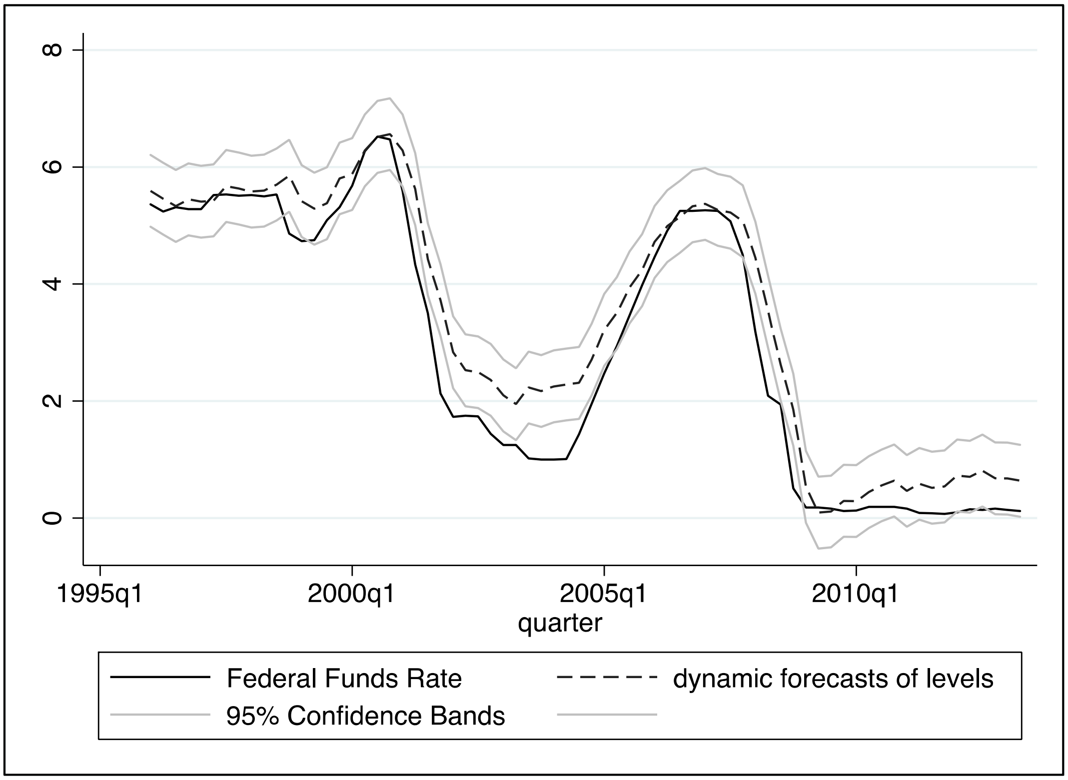


Figure A.3 Counterfactual using GDP Deflator inflation, 1996Q2-2013Q2.

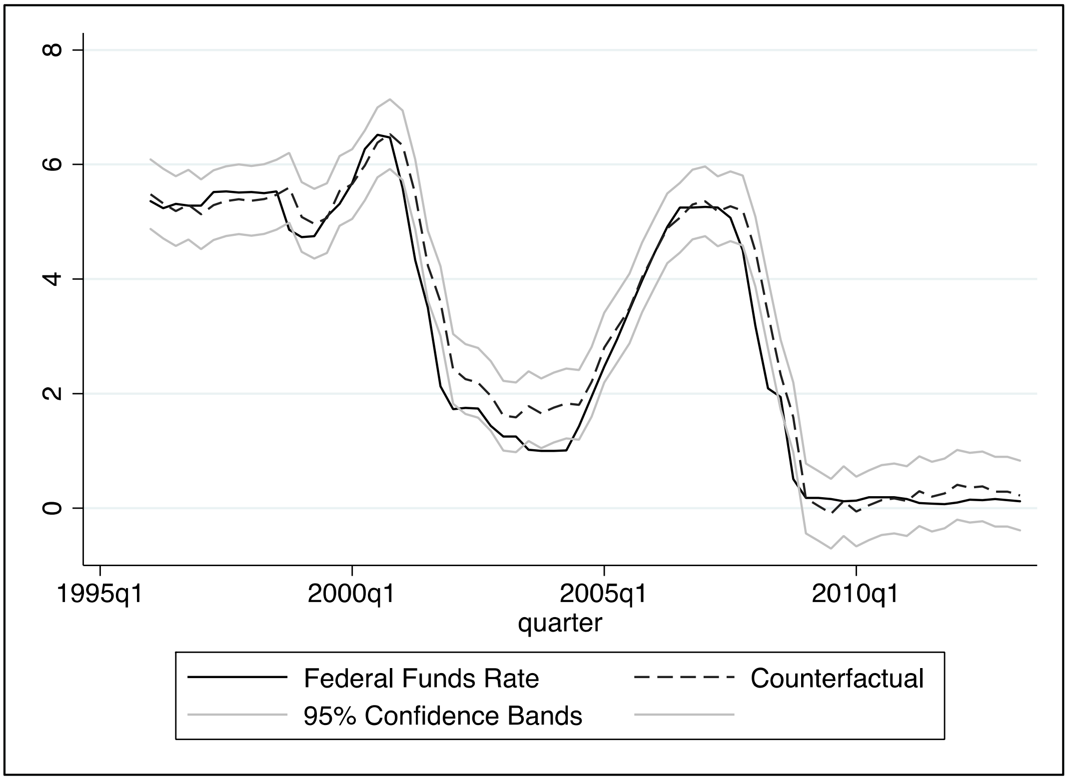


Figure A.4 Counterfactual using PCEX inflation, 1996Q2-2013Q2.

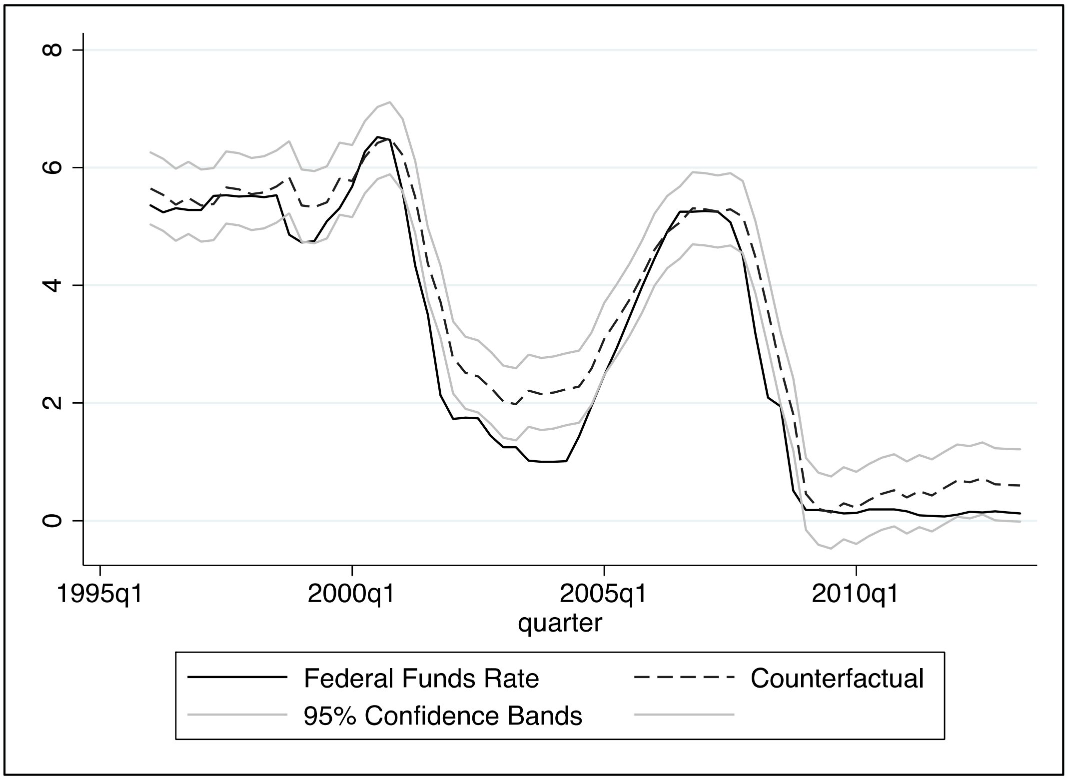


Figure A.5 Counterfactual using *Inflation_var*, 1996Q2-2013Q2.

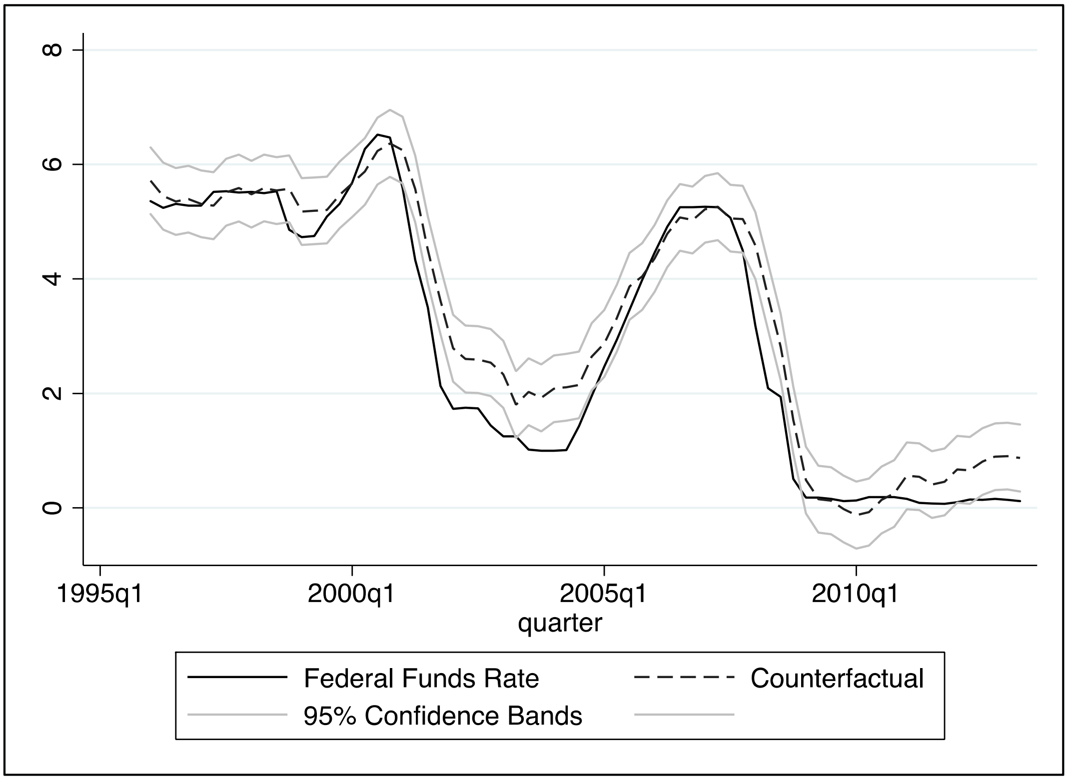
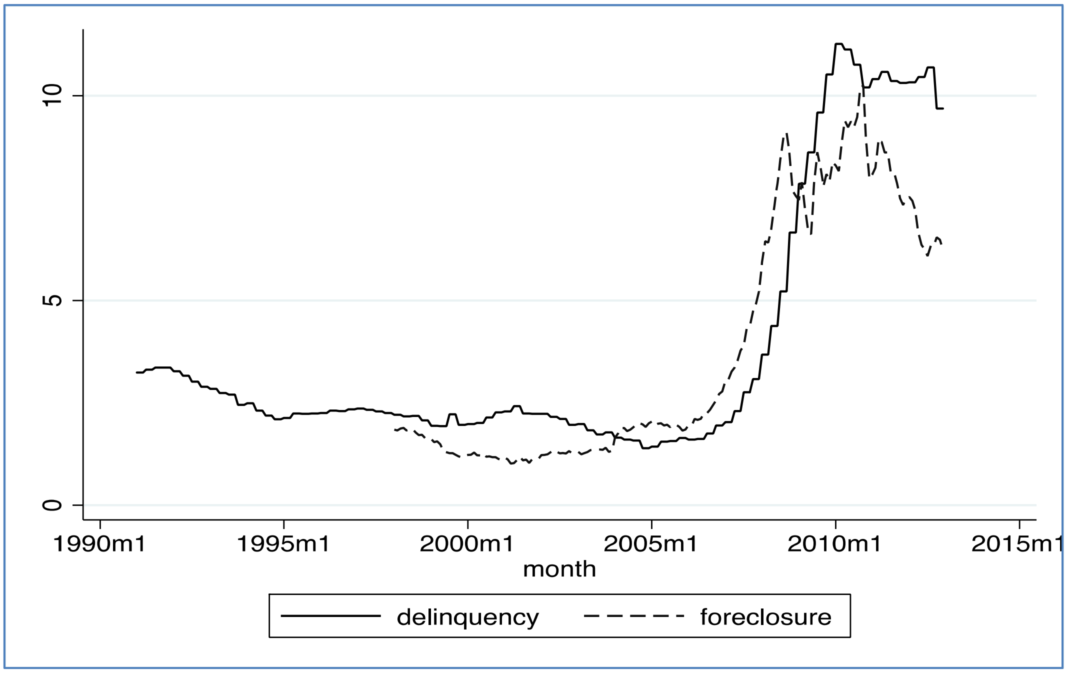


Figure A.6 Counterfactual using CPI inflation and the Unemployment Gap, 1996Q2-2013Q2.

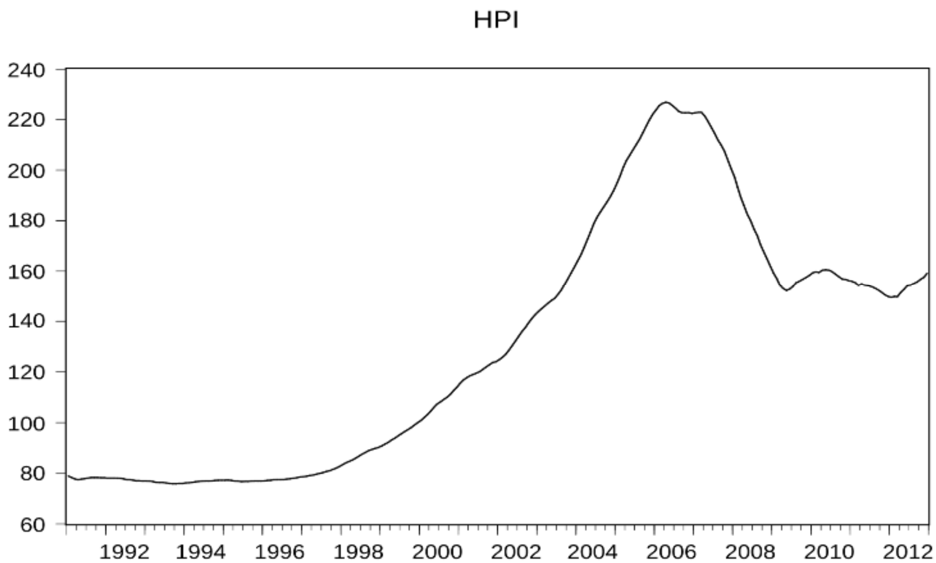
Appendix B

APPENDIX FOR CHAPTER 3



Source St. Louis Federal Reserve.

Figure B.1: Delinquency and Foreclosure Rates.



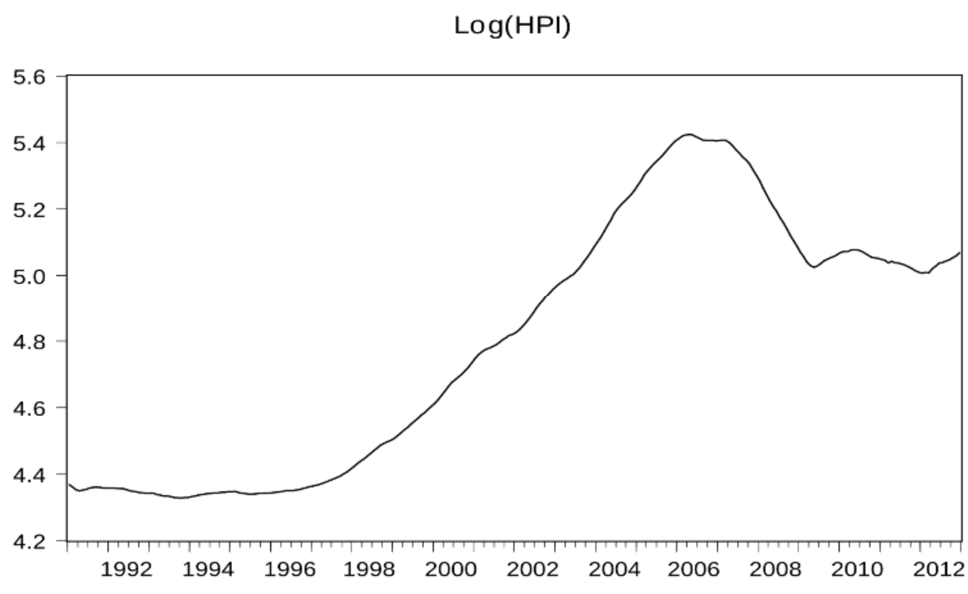


Figure B.2: Case-Shiller 10-City Composite Index Graphs in level and log values, 1991-2012

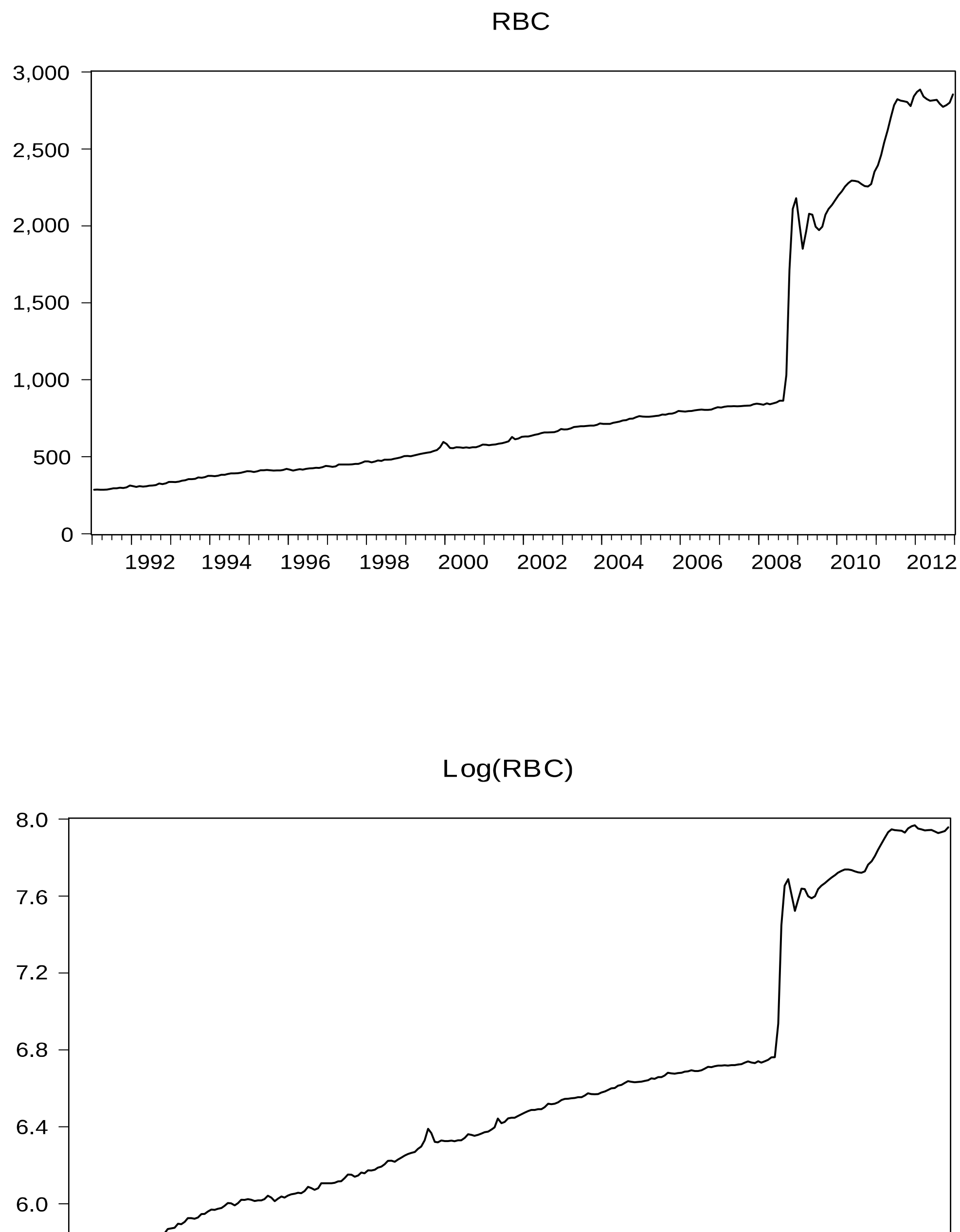


Figure B.3: Federal Reserve Bank Credit Graphs in level and log values, 1991-2012

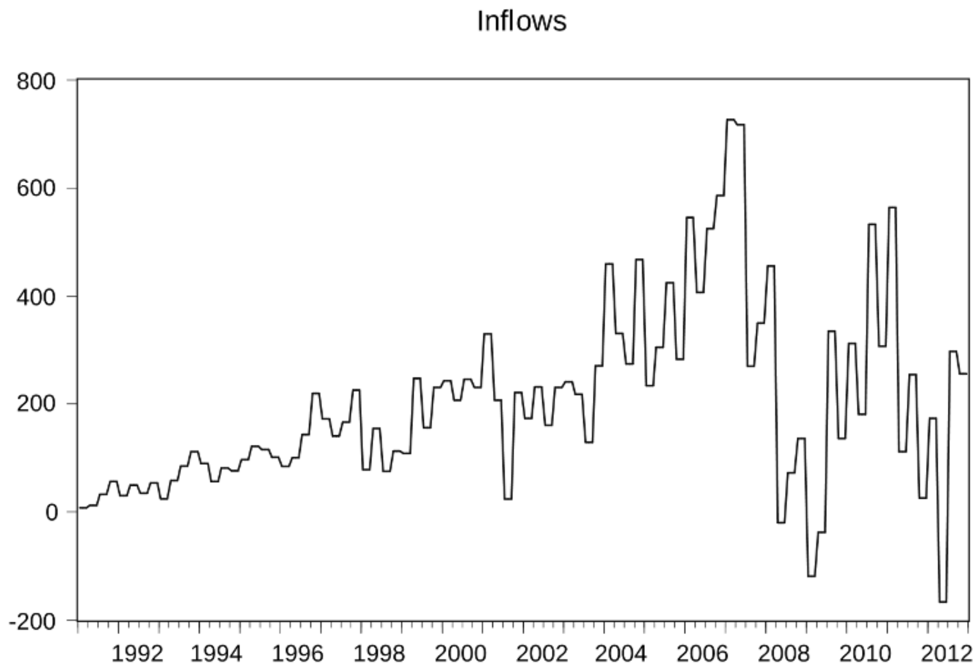


Figure B.4: Balance on Capital Accounts (negative of) Graphs in level and log values, 1991-2012

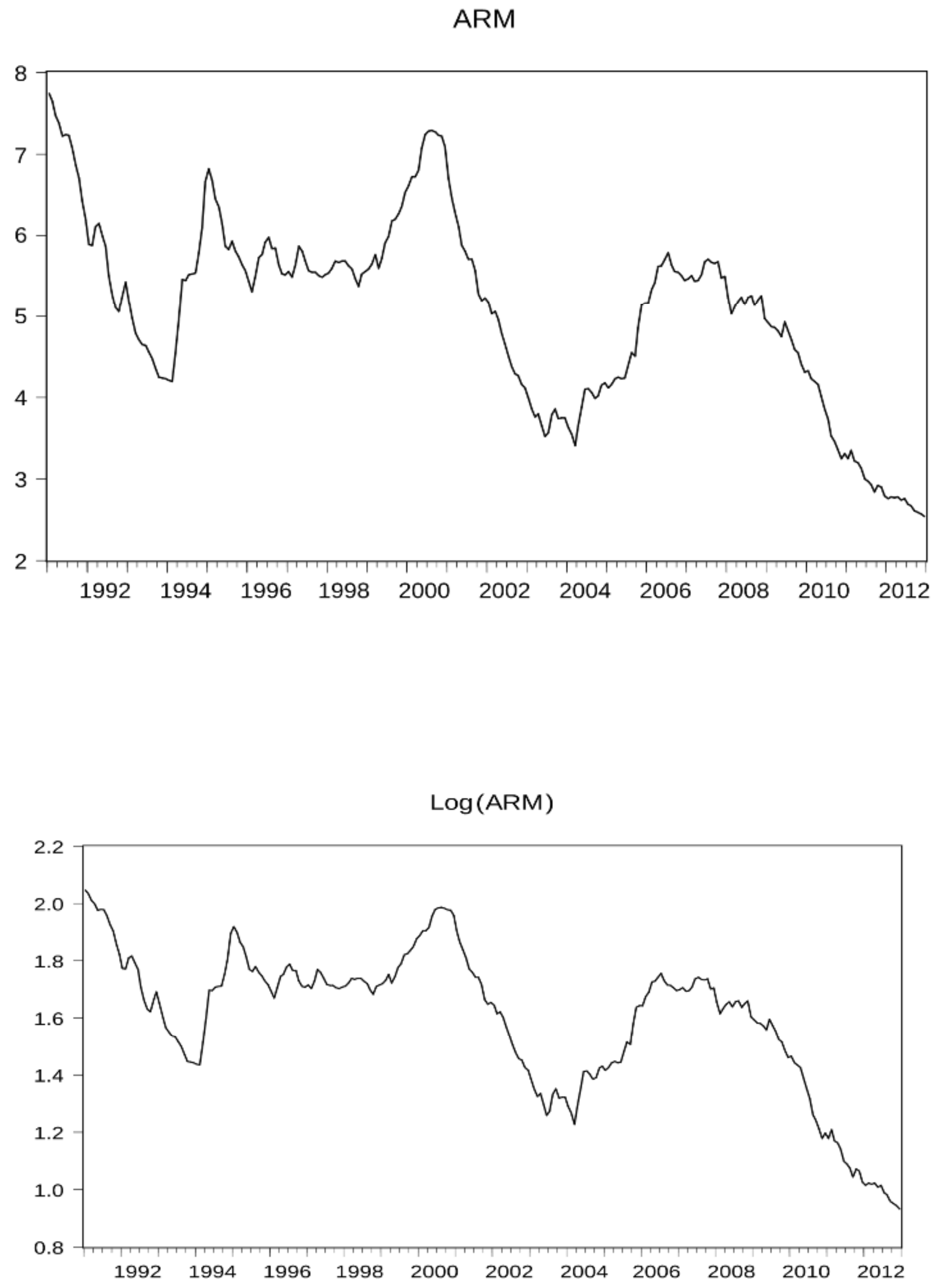
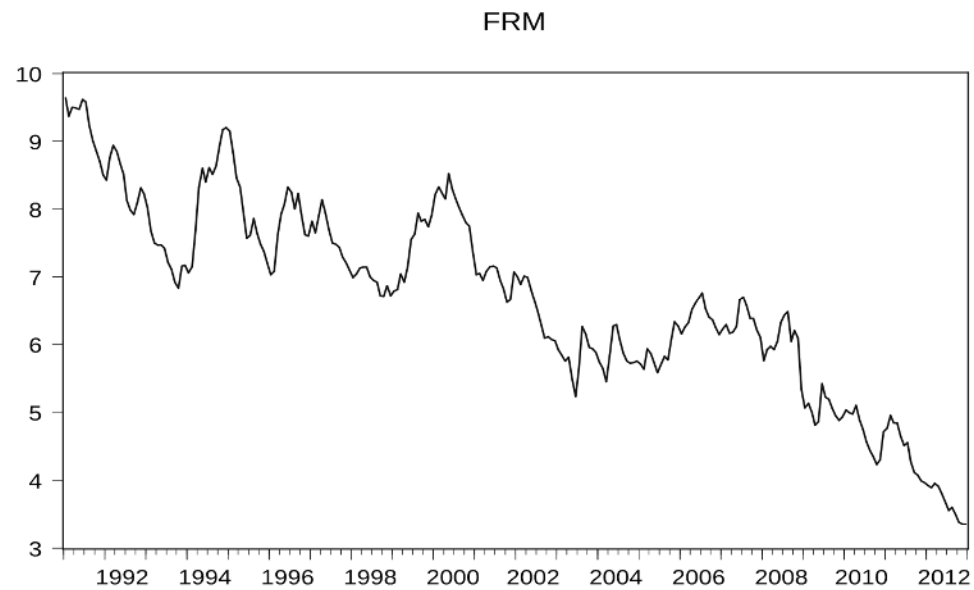


Figure B.5: 1-Year Adjustable Mortgage Rate Graphs in level and log values, 1991-2012



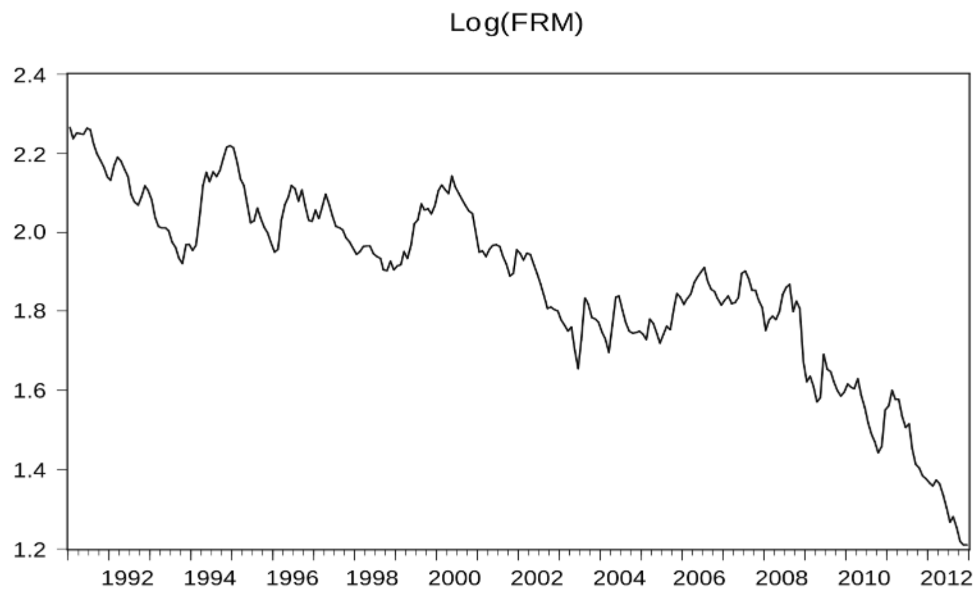
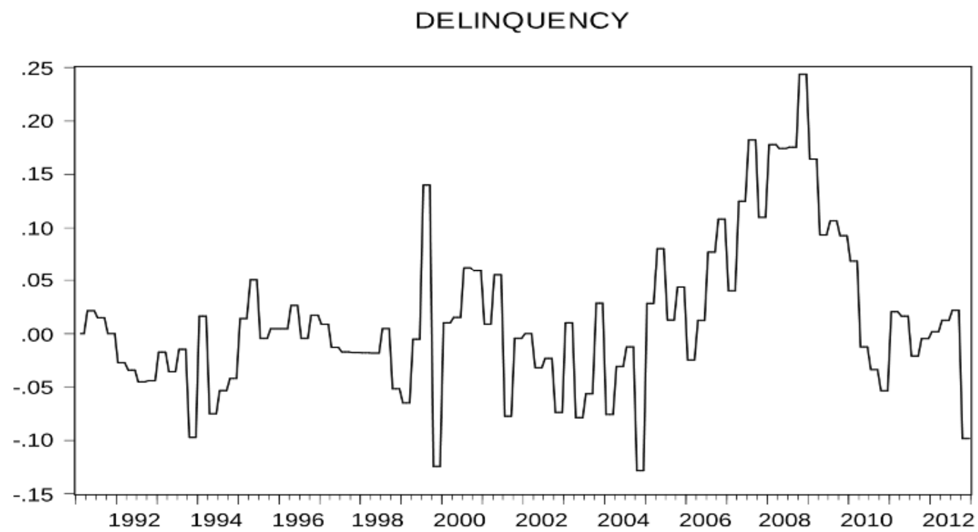


Figure B.6: 30-Year Conventional Mortgage Rate Graphs in level and log values, 1991-2012



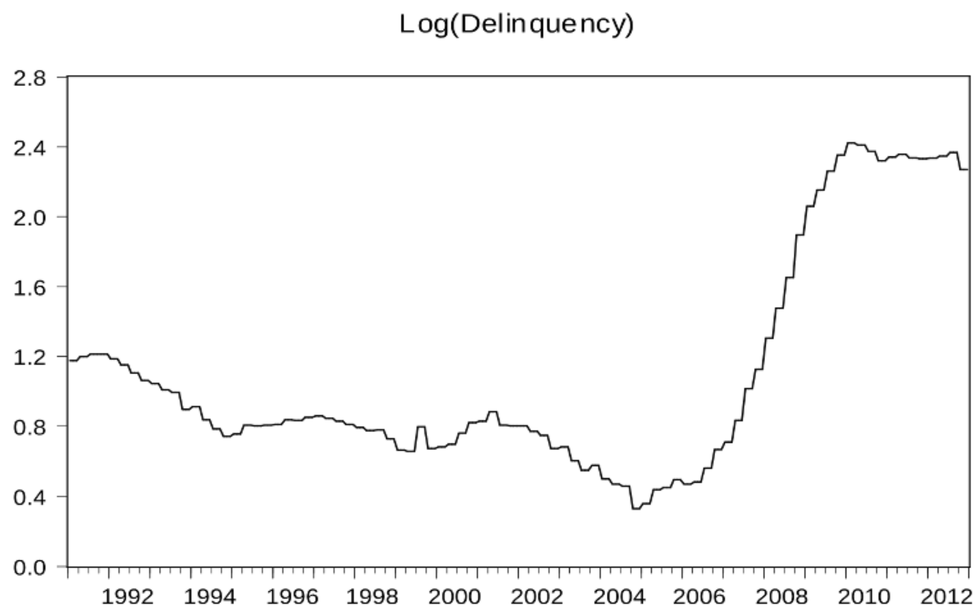


Figure B.7: Average Mortgage Delinquency Rate Graphs in level and log values, 1991-2012

Table B.1: Lag Order Selection Criteria Model 1

Lag	LogL	LR	FPE	AIC	SC	HQ
0	1002.300	NA	1.18E-11	-8.133	-8.047	-8.099
1	1525.784	1017.055	2.21E-13	-12.113	-11.512*	-11.870*
2	1554.470	54.327	2.35E-13	-12.053	-10.938	-11.604
3	1622.298	125.137	1.81E-13	-12.313	-10.683	-11.657
4	1677.725	99.543	1.55E-13	-12.471	-10.328	-11.608
5	1705.459	48.449	1.67E-13	-12.404	-9.746	-11.333
6	1750.171	75.918	1.56E-13	-12.475	-9.302	-11.197
7	1798.069	78.984	1.43e-13*	-12.572	-8.885	-11.087
8	1827.940	47.794	1.52E-13	-12.522	-8.320	-10.830
9	1849.547	33.512	1.73E-13	-12.404	-7.688	-10.505
10	1881.139	47.452	1.83E-13	-12.368	-7.138	-10.262
11	1912.226	45.172	1.94E-13	-12.328	-6.583	-10.015
12	1961.701	69.467	1.79E-13	-12.438	-6.179	-9.918
13	1995.272	45.491	1.88E-13	-12.419	-5.645	-9.691
14	2026.508	40.798	2.03E-13	-12.380	-5.091	-9.445
15	2058.480	40.193	2.19E-13	-12.347	-4.544	-9.205
16	2117.355	71.130	1.91E-13	-12.534	-4.216	-9.184
17	2151.328	39.381	2.06E-13	-12.517	-3.685	-8.960
18	2200.229	54.291*	1.98E-13	-12.622*	-3.276	-8.859

Note: * indicates lag order selected by the criterion
LR: sequential modified LR test statistic (each test at 5% level),
FPE: Final prediction error, AIC: Akaike information criterion,
SC: Schwarz information criterion, HQ: Hannan-Quinn
information criterion

Table B.2: Lag Order Selection Criteria for Model 2

Model 2

Lag	LogL	LR	FPE	AIC	SC	HQ
0	1814.757	NA	1.56E-14	-14.765	-14.680	-14.731
1	2410.455	1157.355	1.62E-16	-19.334	-18.734*	-19.093*
2	2466.806	106.723	1.37E-16	-19.500	-18.386	-19.052
3	2510.299	80.240	1.29E-16	-19.562	-17.932	-18.906
4	2570.800	108.655	1.06E-16	-19.762	-17.618	-18.898
5	2605.062	59.853	1.08E-16	-19.747	-17.089	-18.677
6	2646.997	71.203	1.03E-16	-19.796	-16.623	-18.518
7	2704.710	95.169	8.72E-17	-19.973	-16.286	-18.488
8	2742.045	59.735	8.72E-17*	-19.984	-15.783	-18.292
9	2776.506	53.451	8.95E-17	-19.971	-15.256	-18.072
10	2816.841	60.584	8.79E-17	-20.007*	-14.776	-17.901
11	2842.174	36.810	9.80E-17	-19.920	-14.175	-17.606
12	2882.845	57.107	9.69E-17	-19.958	-13.699	-17.437
13	2918.122	47.803	1.01E-16	-19.952	-13.178	-17.224
14	2942.463	31.793	1.15E-16	-19.857	-12.569	-16.922
15	2986.738	55.660*	1.12E-16	-19.924	-12.122	-16.782
16	3018.180	37.987	1.22E-16	-19.887	-11.570	-16.538
17	3055.542	43.309	1.28E-16	-19.898	-11.067	-16.342
18	3100.770	50.213	1.27E-16	-19.974	-10.627	-16.210

Note: * indicates lag order selected by the criterion LR: sequential modified LR test statistic (each test at 5% level), FPE: Final prediction error, AIC: Akaike information criterion, SC: Schwarz information criterion, HQ: Hannan-Quinn information criterion

Table B.3: Lag Order Selection Criteria for Model 3

Model 3

Lag	LogL	LR	FPE	AIC	SC	HQ
0	1491.770	NA	1.28E-14	-12.121	-12.021	-12.080
1	2084.735	1147.206	1.51E-16	-16.561	-15.761*	-16.239*
2	2135.309	94.955	1.50E-16	-16.574	-15.073	-15.970
3	2220.320	154.754	1.12E-16	-16.868	-14.667	-15.982
4	2285.174	114.356	9.87E-17	-16.997	-14.096	-15.829
5	2332.429	80.621	1.01E-16	-16.983	-13.382	-15.533
6	2393.724	101.075	9.22E-17	-17.083	-12.782	-15.351
7	2462.437	109.380	7.97E-17	-17.244	-12.243	-15.230
8	2517.023	83.774	7.76E-17	-17.290	-11.588	-14.994
9	2581.196	94.818	7.04E-17*	-17.414	-11.012	-14.836
10	2626.081	63.756	7.52E-17	-17.380	-10.278	-14.520
11	2662.885	50.174	8.66E-17	-17.281	-9.478	-14.139
12	2721.509	76.569	8.41E-17	-17.359	-8.856	-13.935
13	2764.997	54.316	9.35E-17	-17.314	-8.111	-13.608
14	2806.451	49.407	1.07E-16	-17.253	-7.349	-13.265
15	2888.087	92.632	8.91E-17	-17.519	-6.915	-13.249
16	2954.481	71.543*	8.54E-17	-17.661	-6.357	-13.109
17	3001.828	48.313	9.73E-17	-17.648	-5.643	-12.813
18	3066.733	62.521	9.79E-17	-17.777*	-5.073	-12.661

Note: * indicates lag order selected by the criterion LR: sequential modified LR test statistic (each test at 5% level), FPE: Final prediction error, AIC: Akaike information criterion, SC: Schwarz information criterion, HQ: Hannan-Quinn information criterion

Table B.4: VAR Residual Serial Correlation LM Tests

	Model 1		Model 2		Model 3	
Lags	LM-Stat	Prob	LM-Stat	Prob	LM-Stat	Prob
1	27.366	0.849	42.201	0.221	47.432	0.537
2	36.976	0.424	40.830	0.267	50.218	0.425
3	50.072	0.060	29.775	0.758	64.774	0.065
4	42.426	0.214	49.283	0.069	76.444	0.007
5	30.717	0.718	30.321	0.735	44.848	0.642
6	46.015	0.123	33.285	0.598	52.097	0.354
7	40.800	0.268	42.629	0.207	52.758	0.331
8	30.368	0.733	39.732	0.307	58.237	0.172
9	43.028	0.196	55.223	0.021	57.181	0.197
10	26.730	0.869	49.539	0.066	58.304	0.170
11	33.842	0.572	45.518	0.133	72.469	0.016
12	35.986	0.469	28.714	0.801	49.055	0.471
13	36.201	0.459	58.955	0.009	57.009	0.202
14	38.416	0.361	33.133	0.606	54.393	0.277
15	29.458	0.771	53.976	0.028	65.115	0.061
16	33.121	0.606	32.754	0.624	52.444	0.342
17	47.501	0.095	32.038	0.658	48.012	0.513
18	50.892	0.051	45.558	0.132	52.030	0.357

Note: Null Hypothesis: no serial correlation at lag order h, Probabilities from chi-square with 36 df for models 1 and 2 and 49 df for model 3.

Table B.5: Granger Causality Test Results for Alternative Specifications of VAR

Model 1	Column I		Column II		Column III	
	Chi-sq.	Prob.	Chi-sq.	Prob.	Chi-sq.	Prob.
FED FUNDS RATE	28.134	0.060	32.385	0.020	41.956	0.000
INFLOWS	35.388	0.008	32.468	0.019	24.153	0.019
ARM	14.325	0.708	18.078	0.451	18.166	0.111
FRM	10.327	0.921	12.848	0.801	14.103	0.294
DELINQUENCY	22.436	0.213	27.191	0.076	21.970	0.038
All	159.332	0.000	154.878	0.000	116.787	0.000

Model 2	Column I		Column II		Column III	
	Chi-sq.	Prob.	Chi-sq.	Prob.	Chi-sq.	Prob.
RBC	26.772	0.083	32.427	0.020	32.956	0.017
INFLOWS	34.233	0.012	30.344	0.034	26.383	0.091
ARM	17.696	0.476	17.966	0.458	17.071	0.518
FRM	17.216	0.508	17.114	0.515	17.300	0.503
DELINQUENCY	23.983	0.156	25.842	0.103	19.051	0.389
All	158.63	0.000	154.16	0.000	141.80	0.000

Note: All columns report Chi-squared values with corresponding probabilities for 18 degrees of freedom. Column I presents results for VAR with current and lagged values for dummy variables representing QE periods as exogenous variables. The sample period is 1991-2012. Column II reports Chi-squared values VAR with a dummy variable for the housing bubble as an exogenous variable. Column III includes a constant as the exogenous variable but the sample period is restricted to 1996-2012.

Table B. 5 Continued

Model 3	Column I		Column II		Column III	
	Chi-sq.	Prob.	Chi-sq.	Prob.	Chi-sq.	Prob.
FED FUNDS RATE	22.744	0.201	22.728	0.201	23.484	0.173
RBC	21.582	0.251	22.763	0.200	23.685	0.166
INFLOWS	32.796	0.018	31.531	0.025	31.847	0.023
ARM	14.584	0.690	17.738	0.473	22.328	0.218
FRM	12.259	0.834	15.877	0.601	18.915	0.397
DELINQUENCY	24.429	0.142	28.223	0.059	19.622	0.355
All	185.27	0.000	182.25	0.000	139.78	0.000

Note: All columns report Chi-squared values with corresponding probabilities for 18 degrees of freedom. Column I presents results for VAR with current and lagged values for dummy variables representing QE periods as exogenous variables. The sample period is 1991-2012. Column II reports Chi-squared values VAR with a dummy variable for the housing bubble as an exogenous variable. Column III includes a constant as the exogenous variable but the sample period is restricted to 1996-2012.

Table B.6: Granger Causality Test Results for Model 3

Model 3

	Chi-sq.	df	Prob.
FED_FUNDS	16.841	18	0.534
RBC	22.006	18	0.232
INFLOWS	32.859	18	0.017
ARM	15.884	18	0.601
FRM	10.457	18	0.916
DELINQUENCY	22.567	18	0.208

Table B.7: Granger Causality Test Results for the Case-Shiller National HPI

Model 1

	Chi-sq.	df	Prob.
FED FUNDS RATE	103.234	18	0.000
INFLOWS	42.910	18	0.001
ARM	20.068	18	0.329
FRM	20.799	18	0.290
DELINQUENCY	23.741	18	0.164
All	268.5631	90	0.000

Model 2

	Chi-sq.	df	Prob.
RBC	121.038	18	0.000
INFLOWS	24.558	18	0.138
ARM	35.059	18	0.009
FRM	31.348	18	0.026
DELINQUENCY	27.166	18	0.076
All	298.672	90	0.000

Model 3

	Chi-sq.	df	Prob.
FED FUNDS RATE	46.474	18	0.000
RBC	58.715	18	0.000
INFLOWS	33.770	18	0.013
ARM	30.908	18	0.030
FRM	28.043	18	0.061
DELINQUENCY	24.465	18	0.140
All	407.679	108	0.000

Table B.8: Granger Causality Test Results for the USFHFA House Price Index

Model 1

	Chi-sq.	df	Prob.
FED FUNDS RATE	76.403	18	0.000
INFLOWS	31.541	18	0.025
ARM	20.168	18	0.324
FRM	19.663	18	0.352
DELINQUENCY	34.635	18	0.011
All	226.656	90	0.000

Model 2

	Chi-sq.	df	Prob.
RBC	98.840	18	0.000
INFLOWS	22.863	18	0.196
ARM	16.876	18	0.532
FRM	18.594	18	0.417
DELINQUENCY	25.336	18	0.116
All	264.965	90	0.000

Model 3

	Chi-sq.	df	Prob.
FED FUNDS RATE	37.645	18	0.004
RBC	54.087	18	0.000
INFLOWS	30.112	18	0.036
ARM	18.235	18	0.440
FRM	19.366	18	0.370
DELINQUENCY	32.691	18	0.018
All	340.884	108	0.000

Table B.9: Granger Causality Test Results for the Freddie Mac House Price Index

Model 1

	Chi-sq.	df	Prob.
FED FUNDS RATE	23.802	18	0.1616
INFLOWS	21.957	18	0.2339
ARM	12.426	18	0.8245
FRM	21.695	18	0.2458
DELINQUENCY	23.969	18	0.1561
All	129.251	90	0.004

Model 2

	Chi-sq.	df	Prob.
RBC	29.909	18	0.038
INFLOWS	13.464	18	0.763
ARM	10.534	18	0.913
FRM	19.460	18	0.364
DELINQUENCY	27.967	18	0.063
All	139.387	90	0.000

Model 3

	Chi-sq.	df	Prob.
FED FUNDS RATE	19.161	18	0.382
RBC	24.402	18	0.142
INFLOWS	19.995	18	0.333
ARM	14.276	18	0.711
FRM	18.948	18	0.395
DELINQUENCY	27.502	18	0.070
All	159.738	108	0.001

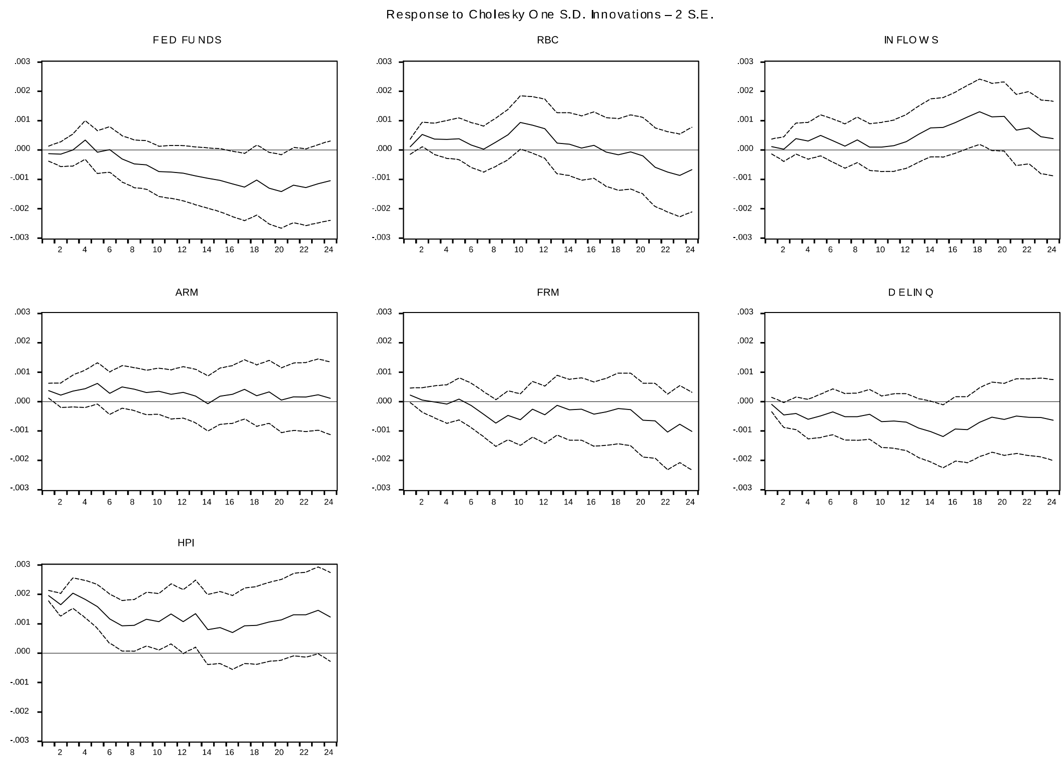


Figure B.8: Impulse Response of House Prices for Model 3

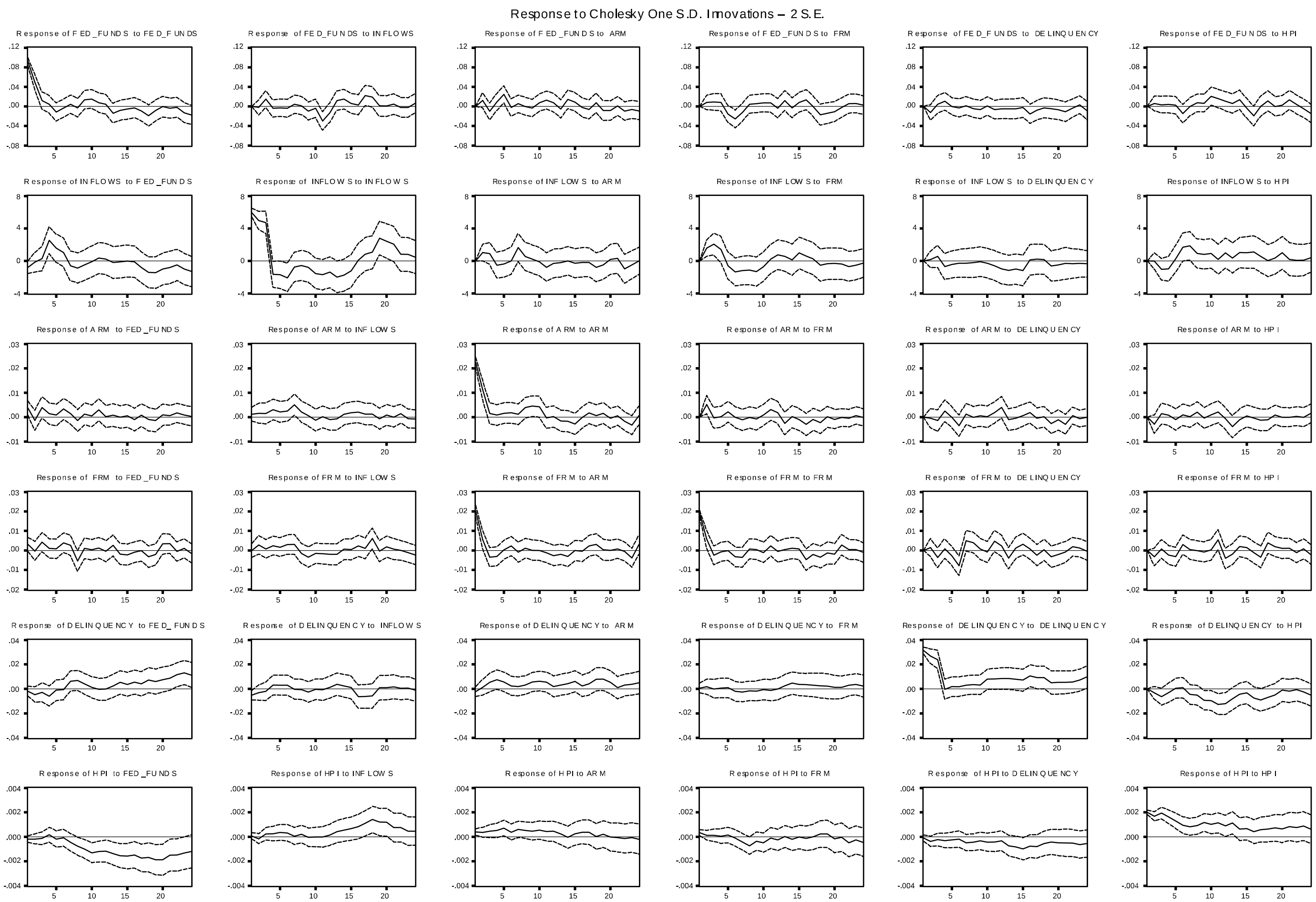


Figure B.9: Impulse Response for Model 1

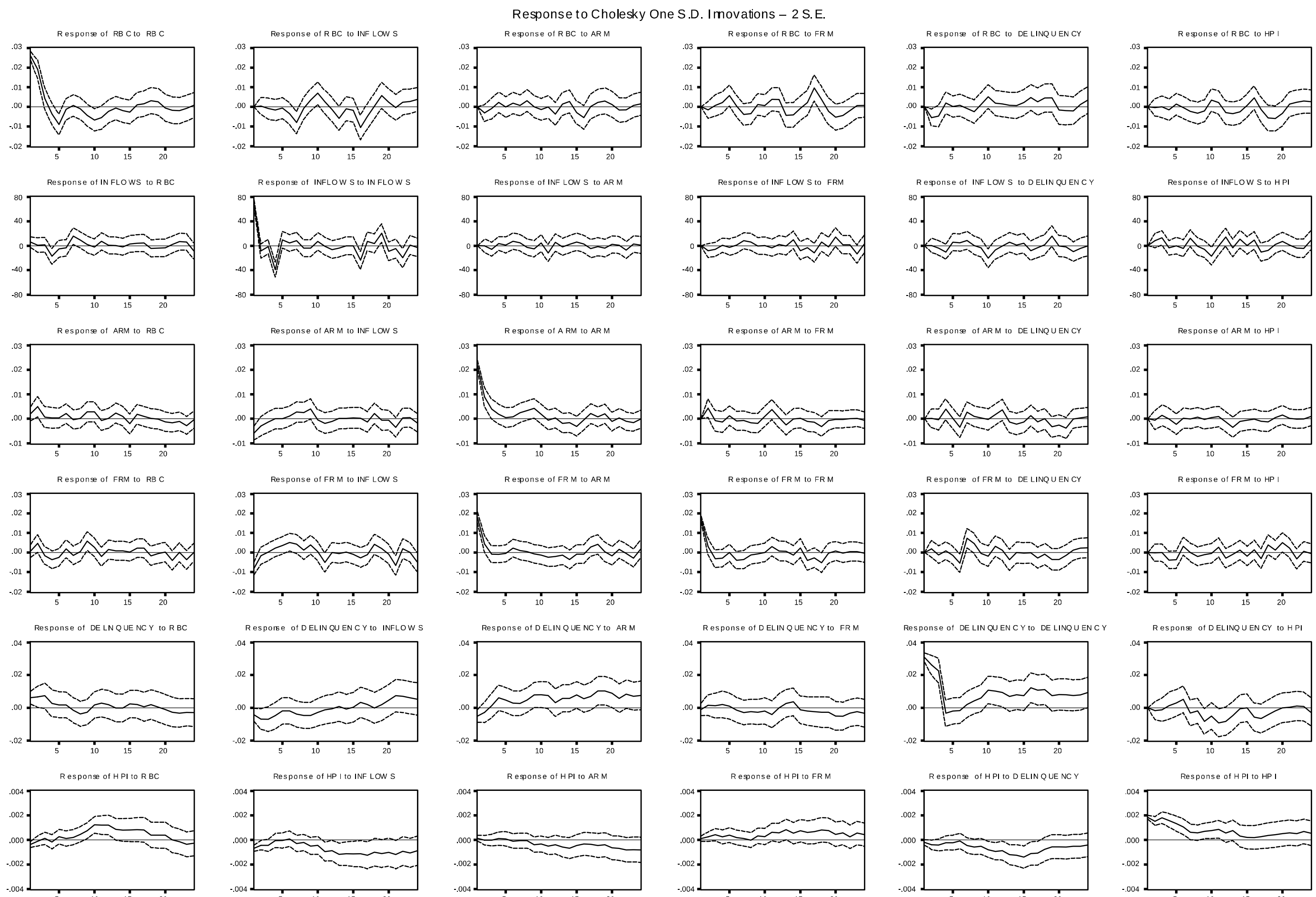


Figure B.10: Impulse Responses for Model 2

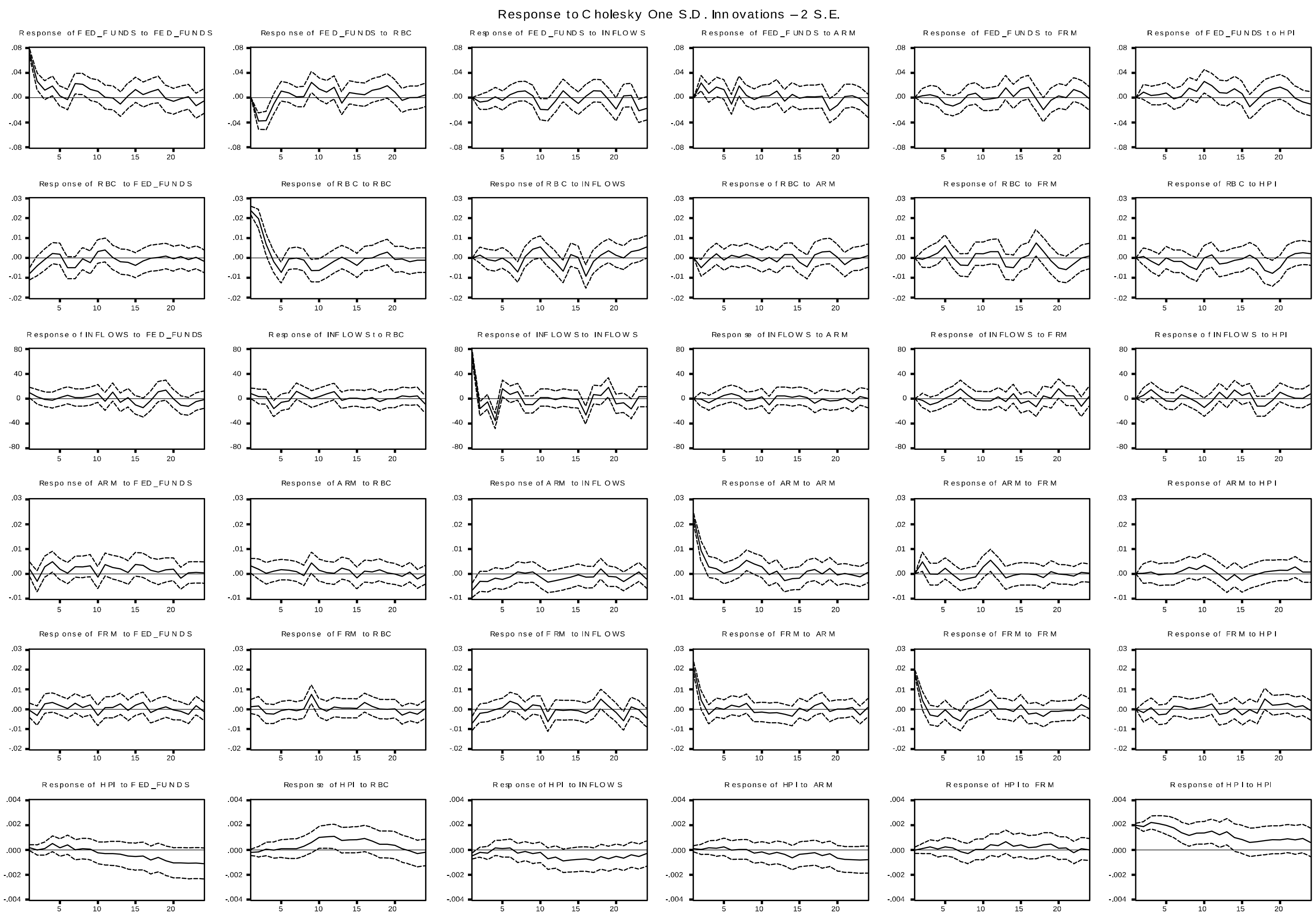


Figure B.11: Impulse Responses for Model 3

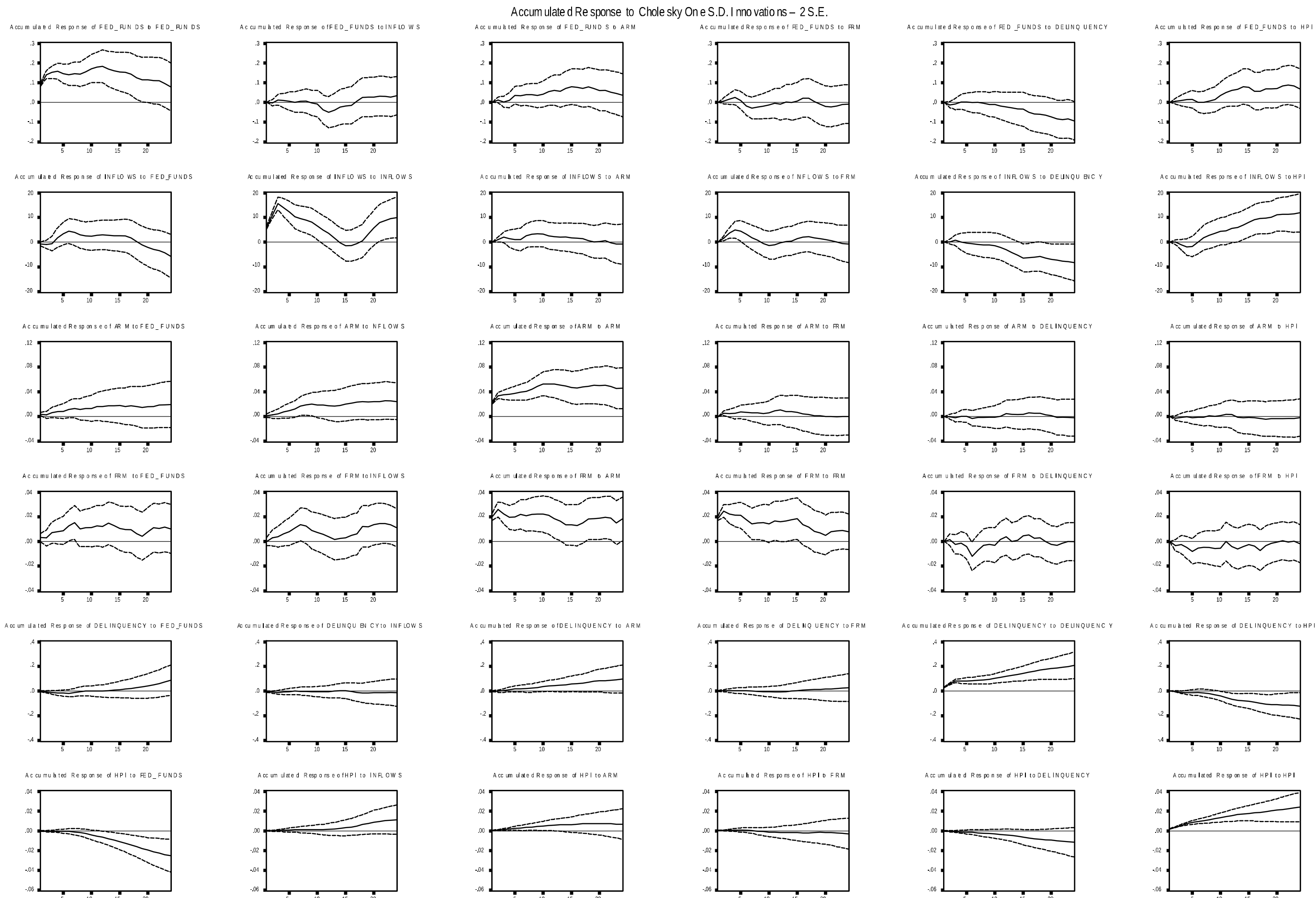


Figure B.12: Impules Responses for Model 1 using accumulated errors

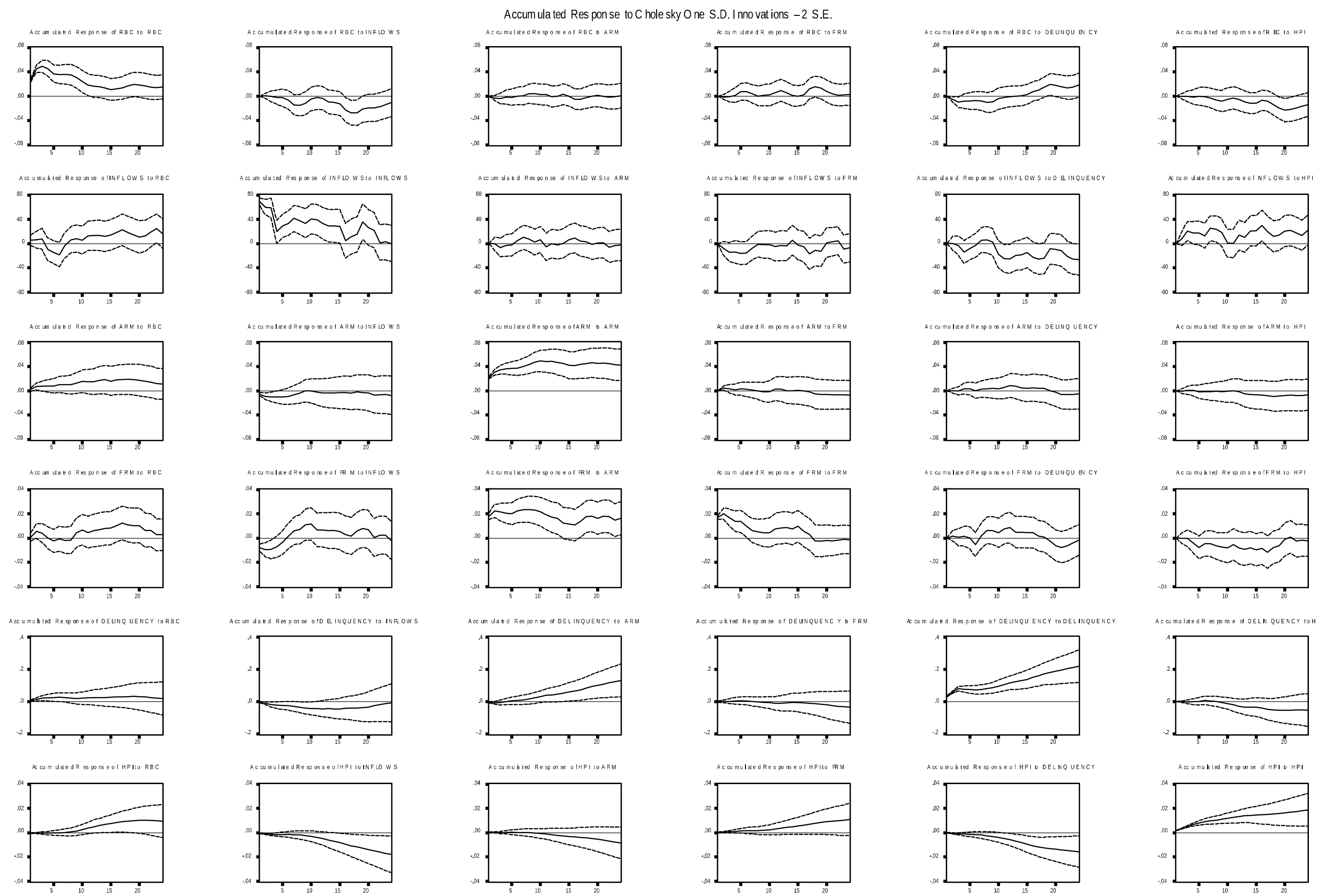


Figure B.13: Impules Responses for Model 2 Using Accumulated Errors

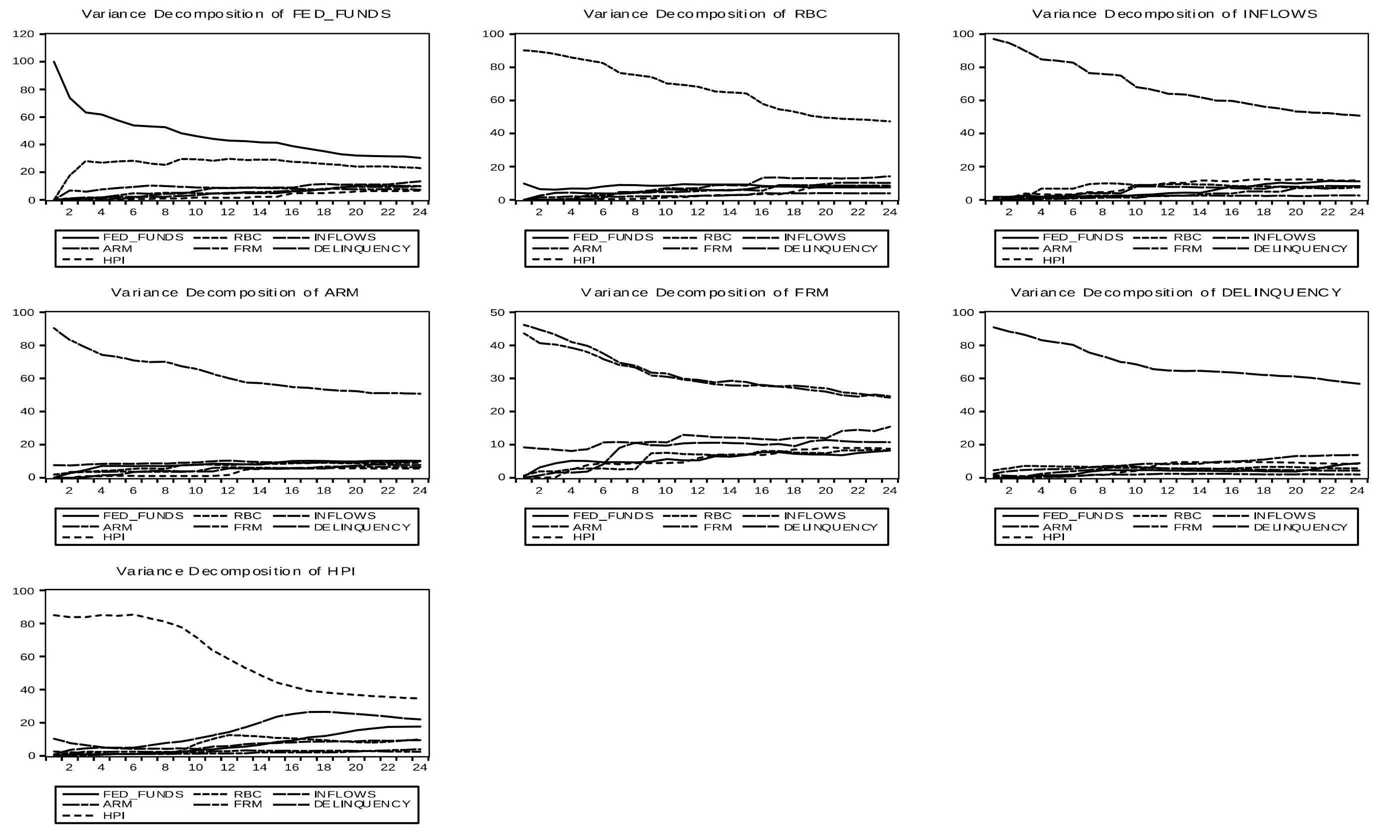


Figure B.14: Variance Decomposition Graphs for Model 3

Table B.10: Variance Decomposition of House Prices for Model 1

Period	S.E.	FED FUNDS	INFLOWS	ARM	FRM	DELINQ	HPI
1	0.002	0.831	0.124	3.581	2.640	0.283	92.541
2	0.003	0.918	0.434	3.836	1.725	2.108	90.979
3	0.003	0.719	0.773	4.335	1.227	1.811	91.135
4	0.004	0.748	1.053	5.244	0.981	2.065	89.908
5	0.004	0.833	1.664	7.508	0.953	2.166	86.877
6	0.004	0.813	2.109	7.827	0.944	2.213	86.094
7	0.004	1.838	1.946	9.044	1.731	3.179	82.262
8	0.005	4.311	1.933	9.294	3.913	3.718	76.829
9	0.005	7.839	1.724	9.067	3.969	3.756	73.646
10	0.005	12.894	1.518	8.959	4.277	4.000	68.351
11	0.006	16.180	1.369	8.694	3.891	4.153	65.713
12	0.006	18.959	1.331	8.629	3.794	4.178	63.108
13	0.006	21.918	1.669	7.872	3.406	5.112	60.023
14	0.006	25.597	2.230	7.165	3.192	6.304	55.512
15	0.007	28.571	2.946	6.615	2.889	7.784	51.195
16	0.007	30.735	4.096	6.404	2.700	8.397	47.667
17	0.007	33.215	5.866	6.038	2.442	8.719	43.720
18	0.008	34.839	8.589	5.488	2.308	8.397	40.379
19	0.008	37.122	10.010	5.080	2.188	7.934	37.666
20	0.009	39.102	11.211	4.687	2.053	7.633	35.315
21	0.009	40.108	11.396	4.463	1.955	7.576	34.502
22	0.009	40.927	11.544	4.275	2.156	7.548	33.550
23	0.009	41.502	11.349	4.114	2.144	7.743	33.148
24	0.009	41.927	11.247	4.037	2.334	7.862	32.594

Table B.11: Variance Decomposition of House Prices for Model 2

Period	S.E.	RBC	INFLOWS	ARM	FRM	DELINQ	HPI
1	0.002	0.062	0.399	2.881	1.443	0.802	94.412
2	0.003	3.200	0.277	1.841	0.884	2.534	91.263
3	0.004	5.199	1.245	1.205	0.804	2.464	89.083
4	0.004	4.619	1.346	1.140	0.650	2.808	89.437
5	0.005	6.276	1.723	1.221	0.759	2.855	87.166
6	0.005	7.448	1.854	1.099	0.690	2.784	86.125
7	0.005	8.224	1.705	1.123	0.891	3.479	84.577
8	0.005	10.183	1.667	1.028	2.216	4.119	80.787
9	0.006	13.054	1.486	0.919	2.264	4.325	77.952
10	0.006	17.736	1.287	0.798	2.328	5.197	72.653
11	0.007	21.608	1.116	0.760	2.038	5.701	68.777
12	0.007	24.772	1.038	0.726	1.939	6.024	65.500
13	0.007	25.190	1.279	0.927	1.765	7.146	63.692
14	0.008	25.856	1.737	1.400	1.641	8.413	60.954
15	0.008	26.138	2.187	1.524	1.524	10.073	58.555
16	0.008	26.649	2.977	1.527	1.474	10.835	56.538
17	0.008	26.763	4.085	1.473	1.390	11.503	54.785
18	0.009	26.329	5.664	1.553	1.327	11.641	53.485
19	0.009	26.241	6.742	1.580	1.282	11.616	52.539
20	0.009	26.248	7.561	1.793	1.269	11.672	51.457
21	0.009	25.873	7.673	1.924	1.242	11.849	51.438
22	0.009	25.485	7.786	2.123	1.435	11.958	51.212
23	0.010	25.036	7.737	2.236	1.448	12.085	51.457
24	0.010	24.811	7.678	2.421	1.682	12.163	51.245

Table B.12: Variance Decomposition of House Prices for Model 3

Period	S.E.	Fed Funds	RBC	INFLOWS	ARM	FRM	DELINQ	HPI
1	0.002	0.103	0.007	0.252	3.877	1.149	0.312	94.300
2	0.003	0.129	2.617	0.160	2.900	0.693	2.838	90.664
3	0.003	0.086	3.050	1.382	2.726	0.415	3.101	89.240
4	0.004	1.047	2.730	1.668	3.172	0.356	4.379	86.648
5	0.004	0.866	2.859	2.557	4.503	0.317	4.953	83.944
6	0.005	0.802	2.857	2.915	4.411	0.375	5.156	83.485
7	0.005	1.111	2.667	2.783	5.051	1.220	6.049	81.119
8	0.005	1.704	2.715	3.059	5.224	3.176	6.567	77.556
9	0.005	2.139	3.343	2.857	5.100	3.674	6.732	76.155
10	0.006	3.035	5.787	2.605	4.900	4.318	7.484	71.870
11	0.006	3.773	7.704	2.423	4.489	3.984	8.036	69.591
12	0.006	4.707	8.953	2.489	4.275	4.079	8.683	66.813
13	0.006	5.775	8.489	3.008	3.907	3.717	10.029	65.076
14	0.007	7.202	8.052	4.174	3.648	3.594	11.712	61.618
15	0.007	8.526	7.503	5.217	3.373	3.397	13.763	58.221
16	0.007	10.152	7.133	6.582	3.204	3.457	14.430	55.042
17	0.008	12.004	6.562	8.223	3.131	3.357	14.871	51.853
18	0.008	12.796	6.107	10.527	2.949	3.196	14.654	49.771
19	0.008	14.297	5.701	11.727	2.890	3.087	14.152	48.146
20	0.009	15.983	5.280	12.714	2.673	3.408	13.624	46.318
21	0.009	17.033	5.060	12.579	2.523	3.751	13.187	45.867
22	0.009	18.086	4.964	12.408	2.362	4.824	12.649	44.708
23	0.009	18.759	5.137	11.918	2.267	5.235	12.291	44.393
24	0.010	19.216	5.086	11.498	2.162	6.115	12.119	43.804